IASDR 2019

DESIGN REVOLUTIONS

IASDR 2019 CONFERENCE PROCEEDINGS | **VOLUME 4**

LEARNING | TECHNOLOGY | THINKING

EDITORS Professor Martyn Evans, Dr Annie Shaw, Dr Jea Hoo Na

iasdr2019.org

Manchester Metropolitan University

MANCHESTER SCHOOL OF ART

IASDR 2019 Conference Proceedings | Volume 4

Edited by Martyn Evans, Annie Shaw, Jea Hoo Na
Published by Manchester Metropolitan University

ISBN 978-1-910029-62-6

About IASDR

The International Association of Societies of Design Research (IASDR) is an international, nongovernmental, non-profit-making, charitable organisation, and is comprised of member societies of design research from around the world. Established on 01 November 2005, its purpose is to promote research or study into or about the activity of design in all its many fields of application, through encouraging collaboration on an international level between independent societies of design research. IASDR members include the Chinese Institute of Design (CID), the Design Research Society (DRS), the Design Society (DS), the Japanese Society for the Science of Design (JSSD) and the Korean Society for Design Science (KSDS).

www.iasdr.net

About Manchester School of Art, Manchester Metropolitan University

Manchester School of Art believes an art school is more than just a place.

Based in Manchester Metropolitan University, Manchester School of Art was established in 1838 and is the second oldest Art Schools in the UK. As one of the largest providers of art and design, we place importance on experimentation and generating creative surprise. We have a playful yet serious approach to media, materials and processes. We are home to around 3,700 students from all corners of the world who study a range of undergraduate and postgraduate courses taking inspiration from specialist staff, Manchester and each other.

www.art.mmu.ac.uk

"Manchester School of Art believes an art school is more than just a place."

Conference Visuals by Benjamin Greenhalgh
www.bybg.co.uk

“This is Manchester,
we do things differently here.”

About the IASDR 2019 Conference

DESIGN REVOLUTIONS

As the cradle of the industrial revolution, Manchester is known for its radical thinking. Through heritage, culture and innovations, it is a city that embraces revolution. As Tony Wilson famously claimed, “This is Manchester, we do things differently here”…

Design Revolutions explored how design drives and responds to revolutionary thinking through questioning the norm, probing the now and embracing the new. For the first time IASDR conference was held in the UK and fostered new thinking towards a compelling, meaningful and radical dialogue regarding the role that design plays in addressing societal and organisational issues.

The biannual conference enables academics, practitioners and students join together to explore contemporary agendas, emerging directions and future challenges that are at the forefront of design research. IASDR 2019 will provide opportunities for the presentation and publication of a collection of high-quality peer reviewed research papers alongside the space to discuss and debate the evolution and revolution of design.

Editorial

In September 2019 Manchester School of Art at Manchester Metropolitan University was honoured to host the bi-annual conference of the International Association of Societies of Design Research (IASDR) under the unifying theme of DESIGN REVOLUTIONS. This was the first time the conference had been held in the UK. Through key research themes across nine conference tracks – Change, Learning, Living, Making, People, Technology, Thinking, Value and Voices – the conference opened up compelling, meaningful and radical dialogue of the role of design in addressing societal and organisational challenges. The conference was a truly international gathering of the key thinkers in design research from 28 countries. 215 papers were presented and 13 workshops delivered alongside two exhibitions. RADICAL RESPONSES was a peer-reviewed exhibition of the research-informed design practice from academic design staffs from Manchester School of Art. This was complemented by an engaging display of design artefacts from the MATERIAL AND PROCESS INNOVATION COLLECTION curated by University's Special Collections. Such diversity enriched the exchange of ideas at presentations, workshops and social events for the duration of the innovative and dynamic event.

Support and contributions from the design research community have made this conference possible. Our thanks go to each one of our 488 authors for the papers and workshops that provided a rich source of inspiration, all 162 reviewers for ensuring quality and rigour and the 44 session chairs for ensuring the effective flow of ideas and discussion throughout the sessions. We also extend our sincere gratitude to all delegates of the conference who questioned the norm, probed the now and embraced the new. We hope you enjoyed your experience of Manchester and look forward to welcoming you to our city once again.

IASDR 2019 was a part of the design revolution in progress. We are excited to see how these proceedings fuel on-going discourse and debate at IASDR 2021 and beyond.

Martyn Evans, Annie Shaw and Jea Hoo Na

Chairs, Committee and Reviewers List

CONFERENCE ORGANISERS

First name	Family name	Contribution	Affiliation
Martyn	Evans	Chair	Manchester Metropolitan University
Annie	Shaw	Co-Chair	Manchester Metropolitan University
Rachel	Cooper	Co-Chair (Advisory)	Lancaster University
James	Moultrie	Co-Chair (Advisory)	University of Cambridge
Steve	Gill	Co-Chair (Advisory)	Cardiff Metropolitan University
Jea H.	Na	Coordinator	Manchester Metropolitan University

TECHNICAL COMMITTEE

First name	Family name	Contribution	Affiliation
Martyn	Evans	Conference Management	Manchester Metropolitan University
Annie	Shaw	Conference Management	Manchester Metropolitan University
Jea H.	Na	Conference Management	Manchester Metropolitan University
Fabrizio	Cocchiarella	Radical Responses (Curator)	Manchester Metropolitan University
Adam	Griffiths	Radical Responses (Visuals)	Manchester Metropolitan University
David	Grimshaw	Special Collections (Curator)	Manchester Metropolitan University
Benjamin	Greenhalgh	Conference Visuals	Manchester Metropolitan University
Janett	Adler	Student Committee	Manchester Metropolitan University
Phoebe	Kowalska	Student Committee	Manchester Metropolitan University
Gemma May	Potter	Student Committee	Manchester Metropolitan University
Sarah	Walker	Student Committee	Manchester Metropolitan University

SESSION CHAIRS

First name	Family name	Affiliation
Katerina	Alexiou	The Open University
Estelle	Berger	Strate School of Design
Gerhard	Bruyns	The Hong Kong Polytechnic University
Kathryn	Burns	Birmingham City University
Xi	Chen	Brunel University London
Rachel	Cooper	Lancaster University
Cees	de Bont	Loughborough University
Michelle	Douglas	Griffith University
Alex	Duffy	University of Strathclyde
David	Durling	Coventry University
Laura	Ferrarello	Royal College of Art
Zhiyong	Fu	Tsinghua University
Ashley	Hall	Royal College of Art
Robert	Harland	Loughborough University
Bianca	Herlo	Berlin University of the Arts
Richard	Herriott	Design School Kolding
Wei-Ken	Hung	National United University
Tiffany	Imron	University of Strathclyde
Yoshimune	Ishikawa	Nagano University
Sunghyun	Kang	Iowa State University
Takeo	Kato	Keio University
Alice	Kettle	Manchester Metropolitan University
Chajoong	Kim	Ulsan National Institute of Science & Technology (UNIST)
Phoebe	Kowalska	Manchester Metropolitan University
Vali	Lalioti	Royal College of Art
Youn-Kyung	Lim	Korea Advanced Institute of Science and Technology (KAIST)
Joseph	Lindley	Lancaster University
Peter	Llyod	Delft University of Technology
Nicole	Lotz	The Open University
Tonya	Meyrick	Deakin University
Enza	Migliore	AIIT, Tokyo Metropolitan University
David	Parkinson	Northumbria University
Gemma	Potter	Manchester Metropolitan University
Paul	Rodgers	Lancaster University
James	Self	Ulsan National Institute of Science & Technology (UNIST)
Annie	Shaw	Manchester Metropolitan University
Jon	Spruce	Manchester Metropolitan University
Hyeon-Jeong	Suk	Korea Advanced Institute of Science and Technology (KAIST)
Fang-Wu	Tung	National Taiwan University of Science and Technology (NTUST)
Sarah	Walker	Manchester Metropolitan University
Dave	Wood	Northumbria University
Toshimasa	Yamanaka	University of Tsukuba
Theodore	Zamenopoulos	The Open University
Lanyun	Zhang	Loughborough University

PAPER REVIEWERS

First name	Family name	Affiliation
Katerina	Alexiou	The Open University
Can	Altay	Istanbul Bilgi University
Mauricy	Alves da Motta Filho	University of Twente
Toshinori	Anzai	Sapporo City University
Stephen	Awoniyi	Texas State University
Joon Sang	Baek	Yonsei University
Siobhan	Barry	Manchester Metropolitan University
Weston	Baxter	Imperial College London
Chris	Becker	Colorado State University
Estelle	Berger	Strate School of Design
Katie	Beverley	Cardiff Metropolitan University
Jo	Briggs	Northumbria University
Kathryn	Burns	Birmingham City University
Daniele	Busciantella Ricci	University of Trento
Rebecca	Cain	Loughborough University
Hernan	Casakin	Ariel University
Yu-Ming	Chang	STUST
Chun-Di	Chen	National Taipei University of Education
Xi	Chen	Brunel University
Pei-Jung	Cheng	Harbin Institute of Technology, Shenzhen
Peiyao	Cheng	Department of Media Design
Lin	Chia-Hua	Tatung University
Luisa	Chimenz	University of Genoa
Dong-xiao	Chu	Wuhan University
Ya-Liang	Chuang	Eindhoven University of Technology
Violeta	Clemente	University of Aveiro
Aykut	Coşkun	Koc University
Theresa	Coburn	Heriot-Watt University
Fabrizio	Cocchiarella	Manchester Metropolitan University
Jillian	Coorey	Kent State University
Scott	Cressman	Alberta University of the Arts
Carmela	Cucuzzella	Concordia University
Cees	de Bont	Loughborough University
Michelle	Douglas	Griffith University
Paulo	Dziobczenski	Aalto University
Deniz	Ekmekçioğlu	Ondokuz Mayıs University
Martyn	Evans	Manchester Metropolitan University
Fei	Fei	Japan Advanced Institute of Science and Technology
Laura	Ferrarello	Royal College of Art
Ana	Ferreira	IADE - Universidade Europeia
Jodi	Forlizzi	Carnegie Mellon University
Zhiyong	Fu	Tsinghua University
Cathy	Gale	Kingston University
Francesco	Galli	IULM university

Maliheh	Ghajargar	Malmö University
Goncalo	Gomes	Universidade de Aveiro
Miaosen	Gong	Jiangnan University
Bethan	Gordon	Cardiff Metropolitan University
Raghavendra	Gudur	University of Canberra
Weimin	Guo	Design School of Jiangnan University
Ashley	Hall	Royal College of Art
David	Hands	Lancaster University
Michael	Hann	University of Leeds
Robert	Harland	Loughborough University
Leigh-Anne	Hepburn	The University of Sydney
Bianca	Herlo	Berlin University of the Arts
Gabriela	Hernandez	University of Florida
Richard	Herriott	Design School Kolding
Amic	Ho	National Cheng Kung University
Chun-Heng	Ho	The Open University of Hong Kong
Yinghsiu	Huang	National Kaohsiung Normal University
Yujia	Huang	Lancaster University
Tania	Humphries-Smith	Bournemouth University
Wei-Ken	Hung	Department of Industrial Design
Hyunwook	Hwangbo	Cardiff Metropolitan University
Minako	Ikeda	Kyushu University
Akiyoshi	Inasaka	Chiba Institute of Technology
Yoshimune	Ishikawa	Nagano University
Kazunari	Ito	Aoyama Gakuin University
Banhi	Jha	National Institute of Fashion Technology
Hao	Jiang	SDKKK
Eui Chul	Jung	Seoul National University
Jeyon	Jung	Kyung Hee University
Sunghyun	Kang	Iowa State University
Wendy	Keay-Bright	Cardiff Metropolitan University
Chajoong	Kim	UNIST
Yujin	Kim	Kongju National Univ.
Georgios	Koronis	Singapore University of Technology and Design
Jessica	Korte	University of Queensland
Nathan	Kotlarewski	University of Tasmania
Elizete	Kreutz	UNIVATES
Albrecht	Kurze	Chemnitz University of Technology
Blair	Kuys	Swinburne University of Technology
Vali	Lalioti	Royal College of Art
Newman	Lau	The Hong Kong Polytechnic University
Boyeun	Lee	Lancaster University
Chang-Franw	Lee	National Yunlin University of Science and Technology
Yi-Chang	Lee	National Taiwan Ocean University
Younjoon	Lee	Hongik University
Catarina	Lelis	University of West London

Pierre	Levy	Eindhoven University of Technology
Elena	Li	Yuan Ze University
Claudia	Libanio	Federal University of Health Sciences of Porto Alegre
Yong Hun	Lim	Bournemouth University
Youn-kyung	Lim	KAIST
Fang-Suey	Lin	National Yunlin University of Science and Technology
Yang-Cheng	Lin	National Cheng Kung University
Zhenyuan	Liu	Tongji University
Leon	Loh	Kyushu University
Nicole	Lotz	The Open University
Gareth	Loudon	Cardiff Metropolitan University
Yuan	Lu	University of Technology Eindhoven
Min-yuan	Ma	National Cheng Kung University
Piyush	Madan	IBM
Deepak John	Mathew	Indian Institute of Technology Hyderabad
Nolwenn	Maudet	Tokyo University
Mike	Mcauley	Queensland college of Art
Lisa	Mercer	University of Illinois at Urbana-Champaign
Ozge	Merzali Celikoglu	Istanbul Technical University
Tonya	Meyrick	Deakin University
Enza	Migliore	AIIT, Tokyo Metropolitan University
Alison	Miyauchi	Watkins College of Art
Daijiro	Mizuno	Kyoto Institute of Technology
Tina	Moor	Lucerne University of Applied Sciences and Arts
Christos	Mousas	Purdue University
Isabel Rosa	Müggler Zumstein	University of Applied Sciences & Arts Lucerne
Jea Hoo	Na	Manchester Metropolitan University
Morteza	Nagahi	Mississippi State University
Yukari	Nagai	Japan Advanced Institute of Science and Technology
Tek-Jin	Nam	KAIST
Esra	Nasır	Izmir University of Economics
Callum	Nash	Northumbria University
Marco	Neves	Lisbon School of Architecture, University of Lisbon
Koichi	Nishio	Fukui University of Tecnology
Bryan	Orthel	Indiana University Bloomington
Verena	Paepcke-Hjeltness	Iowa State University
Ian	Parkman	University of Portland
Isidoros	Perikos	University of Patras
Louis Shek Wing	Poon	Caritas Bianchi College of Careers
Vesna	Popovic	Queensland University of Technology
Annabel	Pretty	Unitec Institute of Technology
Sebastien	Proulx	The Ohio State University
Katelijn	Quartier	Hasselt University
Milena	Radzikowska	Mount Royal University
Anne-lyse	Renon	University of Strasbourg
Joomyung	Rhi	Yonsei University

Daniel	Richards	Lancaster University
Traci	Rider	North Carolina State University
Juan	Salamanca	University of Illinois
Ricardo Mejia	Sarmiento	Delft University of Technology
Pam	Schenk	Heriot-Watt University
Laura	Scherling	Columbia University Teachers College
Peter	Scupelli	Carnegie Mellon University
James	Self	Ulsan National Institute of Science & Technology
Annie	Shaw	Manchester Metropolitan University
Kin Wai Michael	Siu	The Hong Kong Polytechnic University
Nicholas	Spencer	Northumbria University
Jon	Spruce	Manchester Metropolitan University
Michelle	Stephens	Manchester School of Art
Mark	Strachan	Swinburne University of Technology
Hyeon-Jeong	Suk	KAIST
Shanti	Sumartojo	Monash University
Irina	Suteu	NABA Nuova Accademia di Belle Arti
Gunnar	Swanson	East Carolina University
Sarah	Teasley	Royal College of Art
Briony	Thomas	University of Leeds
Poldma	Tiiu	Université de Montréal
George	Torrens	Loughborough University
Jui-Che	Tu	National Yunlin University of Science and Technology
Fang-Wu	Tung	National Taiwan University of Science and Technology
Sylwia	Ulicka	Instituto Tecnologico de Estudios Superiores de Monterrey
Andrea	Weber Marin	Hochschule Luzern
Huaxin	Wei	The Hong Kong Polytechnic University
Wan-Li	Wei	Ming Chuan University
Timothy	Whitehead	Aston University
Matthew	Wizinsky	University of Cincinnati
Yi Lin	Wong	The Hong Kong Polytechnic University
Dave	Wood	Northumbria University
Fong-Gong	Wu	National Cheng Kung University
Takanobu	Yakubo	Sapporo City University
Ching Chiuan	Yen	National University of Singapore
Yuanyuan	Yin	University of Southampton
So-Yeon	Yoon	Cornell University
Go	Yoshizawa	Oslo Metropolitan University
Theodore	Zamenopoulos	The Open University
Duoduo	Zhang	Hunan University
Jason Shuo	Zhang	University of Colorado Boulder
Lanyun	Zhang	Loughborough University

Table of Contents

LEARNING

DESIGN IS INHERENTLY A LEARNING PROCESS THAT SUPPORTS CREATIVITY TO TRANSFORM CURRENT SITUATIONS TO PREFERRED ONES. WHILE CREATIVITY IS CONSIDERED CRITICAL IN EDUCATION, IS DESIGN BEING ECLIPSED BY STEM SUBJECTS? HOW SHOULD WE RESPOND TO THE CURRENT CHALLENGES PRESENTED IN EDUCATION? WHAT WAYS CAN DESIGN ENHANCE LEARNING EXPERIENCES? HOW SHOULD DESIGN NURTURE CREATIVITY TOWARDS NEW WAYS OF LEARNING?

A Study on the Effective e-Learning Content Image Composition and Direction Method for Generation Z

Bae, Sung-Han*[a]; Lee, Ki Ho*[b]

[a] School of Art and Design Convergence, Sejong Cyber University, Seoul, South Korea
[b] Division of Design Visual, Baekseok Arts University, Seoul, South Korea

It has been more than 20 years that e-learning has spread in Korea in earnest. In this process, many universities have introduced and operated e-learning. However, due to changes in the media environment, the tendency toward media adoption by the 'Generation Z*' has diversified, and the content creation environment has also undergone many changes. This change in environment has a lot of influence on e-learning. The proliferation of smart devices and MOOC(Massive Open Online Courses) has caused many changes in learning environment and learning behavior of e-learning, making it difficult to expect learning effect with existing e-learning production method. The purpose of this study was to examine how the composition and design of online education contents should be changed and applied according to the tendency of learners who have evolved in various ways. Several suggestions have been drawn from the study. First, the design approach to the e-learning screen composition. Second, fragmentation into small chapters. Third, the speed of lecture, the diversity of accent, and the proper screen switching speed. Fourth, the natural appearance of daily life. All of these things can be summarized as a necessary factor for successful e-learning.

* Generation Z: The generation reaching adulthood in the second decade of the 21st century, perceived as being familiar with the Internet from a very young age. 1990s as the next in the alphabetical sequence of Generation X and Generation Y.(Oxford Dictionary)

Keywords: e-learning; personal media; video directing; contents planning; teaching and learning

1 Introduction

Online education has developed with the development of science and technology.

Gráinne Conole (2013) presents a timeline to introduce the key techno logical developments in online education over the last 30 years as shown in Table 1.

Table 1 A timeline to introduce the key techno logical developments in online education

Timeline	The key techno logical developments in online education
1980s	Multimedia resources
1993	The Web
1994	Learning objects
1995	LMS(Learning Management System)

1998	Mobile devices
1999	Learning Design
2000	Gaming technologies
2001	Open Educational Resources
2004	Social and participatory media
2005	Virtual worlds
2007	e-Books and smart devices
2008	MOOC(Massive Open Online Courses)
2010	Learning analytics

Source: Gráinne Conole (2013)

And according to the e-learning status announced by the Ministry of Education and Human Resources Development of Korea, it is stated that Korean e-learning started with the spread of computer use to education in the 1980s. In 1998, 15 institutions were generalized to the public while piloting cyber universities. In the early 2000s, the evaluation of cyber universities was smooth and commercialized in primary and secondary education. In 2003, e-learning support centers were established in each area. The reason why online education is spreading and developing is that online education is able to do learning activities beyond the limit of time and space. In addition, it does not limit the specific time of content in terms of learning achievement, This is because it has the advantage of being able to learn repeatedly until fully understandable. Therefore, online learning is focused on improving learning achievement rather than learning time, so content production has been developed to improve achievement. In recent years, however, people habitually use mobile on a daily basis, and these lifestyles have been reflected in the educational environment, so people are becoming accustomed to short and dynamic content such as YouTube videos and increasingly emphasizing the convenience of content. Table 2 summarizes the Korean e-learning trends by timeline. Of course, education does not have to meet the demands of education consumers or consumers unconditionally, but because of the characteristics of online education contents that depend on changes and developments of media, it is important to focus on the tendency of learners according to the age change and personalized education we must not overlook the current direction of education. Therefore, the purpose of this study is to examine how the constitution and design of online education contents should be structured and directed according to the tendency of the learners who are changing in various ways.

Table 2 A timeline of Korean e-learning trends

Timeline	Periods	Trends
1980s	Early-stage	e-Learning started with the spread of computer use to education
1998	Settlement	15 universities were generalized to the public
2000s	Development	Commercialized in primary and secondary education
2003	Stable period	e-Learning support centers were established in each area
2019	Diffusion	21 universities. Widely and easily spread by Mobile and YouTube

2 Online education contents and video image design

Most e-learning contents consist of images using media. So Jyoti Chauhan and Anita Goel (2015) point out that the instructors who make video lectures focus on various aspects of video, including video interfaces, functions and characteristics, as well as lecture notes. "Video length, speaking speed, and the type of production." In other words, if the understanding of the characteristics and elements of the image is supported, the pedagogy can be accurately designed according to the intention of the instructor, which will affect the learning effect.

Visualization refers to visualizing a message to be delivered based on storytelling as a moving image. In order to visualize a moving image, it must be configured according to the communication grammar of the image so that the correct message can be transmitted. This visual grammar means the method of presentation, and visualizing it is the composition of the screen.

2.1 Aesthetic composition of screen

The composition of the image is represented by mise-en-scene. Mise-en-scene refers to the composition of the screen, that is, the aesthetic composition of the screen. A composition is the most basic image structure as a matter of how to arrange objects in the screen. Among the various image principles, the third law is a typical method of drawing a virtual line by horizontally dividing the screen into thirds and then arranging the object so that the object is arranged on the virtual line as much as possible. Since the image expresses a moving object as a visual message, the rhythm, beat, lightness, intensity, and magnitude of the motion in the screen determine the nature of the image and stimulate the complex senses of the human being through the visuospatial attributes related thereto Emotions. According to Herbert Jettle (2013), the viewer's view is through the camera, so the screen chosen by the cameraman should be centered on the facts of the incident, as well as identifying the crucial nature of the event and effectively communicating it.

Table 3 Four components of the shot related to the composition of the camera..

Components of shot	Screen compositions with the camera angle
Camera position	front shot, side shot, slice shot, back shot
Camera angle	level shot, high angle shot, low angle shot
Camera size	extreme close up, close up, medium shot, long shot, extreme long shot bust shot, waist shot, knee shot, full shot
Point of view	bird-eye view, high level position, eye level position, waist level position, low level position

The purpose of screen composition is to get the viewer's interest and reaction. In Table 3, the camera position refers to the position of the camera with respect to the subject, and is an important factor that directly affects the screen composition with the camera angle. The size of the shot depends on the size of the subject on the screen. Appropriately arranging the personality and viewpoint in terms of the interaction between the visual content and the viewer is a mediator that causes various interactions from the viewer. Therefore, the screen composition of the e-learning contents should be structured so that the learners can naturally immerse themselves in the screen in harmony with the overall flow of the program.

2.2 Changes in learning time

The playing time of the e-learning lecture video contents defined by the Ministry of Education of Korea is defined as at least 25 minutes for the online contents to be played for 50 minutes in offline class. This is 25 minutes of pure lecture content, excluding the time that occurs between faculty and students in the lecture room. For 3 credits, students must take 75 minutes of lecture content. Anna Hansch et al. (2015) noted the length of the video and said, "Students prefer short videos." In fact, most of the MOOC content is composed of short videos within 10 to 20 minutes. Barbra Burch (2018) reported that "the majority of students liked that video content was helpful for learning, and the video's running time was kept to less than 15 minutes". Professor Philip Guo (2013) from the University of Rochester also emphasized the usefulness of short videos, saying, "Optimal video length is less than six minutes." Debbie Morrison (2014) Increase the degree. Student participation is drastically lowered after 6 minutes of running time". Particularly, due to the smart device, the consumption place of the contents spreads to the street, and the format of the image contents is changed to a short unit time of less than 5 minutes. E-learning content should also be approached as a chapter-type content strategy considering short learning time according to the changes of learners and learning environment. The most significant difference between general e-learning contents and chapter type contents is the difference of teaching-learning design due to difference of learning time per unit contents. While there is no clear academic evidence that short videos can help improve learning success rates, examples of successful learning completion are characterized by short running-time videos. Based on the results of many researches that high learning satisfaction leads to high academic achievement, it can be predicted that contents with a short playback time will contribute to enhancement of academic achievement in the modern educational environment where media is deeply extended in our lives.

3 Changes in generation Z and visual content

In the study of recognition of the success factors of the e-learning lessons of Korean-ASEAN cyber university teachers, Jung Young-Ran et al. (2016) pointed out that the lesson design is "whether or not the interesting composition of the contents was made so as to induce learning motivation" Learning motivation skill in class "as an important success factor. These results suggest that how to motivate learners and keep them motivated in e-learning is an important success factor in e-learning class. In other words, in order to induce motivation of learners, content design should be done considering the habit of learners.

3.1 Daily naturalness

Among the components of the e-learning image, the outlier is a component called 'lecturer'. It is similar to the roles of actors and characters in movies, advertising, and animation. The learner takes the lecturer's natural dialogue lecture, gesture, expression, pronunciation and voice very seriously. Therefore, it would be desirable to produce images that include natural movements, such as in a lecture room, such as a gesture of a teacher and a writing style. As a result of the research by Choi Yoo-mi (2018) on the actual learners, the learners seemed to be uncomfortable to the learners because the sight of the professor gazed at the air or side, and the gaze did not meet with the students, while they’re talking. The 'Generation Z', born in the mid-1990s and early 2000s, features a 'digital native' generation that has grown in digital environments since childhood. They are familiar with the Internet and IT, preferring images and video content rather than smartphones and texts over TV and computers. For them, video is the language of daily life. For them, the unnatural appearance of a teacher would be a factor in avoiding the learning contents itself. In recent TV screen programs, the scenes of mistakes that were considered to be NG in the past are being broadcasted without filtering, and the moderators naturally acknowledge that they are mistakes and changed to a format that continues the program. This phenomenon is interpreted not as an artificial and formal content but as a tendency of a generation Z that desires non-formal and improvisational daily naturalness. In addition, the appearance and upbringing of the video production staff are exposed on the screen. The fact that the director, camera director, writer, lighting and sound engineer, and even the manager, not to make mistakes in production appear on the screen means that the image is not a video but a reality. In other words, for media generation, video is a part of life connected with daily life. Future contents of e-learning should be based on the needs of generations. The active and natural activity of the instructor, the lecture at a speed faster than usual daily conversation, and the most important eye contact are the making-content strategies of daily life that can be shared with the generation Z, in terms of e-learning teaching and learning methods.

3.2 Changes in Video Editing

Screen composition of video contents and speed control of video flow in scene change are very important editing factors. The video speed of the e - learning contents is not only the learning effect but also the learning motivation and learning continuity. On the audio side, Guo, Kim & Rubin (2014) suggests that lecturers feel enthusiastic, fast-paced videos that make learners feel more attractive and ultimately achieve better learning outcomes. According to Choi Yoo-mi (2018), many students actually watch the lecture 1.2 times faster than the normal speed when taking the contents of e-learning lectures. This means that the learners do not need to speak intentionally slower than usual because they can listen again whenever they want. Most of the content ranked high on the popularity of YouTube, which is one of the media in recent years, can feel the speed of word is quite fast. Even the breathing space between the syllable of narration is removed to make it feel as if it is a mechanical noise.

On the video side, the speed of screen switching is considered to be a very important part in terms of giving the learner a constant visual stimulus. The screen composition of the e-learning contents is basically a case where the instructor and lecture material are synthesized on one screen. As a result, the screen switching speed according to the lecture contents of the instructor is shortened so that the screen can not be switched from one minute to longer than 10 minutes. Since the movements of the instructor are generally the movements of the hands and arms, the learner must watch the fixed boring screen for a long time. The recent conversion of YouTube media contents is directed to not exceed 3 seconds on average. Broadcast entertainment programs are also edited to allow continuous conversion without exceeding a maximum of 4 seconds per cut.

Screen switching from 3 to 4 seconds is a normal speed for the Z generation who are born from the media. The fixed screen for more than one minute is forced to get away from the content of the content. This is why in-depth academic research on media acceptance patterns of media generation should be supported during e-learning production. A storyboard review of the screen must be made so that effective transition can be made along with the design of the contents of the e-learning contents.

4 Conclusion

E-learning is based on images. Video content can not be made by the efforts of a performer. Broadcasting and movies are all arts and designs that require collaboration of dozens of professionals such as planning, directing, screenplay, photography, editing, sound and costume.

The following points can be summarized in planning the e-Learning contents suitable for the media generation derived in this study.

First, a design approach to screen composition is needed for aesthetic composition of e - learning contents screen. Continuous screen composition studies should be done on the visual aspects that can be synchronized to the media generation by applying various image presentation techniques.

Second, the learning time of lecture contents should be divided into short chapters according to change of environment and consumption pattern of media, and concentration should be increased. As the place of media consumption expands, the burden of lecture should be reduced.

Third, the professor should focus on fast speed and intonation like everyday conversation rather than slow and clear speech according to traditional teaching method. It is also desirable to be able to maintain a proper screen switching speed in accordance with the respiration rate of the media generation in the post-work such as editing, thereby causing visual interest.

Fourth, it is necessary to design instructional contents and contents to link the naturalness of daily life to e-learning content. The teaching professor is moving away from the recognition that he is an 'educator', and the consciousness of being a member of entertainment in the viewpoint of educational entertainers is required to be changed. The teaching designers and production staffs are continuously researching teaching methods and screen element design appropriate to the communication grammar of the media generation and new initiatives need to be introduced.

Finally, we need to think about the value of e-learning. This is related to exploring what qualitative goals e-learning is seeking. A good e-learning is possible when teaching development, contents planning and production operation are performed based on consensus on the value goals that teachers, learners, managers, and producers pursue through e-learning.

5 References

Jung Hoon Leem, Eun Mo Sung, Byung Ro Lim. (2013). What is the Concept of Smart Eduction and the Typology of Smart Education Contents. Journal of Educational Technology, 29(3), 459-489.

Hye-Young Kim, Hee-Soo Lee (2009). “Analysis of e-Learning Content Types and Learner Satisfaction : Focused on Development Cases and Content Types of K Cyber University”, The e-Business Studies. Vol 10, No 4. pp. 299~316.

Lee, Ki Ho. (2015). The E-Learning for Practice Training Using Augmented Reality in the College Education. *Cartoon and Animation Studies*, 443-476.

Yoomi Choi. 2018. Design strategy for MOOC's video. Doctoral Dissertation, The Graduate School of Seoul National University

Keum, Sunyoung. (2017). Segmentation Strategies for SPAT format Learning Materials in Mobile Learning. Doctoral dissertation, The Graduate School of Seoul National University

Cho, Young-Joon. (2014). The Study on Improvement of Broadcast Metadata about Clip Video at Broadcast Content Managements. The Korean Institute of Broadcast and Media Engineers conference, 59-63.

Chauhan, J., & Goel, A. (2015, May). An Analysis of Video Lecture in MOOC. In ICTERI (pp. 35-50).

Zettl, H. (2013). Sight, sound, motion: Applied media aesthetics. Cengage Learning.

Kim, Su-Jin. 2018. A study on learner perception and satisfaction of segmental contents in online education. Latin American and Caribbean Studies. 37(3). 211~244

Hansch, Anna, McConachie, Katherine, Schmidt, Philipp, Hillers, Lisa, Newman, Christopher, Schildhauer, Thomas(2015), “The Role of Video in Online. Learning: Findings From the Field and Critical Reflections”. http://www.hiig.de/wp-content/uploads/2015/02/TopMOOC_Final-Paper.pdf.

Burch, Barbra(2018), “Video Length in Online Courses: What the Research Says
. https://www.qualitymatters.org/qa-resources/resource-center/articlesresources/

research-video-length.
Morrison, Debbie(2014), "MOOC Design Tips: Maximizing the Value of Video Lectures" https://onlinelearninginsights.wordpress.com/2014/04/28/mooc-design-tips-maximizing-the-value-of-video-lectures/.
Guo, Philip(2013), "Optimal Video Length for Student Engagement". https://blog.edx.org/optimal-video-length-student-engagement.
Renz, Jan, Bauer, Matthias, Malchow, Martin, Staubitz, Thomas, Meinel,.
Christoph(2015), "Optimizing the Video Experience in MOOCS" https://hpi.de/fileadmin/user_upload/fachgebiete/meinel/papers/Web-University/2015_Renz_EduL earn.pdf.
Manallack, David T., Yuriev, Elizabeth(2016), "Ten Simple Rules for Developing a MOOC", https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5072615/
Youngran Joung, Seungyeon Han, Jongsun Park (2016). "A study of Awareness on Success Factors in e-Learning Course of participants of Korea-ASEAN cyber university" Journal of Educational Technology, Vol 32, No 4, 955-986
Seunghwan Kim, Cheolki Kim (2018). A Study on Flow-emotion-state for Analyzing Flow-situation of Video Content Viewers. Journal of Korea Multimedia Society Vol. 21, No. 3 400-414
Hye-Jung Lee, Seri Kim, Kyoung-Ae Choi (2010), "International Study on Coree-Learning Management Strategies in Higher Education", The Journal of Educational Information and Media, Vol 16, No 1, 95-124.
Cheawjindakarn, B., Suwannatthachote, P., & Theeraroungchaisri, A. (2012). Critical success factors for online distance learning in higher education: A review of the literature. Creative Education, 3, 61-66.
Northwestern University(2018), "MOOC Creation Guidelines" https://www.northwestern.edu/provost/docs/MOOC_Creation_Guidelines.pdf.
Rossiter, J. A.(2015), "Education resources and teaching methodologies for the modern student and busy academic" https://ac.els-cdn.com/S2405896315024982/1-s2.0-S2405896315024982-main.pdf?_tid=fdea1111-0682-4b80-b9cf-d1f5b31f47bc&acdnat=1531640844_e3a5caf274a76ca2d7febd29c8ab8af5.
Guo, P. J., Kim, J., & Rubin, R. (2014, March). How video production affects student engagement: An empirical study of MOOC videos. In *Proceedings of the first ACM conference on Learning@ scale conference* (pp. 41-50). ACM.
Jermann, Patrick, Dillenbourg, Pierre, Noukakis, Dimitris, Aberer, Karl(2013), "MOOCS@EPL" http://www.aca-secretariat.be/fileadmin/aca_docs/images/members/Karl_Aberer.pdf.
NAVER https://terms.naver.com/entry.nhn?docId=74871&cid=43667&categoryId=43667 . search: Z generation
National Institute of Lifelong Education (2018), "K-MOOC through 4C system"
https://blog.naver.com/kmooc_kr?Redirect=Log&logNo=221181266275

About the Authors:

Bae, Sung-Han: Professor, Game and Entertainment, School of Art and Design Convergence, Sejong Cyber University, Seoul, South Korea | Research Scientist, SERI, Korea Institute of Science and Technology, Seoul, South Korea | PhD. Completion, Design Strategy, Kyushu University, Fukuoka, Japan | M.A., Computer Graphics, New York Institute of Technology, New York, U.S.A. | B.E., Electronic Engineering, Hanyang University, Seoul, South Korea | shbae@sjcu.ac.kr

Lee, Ki Ho: Professor, Division of Design Visual, Baekseok Arts University, Seoul, South Korea | Senior Researcher, National Strategy Institute, Seoul, South Korea | PhD., Visual Art, Hongik University, Seoul, South Korea | M.A., Media Art, Long Island University, N.Y., U.S.A. | B.A., Graphic Design, Hongik University, Seoul, South Korea | front@bau.ac.kr

Acknowledgement: Especially thanks to Prof. PhD. Kiyoshi Tomimatsu, Prof. PhD. Daewoong Kim and Prof. PhD. Ryoichi Tamura, Department of Design Strategy, Faculty of Design, Kyushu University, Fukuoka, Japan.

An Interdisciplinary Methodology for Facilitating Growth Mindsets of Creativity for College Students: Gameplay, Co-design and Group Dynamics

Yu, Shasha*; Sanders, Elizabeth B.-N.

The Ohio State University, Columbus, US
* susanyue12@gmail.com

Collaborative creativity is crucial because we are facing increasingly complex challenges which no single discipline or skillset can solve. A growth mindset of creativity, in which people believe their creativity can be improved, plays a crucial role in collaborative creative performance. People with growth mindsets are more open to critique and conflict and more willing to engage in dialogue and negotiation, which are essential for fostering collaborative creativity. However, few studies focus on how to facilitate growth mindsets of creativity. This research integrates gameplay, co-design, and group dynamics to explore ways of facilitating growth mindsets of creativity. Four studies have been conducted. We measured participants' engagement, their perceived creative potential, and their perceived collaborative performance. We found that students were highly engaged in the process even when their strategies were evaluated with low scores. 57% of participants, felt more confident in their creativity and in their potential to improve their creativity after participating. Also, participants perceived the collaborative performance to be more creative than what they expected.

Keywords: growth mindset; creativity; adults, gameplay, co-design, group dynamics

1 Introduction

1.1 Background

Collaborative creativity*, which "can yield an outcome that is more creative than the sum of individual contributions" (Bishop, 2018),* is crucial because we are facing increasingly complex challenges which no single discipline or skillset can solve. Diverse groups are more creative because the input of multiple opinions, perspectives, and critique inspires more original and complex ideas (Sawyer, 2007; Pentland, 2014). However, building good collaborations among diverse people is not easy as not all group collaborations lead to more creative outcomes than those produced by individuals. For example, studies have shown that group brainstorming is usually a waste of time (Mullen et al., 1991). There are many reasons. Social inhibition, which is when people in a group hesitate to express ideas for fear of what the others will think, and social loafing, which is when people who are in a group don't feel as responsible for the outcome as they do when they're working alone, will impair the productivity of group creativity (Sawyer, 2012, p.66).

Mindset has been shown to have a huge influence on people's academic, social, and work achievements. Based on Carol Dweck's (2006) theory of growth mindset, students who have a *growth mindset*, which is the belief that an individual can improve their ability through their efforts, their strategies and help from others, outperformed those who have a *fixed mindset*, which is the belief that an individual's ability is set and cannot be changed. A *growth mindset of creativity*, which means an individual believes their creativity can be improved, and plays a crucial role in individual and collaborative creative performance. Research showed that people with a *growth mindset of creativity* showed better insight problem-solving performance and are more confident in their creativity than those who had a *fixed mindset of creativity*. (Karwowski, 2014; Hass, 2016).

Also, a growth mindset makes people more open to critique and conflict, more willing to engage in dialogue and negotiation, and more likely to share their experiences and views, all of which are essential for fostering collaborative creativity (Sawyer, 2007). A growth mindset decreases a shy person's performance anxiety in a group (Valentiner et al., 2011), which empowers them to be more engaged in a group activity and better contribute to collaborative creativity. In addition, people with growth mindsets of creativity are more willing to take more complex challenges, which is essential for solving the complex challenges. However, in a survey of five thousand adults from US, UK, Germany, France and Japan, 59% of people didn't perceive themselves as creative and 65% reported their creativity has been stifled ("State of Creativity: 2016", 2016). In other words, these people didn't see the potential to improve their creativity. Therefore, how to develop a growth mindset of creativity for adults is a critical topic for our complex challenges.

1.2 Research Focus

The established methods used to develop a growth mindset are one-on-one interventions, such as asking participants to read a research paper about what growth mindset is and the benefits of having a growth mindset. However, these methods have been developed mainly to foster a growth mindset of intelligence. Creativity, unlike intelligence, is more about group work than individual work as many creative inventions came from collaboration. For example, the light bulb was not invented by Thomas Edison alone, but by the collaboration between him and his team members (Sawyer, 2007). Also, currently, no research is focused on the methods of facilitating a growth mindset of creativity. Therefore, a new methodology to develop a growth mindset of creativity at a group level is critical.

Play, or "*engaging in activity for enjoyment and recreation without a practical purpose*", is a common approach to foster creativity in the arts, like free play or *improvisation* (Nachmanovitch, 1990). It is impressive to see a group of people spontaneously play together to create beautiful music or a fantastic acting performance. Maketools (visual materials for making that are composed of a carefully selected set of playful components) have been used in co-design, *a participatory design approach that involves all stakeholders in the process*, to inspire interdisciplinary groups in collaborative explorations of future opportunities (Sanders & Stappers, 2012). However, play alone is not enough to foster a growth mindset of creativity in a collaborative situation because group dynamics are essential. Therefore, in this research, we aim to enhance collaborative creativity by integrating play from co-design with a group interaction approach from social science to explore the development of growth mindsets of creativity.

1.3 Contributions

This research explores the integration of methods and practices spanning design and other fields, which sparks interdisciplinary collaboration and encourages innovation in methodology development in design. Also, the practice of the methodology will empower adults to discover their creative potential, increase their openness to constructive criticism, and embrace challenges to enhance collaborative creativity.

2 The Design Research

In this research, four studies were conducted to explore ways to facilitate a growth mindset of creativity for college students (Figure 1). The first study examined the fixed mindset triggers*, i.e., the elements that could impair people's confidence in their creative potential*. The second and the third studies examined whether gameplay in co-design was an appropriate approach to help adults facilitate growth mindsets of creativity when they encountered fixed mindset triggers. They also identified what principles were important for the methodology to facilitate a growth mindset of creativity. The fourth study explored whether this methodology would be applied to a daily life environment instead of a lab environment.

Study 1

Examine Fixed Mindset Triggers

Examined what elements inhibit people from developing a growth mindset of creativity.

Study 2

Explore Gameplay in Co-design

Examined whether gameplay in co-design is helpful when encountering fixed mindset triggers.

Identified the essential principles.

Study 3

Update Gameplay and Test it

Updated the gameplay based on the results in Study 2.

Examined whether the updated methodology would work.

Study 4

Apply the Methodology to Classroom Environment

Examined whether this methodology can be integrated into class activities.

Figure 1. Research process

2.1 Examine the Fixed Mindset Triggers

The objective of *Study 1* was to examine *fixed mindset triggers, i.e., the elements that could impair students' confidence in their creative potential*. Seventeen students participated in the study and finished an online survey regarding their perceptions of creativity, e.g., "How creative do you think you are?" "Could you describe a moment in which you felt you were not creative?" The results from the survey show that five main elements can impair students' confidence in creativity: 1) Judgment 2) Comparison. 3) Failure. 4) No ideas. 5) Lack of Visualization skills

These results are consistent with previous studies (Kelley & Kelley, 2013; Dweck, 2015). Judgment or critique could impair students' confidence in their creative potential. However, judgment or critique is also important for fostering collaborative creativity (Sawyer, 2007). How to facilitate students' growth mindset of creativity even when they encounter those fixed mindset triggers? Research shows that games have the potential for promoting confidence for college students when they are struggling in STEM majors (Mayo, 2009; Kao, D. et al., 2015; Melcer, E. et al., 2017) and games also have been applied as an intervention to promote a growth mindset in children (O'Rourke, E. et al., 2016). Co-design is a *participatory design approach that involves all stakeholders in the process to meet users' needs*. Visual toolkits in co-design facilitate participants' creative explorations and enhance their creative confidence (Sanders & Stappers, 2012). Therefore, we integrated gameplay into co-design to examine whether it is helpful for facilitating the development of growth mindsets of creativity even when participants are encountering judgement or critique. We designed *a mindset change card* game based on the results of *Study 1.* The game was applied in the Co-design workshop in *Study 2.*

2.2 Examine Gameplay in Co-design When Encountering Judgment or Critique

In *Study 2*, we applied the *mindset change* card game to co-design to examine whether gameplay in co-design has the potential to facilitate growth mindsets of creativity. Sixteen participants were grouped in teams of four people. We gave each group one persona who had a fixed mindset, *e.g., Susan, a freshman in design major, doesn't think she is creative and is thinking to change her major*. One student acted as the persona, and the others tried to help her/him to develop a growth mindset of creativity. If the persona's mind was changed successfully, he/she would lose the game. Students played this game for 15 mins, then they worked together to come up with a solution to facilitate the persona to develop a growth mindset (Figure 2). Also, we identified the principles that are essential to facilitate growth mindsets of creativity by examining the gameplay elements and group interaction dynamics.

Data from observations, participants' self-reports, and their game playing strategies were collected. The results showed that gameplay has many benefits to develop the growth mindset of creativity. For example, judgment-behaviour-feedback loops (Garris, 2002) in the game motivated people to engage in problem-solving without impairing their confidence in their creativity when being evaluated by others. Based on the data, four important principles for facilitating growth mindsets for adults emerged: *Support (collaborate)*, *Challenge (problem-solving), Intrinsic Rewards, and a Safe Environment.* Also, we examined the interaction dynamics. The results showed that the current interaction dynamics were not stable, and not everyone was engaged in the process and there are some defensive behaviours at the beginning of the game which could destroy the smooth conversation within the group. Based on the data, three elements of interaction dynamics, *i.e., equality of conversation, feedback, and evaluation* are essential for facilitating growth mindsets of creativity.

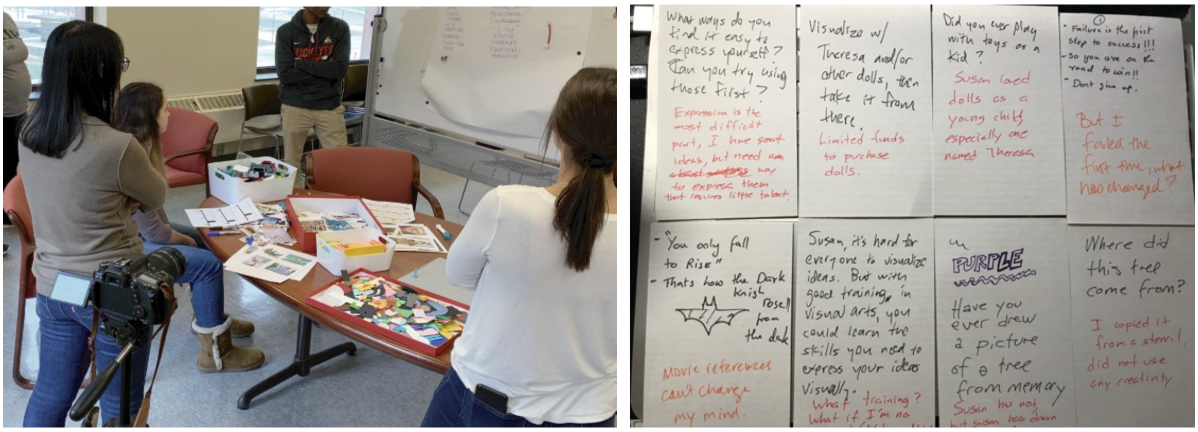


Figure 2. Gameplay in co-design

In *Study 3 (Figure 3.1)*, we designed a new game based on the results of *Study 2*. For example, students had teammates to work together to solve the problem. Random images were available to inspire them regarding strategies. The problem that they were trying to solve was challenging but not too hard. We asked participants to write each strategy on one card and evaluate it before they gave it to another person. That person evaluated it based on how helpful the strategy was to him/her and then provided feedback. This time, we set the goals for the two roles (problem solvers and a person who had a fixed mindset on his/her creativity) in a collaborative way instead of a competitive way to make the interaction smoother. Also, everyone in the group had the opportunity to share ideas. Twenty-three college-age participants from different backgrounds participated in the study. We measured participants' mindsets on the potential to improve their creativity before the study and after the study, their perceptions on their creative outcomes and their engagement when their strategies are evaluated with low scores. They played the game for 15 minutes and then they switched roles and played the game for 15 minutes again. After that, they worked together to come up with strategies to help the fixed mindset person develop a growth mindset. The visual materials (such as photos and paper shapes) were available to inspire students to come up with strategies. The results showed that participants were highly engaged in the process and continued to improve their strategies to solve the posed problems when their strategies were critiqued. They didn't view the critiques as threats but rather as constructive feedback to help them improve their strategies. Fifty-seven percent of the participants, who initially believed their creativity could not be improved, felt more confident in their creativity and in their potential to improve their creativity after participating in the workshop (Figure 3.2, 3.3). Also, they perceived the collaborative outcomes were more creative than they expected (Figure 3.4)

Figure 3.1. Updated gameplay in co-design

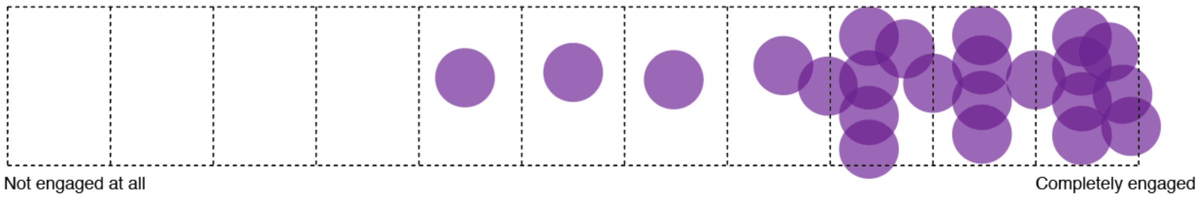


Figure 3.2. Participants were highly engaged in the process

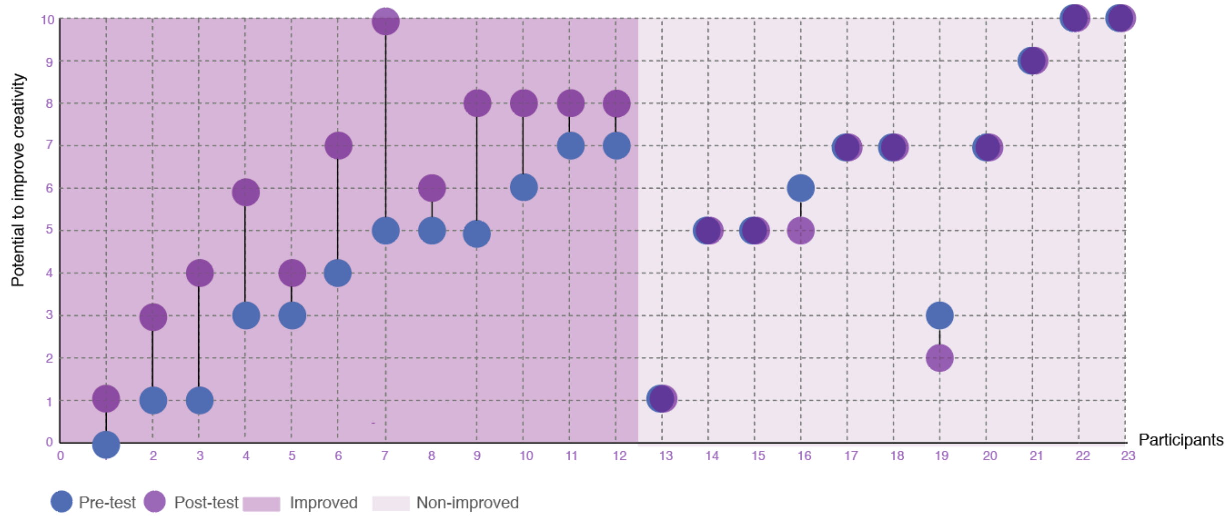


Figure 3.3. 57% (12 out of 21) of the participants were more confident in the potential to improve their creativity

Ps: No.22 and No.23 were not included because both before and after the test, the score was 10.

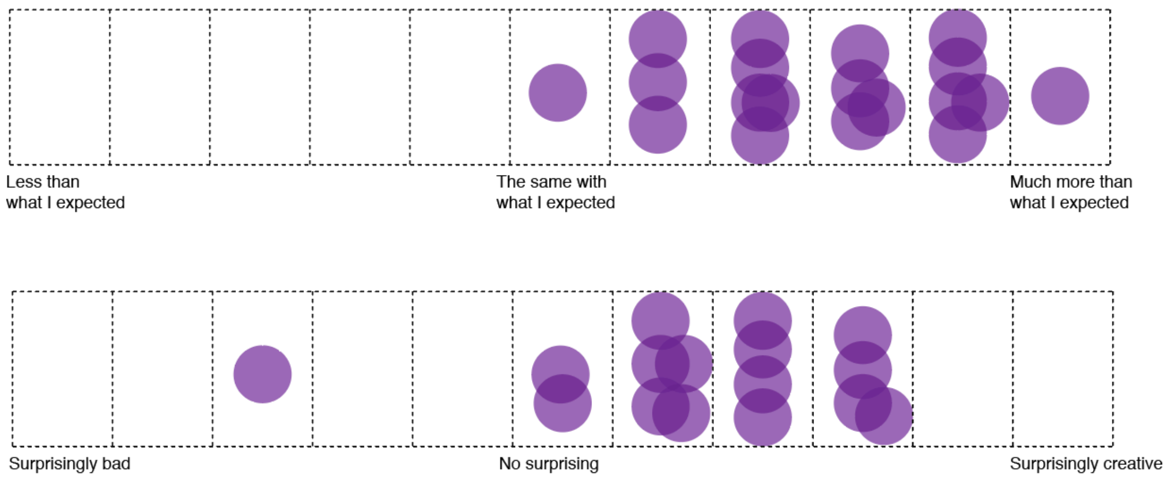


Figure 3.4. Students perceived collaborative performance as more creative than they expected

2.3 Apply this methodology to a classroom environment

The current results are promising. However, one remaining question is how to apply this methodology to daily life environments, such as classrooms? How would instructors integrate this methodology into class activities to facilitate the development of students' growth mindsets of creativity to enhance collaborative creativity? To explore how to make the methodology accessible to more people and empower them through daily life activities, we conducted *Study 4* in a classroom environment (Figure 4).

Figure 4: Classroom activities

The class workshop was an optional assignment in a design introduction course. Twelve students from different backgrounds took part in the workshop. They were grouped with four students and they didn't know each other before they attended this workshop. Each group was given a problem to solve. We intergrated the workshop to the course content. The instructor was available in the workshop to introduce some concepts, like brainstorming and iteration to the group. There were two sections with different activities in the workshop. In the first section, participants worked together to reframe the problem, generate the pain points of their target audience, and conduct brainstorming for the solutions. Then they played the same game as was used in Study 3. One person acted as the persona and others were the problem solvers. The problem solvers evaluated their strategies before they gave them to the persona, then the persona evaluated the strategies and gave feedback to the problem solvers. After that, they worked together to come up with solutions to the posted problem. In the second section, participants played the same game and we gave them the same visual materials as were used in Study 3, i.e., paper shapes and images. We measured participants' mindsets on the potential to improve their creativity before the study and after the study, their perceptions on their creative outcomes and their engagement when their strategies are evaluated with low scores. Also, we compared participants' engagement between the first workshop and the second workshop to see whether there were differences.

The data from the classroom workshop showed a similar pattern to that in Study 3. 58%(7/12) of the participants who initially believed their creativity could not be improved, felt more confident in their creativity and in their potential to improve their creativity after participating in the workshop. Also, participants were engaged in the process and continued to improve their strategies to solve the posed problems when their strategies were critiqued. They didn't view the critiques as threats but rather as constructive feedback to motivate them to improve their strategies.

The visual materials (images and shapes) were helpful for them to get started. They liked the game in the first workshop, but they felt it was difficult and struggled to start to come up with strategies. The visual materials in the second workshop were helpful for them to get started quickly. In addition, this workshop also showed that the ideal length of the game should be less than 30 minutes, otherwise students would feel that the game is repetitive and boring. By comparing students' collaboration between those two workshops, we found that students in the gameplay section were more likely to share ideas and views especially for some students who were introverted. More classroom workshops in different courses will be conducted in the near future to see whether there is a similar pattern.

3 Discussion

Everyone is creative (Sanders & Stappers, 2012). Creativity is something you practice, not just a talent you are born with (Kelley & Kelley, 2013). Given gameplay in co-design has the potential to facilitate students' growth mindsets of creativity, it behooves us to study the methodology by which students perceive the fixed mindset triggers, *i.e., judgement and critique* as opportunities to growth. In this research, we examined students' fixed mindset triggers, whether this methodology would enhance students' confidence in their creativity, facilitate students to see their creative potential, or motive them to try new strategies to improve their creativity. Students perceived the game to be fun and easy which made it easier for them to get started. For example, when we told students they would play a game, they felt excited and looked forward to playing it instead of hesitating to try. The elements that we generated in this research, e.g., *Support (collaborate)*, *Challenge (problem-solving), Intrinsic Rewards, Equal Conversation, and Feedback,* are important for the success of the game. For example, when students were struggling with coming up with strategies, they could talk with their teammates and they could turn to the visual materials to get inspirations. The task in the game was challenging but not too hard which could motivate them to try but not make them feel too frustrated. The equal conversation gave everyone the opportunity to share ideas, which was important to foster collaborative creativity. Also, the feedback and evaluation from others were helpful for them to adjust and improve their ideas. In addition, we applied this methodology into a class environment to examine whether it works in a daily life environment in addition to a lab environment. Our findings suggest a provocative new relationship and interaction between adults' growth mindsets of creativity and gameplay, where students kept trying new strategies to improve themselves.

4 Future Work

In this research, we measured participants' perceived collaborative performance. However, we didn't measure the collaborative performance from the views of creative experts outside of the group. In future studies, we will measure experts' views on the collaborative performance to examine whether this methodology can enhance collaborative creativity.

About 60% of the participants perceived their creative potential could be improved after participating in the study. However, 40% of them didn't perceive their creative potential could be changed at all. In future studies, we will examine the mechanisms of this methodology further to explore whether there are some principles which are essential for facilitating growth mindsets of creativity for all people.

In the current study, we examined whether students' perceptions changed immediately after the study. In the future, we will conduct a longer term study to evaluate whether this effect lasts longer.

5 Reference

Bishop, L. (2018). Collaborative musical creativity: How ensembles coordinate spontaneity. *Frontiers in Psychology*, *9*.

Dweck, C. S. (2006). Mindset: The new psychology of success, Random House. *New York, NY*.

Dweck, C. (2015). Carol Dweck revisits the growth mindset. *Education Week*, *35*(5), 20-24.

Garris, R., Ahlers, R., & Driskell, J. E. (2002). Games, motivation, and learning: A research and practice model. *Simulation & gaming*, *33*(4), 441-467.

Hass, R. W., Katz-Buonincontro, J., & Reiter-Palmon, R. (2016). Disentangling creative mindsets from creative self-efficacy and creative identity: Do people hold fixed and growth theories of creativity? *Psychology of Aesthetics, Creativity, and the Arts*, *10*(4), 436.

Kao, D. & Harrell, D. F. (2015). Mazzy: A STEM learning game. *Proceedings of the 10th International Conference on the Foundations of Digital Games (FDG 2015)*, *June 22-25, 2015, Pacific Grove, CA, USA. ISBN 978-0-9913982-4-9.*

Karwowski, M. (2014). Creative mindsets: Measurement, correlates, consequences. *Psychology of Aesthetics, Creativity, and the Arts*, *8*(1), 62-70.

Kelly, D. & Kelly, T. (2013). *Creative confidence: Unleashing the creative potential within us all*. New York, NY: Crown Business.

Mayo, M. J. (2009). Video games: A route to large-scale STEM education? *Science*, *323* (5910),79-82.

Melcer, F. E., Hollis, V., Isbister, K. (2017). Tangibles vs. mouse in educational programming games: influences on enjoyment and self-beliefs. *Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems, Denver, CO, USA Denver, ACM 978-1-4503-4656-6/17/05.*

Mullen, B., Johnson, C., & Salas, E. (1991). Productivity loss in brainstorming groups: A meta-analytic integration. *Basic and Applied Social Psychology*, *12*(1), 3-24.

Nachmanovitch, S. (1990). *Free play: Improvisation in life and art*. Penguin.

O'Rourke, E., Haimovitz, K., Ballweber, C., Dweck, C., & Popović, Z. (2014). Brain points: A growth mindset incentive structure boosts persistence in an educational game. *In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. 3339-3348. ACM.*

Pentland, A. (2014). *Social physics: how good ideas spread-the lessons from a new science*. Penguin.

Premuzic C. T. (2015). Why group brainstorming is a waste of time. *https://hbr.org/2015/03/why-group-brainstorming-is-a-waste-of-time.*

Sanders, E. B.-N. & Stappers, P.J. (2012). *Convivial toolbox: Generative research for the front end of design*. Netherlands: BIS Publishers.

Sawyer, K. (2007). *Group genius: The creative power of collaboration*. Basic Books.

State of Create: *2016 https://www.adobe.com/content/dam/acom/en/max/pdfs/AdobeStateofCreate_2016_Report_Final.pdf*

Valentiner, P. D., Mounts, S. N., Durik, M., A, Lonsway, L. S. (2011). Shyness mindset: Applying mindset theory to the domain of inhibited social behavior. *Personality and Individual Differences*, *8*,1174-1179.

About the Authors:

Shasha Yu: Shasha is a graduate student in the Department of Design at the Ohio State University. Prior to OSU to pursue her M.F.A. degree, she had a master’s degree in Psychology and worked as a UX researcher in a global Game Design company for three years. Her expertise is in gameplay in education, co-designing, and information visualization.

Elizabeth B.-N. Sanders: Liz teaches design research and participatory design in the Design Department at The Ohio State University. As a practitioner, Liz introduced many of the methods being used today to drive design from a human-centered perspective.

Applying Interactive Technology with Technology Acceptance Model into Digital Media Basic Modeling Course

Xu, Song*[ab]; Fan, Kuo-Kuang[a]; Li, Chen[ab]

[a] Graduate School of Design, National Yunlin University of Science and Technology, Yunlin, Taiwan
[b] Beijing Institute of Technology, Zhuhai, Zhuhai, Guangdong, China
* 85834048@qq.com

The wide application of interactive technology brings new opportunities and challenges to digital media design teaching. This study aims to find how to integrate interactive technology into the classroom teaching of digital media basic modeling and explore the acceptance of interactive technology through the combination of technology acceptance model (TAM) and fixation, inspiration & creativity. This study combines questionnaires with classroom reforms to investigate students' attitudes toward interactive technologies. The survey results found that most of the students accepted the introduction of interactive design in the course, very few people held a negative attitude, and some students proposed to increase the interactive devices in the classroom for better learning.

Keywords: design education; digital media modeling, interactive technology, technology acceptance model

1 Introduction

Advances in technology have contributed to the continuous development of design disciplines. With the rise of new media, digital media design major has blossomed throughout China. The novel interaction, cool animation, rich user experience, and diverse information visualization show the charm of digital media discipline from different angles, and these colorful classifications are now inseparable from the help of interactive technology. Without interactive technology, the digital media design will exhaust on nutrients, like the fish that left the water, and gradually abandoned by the public. In fact, this situation was raised many years ago by McLuhan and others. When technology as human extended is no longer willing to undertake its natural mission, its identity and existence will also be questioned by common people (McLuhan, 1994).

In order to let the junior students in the lower grades gradually understand the digital media design from the rational and the perceptual, the teachers need to involve the corresponding scientific and technological knowledge in the curriculum design, especially the basic interactive technology. However, when the freshmen who have just entered the school are mostly artistic backgrounds and lack the professional quality of the science and engineering disciplines, they need to carefully arrange the course content and carefully cultivate their interest in the teaching process. Related design education problems appear in two aspects: First, some of the teachers themselves are not from the digital media design profession. They lack the overall educational vision of the profession. The knowledge in the curriculum is limited, resulting in an insufficient connection between the classroom content and other professional courses. Second, the artistic background freshmen have some natural stereotypes about technology, fear and rejection of learning technology, lack of interest in learning and self-confidence, and need to be better guided and encouraged in the curriculum.

As early as a decade ago, some scholars discussed the impact of digital hardware software on inscription characteristics in design (Cleveland, 2004). In the research, the contradiction between design willingness and technical possibility was discussed in depth and point out "The commands are controlled by the algorithms that control the way images are constructed." A few years later, another design team compared the differences between traditional design tools and digital design tools. They believe that although computers have speed advantages in design activities such as previewing fonts, they present an inferiority in efficiency compared to traditional design tools. In addition, they also indicate "If, for instance, students received focused training on using digital tools in the preliminary stages of design, results may be different." (Stones & Cassidy, 2007). Subsequently, several research teams conducted in-depth research on traditional design and digital design. Among them are the study of planar 2D mapping processes (Tang, Lee & Gero, 2011), the study of 3D modeling processes (Alcaide-Marzal, 2013), and the impact of using different digital design tools on the designer's thinking process (Xu & Fan, 2017).

Based on previous research results and the current problems in digital media undergraduate teaching, this research is devoted to exploring the interdependence between interactive technology and digital media design course. Two important issues need to identify in the study:

First, in the digital media undergraduate course, can teachers avoid talking about interactive technology and reduce the learning pressure of art students?

Second, how to redesign classroom teaching according to the different needs of students, and use scientific methods to interpolate interactive technology into the digital media basic modeling course?

2 Literature Review

Students need a scientific teaching method to learn the basics digital media modeling at school. How to carry out digital modeling activities in the digital space is the main content of teaching.Interactive technology as an inevitable theme of the digital media profession needs to be discussed. The TAM model was introduced to understand students' attitudes toward interactive technologies.

2.1 Design Education

The foundation of digital media modeling will directly affect the study of digital media design for first-year freshmen. It needs students to put the traditional design modeling awareness on hold, understand what is the difference between digital space and real space. Learn how to carry out conceptual modeling in digital space and physical modeling in real space, so as to make the connection between the digital world and the real world, and finally complete a design task. Corsini and Moultrie (2018) found that collaborative work with digital tools can provide creativity, and the use of more interactive digital production processes can drive creative production. Thoring, Desmet and Badke-Schaub (2018) pointed out in their research that there are five types of design space: Personal space, Collaboration space, Making space, Presentation space, Intermission space. The specific spatial environment helps to promote the designer's creative work and learning process, and it is important to be able to fluently convert space type and smooth workflows. In the field of design education in higher education, Jeffries (2007) designed a web-based creativity analysis tool from a quantitative perspective.

2.2 Digital Media Modeling

Digital media modeling mainly refers to the activities of designers using digital media for model, usually divided into concept model and physical model. Vardouli (2015) studied at how to look at human-artifact engagement in design activities from the perspective of design-communication-using three centers. Knight & Stiny (2015) explores the changes in design activities from shape grammar to design computing. Another group's research on making of and making for takes digital media modeling a step further. They separate information processing from material processing, and the digital media modeling process tends to be more traceable. (Gursoy & Ozkar, 2015). Even some research groups have developed a conceptual design model based directly on Scientific Ontology and intentionality theory (Chen, Zhang, Xie & Zhao, 2015), which can be used to test the conceptual basis of existing design methods or models. It can also be used to create custom concept design tools.

2.3 Interactive Technology

Interactive technology is an integral part of digital media modeling. In the information age, its main dependence is computer science, because designers have no other effective way to control design objects in the digital world except computers. Bernal, Haymaker & Eastman (2015) uses the power of computers to integrate different forms of design knowledge into the same platform. Some scholars have explored the human-machine design process by case studies, and through the three-layer framework of “imitation, iteration and improvisation”, it is found that learn making and make learning is emerging in the process of making (El-Zanfaly, 2015). By studying the visual divergence of humans and machines, Sosa, Rojas, Gero & Xu (2016) developed a set of methods to define simple design tasks for research purpose.

2.4 Technology Acceptance Model

Tachnology Acceptance Model (TAM) is an evaluation model proposed by D. Davis (1985). It is mainly used to test the end-user's acceptance of information systems and the impact of system characteristics on user acceptance. Venkatesh & Davis (2000) also improved the model by adding seven factors to the original four factors. Subsequently, Legrisa, Inghamb & Collerette (2003) conducted experiments using the new model and pointed out that there are important uncertain factors in the model. Taherdoost (2018) conducted a literature review of all Adoption / Acceptance Models, including TAM.

2.5 Fixation、Inspiration & Creativity

Fixation, inspiration, and creativity are three important indicators of design value. Among them, fixation may lead to design failure, inspiration may promote design success, and creativity can improve design quality and provide better solutions. Cheng, Mugge &

Schoormans (2014) shows that using specific design strategies can break the fixed design thinking and enhance design creativity. Vasconcelos & Crilly (2016) also from a methodological perspective collated recent years research on inspiration and fixation in the design field. The study of idea generation and design fixation by Atilola, Tomko & Linsey (2016) shows that sketch representations can cause fixation and function trees can reduce idea fixation. Crilly & Cardoso (2017) through international workshop to further explore the fixation of creativity and inspiration.

3 Research Design

3.1 Research Framework

The core purpose of this research is to discover the role of interactive technology in digital media undergraduate design education, and to figure out the understanding and perceptions of interactive technology among junior college students in digital media major. Based on the discussion of related theories and concepts, the research summarizes two questions: First, the three indicator concepts in the teaching of digital media are fixation, inspiration and creativity, and good interactive technology needs to help students focus, inspiration and creativity in the course; secondly, according to the perspective of the technology acceptance model, students' perceived usefulness and perceived ease of use will influence their intention to use and usage behavior of interactive technology. This study needs to understand the students' perceptions and real use of the interactive technologies in current course and find out whether such influences also exist in digital media design education. Research design hopes to clarify the significance and value of interactive technology for digital media undergraduate design education based on these two issues. Therefore, the researcher developed the research structure as follows (Table 1).

Table 1 research framework

	Fixation (F)	Inspiration (I)	Creativity (C)
Perceived Usefulness (PU)	The practicality of interactive technology for students to reduce fixation	The practicality of interactive technology for students to get inspiration	The practicality of interactive technology to enhance students' creativity
Perceived Ease of Use (EU)	Interactive technology reduces the ease of use of fixation for students	The ease of use of interactive technology in getting students' inspiration	The ease of use of interactive technology as students enhance their creativity
Intention to use (IU)	Are students willing to use interactive techniques to reduce fixation?	Are students willing to use interactive technology to get inspiration?	Are students willing to use interactive technology to enhance inspiration?
Usage Behavior (UB)	Does the student actually use interactive techniques to reduce fixation?	Are students using interactive technology to get inspiration?	Whether students actually use interactive technology to enhance creativity

3.2 Method

This study used questionnaires to collect relevant research data to explore students' attitudes toward applying interactive techniques to the digital media basic modeling course. The design of the questionnaire consists of three parts:

The first part is basic information, including the student's gender, age, grade, and length of study.

The second part is the student's acceptance of interactive technology. Using the scale method, 12 questions (Table 2) are designed based on the concepts and contents involved in the research structure. This study used the Likert 5-point scale to survey students' recognition of problem descriptions.

Table 2 Items in the second part of the questionnaire

	Factor	Question
PU	Fixation	1. For me, interactive technology is not very useful.
	Inspiration	2. Using interactive technology can give me more inspiration.
	Creativity	3. Use interactive technology can enhance my creativity.
EU	Fixation	4. I can learn well without interactive technology.
	Inspiration	5. Interactive technology can easily inspire me.
	Creativity	6. Interactive technology can easily bring me creativity.
IU	Fixation	7. I don't want to use interactive technology.
	Inspiration	8. I want to try interactive technology to enhance my inspiration.
	Creativity	9. I want to use interactive technology to help me improve my creativity.
UB	Fixation	10. I did not use interactive technology for classroom learning.
	Inspiration	11. I used interactive technology to enhance my inspiration.
	Creativity	12. I used interactive technology to help me improve my creativity.

The third part is the student's comprehensive view of the digital media course, in the form of semi-open questions, allowing students to freely play their views on the topic. There are three questions: (1) If you think interactive technology is useless, describe why? Then what kind of use do you want it to be? How would you learn digital media basic modeling without using interactive technology? (2) If you think interactive technology is very useful, please list several places that you think it works, for example: why you think it can bring you inspiration and creativity. (3) If you use interactive technology to learn the digital media basic modeling, please briefly describe how you will use it, for example: how you can use interactive technology to enhance your inspiration and creativity.

3.3 Participants

The subjects are undergraduates the digital media art of class 2018 in a university with engineering background in Zhuhai, Greater bay area of China. Among them, 16 were boys and 19 were girls. They were between 18 and 20 years old; the ages are between 18 and 20 years old; they are currently in their first year, and they have been studying digital media design for less than one year.

3.4 Procedure of Questionnaire survey

The questionnaire survey of this study was conducted synchronously with the professional course "Digital Media Basic Modeling". This course involves 48 class hours. The course involves two interactive technologies processing and Arduino, corresponding to concept modeling and physical modeling. The course requires students to create an entity's digital media modeling work in the form of a group. Questionnaires were distributed and collected through the online questionnaire platform. The quantitative data collected from the questionnaire were analyzed using SPSS 22.0, and the open questions were extracted by coding.

4 Results and Discussion

After the questionnaire is completed, they will be collected uniformly, the access permission of the online questionnaire will be closed, and the result of the questionnaire will be exported to XLSX format for subsequent processing. 35 questionnaires were issued, 35 questionnaires were returned, 35 valid questionnaires, and 0 invalid questionnaires. First of all, the questionnaire answers are processed separately in this study, and multiple-choice questions and short-answer questions are divided into two parts for separate processing. Secondly, according to the research framework, the factors are processed one by one.

4.1 Student acceptance of interactive technology

1. Perceived usefulness of interactive technology

Only one student made it clear that interactive technology is useless. The rest of the students said that interactive technology is useful for learning the digital media basics modeling, and one in four people made “very useful” choices. But almost all of the students said that “interactive technology helps to increase their inspiration and creativity”. Even the one who opposed the interactive technology chose the answer of the positive attitude "agree".

2. Perceptual interactive technology ease of use

For the project, half of the students said that there is a close correlation between interactive technology and better learning digital media modeling, while the other half choose “no feeling”. Among the questions about interactive design that can be inspiring, one-third of the students chose “no feeling”, 1/3 chose “agree”, and the rest chose “disagree”. In the question about the interaction design that can bring creativity, basically the same as the previous question, in the question about the interaction design can bring inspiration to the person who chose “no feeling”, also choose "no feeling" in the creativity question.

3. Willingness to use interactive technology

Except for one classmate who made it clear that he didn't want to use interactive technology, the remaining students made it clear that they wanted to use interactive technology. Among them, half of the students chose “completely disagree” and the other half chose “disagree”. In the question of trying to use interactive technology to enhance inspiration and creativity, all students chose “agree”, and one of them chose “completely agree” in the inspiration question, and two of them were chose “completely agree” in the creativity question.

4. Usage behavior of interactive technology

In the question of using interactive technology in the classroom, two-thirds of the students said they used interactive technology. In the question of using interactive technology to enhance their design inspiration and creativity, most students chose “agree”, and only a few students chose “no feeling”.

4.2 Students' comprehensive view of digital media courses

1. About the practicality of interactive technology

Most of the students' responses are positive, such as "I don't think interactive technology is useless", "I think interactive technology is useful", "useful" and so on. In addition, in the sub-question "What do you want interactive technology to use?", some students said that "I hope that through interactive technology can bring me more help in design" and "I hope to be able to use it in the classroom." Other students suggest "I hope to have some interactive devices for everyone to experience in the classroom." In the last sub-question, students said that if they don't use interactive technology, they will pay more attention to "using drawing software on the computer", "film, CG, animation, etc.", "photography or filming video microfilm", “Pay more attention to artistic modeling”.

In general, the attitude of students to interactive technology is generally accepted, but the scope of interactive technology is not clear. The students' understanding of the basics of digital media shows a two-pole pattern, one end is interactive design, and the other end is film and photography.

2. About the ease of use of interactive technology

Nearly half of the students said that the interactive technology is very fresh, interesting and impression. In addition, some students mentioned that “can develop oneself very big imagination space”, “I think it is very fun and lead to thinking, ..., so creativity is also improved.” “This will make me think in many ways... There will be a lot of different inspirations in the process...and this is a process of creation itself, "I can think more broadly in an interactive world" and so on. Some students think that the interactive technology "can be more convenient to make... can create different things at any time, can modify the dissatisfaction", "thinking about the interaction mode will make me adjust the details of the work, maybe the inspiration will come out from the details I don’t pay attention to”, “Let me have more choices when I create.”

In general, most of the students' ease of use of interactive technology is still in the stage of rational understanding. The understanding of interactive technology is mainly judged by their former own life experience, not the interactive technology itself, but they can still experience the convenience that interactive technology brings to their design activities.

3. About the usage behavior of interactive technology

In the question of how to use interactive technology, the students' answers lacked a sense of unity. Some students said that "to make our game more real and interesting, can interact with real people", and some students want to "do some small things that they can usually use in the dormitory, to facilitate themselves, and to add some fun to the dormitory life." Some students "hope that the teacher can take us to try to do a complete project, step by step to complete such a process." Some students want to “build an interactive design game”, “pay more attention to visual beauty in their own designs”, and “make a simple interaction behavior become interesting”.

In general, students have their own unique ideas on how to use interactive technology, which can be roughly divided into three categories. The first category, independent, this type of students generally hope to use interactive technology to improve their design; the second category, explorer type, this type of students will try to use interactive technology to carry out design activities, but there is no clear Design goals; the third category, which requires help, this type of classmates need external assistance for learning interactive technology.

5 Conclusion

The survey results show that interactive technology is not only an integral part of the basics of digital media, it can also enhance design inspiration and creativity for first-year students who have just entered the campus. Not everyone accepts the introduction of interactive technology into the classroom, so students need to adjust the syllabus and change teaching methods. In addition, the scope and content of the interaction design is not very clear, and the corresponding knowledge points need to be covered in the subsequent courses. In the digital media basic modeling course, the practicality, ease of use and intention to use interactive technology are introduced. The students generally show a positive attitude and embrace the interactive technology rather than hostile attitude. This is similar to the previous studies. However, in terms of the use of interactive technology, the students' responses are slightly different. In addition to the regular use of interactive technology, there is a need to add more interactive devices in the classroom, and more technical assistance is needed from teachers. However, it is worth noting that almost all of the responses do not involve content that works with others, although the class is grouped in the very first time and the group continues until the end of the course. In terms of fixation, inspiration, and creativity, the most difficult problem to solve is still in fixation. Even if visual effects such as generative art, parametric design, and information visualization are introduced in the classroom, some students still maintain the attitude of “away from the computer and embrace the brush”. This is also the case when teaching related computer-aided design courses. The last problem found in the study was the relationship between interaction design, photography and film and television design. Some students don't know much about these concepts. They can only use the production tools to classify them, but they can't really understand these nouns, the meaning behind it and its historical roots are also the areas that need to be introduced in the future curriculum design.

6 References

Alcaide-Marzal, J., Diego-Más, J. A., Asensio-Cuesta, S., & Piqueras-Fiszman, B. (2013). An exploratory study on the use of digital sculpting in conceptual product design. Design Studies, 34(2), 264-284.

Atilola, O., Tomko, M., & Linsey, J. S. (2016). The effects of representation on idea generation and design fixation: A study comparing sketches and function trees. Design studies, 42, 110-136.

Bernal, M., Haymaker, J. R., & Eastman, C. (2015). On the role of computational support for designers in action. Design Studies, 41, 163-182.

Chen, Y., Zhao, M., Xie, Y., & Zhang, Z. (2015). A new model of conceptual design based on scientific ontology and intentionality theory. Part II: The process model. Design Studies, 38, 139-160.

Cheng, P., Mugge, R., & Schoormans, J. P. (2014). A new strategy to reduce design fixation: Presenting partial photographs to designers. Design Studies, 35(4), 374-391.

Cleveland, P. (2004). Bound to technology—the telltale signs in print. Design Studies, 25(2), 113-153.

Corsini, L., & Moultrie, J. (2018). A review of making in the context of digital fabrication tools. Proceedings of International Design Conference, DESIGN, 3 1021-1030.

Crilly, N., & Cardoso, C. (2017). Where next for research on fixation, inspiration and creativity in design?. Design Studies, 50, 1-38.

Davis, F. D. (1985). A technology acceptance model for empirically testing new end-user information systems: Theory and results (Doctoral dissertation, Massachusetts Institute of Technology).

El-Zanfaly, Dina. (2015). [i3] imitation, iteration and improvisation: embodied interaction in making and learning. Design Studies, 41, 79-109.

Gürsoy, B., & Özkar, M. (2015). Visualizing making: Shapes, materials, and actions. Design Studies, 41, 29-50.

Jeffries, K. K. (2007). Diagnosing the creativity of designers: individual feedback within mass higher education. Design Studies, 28(5), 485-497.

Knight, T., & Stiny, G. (2015). Making grammars: From computing with shapes to computing with things. Design Studies, 41, 8-28.

Legris, P., Ingham, J., & Collerette, P. (2003). Why do people use information technology? A critical review of the technology acceptance model. Information & management, 40(3), 191-204.
McLuhan, M., MCLUHAN, M. A., & Lapham, L. H. (1994). Understanding media: The extensions of man. MIT press.
Sosa, R., Rojas, N., Gero, J. S., & Xu, Q. (2016). Visual divergence in humans and computers. Design Studies, 42, 56-85.
Stones, C. , & Cassidy, T. . (2007). Comparing synthesis strategies of novice graphic designers using digital and traditional design tools. Design Studies, 28(1), 59-72.
Taherdoost, H. (2018). A review of technology acceptance and adoption models and theories. Procedia manufacturing, 22, 960-967.
Tang, H. H., Lee, Y. Y., & Gero, J. S. (2011). Comparing collaborative co-located and distributed design processes in digital and traditional sketching environments: A protocol study using the function–behaviour–structure coding scheme. Design Studies, 32(1), 1-29.
Thoring, K., Desmet, P., & Badke-Schaub, P. (2018). Creative environments for design education and practice: A typology of creative spaces. Design Studies, 56, 54-83.
Vardouli, T. (2015). Making use: Attitudes to human-artifact engagements. Design Studies, 41, 137-161.
Vasconcelos, L. A., & Crilly, N. (2016). Inspiration and fixation: Questions, methods, findings, and challenges. Design Studies, 42, 1-32.
Venkatesh, V., & Davis, F. D. (2000). A theoretical extension of the technology acceptance model: Four longitudinal field studies. Management science, 46(2), 186-204.
Xu, S., & Fan, K. K. (2017). A Silent Revolution: From Sketching to Coding–A Case Study on Code-based Design Tool Learning. Eurasia Journal of Mathematics, Science and Technology Education, 13(7), 2959-2977.

About the Authors:

Song Xu: He is currently a doctoral candidate at National Yunlin University of Science and Technology (YunTech). He is also a lecturer in Beijing Institute of Technology, Zhuhai. His areas of specialty are interaction design, artificial intelligence, and design education.

Kuo-Kuang Fan: He is currently a professor at the Graduate School of Design at the National Yunlin University of Science and Technology. His areas of specialty are design theory, media research, game and interactive design, cross-cultural research.

Chen Li: She is currently a doctoral candidate at National Yunlin University of Science and Technology (YunTech). She is also a lecturer in Beijing Institute of Technology, Zhuhai. Her areas of specialty are gerontechnology design, wearable technology, and design education.

Acknowledgement: We would like to thank the School of Design and Art of Zhuhai College of Beijing Institute of Technology for supporting this research.

Being Animal by Design

Johnson, Sarah

Kingston University, London, UK
sarah@redesigndesign.org

This paper introduces *Being Animal*, an ecoliteracy tool for use in Upper Primary (years 3 to 6), created as part of ongoing AHRC-funded practice-based Design PhD research. The tool utilses design process for educative ends-in-themselves; this is termed by the author *Design as a Learning Process* (DLP). DLP is an engaging, active pedagogy; learner-centred it puts subject knowledge to work with intuitive creative insight to synthesise new ideas and create artefacts that further enhance learning. Through a 'nature-based' design process *Being Animal* seeks to educe ongoing dispositional empathic connection with and as 'nature', known here as *Regenerative Empathy as Nature* (REN). Through a seven stage process pupils connect physically, emotionally and knowledgably with an animal they design as / with / for. It is proposed that practicing relating and appropriately responding to the needs of other-than-humans at this pivotal development stage helps establish an ecocentric, caring, communal, and creative orientation that will rise positively to future personal, social and environmental challenges.

Keywords: Learning

1 Socio-Environmental Context

- Halve CO2 emissions by 2030 and decarbonise by 2050 to keep global warming to liveable levels. (IPCC 2018)

- Restore habitat and end pesticide misuse or insects may be extinct within decades. (Sanchez-Bayo & Wyckhuys 2019)

- 1st May 2019, the UK Parliament unanimously declares an environment and climate emergency

The perilous state of life on earth as we know it is unsurprising to those engaged in an environmental movement that has sounded the alarm for over five decades. We have now reached the endgame. Whether or not we are able to avert the worst-case scenarios of climatic, biological and social collapse (Bendell 2018), it is clear change is coming.

We can either proactively rise to the systemic challenges inherent in the 'wicked problems' (Rittel & Webber 1973) of the Anthropocene, refiguring humankind's relationship with the earth to one of Sustainment (Fry 2012), celebrating our entanglement (Haraway 2016) with the more-than-human (Abram 1996, 2011) and mitigating disaster; or we will need to reactively adapt to a planet radically less hospitable to human life. For good or bad, new ways of being in the world will be required for a time of transition. Both pro- and re-active scenarios call for a resurgence in creativity, and human and other-than-human [re]connection.

2 Ecoliteracy in Schools

In England all local authority maintained schools must adhere to the National Curriculum. Free schools, academies and private schools have freedom to utilise other curricula, or design their own. Of the 16,941 Primary-stage state schools in England 5,444 are academies, 213 free schools, and 11,284 local authority maintained schools (https://www.get-information-schools.service.gov.uk/Establishments/). Whilst only two-thirds of public Primary-stage state schools are required to follow the National Curriculum, all government-funded schools are subject to high-stakes Standardised Attainment Tests (SATs) in English and Mathematics, and formal Teacher Assessment in Science – all aligning with National Curriculum content.

The National Curriculum at KS2 was last overhauled under Michael Gove in 2013. With a narrow and deep focus on English and Mathematics, Gove's changes were pilloried by progressive education experts at the time (Bassey et al, 2013). The National Curriculum in England Key Stages 1 and 2 Framework Document contains statutory requirements and non-statutory notes on the compulsory subjects. 66% of the document's subject pages are given over to Mathematics and English and 19% to Science, leaving just 15% for other subjects. The National Teachers' Union is one of many educational organisations critical of the curriculum and the SATs that drive it (NUT, 2017).

Prior to Gove's intervention, Education for Sustainable Development (ESD) was a stated purpose within the National Curriculum, and various government schemes lent support to ESD policies including Sustainable Schools 2020, Every Child Matters and Building Schools for the Future. According to Sustainability and Environmental Education (SEEd 2017) over 500 organisations worked on ESD in UK schools, providing a support network that has since all but collapsed. In light of disappearing government drivers for sustainability in education, and with no mention of climate change, or biodiversity in the curriculum, there is little external motivation to cover this vital area. The pressures of delivering the core subjects with their attendant testing leaves little space for teachers to explore and pursue sustainability learning. A 2016 survey by SEEd found that time was the most often cited challenge to teaching sustainability (2/3 of respondents). The survey also highlighted a significant skills gap – with 9/10 teachers having received no ESD in their teacher training.

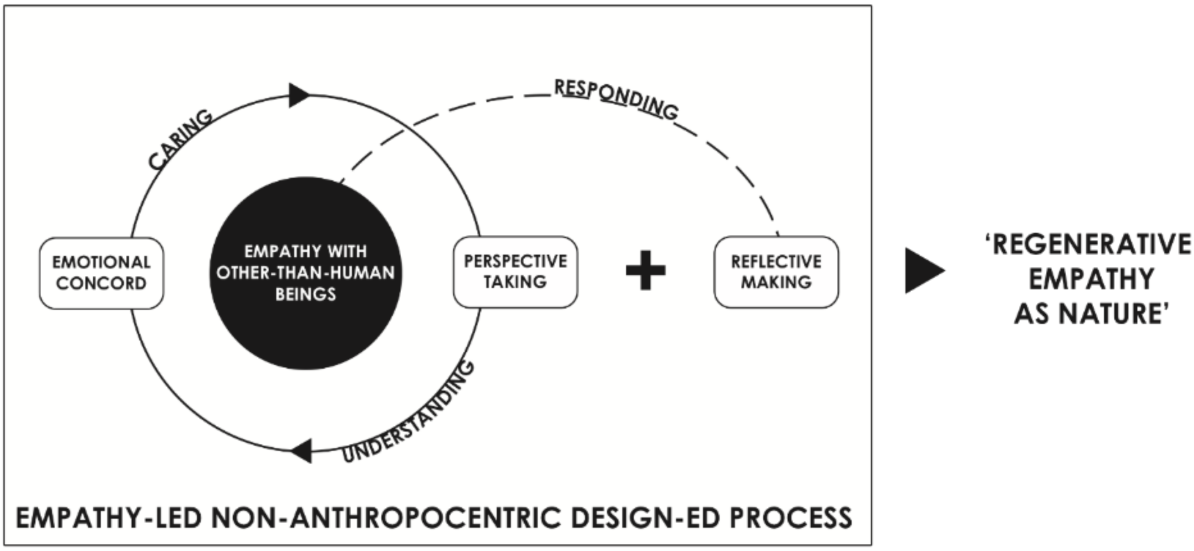
NGOs have attempted to fill the ESD policy gap, and partially inspired by Louv's seminal work on 'nature-deficit order' in children (Louv 2005, 2016) a growing number of programs push for and facilitate outdoor learning and play opportunities for children. These programs are bolstered by plentiful research showing self-reported wellbeing rises from these interventions (RSPB, 2013. National Trust, undated). Intervention by NGOs is welcome, and is supported by a growing evidence base (Lumber 2017), but lacks cohesion.

As it stands the KS2 primary curriculum in England is far removed from the holistic, transformative pedagogical approach advocated by environmental educationists (Kahn 2009, Orr 2004, Jickling & Sterling 2017) and appears to be ever distant from the promotion of an education conducive to uptake of the attributes and skills needed to create future environmental stewards. It is essential that this tide is turned, and reoriented towards creative, whole-school systems-based approaches that promote wellbeing of people and planet. But whilst there is no sign that the current UK government is responding to this need, and any likely alternative sits in the UN 'sustainable growth' dichotomy (Jickling & Sterling, 2017), it is also imperative that appropriate, affective environmental education interventions are targeted within the current system. These interventions should fit the needs of teachers whilst disrupting the current flow. *Being Animal* seeks to fulfil this task.

3 Being Animal Tool

The *Being Animal* teaching tool aims to boost creativity and help [re]connect people to nature and each other. Connection to nature is linked to pro-environmental behaviours, and supports positive mental health outcomes (Lumber 2017). The tool uses a *Design as a Learning Process* (DLP) to draw out *Regenerative Empathy as Nature* (REN) in middle childhood (7-11). It is proposed that practicing relating and imaginatively responding to the needs of other-than-humans at this pivotal development stage helps establish an ecocentric (Leopald 1949), biophilic (Wilson 1993), caring, communal, and creative orientation that will rise positively to future personal, social and environmental challenges. The tool is designed to guide and support whole class delivery of hands-on, affective, empathy-led, formative DLP experiences that educe, nurture and embed REN in Key Stage 2.

The process is designed to create empathy with other-than-human beings through perspective taking exercises. Responding creatively and compassionately to animal needs helps participants to see themselves as nature. The intent is to break down the human-nature divide to create REN – an ongoing, empathic connection as and with the living world.



4 PROCESS OVERVIEW

Being Animal can be delivered as a short project over one or two full days, but is recommended as an extended topic over a half term. Whatever the timeframe chosen for delivery, the seven stages are offered as discrete lessons, and the class moves through the process together.

I FINDING FOCUS	II THROUGH OTHERS EYES	III FRAMING CONTEXT	VI CURIOSITIES	V IDEATION	VI MAKING	VII REFLECTION
Choosing an animal to connect and work with	Taking this animal's perspective	Looking at this animal's needs	Identifying interest opportunity areas	Idea formation designing as / with / for nature	Prototyping designs	Looking back, sharing process

5 STAGES DETAIL

I FINDING FOCUS

Choosing an animal of this land, with an embodied connection by place or presence. Native, local, agricultural, zoo animals can all be picked. A focus on the local is advised in for hands-on scientific enquiry. Teacher choice – select one pathway:

INSIDE

1. Audio Tails: natural history bird audios (choice of 10) supplied online, measure each other to find a dimension that fits (wingspan, beak length etc), listen to matched bird intro in groups
2. ££Handler Visit: animal visits can be an effective way to gain direct experience of different animals, explore feelings, sensations, group by interest
3. £Eye to Eye Cards: print out (in colour on heavyweight stock) and distribute the British animal eye cards supplied
4. Pets: parent bring a pet to class at start of day

INSIDEOUT

5. Recency: the last animal you were with and can remember by touch, sight, smell, evoking memory through sense cues
6. Affection: an animal that is well known to you e.g. a pet, a bird table visitor, a connection that makes you feel warm
7. Alphabet: an animal that begins with the same letter as your first or surname, list as many UK animals as you can think of, share, pick one
8. Character: an animal like you, explore the physical and personality traits you share, and those you wish you shared
9. Visioning: utilising the spoken script supplied to find an animal connection
10. £Literature: stories / poems / natural histories from or about animals e.g. Lost Words, The Last Wild

LOCAL ENVIRONS

11. Nature Spot: visit your local park, use all your senses, upturn deadwood to find mini-beasts, shake a branch onto a cloth, look up/down/across, chart findings, which are you drawn to
12. School: what animals are in your grounds, what stays, what passes through, stopping and looking closely up/down/across, capturing data over time day/night visitors - mammal tunnels, camera, bird table, which are you drawn to
13. Walk and Talk: find a circular walk to go animal spotting, groups of 6 keeping eyes and ears open, take turns to focus up/down/across, stopping, investigating and recording animals en route, which are you drawn to

TRIP

14. £Pond-dipping: a local stream, pond, lake edge provide a rich environment for

exploration (nets, dipping trays, identification sheets, magnifying pots, pipettes)
15. ££Zoo:
16. ££Farm: petting

II THROUGH ANOTHER'S EYES
Taking an alternative perspective. Sensing and imagining through the lens of the chosen animal body. Teacher path choice – select one:
INSIDE
1. Imajourney: blindfolded sensory weather journey, using props (e.g. cardboard wind, spray rain, heater sun), use question prompt sheet)
INSIDEOUT
2. Visioning & sharing: guided using script
3. Day in the life: first person storytelling
4. Embodying animality: moving/dancing/expressing as animal
5. Improvisation: group 'yes and' session, set up scenarios
6. Mask making and speaking as: using natural or scrap materials, listening circle
7. Doctor Dolottie: finger puppet interviews
8. Play on: creating rhythmic music conveying animal movement, culminating in a celebratory party
9. Storyboarding: a social interaction
LOCAL ENVIRONS
10. NatureVoice: photographs or drawings from nature
TRIP
11. ££Natural History Museum

III FRAMING CONTEXT
Looking at the needs of this animal.
INSIDEOUT
Print worksheet provided, research, imagine, complete all:
a) Draw home
b) Family tree
c) Ideal weather
d) Favourite food
e) Play friends
f) Threats and fears
g) Hopes
h) Mission
i) Map habitat and connections
Find links to animals chosen by other participants.

IV CURIOSITIES
Teaming up to probe interest area using mind maps or bubble diagrams
INSIDEOUT
Create Bubble diagram of all:
a) Queries
b) Notes
c) Opportunities
d) Ideas
e) Problems
f) Who, What, Why, Where, When?

g) What ifs?
Answering own questions through research, discussion, reflection.

V IDEATION
Designing as, with or for nature
INSIDEOUT
Perspective (teacher choice – select one):
1. Design AS your animal, consider unique quirks, powers and attributes
2. Design WITH your animal as guide, inspiration and critic
3. Design FOR your animal, something that might be good for them
Briefing area (teacher choice – select one or print and make randomise tool):
1. Communicate
2. Shelter
3. Eat
4. Play
5. Move
6. Clean
7. Safety
8. Rest

VI MAKING
Prototyping designs using a limited selection of recycled and/or natural materials. Teacher choice – select one from INSIDE selection, or up to three from INSIDEOUT:
INSIDE
1. £Scraps sewing (distribute email to parents) Needles
2. Collage (distribute email to parents)
3. Reclaimed packaging modelling (distribute email to parents) optional £Makedo reusable fixings
4. Lego (from Infant classrooms)
INSIDEOUT (perhaps you can make in situ)
5. £Playdough Flour, Salt
6. Sticks (go out and collect)
7. £Cardboard (distribute email to parents) and washi tape
8. £Clay
9. £Paper cutting Craft knives
10. Drawing
11. Painting

VII REFLECTING
On learning and process. Teacher choice – select two to four methods:
1. Open pair and share
2. Likes and dislikes
3. Opportunities for action
4. 5 Whys
5. Sharing circle
6. School display
7. Assembly

6 National Curriculum Links

In order to enhance relevance and uptake the *Being Animal* process ties into the statutory KS2 National Curriculum framework for Science (yr3-6 animals, yr4-6 living things and their habitats). It also supports Art & Design and Design & Technology (yr3-6 practice) through DLP. *Being Animal* is inherently cross-curricular in approach, touching multiple subject areas:

Core Subjects	Connections on all Pathways	Possible choices
English	Spoken language	Composition
Mathematics		Measure, Compare, Interpret and present data
Science	Everyday material properties, Animals, Living things and their habitats, Life cycles	Questioning, Observing, Gathering, recording, reporting data, Weather
Foundation Subjects		
Art & Design	Sketchbooks, Mastery	
Computing		Data representation, Networks
Design & Technology	Design, Make, Evaluate, Technical Knowledge, Ingredients	
Geography	Human/Natural Environments	Mapping, Fieldwork
History		Local history
Music		Create, Compose
Physical Education		Develop, Dance, Outdoor Adventure, Active Lives
Other Subjects		
PSHE	Personal, Social, Health	

Additionally Being Animal supports Social and Emotional Aspects of Learning (SEAL) and traditional 21st Century Skills alongside environmental sensitivity:
Care – empathy, compassion, fairness, humility, kindness
Community – connection, conflict resolution, co-operation, listening
Creativity – curiosity, envisioning, flexibility, responding
Ecocentricity – biophilia, acting as nature, networks
Resilience – intrinsic motivation, self-regulation, self-governance

7 Progressive Pedagogy

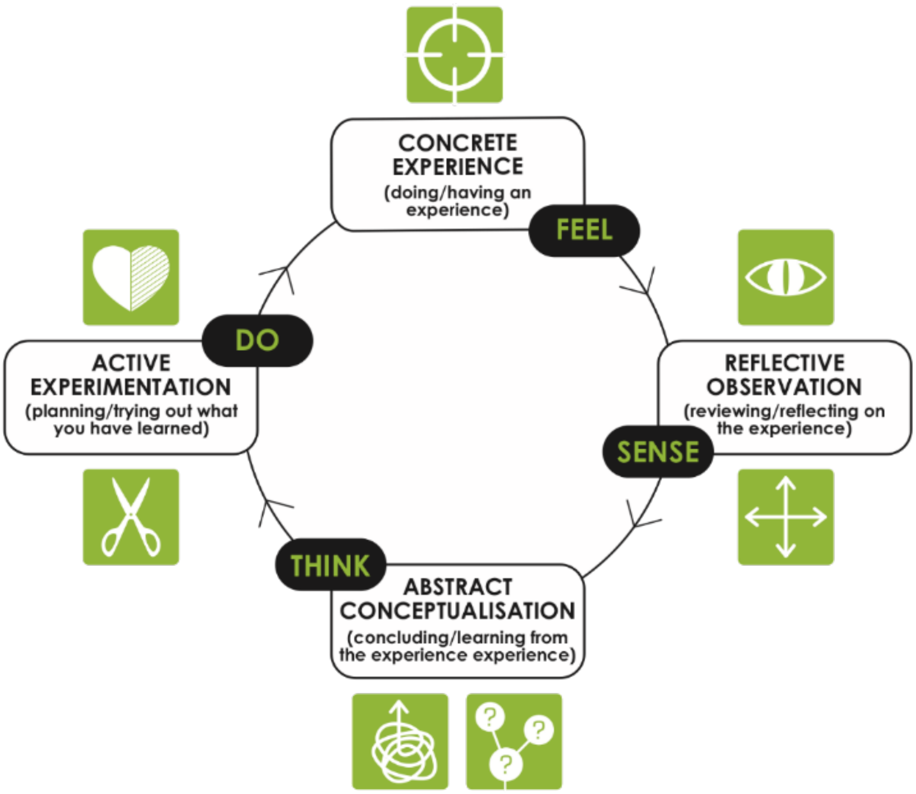
Being Animal draws on ecoliteracy models that emphasise nature connectedness, alongside real world action learning pedagogy and Design-as-Practice (Kimbell 2012). Key influences include Head-Heart-Hands (Orr 1992), which links to Bloom's Cognitive-Affective-Psychomotor Domains (Aubrey & Riley 2019). The Head-Heart-Hands model suggests that engaging a learner mentally, emotionally and physically will have positive long-term outcomes. Systems Thinking (Meadows 2008) allows us to engage in complexity by stepping back see the wider picture. From Deep Ecology (Macy & Brown 2014), comes the idea of dissolving the human / nature divide, and humans acting [and designing] as nature.

The *Being Animal* learning approach is constructivist, influenced by Friere's critical pedagogy (2014), alongside Dewey's notions of progressive democratic learning, Schön's reflective practice and Claxton's learning power (Aubrey & Riley 2019). *Design as a Learning Process* (DLP) has the potential to engage learners at the highest levels of Bloom's taxonomy. When using this tool in KS2 the expectation is that pupils will; apply knowledge, organise and conceptualise stimuli, and engage in non-verbal, artistic communication:

COGNITIVE DOMAIN (knowledge and information)	AFFECTIVE DOMAIN (attitudes and emotions)	PSYCHOMOTOR DOMAIN (practical and physical skills)
Knowledge	Receiving	Reflex movements
Comprehension	Responding	Basic fundamental movements
Application	Valuing	Perceptual abilities
Analysis	Organising and Conceptualising	Physical abilities
Synthesis	Characterising by value or value concept	Skilled movements
Evaluation		Non-discursive communication

Bloom's Domain Taxonomy Hierarchies, adapted from Aubrey & Riley (2019), complexity engaged by Being Animal in KS2.

The seven-stage *Being Animal* process loops into Kolb's learning cycle, with successive stages commencing at later points in the circle.



KOLB'S LEARNING CYCLE
with Being Animal process stages

8 Next steps

The project is an action research testing phase. *Being Animal* will be co-delivered with teachers across 4 schools over different timeframes – from 2 days to 8 weeks. Whatever period is chosen for delivery, the seven stages are offered as discrete lessons, so the class moves through the DLP together. Teachers are encouraged to undertake a significant portion of the process outside, with outdoor classroom, and nature visits inherent in the approach. Observation and unstructured interview data will feed into the next iteration – an online *Being Animal* teaching resource. Beyond the PhD there is scope for the tool to be developed for different users and contexts, and alternative empathy targets.

References

Abram, D. (1996, 2017). The spell of the sensuous: perception and language in a more-than-human world. USA: Vintage Books.

Abram, D. (2011). Becoming animal: an earthly cosmology. USA: Vintage Books.

Aubrey, K. & Riley, A. (2019). Understanding and using educational theories (2nd edition). UK: SAGE

Bendell, J. (2018). Deep Adaptation: A Map for Navigating Climate Tragedy. IFLAS Occasional Paper 2.

Bassey et al. (2013). Independent Letters: Gove will bury pupils in facts and rules. http://www.independent.co.uk/voices/letters/letters-gove-will-bury-pupils-in-facts-and-rules-8540741.html

DfE 2013, The national curriculum in England: Key stages 1 and 2 framework document. https://www.gov.uk/government/publications/national-curriculum-in-england-primary-curriculum

Freire, P. (2014). Pedagogy of hope: reliving pedagogy of the oppressed. UK: Bloomsbury Academic.

Fry, T. (2012). Becoming human by design. London: Berg.

Haraway, D. (2016). Staying with the trouble: Making kin in the Chthulucene. USA: Duke University Press.

IPCC. (2018). Summary for policymakers. Global warming of 1.5°C. An IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. Switzerland: IPCC.

Jickling & Sterling. (2017). Post-sustainability and environmental education: Remaking education for the future. Palgrave: Switzerland

Kimbell, L. (2012) Rethinking Design Thinking: Part II, Design and Culture, 4:2, 129-148

Kahn, R. (2009). *Critical pedagogy, Ecoliteracy, and planetary crisis*. Oxford: Peter Lang

Leopold, A. (1949, 1968). A sand county almanac and sketches here and there. USA: Oxford University Press.

Louv, R. (2005). Last child in the woods: Saving our children from nature-deficit disorder. Atlantic Books: London.

Louv, R. (2016). Vitamin N: The essential guide to a nature-rich life. Atlantic Books: London.

Lumber, R. et al. (2017). Nature connections 2016 conference report: Implications for research and practice. Derby: University of Derby.

Macy, J. & Brown M. (2014). Coming back to life. Canada: New Society Publishers.

Meadows, D. (2008). Thinking in systems: a primer. USA: Chelsea Green Publishing.

National Trust (undated). Children & Nature https://www.nationaltrust.org.uk/children-and-nature

Orr, D. (1992). Ecological literacy: education and the transition to a postmodern world. USA: State University of New York Press.

Ore, D. (2004). Earth in mind: On education, environment and human prospect. Island Press.

Rittel, H. & Webber, M. Policy Sci (1973) 4: 155. https://doi.org/10.1007/BF01405730

RSPB. (2013). Connecting with nature. http://www.rspb.org.uk/our-work/our-positions-and-campaigns/positions/education/research/connection-to-nature.aspx

Sanchez-Bayo, F. & Wyckhuys, K. (2019). Worldwide decline of entomofauna: A review of its drivers

SEEd. (2016). SEEd ESD Survey 2016: An update on the challenges and barriers to embedding ESD in the school system in England. Hove: SEEd.

SEEd. (2017). EASEE Launch Event, London Southbank University

Wilson, E. (1993). The Biophilia Hypothesis. Washington: Shearwater.

About the Author:

Sarah is a changemaker, propagating socio-environmental flourishing through design. On graduating Goldsmiths EcoDesign BA in 2003 she founded [re]design, to help move the industry towards sustainability. A keen collaborator Sarah's diverse output includes tools, books, workshops, lectures, products and exhibitions.

Acknowledgement: This research is funded by LDoc and supervised by Dr Paul Micklethwaite, Kingston University London.

Creativity assessment in design: an experimental study

Iacob, Alis*; Hudson, Grahame

De Montfort University, Leicester, United Kingdom
alis.iacob@dmu.ac.uk

This research study presents an investigation of creativity assessment in design education. 50 years of research in field seemed to have lead to more questions than answers, as despite a theoretically rich body of knowledge, it is yet to be determined what is creativity and how is this assessed in design education. The gaps in the literature which ranged from not having a clear, universally agreed upon assessment criteria to not knowing who should assess creativity, exposed an opportunity for contribution to creativity in general, and creativity in design academia, in particular. Set as experimental study, this research proposed a theoretically underpinned method of investigation, the Creativity Genoplore that implied a two-stage study: design product generation (geno) followed by design product assessment exploration (plore). Following the development of a simple creativity problem (CBoard), 68 design students produced design outcomes, which were consequently assessed by 47 design academics. Upon the analysis of the results, it was found that while from a theoretical point of view, a universal understanding of creativity does not exist, within the remits of this experiment the academics agreed with each other on the creativity of the design outcomes. The results of the study also found that there might be value in centring further investigations on what does not constitute a creative design outcome.

Keywords: creativity, creativity assessment, creativity in education, design creativity

1 Introduction

The following document has at its centre the study of creativity assessment in design higher education. The investigation emerged after an anecdotal observation promised a research project, which had the potential to enable contributions to the field of creativity and design education. The observation was a simple one: within the academic environment, both students and academics often used the word creativity, but they seemed to struggle to articulate its meaning. On one hand, creativity seemed to fit comfortably in everyday academic vocabulary, while on the other hand, clear explanations on what is creativity and particularly how is this assessed in design academia, became polarising.

Set as an experimental study, the investigation aimed to isolate the assessment of creativity by following a theoretically underpinned method of investigation: the Creativity Genoplore (CG). This implied a two-stage study design: design product generation (geno) followed by design product assessment and exploration (plore). The CG model was proposed as the literature exposed a methodological gap, which was caused, by the limited number of creativity studies conducted at the cross between design and education. 50 years of research in field seemed to have lead to more questions than answers as despite a theoretically rich body of knowledge, a universally agreed upon understanding of creativity is yet to be established.

While gaining momentum since 2009, creativity and the creative economy, are only now on the global agenda, as experts urge that academia cannot afford any longer to only vaguely understand creativity. The gaps in the literature, which ranged from: **(a)** The absence of a clear definition of creativity in design education; **(b)** a fragmented understanding of assessment criteria; **(c)** The ambiguity around how should the assessment of a design product be carried out. These gaps showed that creativity and its assessment are yet to be fully understood.

2 Research Background

An initial review of the available material in creativity education was made possible by looking into the findings of a project published by Williams, Runco and Berlow (2016) who mapped out creativity as a research field. Employing a content and trend analysis on 1891 articles published between 1965 and 2012, Williams, Runco and Berlow (2016) reported amongst other findings that creativity in education has been previously investigated. While the number of documents published around creativity in education was low 98/1891 the review did show that the topic has been explored. According to Williams, Runco and Berlow (2016) design was researched in creativity in combination or in context with other keywords such as:

> *design, chance discovery, drawing, human-computer interaction, methodology, outcomes, craft, learning, examples, creative product, constraints, teaching (P.390)*

Looking beyond this review, it was found that 2009 was a year of significance within the field of creativity, as efforts to identify practical ways to understanding it in education have been reported since then. According to Villlalba (2012) the Joint Research Centre of European Commission together with the Creativity Research Journal initiated in 2009 a debate on the importance of understanding creativity from a policy maker perspective. European Commission researchers urged that creativity should be included when making decisions on educational systems (European Commission, 2011). The results of this initiative lead the European Council to conclude that education can no longer afford to ignore creativity within their curriculum. These findings, showed that while creativity in education was not necessarily on the global research agenda before 2009 and comparatively not much had been published around the topic within the last 25 years, efforts to draw attention towards it are proactively made. The 2009 spike in the research trends was also interpreted as evidence that globally creativity is becoming relevant. Despite this, in the European Journal of Education, Collard and Looney (2014) stated:

> *There is no widely shared definition of creativity in education policy or in school curricula (Cachia et al., 2010). Nor are there any clear reference standards for judging the quality of learners' creative products (…) At the same time, learners receive little guidance on how they might improve or deepen their work. Neither teachers nor learners are encouraged to develop their own sense of what counts as high-quality creative work (P.351)*

Further looking into the literature, it was found that while a sense of urgency to understand creativity exists, globally, when filtered trough to education, creativity as research topic is even more ambiguous and vague (Perry and Collier, 2007). While this was a less comfortable finding to accept, it appeared that creativity is not understood in education, meaning that its assessment is as expressed by Plucker, Beghetto and Dow (2004) done following a 'know it when you see it' approach. Furthermore, a theoretical tension was also observed in the literature. On one hand globally, creativity was seen as economic currency, which possibly caused a rise in its research, while education was answering to this need somewhat blindly. In an editorial published in the London Review of Education (2012) the authors Coate and Bolous (2012) commented on this imbalance by stating that:

> *universities are called upon becoming centres for creativity and innovation at the heart of knowledge economy, but they are expected to do so without a shared understanding of what creativity is (p.135)*

These findings showed that education is perhaps taking a reactive approach to understanding creativity as opposed to looking at this proactively. As such, opportunities to make contributions to this area seemed possible.

3 A proposed answer: The Creativity Genoplore study design model

In an attempt to pin down how the assessment of creativity in design education was being carried out, the research project followed, as previously stated, an experimental methodological approach by proposing a Creativity Genoplore model (*Genoplore is a notion which is defined as methodological approach which implies two stages: generation and exploration*).

In this particular case, the proposed Creativity Genoplore model implied the generation of a designed product, in order to explore its assessment implications. The Creativity Genoplore model was based on a review of creativity as a field of research and included areas such as past and present creativity assessment techniques in the context of controlled experimental research. This in turn, meant that in stage one: generation stage, a creativity problem had to be put together in order to produce new design products; while in the exploration stage the assessment of the objects was considered.

Literature on the fundamentals of design such as: shape, colour, size and structure informed the proposed creativity problem, which was named the Creativity Board Problem (CBoard©). Consequently, design students were recruited to answer the problem and generate a design product (as per the stage one of the Genoplore study design). The design problem consisted in asking students from a variety of design disciplines to generate a creative composition by using 16 shapes (eight quarter of circles and squares black and blue) in a predefined space (40x40cm). To complete the problem, the students were given three minutes.

Upon responding, individually, to the CBoard© creativity problem, 68 design products were generated (please refer to the image below).

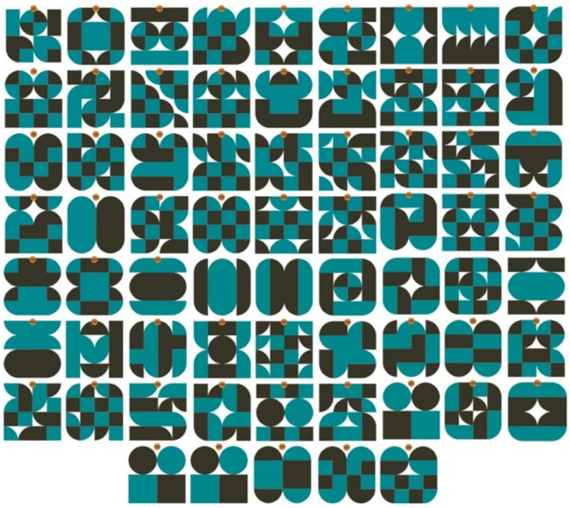


Fig. 1: CBoard responses

In line with the methodology and the Creativity Genoplore study design model, the second stage was to explore the assessment of the 68 newly generated design products. Within this stage, 47 design academics, mostly from De Montfort University, were asked to judge the CBoard© responses generated by the students.

The experiment hoped to mimic the assessment process in design education, however this had to accomplished in controlled settings. As such, the protocols for assessing the newly generated CBoard© responses were set according to literature findings and implied the application of an existing technique: Consensual Assessment Technique (CAT) (Amabile, 1996). According to the CAT, the assessment of the products had to be made independently and agreement must be achieved without the opportunity to influence one another. Another essential condition expressed by Amabile (1996) indicated relative judgement; as the academics were to rate products relative to each other and not against an absolute standard. Lastly, the products had to be always presented to the assessors in a different random order (Amabile, 1996). As a result, following the CAT protocols the design academics were asked to sort the 68 products on a Likert scale as follows: very uncreative (1), rather creative (2), undecided (3), rather creative (4) and very creative (5). During the individual judging process, the academics were also asked to 'think aloud' in order to externalise their thinking process. The judging activity concluded with an open question in an attempt to find out what do the design academics think creativity means in the given context.

4 Preliminary findings

Following a statistical analysis of the assessment of the 68 CBoard© design objects, the formulation of the following conclusions was made possible.

4.1 Agreeing on the extremes

In the controlled settings of the experiment, the 47 academics agreed with each other on which are the very uncreative and very creative CBoard© responses. Employing a Cronbach Alpha statistical analysis, the agreement scores were 0.831 which was considered according to the literature good (Silvia et al, 2008). For example 42 out of the 47 design academics scored the composition on the left 1 (very uncreative) while 43/47 scored the composition on the left 5 (very creative). These agreement scores, indicated, in turn, that while there is no written agreement on what is creativity and how is this assessed, academics still know what they are looking for when it comes to the creativity of a design outcome. As such, it would appear that creativity is not assessed on a ‘know it when you see it approach’.

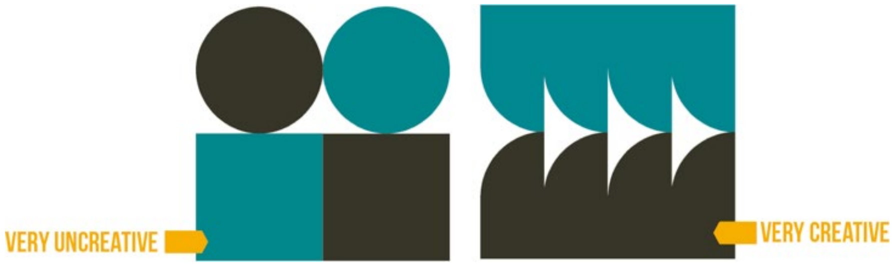


Fig. 2: CBoard© responses: very creative vs very uncreative

4.2 Easier to judge what is not creative

Based on the frequency of the very uncreative and rather creative scores; the academics appeard to be able to judge easier what was not creative. This conclusion was supported by averaging the 1-5 scores in relation to the agreement scores. The data showed that 39 out of the 68 responses generated by the students were placed by the academics in the very uncreative or rather uncreative categories. This further showed that academics might find it easier to pin point what is making a design response uncreative rather than creative. The ‘know it when you see it approach’ would therefore be reframed to ‘ know it when you don’t see it’.

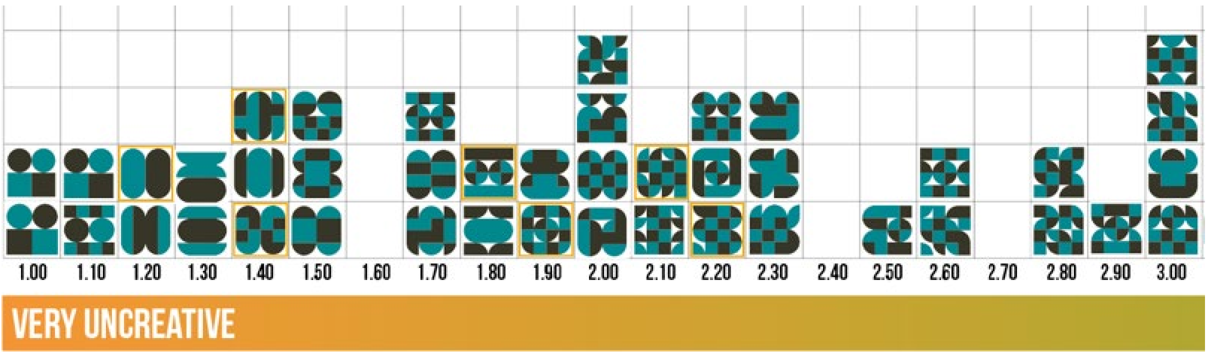


Fig. 3: CBoard© responses: very uncreative

5 Preliminary Conclusions

While the findings of this investigation are more complex and the data is yet to be fully analysed, these preliminary results seem to show that there is a possibility to contribute to the ongoing dialogue on assessing creativity in design higher education. The findings showed that reframing the research problem might provide some much needed answers. Based on this and following the controlled experimental methodology, this investigation proposed to ask why design outcomes produced by the students are not creative instead of asking why these are. By doing so, perhaps education could take a proactive approach in the journey to finding a universal understanding of creativity; even if this means exploring what creativity is not.

6 References

Amabile, T. (1996). Creativity in context: Semantic and perceptual processes in symbolic comparisons. *Journal of Experimental Psychology: Human Perception and Performance*, 3, 278– 290.

Cachia, R., Farrari, A., Kearney, C., Punie, Y., Van den Berghe, W., & Wastiau, P. (2009). Creativity in Schools in Europe: A Survey of Teachers (*JRC Public Information Documents, JRC* 55645).

Collard and Looney (2014) Nurturing Creativity in Education European *Journal of Education* 49 (3)

European Commission (2011) Conference Can creativity be measured? Available from: http://c.europa.eu/education/lifelong-learning-policy/doc1427_en.html Accessed [11.07.2015]

Plucker, Beghetto, & Dow (2004) Why Isn't Creativity More Important to Educational Psychologists? Potentials, Pitfalls, and Future Directions in Creativity Research *Educational Psychologist* 39(2):83-96

Silvia, P. J., Winterstein, B. P.,Willse, J. T., Barona, C. M., Cram, J. T., Hess, K. I., et al. (2008). Assessing creativity with divergent thinking tasks: Exploring the reliability and validity of new subjective scoring methods. *Psychology of Aesthetics Creativity, and the Arts*, 2, 68–85.

Seville: European Commission - Joint Research Centre - Institute for Prospective Technological Studies. Available at: http://ipts.jrc.ec.europa.eu/publications/pub.cfm?id=2940 Accessed [12/07/2018]

Villlalba (2012) Searching for the Holy Grail of Measuring Creativity Creativity Research Journal 24:1

Williams, Runco and Berlow (2016) Mapping the Themes, Impact, and Cohesion of Creativity Research over the Last 25 Years *Creativity Research Journal*, 28:4, 385-394

About the Authors:

Alis Iacob: Alis Iacob is a Phd candidate at De Montfort University focusing on developing a tool to measure creativity performance in design. She is a lecturer in the Creative Industries with a particular interest in Branding and User Interface Design at De Montfort University / Leicester. Alis is currently combining her creativity related research interests with the practical applications of design as a senior graphic designer.

Grahame Hudson is an Associate Head, postgraduate subject leader and Associate Professor in Design Management at De Montfort University. He is a Senior Fellow of the Higher Education Academy (HEA) and the programme leader for the MA Design Management and Entrepreneurship and a PhD supervisor. His teaching and research areas include design management, design thinking, design project management, business planning, technology transfer and research commercialisation.

Design Thinking for Preschoolers: Encouraging Empathy through Play

Coorey, Jillian; Caldwell Rinnert, Gretchen

School of Visual Communication Design, Kent, United States

Over the last two decades, we've seen an emphasis on math and science education, along with standardized testing, a direct result of legislation and educational reforms meant to improve education for children. The Common Core (CCSS) moved educational decision making out of the hands of local school systems and moved that power to a national level (McCluskey, Rebarber, & Wolf, 2018). Funding for art education was removed, minimized or relegated to the extra-curricular activities. Art and Design programs in the United States are seeing the results in higher education as these children have now matriculated to the college level. Recent graduates are showing less aptitude for creative thought and critical thinking (Land, 2013). Attention and focus have turned towards the reintroduction of art and design in K-12 education with the recent STEAM initiatives (STEAM = Science, Technology, Engineering, Mathematics + Art+ Design) that also emphasize *art and design*.

Many programs and research within this area focus on older children, but preschool curriculum is inherently playful and curious, as such provides a well-suited context for introductory design education. This study seeks to explore how might design be integrated effectively into a Pre-K classroom. Through the integration of design methods, do students begin to display design thinking tasks such as empathy, creative thinking, empathy, and collaboration? To answer these questions, we worked with a preschool summer program to develop design curriculum based on play and inquisitive making. We explored critical thinking and creativity through visual tools and popular children's literature as a starting point, helping to ground the design activity.

Keywords: design thinking; design pedagogy; preschool learners; design thinking; empathy

1 Introduction

Over the past couple of decades, specifically within the United States, there has been a rise in educational standards which prioritize science and math over other subjects. Education reforms, such as the No Child Left Behind (NCLB) Act, signed into law in the US in 2002, focused on an effort to ensure no child would be overlooked. NCLB prioritized core subjects and standardized testing within school systems as a measurement of success. To meet needed scores, "teachers drove their students, often eliminating subjects such as social studies and the arts, in pursuit of student success" (Wexler, 2014). Eight years later in 2010, the Common Core State Standards (CCSS) state-wide initiative for reform was launched. CCSS emphasized the skills students need for college and career success through a set of

K-12 standards. Similar to NCLB, CCSS “aligned national curriculum and standardized testing to the degree that testing inexorably drives curriculum” (Wexler, 2014). In response, numerous schools allocated funds for math and language courses, at the expense of art education (Metla, 2015). Along with these educational reforms, the STEM (Science, Technology, Engineering, Mathematics) movement, emphasizes the importance of these areas in education for a future of global competitiveness and innovative ideas (Land, 2013).

While they vary slightly, these reforms accentuate core subjects of science, math, language—subjects that are testable and quantifiable. This curriculum emphasizes standardization, a nod to an earlier era of faculty systems with mass production, centralized decision making, and passive compliance (Strauss, 2014). At the heart of the CCSS initiative was that decisions and flexible maneuvering by educators eliminated.

> Common Core is the logical endpoint of nearly three decades of Congressionally-mandated centralization through ‘standards-based reform’ that has moved key curriculum content, sequencing and pedagogical decisions away from local school systems and educators to the state and national levels. Instead of the promised accountability for results or informed school choice, the outcome at the local level has been a culture of compliance (“alignment”) that has intruded into the core function of curriculum and teaching. (McCluskey, Rebarber, & Wolf, 2018)

As a result, recent college graduates are lacking creativity and innovation (Land, 2013). The current education system instructs students how to execute tasks, “but rarely fosters curiosity and self-motivation” (Land, 2013, p. 548). Focusing on innovative problem solving, communication, and critical thinking is critical (Carrol et al., 2010, p. 38).

As we look to the future, some educators are beginning to see value in the STEAM (Science, Technology, Engineering, Mathematics + Art+ Design) platform. “Art + Design are poised to transform our economy in the 21st century just as science and technology did in the last century” (http://stemtosteam.org/). Initiated by Rhode Island School of Design, the STEAM movement advocates for the integration of Art and Design within K-20 education (education from kindergarten through university), as a response to schools removing or significantly reducing art offerings in public education.

This paper presents qualitative research as a case study that explores how design can provide new learning experiences, encourage empathy, and creative thinking at the pre-kindergarten (Pre-K) level. Our goal is to introduce the problem-solving methods used by visual communication designers in a Pre-K learning environment. We choose to focus our investigation with 3-to-5-year-olds as “the quality of children’s learning environments prior to age 6 has an influence on later academic success” (Tippett and Milford, 2017, p. 68).

2 The Design Process

First, it is important to define the type of ‘design’ we are using when approaching designing curriculum for Pre-K students. The author’s degrees and expertise are in graphic design, also referred to as visual communication design, with a specific focus on typography, interaction, and motion design. Design “encourages participants to think outside the box in the pursuit of creative or innovative solutions” (Wolniak, 2017, p. 247). While exact definitions and processes vary slightly, the general design process involves research, ideation, iteration, prototyping, testing, and refining until a solution is reached. This problem-solving process is cyclical, with designers often repeating steps along the way. Dubberly

Design Office (DDO) has produced several information graphics regarding the design process, breaking the design process and people-centered research into the following steps: observe > reflect > make > socialize > implement (Chung J. et al., 2009). They define the creative process as iterative and recursive (Figure 1).

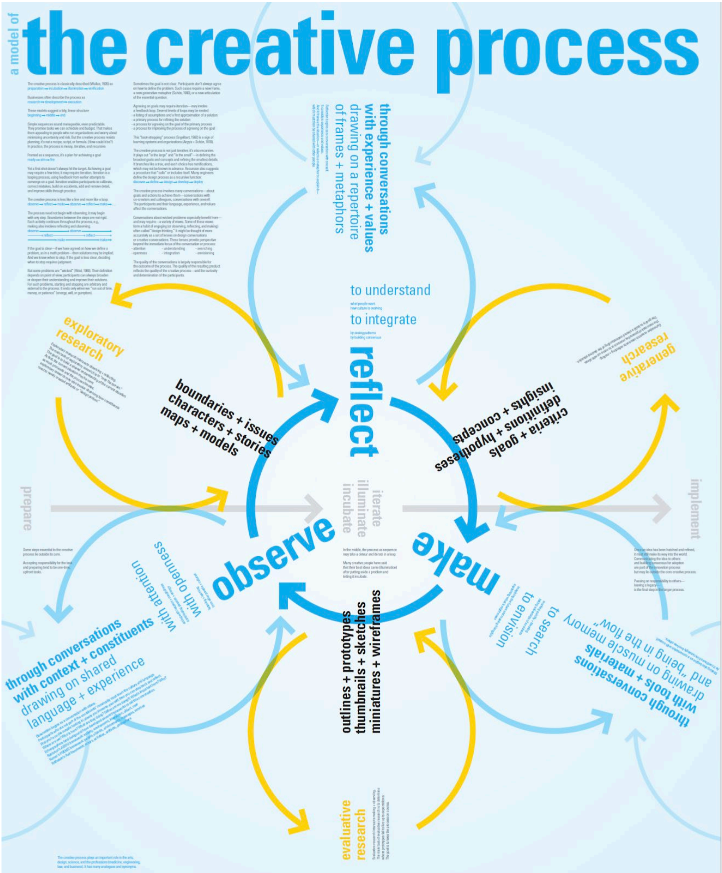


Figure 1. This concept map depicts the creative process. Source: Chung J., Evenson S., and Pangaro, P. 2009.

2.1 Design Thinking

While designers have been utilizing this process for many years, it has recently been popularized by IDEO founder, David Kelley. Design thinking is a methodology which has grown immensely over the years as it is integrated into education and business. Design thinking builds upon the creative strategies that designers use, applying these principles to a range of disciplines from business to social issues (Wolniak, 2017). Along with IDEO, Stanford's d.school uses design as a foundation for learning. According to their website (dschool.stanford.edu), their process involves building upon 'methods from across the field of design to create learning experiences that help people unlock their creative potential and apply it to the world.' The five steps of the d.school's Design Thinking process are: 'Empathize, Design, Ideate, Prototype, and Test'. Similar in nature, the steps in the IDEO Design Thinking model include: 'Discovery, Interpretation, Ideation, Experimentation, and Evolution'.

2.2 Design and design thinking at the PK-12 level

Along with the rise in design and design thinking now practiced in business and higher education, there has been a rise in educators integrating these methods into the PK-12 classroom. At the K-12 level, there are numerous resources and studies (Noel and Liub, 2017; Cook and Bush, 2017; Carrol et al., 2010) of how to integrate design thinking in the curriculum and classroom activities. "As children move from kindergarten to middle school, and then to high school, instruction shifts from stories to facts, from speculation to specifics, and imagination fades from focus. Design thinking is an approach to learning that focuses on developing children's creative confidence" (Carrol, 2010, p. 38). Involving an interactive and dynamic approach to problem-solving, design thinking can enhance the learning experience among preschool and kindergarten students (Lynch, 2018). Not solely related to the subject of design, design thinking used as a learning tool can support a diverse range of interdisciplinary content (Carrol et al., 2010). In contrast to the education reforms involving standardized testing, the design process helps "students develop as deep thinkers and doers, not just as test takers" (Wise, 2016).

The study 'Taking Design Thinking to Schools Research Project' (Carroll et al., 2010), completed in the United States, contributes to research on design thinking within the K-12 classroom. The qualitative study centered around the questions: how did students express an understanding of design thinking, how did affective elements impact design thinking in the classroom, and how is design thinking connected to educational standards and learning (Carroll et al. 2010). The study found that students grasped the design process evident through the vocabulary they used and the artifacts students designed displayed attention to human needs. Through utilizing collaboration, a key element of the design process, they worked together to think creatively and take risks.

In addition to the aforementioned initiatives, there are several organizations looking to reshape the way design is integrated into PreK-12 education. One such example is DESIGN-ED. Established in 2012, the DESIGN-ED coalition's goal is to "develop policies of support for design education at the international, national, state, and local school district levels" (design-ed.org). The organization, which consists of educators, administrators, practitioners and institutions, supports PreK-12 initiatives through resources, events and conferences, and publications.

2.3 Learning Styles and Design Process

The design process may offer a way to engage different learning styles. Kolb's experiential Learning Theory (ELT), based on the work of Dewey, Piaget, and Lewin, provides a "holistic integrative perspective on learning that combines experience, perception, cognition, and behavior" (Kolb, 2014, part 1, section 2, para. 2). Kolb argued that learning is a unique process for each individual "formed and reformed through experience" (Kolb, 2014, part 1, section 2, para. 21).

Kolb identified four modes of learning that provide new experiences and require different abilities: Concrete experience abilities, Reflective Observation abilities, Abstract Conceptualization, and Active Experimentation (Kolb, 2014, part 1, section 2, para. 38). Kolb further explains;

> "Learning requires abilities that are polar opposites, and the learner, as a result, must continually chose which set of learning abilities he or she will bring to bear in any specific learning situation. More specifically, there are two primary dimensions to the learning process. The first dimension represents the concrete experiencing of events at one end and abstract conceptualization at the other. The other dimension has active experimentation at one extreme and reflective observation at the other. Thus, in the process of learning, one moves in varying degrees from actor to observer, and from specific involvement to general analytic detachment" (Kolb, 2014, part 1, section 2, para. 38).

Kolb compared ELT to various models of problem-solving process (Kolb, 2014, part 1, section 2, para. 46). The problem-solving process shares many of the same activities as design thinking, from selecting a problem/goal, evaluating options, selecting and deciding on a way to proceed, executing a final solution and then refining that solution.

Learning theorist Bernice McCarthy summarized learning theories by Kolb and other leading theorists to define 4 unique learner types in her book The 4Mat System:

1. Type 1: Imaginative Learners enjoy developing ideas and brainstorming (McCarthy, 1980, p. 37)
2. Type 2: Analytical Learners create concepts and models. They are abstract thinkers and enjoy summarizing findings. (McCarthy, 1980, p. 39)
3. Type 3: Common Sense learners enjoy practical application and hands-on activities. (McCarthy, 1980, p. 41). These learners would enjoy prototyping.
4. Type 4: Dynamic Learners, who enjoy action, testing and learn by trial and error (McCarthy, 1980, p. 43). These students would enjoy beta testing ideas, and the discovery process that transforms design ideas to verified solutions.

When comparing theories on learning preferences and styles, there is an overlap with the design process, where each learning style is engaged during the act of designing (Figure 2). In a group setting, hypothetically, each child would be able to exercise in their preferred method of learning by using design thinking, therefore taking part and being an active and engaged member of the learning community.

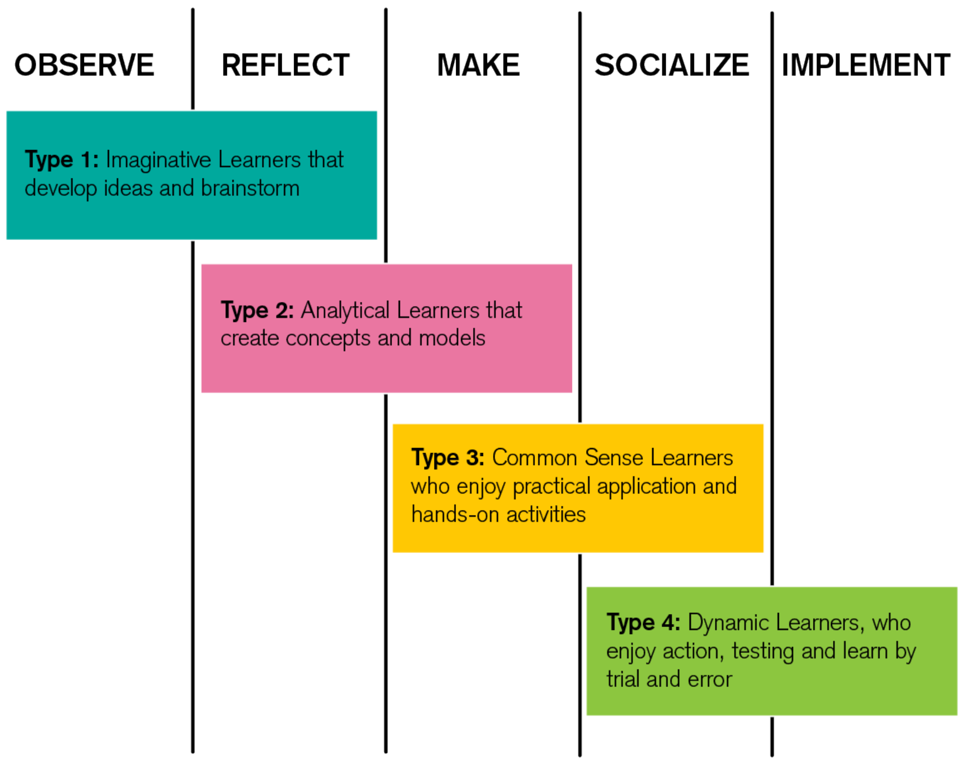


Figure 2: Comparing the creative process to McCarthy's Four Learner Types. Source: Caldwell Rinnert, 2019.

2.4 Skills for the 21st century

With pedagogies involving problem-based learning, human-centered creativity, prototyping, and user testing; most designers would testify to the benefits of introducing children to a design education (Noel and Liub, 2017). "The learning outcomes of design education are consistent with what experts agree are necessary skills, knowledge, and attitudes for individual success and the nation's global competitiveness in the next century" (Davis, 1998, p. 7). According to Meredith Davis, a design educator, the 'problem-solving process' of design affords strategies of use within the K-12 classroom. Since the 1960s, small groups of designers have been working with K-12 educators to demonstrate how design can be used to teach other subjects. The goal is to educate through design by expanding the pedagogical repertoire of teachers in the delivery of content, and, to advocate for creative problem solving within the classroom (Davis, 1998).

In 1997, the National Endowment for the Arts (NEA) published a study titled *Design as a Catalyst for Learning*, which examined how design is being used in K-12 schools. From the case studies teachers cited student benefits including:

- enhances flexible thinking skills
- promotes self-directed learning and assessment
- develops interpersonal and communication skills
- develops responsible citizens
- applies learning to students' lives
- increases student comfort with uncertainty

(Davis, 2004, p. 15)

As shown, research attests to the benefit of an arts and design education. However, within the United States, there has been a decrease in arts education, the effects are especially noted in lower-income and minority populations. Based on a study done by *Americans for the Arts*, in 2008, "African-American and Hispanic students were two times less likely to have access to art programs in their school districts in comparison to their white peers" (Metla, 2015). The National Endowment for the Arts (NEA) reports that low-income high school students who earned few or no arts credits were five times more likely not to graduate from high school than low-income students who earned credits in art, music and design (Metla, 2015).

3 Methodology

This research is a qualitative case study. Our goal was to introduce problem-solving methods used by visual communication designers into a Pre-K learning environment. The following questions directed our research:

1. How might design thinking be effectively integrated into a Pre-K classroom?
2. Through the integration of design methods how will students visually and physically display design behaviors such as creative thinking, empathy, and collaboration?

3.1 Site and participants

Located on a state university campus, the Child Development Center (CDC), is a child care facility primarily used by university employees and cares for children from two through six-year-olds, in toddler, preschool, and kindergarten classrooms. The school's curriculum applies a variety of teaching methods and strategies, and children are exposed to various ways of learning and play. According to their website, part of the CDC's mission includes, "offering an education based on meaningful relationships and, engaging in ongoing inquiry into our own practices". The educators are at the forefront of pre-K pedagogic methods, directly reflective in how they run their individual classrooms. One of the instructors is currently pursuing her PhD, where she has taken courses on how to integrate design in education. Within the current curriculum, the CDC employs learning techniques utilized in design including brainstorming, peer collaboration, prototyping, and experimentation.

During the summer, STEAM camp (Science, Technology, Engineering, Arts, and Mathematics) focuses on weekly themes which introduce various ways of problem-solving to students. The camps are for children ages three, four, and five with each week centering around a different theme. The summer camp attendees are a mix of students, some attend the CDC throughout the year, while others only come for summer programming. Camp sessions last one week and run from 9 AM until noon.

Our involvement consisted of developing the curriculum for a one-week session, detailing supplies, meeting with the instructors prior to the start of the week, and conducting observations. Our curriculum centered on various aspects of design, with each day focusing on a different theme. For this initial research, observational field notes were used for data collection along with photographs of artifacts (prototypes, text, drawings) produced by the students. We rotated between the three different classrooms, which were divided into the age groups of three, four, and five. While daily attendance varied, the average weekly attendance throughout the week consisted of 15 three-year-olds, 8 four-year-olds, and 15 five-year-olds. The students who attend during our session included a mix of races (African American, Caucasian, and Asian), with the gender division between male and female balanced. Additionally, informal conversations with the teachers and students provided supplemental insight into student's comprehension and working methods.

3.2 Curriculum

Each day began with a morning meeting where the weekly theme of design was discussed. Discussion of the design process provided a framework for the children to begin making throughout the week, connecting play and discovery to the design process. Students were read a story that was related to the problem they were going to solve. The stories provided context and information, presented in a familiar and welcoming format. Table 1 is an example of the daily theme along with learning objectives and in class activities.

Table 1 CDC example curriculum chart

MONDAY	
Topic	*Creating Spaces*
Order	Read story, The Black Dog Discussion about the story and locations In class activity Outside activity
Learning objectives	Space and location, scale and contrast
In class activity	Map making of the black dog house, playground, and yard
Outside activity	Hide and seek.
What are they prototyping?	Map poster

While each classroom (3, 4, and 5-year-olds) had the same daily theme, projects varied slightly to account for the students' ages and learning abilities. Within the three-year-old classroom, clear instructions were given and project examples were shown. In contrast, the four and five-year-old activities were open-ended, providing freedom for exploration and inquiry-based learning. The role of the instructor shifts within this environment, evolving from the sole distributor of information to one who designs educational experiences, engaging learners with one another and the material (Love et al., 2014).

To encourage playful interaction and making, everyday recyclable objects, along with general art and craft supplies, were used for most of the projects. A 2017 study by Tippett and Milford conducted research integrating science learning in the Pre-K classroom. Regarding integrating science and STEM learning they state, “Children’s early STEM experiences should be hands-on and allow them to experiment and explore with safe everyday materials in meaningful ways; these types of experiences are related to later academic and social success” (2017, p. 69). Our approach was similar and objects ranging from paper towel rolls to rubber bands, and tin foil provided a platform for creativity (Figure 3). Working with materials is central to art and design education, which is based on doing and making (Noel and Liub, 2017).

Figure 3: Children working with recycled materials. Source: Author, 2018.

4 Observations and results

We began with an analysis of the qualitative data that was collected through our observational notes, photographs, and artifacts of the work produced. Field notes and photographs of the student’s artifacts were used to identify behaviors that were indicative of the design process. Observational notes, consisting of classroom activities and student discussions, were organized by the authors into categories, with evidence of their behaviors noted. From these categories, the authors noted several themes. Students exhibited an understanding of the design process as various themes emerged from their behaviors, displayed in Table 2.

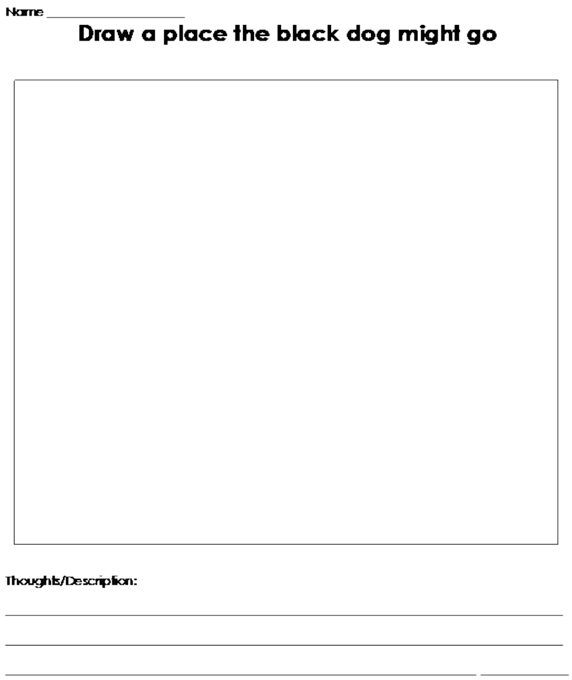
Table 2 Categorizing student behaviors

Category	Behaviors Exhibited	Theme
Student working habits	Two students joining together on a project	Collaboration
	Inventing new aspects of a project, students determined what direction the project would take	Innovation, Creativity, Problem Solving
	Sketching ideas and building plans	Brainstorming, Ideation, Sketching
Exploration of materials	Students were comfortable using a variety of materials with the imaginations to build and construct	Creativity, Innovation
Student discussions	Recognizing others differences and similarities	Empathy
	Defining characteristics of others and characters	Empathy
Student Comprehension	Displaying an understanding of design with how they use terminology. “Design is to create”, “Design is to build”	Design discourse

4.1 Theme: Brainstorming, Ideation, Sketching

Brainstorming is a type of ideation usually used within a team setting to rapidly compile ideas to solve a problem in a non-judgemental and safe space (Dam & Siang, 2018). Brainstorming has been around for a long time and should inspire a group. Brainstorming frequently begins with a problem to solve (Dam & Siang, 2018). Sketching is tightly coupled with brainstorming as people sketch and draw their ideas as they work in order to communicate their thoughts to the group. Sketching can communicate more quickly than text or verbal communication as it gives the participants a mental model to discuss. Sketching can come naturally to children as they often draw ideas and stories for their family and friends. Sketching provides an easy way to communicate complex ideas and thoughts for children who are learning language skills and struggle to express themselves. For children with special needs or experience a speech delay, it may be their preferred method of communication. Brainstorming and sketching activities can help children generate ideas for critical thinking and problem-solving.

Within each classroom three to four learning activities were organized at different stations, as suggested by the CDC educators. Although given a choice with where to begin, the students were instructed to try all activities, even if they might not like something. Within the older classrooms, students were provided with pencils and paper to sketch their ideas prior to making (Figure 4). Terminology such as building plans and brainstorming related this step back to the design process. Upon completion of their sketch, students could begin prototyping.


Name ______________

Draw a place the black dog might go

Thoughts/Description:

Figure 4: Brainstorming paper provided to students. Source: Authors, 2018.

4.2 Theme: Collaboration

Collaboration was evident during the week's activities. Collaboration is a natural part of the design process, as teams work together to solve a problem. A study by Pino-Pasternak, Whitebread, and Neale found that "productive collaboration were marked by demonstrations of positive affect (i.e., smiles, physical proximity, and encouragement); the provision of assistance in the face of challenges; and the presence of interspersed humor and play. These positive behaviors seem to have provided a fertile ground under which students felt confident to engage in cognitive and social challenges" (Pino-Pasternak, Whitebread and Neale, 2018, p.57). They went on to conclude that "dialogue is an extremely powerful tool through which students not only learn content, modes of thinking, or strategies to solve a task, but very importantly, they exert social positions that facilitate or preclude group participation (Pino-Pasternak, Whitebread and Neale, 2018, p.60) They advocated for early childhood collaborative experiences, as even children as young as 5-years-old found it beneficial, but they also expressed a need for curricular planning that managed collaboration and interaction. Collaboration in the classroom can be difficult, and can cause anxiety for everyone involved. Luckily, preschoolers enjoy their peers, and find collaboration to be a social activity. Preschoolers' teachers must play the role of facilitator and note-taker. The maps and "dog traps" the children sketched show the work by multiple children with notes from the teacher, taken as the children discussed their ideas (Figure 5). The design process offers a means to facilitate productive collaboration as children define problems and solutions together, testing and making design prototypes.

Figure 5: Collaborative maps by children and teacher. Source: Author, 2018.

4.3 Theme: Creativity and Innovation

Creativity, linked to problem-solving, is an essential skill which will be needed to generate new solutions to complex problems in the future (Wong and Siu, 2011). Students displayed creativity and innovation throughout the week as they designed solutions to the project prompts. On the first day the teacher read aloud, *Black Dog* by Levi Pinfold, an illustrated children's book about assumptions, fear, and bravery that centers around a black dog in the family's yard. Following story time, the students created maps of the dog's journey throughout a neighborhood as he chases a little girl. Designing a map was part of the project, however, the students took this project a step further as they began to design traps and objects to help catch the dog. Their behaviors display additional complex thinking, and self-initiated exploration. They demonstrated problem-solving behaviors, creativity, and self-directed learning as they used found materials to build and explore.

4.4 Theme: Empathy

The theme of empathy emerged from classroom discussions. After reading the book, *Same, Same But Different* written by Jenny Sue Kostecki-Shaw, which focuses on how humans having similar and contrasting lifestyles, the three-year-olds had a discussion about where they lived and how things were similar but different. Throughout the reading of the book, students were quick to interject with their own comments about how they were alike or different from the characters in the book. At the conclusion when asked about what makes us the same as others, a student stated, 'we all live on earth'. At the heart of these discussions, the students displayed empathy as they began to compare and contrast their lives with each other. "Empathy is a learned skill that is needed not just in design, but in many professions, and therefore empathetic children who grow into empathetic adults are likely to perform better in general and be more successful in life" (Noel and Liub, 2017, p.8). Focusing on empathy through design-based learning is beneficial to all students.

5 Conclusion

Research attests to the importance of a design-based education. However, the creative fields are often overlooked in preference to STEM-based learning. As an alternative to STEM, educators are advocating for the integration of art and design, resulting in STEAM. The STEAM curriculum engages students in cross-disciplinary learning in PK-12 settings and informal education (Bequette and Bequette, 2012).

In response to this challenge, we approached this from early childhood education, beginning in the Pre-K classroom. This initial study engaged Pre-K students in design activities during a weeklong summer program. Through the artifacts created and observations collected, we've begun to see how design can enhance the learning experiences at this level. This study is transferrable to preschool and kindergarten curricula. Since story time is a frequent early learning activity used in both classrooms and libraries, it would be easy to model this strategy in a variety of ways. Story time usually has a focus on literacy. By pairing it with design activities, for instance map making, children are engaged in deep thinking that truly shines when one has a narrative to base ideas on. The narrative provides the children with context and application of the design process connecting literacy with science, math and art/design. By allowing children use story time as the precipice of their exploration, the teachers can engage the class and initiate a conversation, and the activities allowed the children to be makers, creators, artists and designers.

As this was an initial study, further research is needed to fully understand what the best practices are for integrating design at the Pre-K level. Additionally, we acknowledge the limitations of this study. The study was completed during a one-week period and students were not monitored following the program to see if they continued to exhibit design behaviors. The developed curriculum was given to all students, thus there was no control group. Future research could involve developing questions for the parents about their children's use of design terminology outside the classroom, along with conducting follow up interviews with the students and instructors.

6 References

Americans for the Arts. (2008). Decline of Arts Education in Underserved Populations. NEA Office of Research and Analysis. Retrieved March 23, 2019, from https://www.americansforthearts.org/sites/default/files/pdf/2015/by_program/reports_and_data/research_studies_and_publications/ArtsEd_UnderservedPops_2015.pdf

Bequette, J. W., & Bequette, M. B. (2012). A place for art and design education in the STEM conversation. *Art Education*, 65(2),40–47.

Carroll, M., Goldman, S., Britos, L., Koh, J., Royalty, A., & Hornstein, M. (2010). Destination, Imagination and the Fires Within: Design Thinking in a Middle School Classroom. *The Journal of Academic Development and Education*, 29(1), 37–53.

Child Development Center. (n.d.). Retrieved from https://www.kent.edu/ehhs/centers/cdc

Chung, J., Evenson, S., & Pangaro, P. (2009, March 20). A Model of The Creative Process. Retrieved March 23, 2019, from http://www.dubberly.com/concept-maps/creative-process.html

Cook, K. & Bush, S. (2018). Design thinking in integrated STEAM learning: Surveying the landscape and exploring exemplars in elementary grades. *School Science and Mathematics*. 118, 93–103. https://doi.org/10.1111/ssm.12268

Dam, R., & Siang, T. (2018, April). Learn How to Use the Best Ideation Methods: Brainstorming, Braindumping, Brainwriting, and Brainwalking. Interaction Design Foundation Retrieved March 23, 2019, from https://www.interaction-design.org/literature/article/learn-how-to-use-the-best-ideation-methods-brainstorming-braindumping-brainwriting-and-brainwalking

Davis, M. (2004). Education by Design. *Arts Education Policy Review*, 105(5), 15–22. doi: 10.3200/AEPR.105.5.15-22

Davis, M. (1998). Making a Case for Design-Based Learning. *Arts Education Policy Review*, 100:2, 7–14.

Design-Ed. (n.d.). Retrieved from https://www.design-ed.org.

Frequently Asked Questions. (2010). National Governors Association Center for Best Practices (NGA Center) and the Council of Chief State School Officers (CCSSO). Retrieved March 23, 2019, from http://www.corestandards.org/about-the-standards/frequently-asked-questions/

Kolb, D. A. (2014). Experiential learning: experience as the source of learning and development. Upper Saddle River, New Jersey: Pearson Education LTD, 2014. Retrieved from https://proxy.library.kent.edu/login?url=http://search.ebscohost.com/login.aspx?direct=true&AuthType=ip&db=cat02286a&AN=kent.b5694840&site=eds-live&scope=site

Land, Michelle H. (2013). Full STEAM Ahead: The Benefits of Integrating the Arts into STEM. *Procedia Computer Science,* 20, 547–552.

Noel, L., & Liub, T. (2017). Using design thinking to create a new education paradigm for elementary level children for higher student engagement and success. *Design and Technology Education: An International Journal*, 1(22), 501–512.

McCarthy, B. (1987). The 4MAT system : teaching to learning styles with right/left mode techniques. Barrington, Ill. : EXCEL, inc., [1987]. Retrieved from https://proxy.library.kent.edu/login?url=http://search.ebscohost.com/login.aspx?direct=true&AuthType=ip&db=cat02286a&AN=kent.b2188322&site=eds-live&scope=site

McCluskey, N., Rebarber, T., & Wolf, P. J. (2018, September 26). Study Finds Declining Student Achievement and Increased Harm to School Choice Since Common Core. Retrieved March 23, 2019, from https://pioneerinstitute.org/common_core/study-finds-declining-student-achievement-and-increased-harm-to-school-choice-since-common-core/

Melta, V. (2015, May 14). School Art Programs: Should they be Saved? *Law Street*. Retrieved from https://lawstreetmedia.com/issues/education/cutting-art-programs-schools-solution-part-problem/

Pino Pasternak, D., Whitebread, D., & Neale, D. (2018). The Role of Regulatory, Social, and Dialogic Dynamics on Young Children's Productive Collaboration in Group Problem Solving. New Directions for Child and Adolescent Development, 2018(162), 41–66. doi:10.1002/CAD.20262

Strauss, V. (2014, April 2). 10 things wrong with what kids learn in school. *The Washington Post.* Retrieved from http://washingtonpost.com

Tippett, C. & Milford, T. (2017). Findings from a Pre-Kindergarten Classroom: Making the Case for STEM in Early Childhood Education. *International Journal of Science and Math Education,* (15)1, 67–86. doi: 10.1007/s10763-017-9812-8.

Wexler, Alice. (2014). Reaching Higher? The Impact of the Common Core State Standards on the Visual Arts, Poverty, and Disabilities. *Arts Education Policy Review*, 115:2, 52–61. doi: 10.1080/10632913.2014.883897

Wise, Susie. (2016). Design Thinking in Education: Empathy, Challenge, Discovery, and Sharing. *Edutopia*. Retrieved from https://www.edutopia.org/blog/design-thinking-empathy-challenge-discovery-sharing-susie-wise

Wolniak, R. (2017). The Design Thinking Method and its Stages. *Support Systems in Production Engineering,* 6(6), 247–255.

Wong, Y., & Siu, K. (2012). A model of creative design process for fostering creativity of students in design education. *International Journal of Technology and Design Education,* 22, 437–450. doi: 10.1007/s10798-011-9162-8

Designing Active Learning Approach: Students' Satisfaction during a short-term international workshop

Konishi, Hisaka*[a]; Nagao, Toru[b]; Ashizawa, Yusuke[a]; Hatchima, Satoshi[b]
[a] Shibaura Institute of Technology, Tokyo, Japan
[b] Chiba Institute of Technology, Chiba, Japan
* ihisaka@shibaura-it.ac.jp

Active learning methods, such as PBL (Project/Problem Based Learning), workshops, and groupwork, have been integrated into college class so as to develop student skills. Whilst past studies focused on the effect of active learning methods during the class, this study focuses on students' opportunities to participate in short-term workshops involving intercultural communication. In order to design effective active learning environment, this study investigates students' satisfaction with teamwork during a 2-day international workshop. Twenty-six engineering students from one Japanese and one Chinese university participated in the study to interact with unfamiliar team members using limited skills of English and to develop ideas to give a presentation in English at the end of the workshop. Students' satisfaction was evaluated by using 10 reflective questions designed to measure students' contribution to the team. The results indicated that working as a part of a team and enjoying working with teammates were significant predictors of individual satisfaction during the short-term workshop.

Keywords: active learning; teamwork; workshop; satisfaction

1 Introduction

Engineering students around the world has been expected to develop their professional skills, such as problem-solving, communication, teamwork, to succeed in workplace (Lingard, 2010a, 2010b). In response to the increase in demand for those skills, higher educations have utilized active learning methods, such as PBL (Project / Problem Based Learning), workshops, and groupwork, in class (Humphreys, Lo, Chan, & Duggan, 2001; Ruiz Ulloa, & Adams, 2004; Stewart, 2007; Tsuchiya, Silva, Bakar, Chubachi, & Narita, 2015; Channon, Davis, Goode, & May, 2017). Furthermore, students have opportunities to take part in international PBL and workshops (Chen, Lai, Lu, Tsai, Chiang, Huan, & Yu, 2008; Tsuchiya et al., 2015). Nevertheless, there are always dysfunctional groups involving free riding, quiet students, a lack of group dynamics, and student motivation (De Grave, Dolmans, & Van Der Vleuten, 2002; Channon et al., 2017). De Grave et al. s' study (2002) reported that unequal participation often occurred during group work and identified lack of motivation hindered successful learning processes in which students expected tutors to do something to improve it. The study also found lack of interaction was an important inhibitor.

The effect of students' cultural backgrounds on new learning styles varies. Some researchers concern about international students who are familiar with teacher-centred learning style must face several difficulties in active learning settings because they are not used to active learning methods (Stewart, 2007; Xue, 2013). According to a research of an international workshop held in Taiwan, medical students from non-English speaking background showed performance anxiety when they participated in an international PBL workshop where they had to use English to discuss with team members and to give presentations (Chen et al. 2008). Another study, however, showed that Asian international students in New Zealand rather adopted students-centred learning settings within a few months and preferred the new learning style (Wong, 2004). In addition, Asian international graduate students in the U.S. showing changes in their attitudes towards groupwork resulted in getting used to the new environment and developing language competence (Xue, 2013). Hence, students from non-English speaking countries require some time to get familiar with teacher-centred methods.

Past studies focus on long-term research of the effectiveness of active learning methods in mandatory class (e.g., Pang, Tong, & Wong, 2011; Channon et al., 2017). Students who take such class study with people from the same major and speak familiar language to communicate with. In those studies, team effectiveness is evaluated on the basis of team outcomes, the process of group work, or perceived satisfaction (Thurmond, Wambach, Conners, & Frey, 2002; Pang et al., 2011; Channon et al., 2017). Thurmond et al. (2002) point out that students' satisfaction may relate to their preference of course. The present study investigates students' individual behaviours that affect students' satisfaction with teamwork during a short-term international workshop. Those who participated in the workshop were Japanese and Chinese students. Since Asian students are not used to active learning environment (Stewart, 2007; Xue, 2013), it must be challenging for them to work in unfamiliar groups, to interact with people from different cultural backgrounds, to finish tasks, and to give presentations in English in a short-period of time. In order to increase students' satisfaction with teamwork, instructors should know what students' attitudes relate to their satisfaction and provide appropriate support to their students. Investigating their satisfaction with teamwork, a research question was developed for the current study: What student behaviour improves satisfaction with teamwork during an international workshop?

2 Method

2.1 Participants

Of the 32 engineering and design students, 21 Japanese and 11 Chinese, including two graduate students took part in a workshop (11 women, 21 men, age range: 20 - 27). Those students were from one Japanese and one Chinese university. Participation of the workshop was on a voluntary basis. Students were allocated into five teams randomly on the first day of the workshop. Each team was composed of six to seven students including two or three Chinese students and four or five Japanese students.

2.2 Measures

Their experience during the workshop was examined through a reflection sheet. A total of 26 students filled it out at the end of each workshop. The first and second sections of the sheet were open-ended questions asking students what they did and learnt, what were most useful points, what problems they faced, when it happened, and how they dealt with those problems. Chinese students answered those questions in Chinese, and they were translated into English by a bilingual. In order to examine their satisfaction with teamwork, the last section asked respondents to rate 10 questions on a 7-point Likert scale ranging from 1=strongly disagree to 7=strongly agree (see Table 1 and 2). Those questions that were designed based on prior studies focused on how much contributed to their team (Thurmond et al., 2002; Hendry, G. D, Ryan, G. & Harris, J., 2003; Marin-Garcia, J. A. & J. Lloret, 2008; Lingard, 2010b; Pang et al. 2011). The dependent variable was students' satisfaction with teamwork (item7), and the predictor variables were other items identified as students' attitudes towards their team. All statistical procedures were carried out in R software, Version 3.5.2. and RStudio, Version 1.1.463. The results of reliability analysis indicated that the reliability of the 10 questions of both reflection sheets were considered high with Cronbach's alpha at .90 and omega at .97 for the first survey and Cronbach's alpha at .95 and omega at .99 for the second survey. Besides descriptive analysis methods, multiple linear regression analysis was applied to analyse predictors of increasing students' satisfaction. The sample size was very small, but the outcome of the research was important to understand what contributes students' satisfaction with teamwork.

2.3 Procedure

The 2-day workshop was held at a university in Japan. The purpose of the workshop was to explore the value and the meaning of Japaneseness through fieldwork and discussions. The reflection sheet was distributed two times at the end of each day. Table 1 shows the schedule of the workshop. On the first day, students were allocated into five teams and had an ice-breaking activity. In order to reflect their activity at the end of the day, one of students in each team were told to keep a record what his / her team did and where his / her team went during the workshop. After having lunch with team members, they had an orientation and then went to outside of campus to do their fieldwork. They had 3.5 hours to walk around the city with their team members to observe everyday life from various perspectives. They took a lot of pictures when they found out the differences between Japan and China. After that, they organized the pictures with team members and then reflected on their work answering the self-reflection questions. Next day, they went to three Japanese factories to learn a variety of state-of-the-art designs with team members.

Table1 The 2-day workshop schedule

Date	Schedule
18 Oct.	**Workshop**: Ice-braking / Lunch / Orientation / Fieldwork / Self-reflection
19 Oct.	Factory tours
20 Oct.	**Workshop**: Guidance / Arrange data / Additional fieldwork / Group discussion #1/ Lunch / Group discussion #2 and #3 / Presentation / Self-reflection

In the morning of the second day of the workshop, students continued to arrange the pictures they took during the previous fieldwork. They did more fieldwork if necessary. Students had different types of discussions in the afternoon. First, they tried to find conceptually related pictures and classified those into related groups using KJ method. They also named each extracted group and discussed the similarities and differences to place them on a two-dimensional axis. Next, they discussed the classified pictures using the World Café analysis. Once every ten minutes two pairs of students from each team went to other teams, learnt other teams' findings and wrote their comments or ideas on a sticky note and placed them on the whiteboard. Finally, they shared and examined their ideas about the value of the 'Japaneseness' focusing on several points written on the sticky notes. They also names about the groups of pictures assuming those were successive series of groups. After that, they prepared for a PowerPoint presentation. After presentations, they filled out the reflection sheet. Figure3 shows that pictures of students who were classifying the number of pictures they took, and a board displayed their findings.

Figure 3. Pictures of students and their work during the workshop.

3 Results

The details of problems students faced during the first day of workshop is shown in Figure 1. Students' answers in open-ended sections were categorized. 24 out of 26 students identified that they had difficulties when they communicated with team members at first. They tried very hard to speak English and sometimes used Japanese or Chinese so as to explain their thoughts or ideas to their unfamiliar team members. Many participants answered that they solved the communication problems using translation applications and gestures.

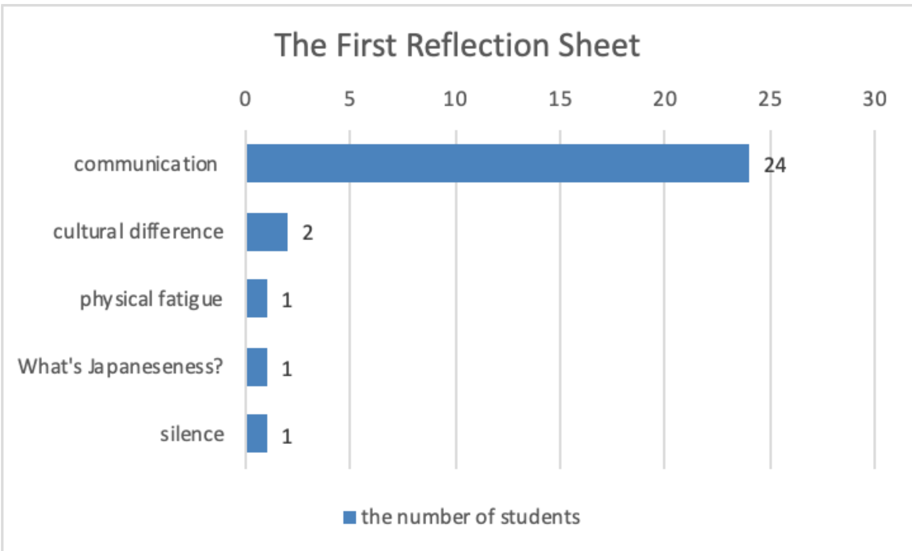


Figure1 The problems students faced during the first day of the workshop (N=26)

Figure 2 shows the problems students faced during the second day of the workshop. According to participants (N = 24), the difficulties they faced had changed. They answered they had difficulties in preparing a presentation with team members, classifying pictures using KJ method, and developing their ideas. Other two students answered that the difficulty in giving a presentation and explaining own culture were their problems. This might be because they were assigned tasks that required students to communicate with team members, develop their ideas and give a presentation, although they still struggled to commutate with team members in English.

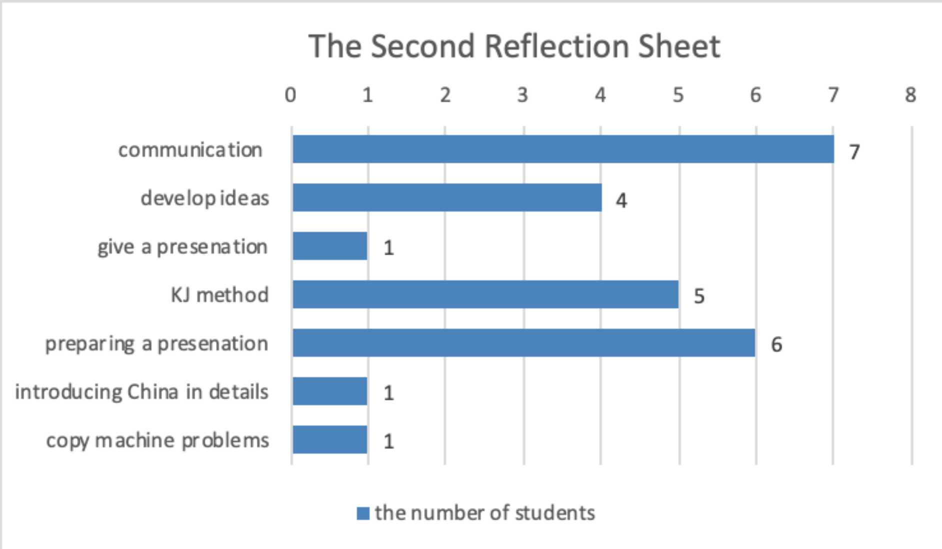


Figure2 The problems students faced during the second day of the workshop (N=25)

The study employed correlation and multiple regression analyses to examine the relationship between teamwork satisfaction and various potential predictors. Sample sizes, means, and standard deviations pertaining to each variable are presented in Table 2 and 3.

Table2 Descripted statistics of the first day of the workshop. (N=26)

Questions	Mean	SD	Mini	Max
1. I actively participated in group discussions.	5.23	1.34	2	7
2. I shared my ideas and opinion.	5.23	1.39	2	7
3. I had positive attitude and respected other people' views.	5.77	1.27	1	7
4. I had productive group discussions.	5.39	1.17	2	7
5. I helped to solve any problems.	4.77	1.03	3	6
6. I did an equal amount of work.	4.5	1.14	2	6
7. I am satisfied with the group work.	**5.61**	**1.53**	**2**	**7**
8. I worked as part of the team.	5.58	1.1	3	7
9. I enjoyed today's group discussion.	5.86	1.14	1	7
10. I enjoyed working with teammates.	5.81	1.39	1	7

Note. item 7 is the dependent variable.

Table3 Descripted statistics of the second day of the workshop (N=26)

Questions	Mean	SD	Mini	Max
1. I actively participated in group discussions.	5.46	1.33	1	7
2. I shared my ideas and opinion.	5.69	1.12	2	7
3. I had positive attitude and respected other people' views.	5.69	1.35	1	7
4. I had productive group discussions.	5.61	1.24	3	7
5. I helped to solve any problems.	4.92	1.06	2	7
6. I did an equal amount of work.	4.85	1.38	1	7
7. I am satisfied with the group work.	**5.77**	**1.39**	**2**	**7**
8. I worked as part of the team.	5.73	1.34	2	7
9. I enjoyed today's group discussion.	5.81	1.52	1	7
10. I enjoyed working with teammates.	5.76	1.5	1	7

Note. item 7 is the dependent variable.

Table 4 shows correlations among 9 questions of the first survey. Correlational analysis was used to examine the relationship between individual satisfaction with groupwork (item7) and other 9 variables. Results of the Pearson correlation indicated that there was a strong, positive association between their satisfaction and enjoy walking with teammates (item10), *r* = .74, *p* <.01. There were moderate positive correlations between the satisfaction and other variables, such as enjoy group discussion (item9), *r* = .68, *p* < .01., work as a part of the team (item 8), *r* = .66, *p* < .01, and share ideas and opinion (item2), r = .65, *p* < .01. No significant relationship was found between the satisfaction and productive group discussion (item4), *r* = .24, n.s., equal amount of work (item6), *r* = .23, n.s., and help to solve problems (item5), *r* = .07, n.s.

Table 4 First survey of correlations with confidence intervals (N=26)

Variable	item1	item2	item3	item4	item5	item6	item8	item9	item10
item7	.56**	.65**	.55**	.24	.07	.23	.66**	.68**	.74**

Note. * *p* < .05. ** *p* < .01.

Table 5 shows correlations among 9 questions of the second survey. There was a strong, positive correlation between the satisfaction (item7) and work as part of the team (item 8), *r* = .80, *p* < .01. Five variables, such as enjoy group discussion (item9), r = .64, *p* < .01, enjoy working with teammates (item10), *r* = .64, *p* < .01, and share ideas and opinion (item2), *r* = .64, *p* < .01, were positively correlated with their satisfaction. The two variables that were no significant in the first survey showed weak correlations; productive group work (item4), r = .48, *p* < .05, and help solve problems (item5), *r* = .42, *p* < .05. Equal amount of work (item6), however, showed no significant relationship with their satisfaction, r = .23, n.s. In summary, the correlation between students' satisfaction with teamwork and other variables tended to change depends on tasks.

Table 5 Second survey of correlations with confidence intervals (N=26)

Variable	item1	item2	item3	item4	item5	item6	item8	item9	item10
item7	.58**	.64**	.62**	.48*	.42*	.23	.80**	.64**	.64**

Note. * *p* < .05. ** *p* < .01.

A multiple linear regression analysis was calculated to develop a model for predicting participants' satisfaction with groupwork (item7) from positive behaviour and respecting (item3), work as a part of the team (item8), and enjoying working with teammates (item10). The results of regression coefficient of the first survey are shown in Table 6. R-squared value of the model was .63 and adjusted R-squired value was .58. The results of the regression indicated that the three predictor model was able to account for 63% of the variance in teamwork satisfaction (R^2=.63, $F(3,22)$ = 12.7, p <.001). The highest estimate was enjoy working with teammates as 0.84 (p <.01, 95% CI [0.33, 1.36]), indicating a student with a point higher score on the scale was expected to increase participants' satisfaction by 0.84. Whilst work as part of the team (item8, B = .64, p <.05) and enjoy working with teammates (item10, B = .84, p <.01) contributed significantly to the model, positive behaviour and respecting did not (item3, B = -.52, p=.11). Participants' predicted satisfaction with teamwork was equal to 0.15 - 0.52 (item3) + 0.64 (item8) + 0.84 (item10).

Table 6 Regression results of pre-survey using item7 as the criterion (N=26)

Predictor	*b*	*b* 95% CI [LL, UL]	*beta*	*beta* 95% CI [LL, UL]	sr^2	sr^2 95% CI [LL, UL]
(Intercept)	0.15	[-1.99, 2.30]				
item3	-0.52	[-1.15, 0.12]	-0.43	[-0.96, 0.10]	.05	[-.06, .15]
item8	0.64*	[0.03, 1.24]	0.46	[0.02, 0.90]	.08	[-.05, .21]
item10	0.84**	[0.33, 1.36]	0.77	[0.30, 1.23]	.19	[-.02, .40]
						R^2 = .63**

Note. A significant b-weight indicates the beta-weight and semi-partial correlation are also significant. b represents unstandardized regression weights. beta indicates the standardized regression weights. sr2 represents the semi-partial correlation squared. r represents the zero-order correlation. LL and UL indicate the lower and upper limits of a confidence interval, respectively.
** indicates p < .05. ** indicates p < .01.*

Table 7 shows the results of the multiple regression analysis of the second survey. The analysis was carried out to investigate whether active participation in discussion (item1), help to solve problems (item5), work as a part of the team (item8), and enjoy working with teammates (item10) could significantly predict participants' satisfaction with groupwork (item7). R-squared value of the model was .73 and adjusted R-squired value was .69. The results indicated the four predictors explained 73% of the variance and that the model was a significant predictor of students' satisfaction with teamwork (R^2 = .73, $F(4, 21)$ = 14.86, p < .001). The highest estimate was work as a part of the team (item8) as 0.82 (p <.01, 95% CI [0.46, 1.19]), indicating a student with a point higher score on the scale was expected to increase participants' satisfaction by 0.82. When the participants' satisfaction was predicted, help to solve problems (item5, B = -.67, p <.05) and work as a part of the team (item8, B = .82, p < .01) were significant predictors. Active participation in discussion (item1, B = .14, p=.42) and enjoy working with teammates (item10, B = .35, p=.09) were not significant predictors. The final predictive model of participants' satisfaction with teamwork was equal to 1.56 + 0.14 (item1) - 0.67 (item5) + 0.82 (item8) + 0.35 (item10).

Table 7 Regression results of post-survey using item7 as the criterion (N=26)

Predictor	*b*	*b* 95% CI [LL, UL]	*beta*	*beta* 95% CI [LL, UL]	sr^2	sr^2 95% CI [LL, UL]
(Intercept)	1.56	[-0.13, 3.24]				
item1	0.14	[-0.21, 0.48]	0.13	[-0.20, 0.46]	.01	[-.03, .04]
item5	-0.67*	[-1.19, -0.14]	-0.50	[-0.90, -0.11]	.09	[-.04, .21]
item8	0.82**	[0.46, 1.19]	0.79	[0.44, 1.15]	.27	[.04, .49]
item10	0.35	[-0.06, 0.77]	0.38	[-0.07, 0.83]	.04	[-.04, .12]
						R^2 = .73**

Note. A significant b-weight indicates the beta-weight and semi-partial correlation are also significant. b represents unstandardized regression weights. beta indicates the standardized regression weights. sr2 represents the semi-partial correlation squared. r represents the zero-order correlation. LL and UL indicate the lower and upper limits of a confidence interval, respectively.
** indicates p < .05. ** indicates p < .01.*

4 Discussion

The results of the study revealed that students' satisfaction with teamwork was increased by several behaviours. Their satisfaction appears to be increasing along with putting emphasis on assertive behaviours. Their passive behaviours, however, influenced their satisfaction negatively. Instructors who organise a short-term workshop should consider the tendency of the students' behaviours. The results of the multiple regression indicated that 2 out of the 9 items, work as a part of the team (item8) and enjoying working with teammates (item10), contributed to predicting students' teamwork satisfaction positively during the first day of the workshop. Therefore, encouraging self-expression may increase their satisfaction. However, the question about positive behaviour and respecting (item3) was a negative predictor of their satisfaction. Such students' passive behaviours indicate that students focus on positively understanding others rather than showing self-expression. This may hinder their satisfaction. As a result, instructors should consider those aspects of satisfaction and set up at a plan for students' activities in order to increase their satisfaction with teamwork during short-term workshops.

There are several possible interpretations for the findings. According to Dolmans, Wolfhagen, & Van der Vleuten (1998), their study found that interaction among teams through discussion and listening teammates' point of views was the key to success of tutorial groups for medical students. Students in the present study participated independently, and such students tend to communicate with others well and to work others positively. Thus, they might have positive interaction among team when they enjoyed working with teammates as part of a team. With respect to working as a part of a team (item8), students might have developed a sense of belongingness to the team during the workshop. Baumeister & Leary (1995) points out that belonginess is a fundamental human need that individual has to belong to others. Borrott, Day, Sedgwick, Levett-Jones' study (2016) found out that nursing students identified achieving the sense of belonging which affected their workplace satisfaction. Another research by Braun, Peus, Weisweiler, & Frey (2013) showed that developing sense of belongingness led employee to satisfy with their job while building trust within a team. Pang et al. (2011) researched business students and found that three factors, such as *workload sharing*, *mutual support*, and *communication*, significantly and positively contributed individual satisfaction in team settings (p.98). They state that if individual considers team members' workload is equally divided, they will develop a sense of belonging, ownership, and responsibility to the team. In the present research, however, the mean score of question about equal amount of work (item8) was the lowest comparing to other items. This suggests that students were not distribute the workload equally, which trend was also seen in the second day of the workshop. Students had only two days to develop relationship among teammates, so they might not have enough time to come up with ideas to share workload. Hence, they might develop the sense of belongingness in a different way. This should be investigated as the further study.

In contrast, their satisfaction may be decreased when they have positive attitudes and respect others' opinion. According to the answers of open-ended questions, students in the present study struggled to communicate with unfamiliar teammates who have different linguistic and cultural backgrounds from the beginning of the workshop because of the lack of language skills. They reported they solved the problem using translation application and body language, but they did not fully understand each other. If they struggled to explain their opinion as well as to understand teammates' opinion, they would be tired of having positive attitude and respecting others' ideas. The schedule of the workshop might also affect the result. Although students were assigned into groups randomly, they were familiar with teacher-centred learning style. When students are not used to student-centred approach, students require some time to get used to the new approach (Wong, 2004; Xue, 2013). In such situation students might not know how to communicate with others and express their ideas to the unfamiliar students. Furthermore, if they did not have enough time to develop relationship between teammates, they would hesitate to express their ideas and rather prefer listening other's opinion.

The results of the second day of the workshop also shows several students' assertive behaviours improve their satisfaction with teamwork. The results indicated that both students' behaviours, work as a part of the team (item8) and enjoy working with teammates (item 10), were also significant predictors to increase students' satisfaction as the first results. In addition to those two behaviours, active participation in discussion (item1) was selected as a significant predictor. Students' active participation also associate with students' assertive behaviours as item8 and item10. Their satisfaction, however, decreased when students helped to solve any problems (item5), which indicates improving their satisfaction requires students to foster personal expression.

There are possible reasons for the behaviour that decrease their teamwork satisfaction. Although one of factors that positively contribute individual satisfaction in team settings is *mutual support* (Pang, et al., 2011, p.98), the question about helping to solve problems (item5) in the present study asked only one side of students' behaviour, resulting in negative effect their satisfaction. Consequently, students may require not only to help teammates, but also to receive support from them to improve their satisfaction with teamwork. In addition, the study by Ruiz Ulloa, & Adams (2004) revealed that one of essential factors of the positive relationship between effective teams and students' attitudes towards teamwork was psychological safety. Psychological safety is defined as shared belief that team members think that a team is safe for interpersonal risk taking, and which allows students to speak up without embarrassment or punishing (Edmondson, 1999). In the present study, therefore, psychological safety might not be developed in teams and students could not to express their ideas comfortably. This might be affected by experiencing unfamiliar learning methods, talking to new people, helping each other, and speaking English. Mpofu, Das, Stewart, Dunn and Schmidt (1998) point out that when students are not familiar with teammates, each students' communication contribution may be hindered. Lingard (2010a) also claims that helping teammates and asking for help are one of essential acts to improve teamwork skills. However, students are likely to reluctant to give or ask help because asking for some help relates to show some inadequacy that results in solving issues by themselves. Lingard (2010b) insists that students' teamwork skills can be developed by practicing and immediate peer feedback. He, therefore, points out that students need to learn how to deal with it. Students in the present study might not know how to ask for help as well as to give help. As a result, they might reluctant to help teammates to solve some issues they faced. Their lack of English skills might also prevent students from helping others. When they were not able to clearly address the problems to teammates, teammates would hesitate to solve problems. Thus, students require some sort of practices to develop and improve English skills. Instructors should take into consideration the importance of increasing opportunities of working in team settings whereby students can develop professional skills and English skills to make such experience successful. Along with those opportunities, students' satisfaction with teamwork may increase.

5 Conclusion

Active learning is increasing opportunities for students to develop professional skills in workplace. There are a lot of research about the effectiveness of active learning methods in class, but not in short-term international workshops. This study investigates what student behaviours affect individual satisfaction with teamwork during a short-term international workshop and identifies gaps between past studies and the present study. The results of analyses indicate that students' assertive behaviour increases students' satisfaction with teamwork. Encouraging self-expression are likely to help students to improve their satisfaction with team. Especially, when students can work as part of the team and enjoy the time working with team members, their team experience may show an increase in their satisfaction. On the other hand, students' passive attitudes toward a team, such as positive behaviour and respecting and help to solve problems, may inhibit their satisfaction. Instructors should consider the tendency of students' behaviours when they plan to introduce active learning methods to students. There are limitations in this study. Sample size was very small, so the results should be carefully examined. In order to develop a better model about students' satisfaction, testing in larger sample size should be necessary. Hence, further investigations should be conducted. First, the study should be carried out an experimental research comparing two groups in which one of groups have time for individual working and group discussion. In addition, questions to identify students' satisfaction with teamwork should be examined and developed from several perspectives, such as workload, mutual support, English language skills. There is also various satisfaction which associated with perceived group development and outcome variables, such as "satisfaction with the group solution, confidence in the solution, satisfaction with the interaction process, perceived quality of discussion, and level of teamwork" (Ocker, 2002, p.2). Considering those aspects also help us understand students' satisfaction with teamwork. Furthermore, negative predictors identified in the present study were based on student passive behaviours, but this result may be changed by adding other factors, such as age and exitance of siblings. Conducting further research based on those various perspectives will lead to further understanding of individual satisfaction with teamwork.

6 References

Baumeister, R. F. & Leary, M. R. (1995). The Need to Belong: Desire for Interpersonal Attachments as a Fundamental Human Motivation. *Psychological Bulletin, 117*, 497–529.

Borrott, N., Day, G., Sedgwick, M., Levett-Jones, T. (2016). Nursing students' belongingness and workplace satisfaction: quantitative findings of a mixed methods study. *Nurse Education Today 45,* 29–34.

Braun, S., Peus, C., Weisweiler, S., & Frey, D. (2013). Transformational leadership, job satisfaction, and team performance: A multilevel mediation model of trust. *Leadership Quarterly, 24*, 270-283.

Channon, S. B., Davis, R. C., Goode, N. T. & May, S. A. (2017). What makes a 'good group'? Exploring the characteristics and performance of undergraduate student groups. *Advances in Health Sciences Education, 22,* 17-41.

Chen, C., Lai, C., Lu, P., Tsai, J., Chiang, H., Huan, I., & Yu, H. (2008). Performance Anxiety at English PBL Groups Among Taiwanese Medical Students: A Preliminary Study. *The Kaohsiung Journal of Medical Sciences, 24*(3), S54-S58.

De Grave, W. S., Dolmans, D. H. J. M., van der Vleuten, C. P. M. (2002). Student Perspectives on Critical Incidents in the Tutorial Group. *Advances in Health Sciences Education, 7*, 201–209.

Dolmans, D. H. J. M., Wolfhagen, I. H. A. P., & Van der Vleuten, C. P. M. (1998). Thinking About Student Thinking: Motivational and Cognitive Processes Influencing Tutorial Groups. *Academic Medicine*, *73*(10), S22-24.
Edmondson, A. (1999). Psychological Safety and Learning Behavior in Work Teams. *Administrative Science Quarterly*. *44*(2), 359-83.
Hendry, G. D, Ryan, G. & Harris, J. (2003). Group Problems in Problem-Based Learning. *Medical Teacher, 25*(6), 609-616.
Humphreys, P., Lo, V., Chan, F., & Duggan, G. (2001). Developing Transferable Groupwork Skills for Engineering Students. *International Journal of Engineering Education, 17*(1), 59-66.
Lingard, R. W. (2010a). Teaching and Assessing Teamwork Skills in Engineering and Computer Science. *Journal of Systemics, Cybernetics and Informatics, 8*(1), 34-37.
Lingard, R. (2010b). Improving the Teaching of Teamwork Skills in Engineering and Computer Science. *Journal of Systemics, Cybernetics and Informatics*, 8(6), 20-23.
Marin-Garcia, J. A. & J. Lloret (2008). Improving Teamwork with University Engineering Students: The effect of an Assessment Method to Prevent Shirking. *WSEAS Transactions on Advances in Engineering Education*, *5*(1), 1-11.
Mpofu, D. J. S., Das, M., Stewart, T., Dunn, E., & Schmidt, H. (1998). Perceptions of Group Dynamics in Problem-Based Learning Sessions: A Time to Reflect on Group Issues. *Medical Teacher*, *20*(5), 421-27
Ocker., R. J. (2002) The mediating effect of group development on satisfaction in a virtual and mixed-mode environment, *Proceedings of the 35th Annual Hawaii International Conference on System Sciences*.
Pang, E., Tong, C., & Wong, A. (2011). Key Determinants of Student Satisfaction When Undertaking Group Work. *American Journal of Business Education, 4*(10), 93-104.
Ruiz Ulloa, B. C. & Adams, S. G. (2004). Attitude toward teamwork and effective teaming. *Team Performance Management, 10*(7/8), 145-151.
Stewart, R. A. (2007). Investigating the Link Between Self-Directed Learning Readiness and Project-Based Learning Outcomes: The Case of International Master Students in an Engineering Management Course. *European Journal of Engineering Education*, *23*(4), 453-465.
Thurmond, V.A., Wambach, K., Conners, H.R. & Frey, B.B. (2002). Evaluation of Student Satisfaction: Determining the Impact of a Web-Based Environment by Controlling for Student Characteristics. *American Journal of Distance Education, 16*(3), 169-189.
Tsuchiya, Y., Silva, L. C. D., Bakar, M. S. A., Chubachi, Y., and Narita, M. (2015). Robot services development by international collaborative PBL (Project Based Learning) with universities in three countries, *2015 IEEE/SICE International Symposium on System Integration, 650-655.*
Wong, J. K. (2004). Are the learning styles of Asian international students culturally or contextually based? *International Education Journal, 4*(4), 154-166.
Xue, M. (2013). Effects of Group Work on English Communicative Competence of Chinese International Graduates in United States Institutions of Higher Education. *The Qualitative Report, 18*(7), 1-19.

About the Authors:

Hisaka Konishi is Research Assistant Professor of Engineering and Design at Shibaura Institute of Technology and also a PhD student in the Department of Engineering at Chiba Institute of Technology. Her research interests include the use of active learning.

Toru Nagao (PhD) is Dean of Graduate School of Engineering, Chiba Institute of Technology, Japan. He received the Doctor degree from Chiba Institute of Technology. His specialized field is an interaction design and product design.

Yusuke Ashizawa. Ph.D., Assistant Professor in Shibaura Institute of Technology. He graduated from Department of Design, Chiba University, and has specialized in Design Management and System Design. Now he has been trying to reveal brain mechanism of design thinking.

Satoshi Hachima Professor, Ph.D. in Engineering, Department of Design, Chiba Institute of Technology. Graduated from Department of Design, Chiba University. Research interests are landscape and social design. Book publications include “European Infrastructures Guide for an Amazing Tourism (2015)”.

Exploring the landscape of service design education: A preliminary review of current programmes in higher education

Becermen, Begüm*; Simeone, Luca
Aalborg University, Copenhagen, Denmark
* beg@create.aau.dk

Service design is a relatively young multidisciplinary field and in the past two decades has gained more attention in both the service industry and academia. Even though service design programmes are still not evenly widespread around the world, they are growing and expanding (mostly in Europe). These programmes are provided by different institutions - ranging from design faculties, all the way up to business and management schools - and differ as regards their curricula. This short paper explores this diversity by looking into a curated selection of master's degrees in service design and their curricula, by discussing the initial findings and by hinting at possibilities for future studies.

Keywords: service design; design education; service design education

1 Service design: The shift from a new discipline to an established field

The term service design was introduced in marketing studies by Lynn Shostack (Shostack, 1982, 1984) and got codified as a distinct field through the work of a group of design researchers (Hollins & Hollins, 1991; Morello, 1991; Manzini, 1993; Erlhoff, Mager, & Manzini, 1997) and service industry consultancies (Sangiorgi & Prendiville, 2014). All these developments prompted some universities - the University of Applied Sciences in Cologne, followed by the Politecnico di Milano, Carnegie Mellon University and Linköping University - to establish service design courses (Mager, 2008, 2009). The first academic conference dedicated to service design (ServDes)[1] was held in 2009 in Oslo. The first master's degree in Service Design was started at the Laurea University of Applied Sciences in 2009 (Ojasalo, 2012). Since then, there has been a continuous growth in the number of higher education programmes dedicated to service design (Polaine, 2011; White & Holmlid, 2012). Although today service design has reached a certain credibility in practice, research and education (Mager, 2008) and can no longer be considered as an emerging discipline, the discipline still seems to have "no clear home in academia" (Polaine, 2011, p. 50). Varied programmes are taught across as diverse schools as arts, design, business and engineering - to name a few. To date, this proliferation of curricula has not been systematically examined and reviewed.

[1] http://www.servdes.org/about-servdes/

This short paper aims to present the preliminary results of a study that goes in this direction and tries to explore the landscape of service design education more closely.

2 Previous studies in service design education

Existing studies tend to focus on the establishment of a particular educational programme (Ojasalo & Ojasalo, 2009; Al-Yassini, Kim, & Selzer, 2011; Blomkvist, Holmlid, & Segelström, 2011; Ojasalo, 2012; Pacenti, 2011; Penin, 2011; de Götzen, Morelli, & Grani, 2014; Morelli & de Götzen, 2014). Other studies discuss more general aspects, e.g. the required knowledge and skills for tomorrow's service designers (White & Holmlid, 2012), or the opportunities and challenges facing service design education (Polaine, 2011). Further research focuses on in-class teaching (Guersenzvaig, 2011; Howard, 2011; Ali, Grimaldi, & Biagioli, 2017; de Götzen, Simeone, Morelli, & Kun, 2018), or on how to use service design education to improve university services (Faust, 2011). Although these publications offer valuable contributions to understand specific aspects of service design education, none of these studies provides a comprehensive analysis of the current education in service design.

An article that goes in this direction is a comparative study on service design education, which attempts to provide a holistic view of various programmes (Ferruzca, Tossavainen, Kaartti, & Santonen, 2016). However, the researchers chose to look into the top 50 universities according to the ranking of the Times Higher Education[2] and to analyse the educational programmes that are more similar to service design - even though these programmes do not specifically contain the words "service design" in their titles. As such, their analysis also focuses on programmes that are not directly service design-centred. The research presented in this paper intends to complement these studies by narrowing the focus of analysis as to only include those higher education programmes specifically and explicitly geared toward service design.

3 Research methods

The data collection was mostly based on a desk-based research (Neale, 2008) carried out between September 2018 and March 2019. This desk-based research was articulated into two distinct phases: an initial data gathering period in which the authors looked into two existing databases hosted by the Service Design Network[3] and the Politecnico di Milano (Service Design Landscape[4]) and performed some searches in Google and Google Scholar (using the keywords "service design education", "master's in service design" and synonyms) and a subsequent data analysis.

After gathering data from these two databases and integrating it with additional searches through search engines, the data was analysed as to more strictly focus on those master's degrees specifically geared at service design. It is worth noting that a large number of master's degrees currently offer design and design thinking courses that can be broadly used to design services; however, oftentimes, the curricula of these master's degrees are not centred around service design. Rather, service design is taught in single courses alongside other design specialisations. This study deliberately narrows its scope by targeting only those programmes that put service design as the core element of their offering. For each programme, the curricula were collected, compared and further analysed.

[2] https://www.timeshighereducation.com/world-university-rankings
[3] https://www.service-design-network.org/organisations
[4] https://www.servicedesignmap.polimi.it/

An important limitation of this study is that it only reviewed master's programmes whose curricula were available in English.

4 Key findings

The authors analysed 24 different selected master's degrees that are specialised in service design (see Table 1). Among these master's degrees, 20 of them contain the label "service design" as the main descriptor in their official title (e.g., "Master's Programme in Service Design"), whereas 4 of them offers a service design specialisation (see #b, #h, #m and #q). Out of these 24 programmes, 13 offer a two-year education. The programmes are located in Europe (22, with 6 of them in the United Kingdom), the US (1) and Asia (1).

The name of the master's degrees vary, and also the faculties that offer these programmes, which range from Master of Design (M.Des.), up to Master of Arts (M.A.), Master of Fine Arts (M.F.A.), Master of Science (M.Sc.) and Master of Business Administration (M.B.A.). The curricula and given courses mostly differ according to which faculty provides the education rather than other factors (e.g., the country offering the programme).

Table 1 The 24 master's degrees analysed in this study.

	Country	University	Duration	Credits
#a	Denmark	Aalborg University Copenhagen M.Sc. in Service Systems Design	2 years	120 ECTS
#b	Denmark	IT University of Copenhagen M.Sc. in Digital Innovation & Management * *(specialisation in service design)*	2 years	120 ECTS
#c	Estonia	The University of Tartu M.A. in Service Design and Management (M.A. in Service Design (in Estonian)) M.A. in Wellness and Spa Service Design and Management (in English)	2 years	120 ECTS
#d	France	Lisaa - School of Art & Design Master in Interior Architecture & Service Design	2 years	120 ECTS
#e	Finland	Laurea University of Applied Sciences M.B.A. in Service Innovation and Design	1,5 years	90 ECTS
#f	Finland	Novia University of Applied Sciences The Master's degree programme in Leadership and Service Design	Master of Culture and Arts, Leadership and Service Design:1,5 years 60 credits Master of Business Administration, Leadership and Service Design: 2 years 90 credits Master of Hospitality Management, Leadership and Service Design: 2 years 90 credits	60-90 ECTS
#g	Finland	Turku University of Applied Sciences M.B.A. in Leadership and Service Design	2 years	90 ECTS

#h	Germany	Köln International School of Design Master of Integrated Design* *(specialisation in service design)*	3 semesters	90 ECTS
#i	Italy	Domus Academy Master in Service Design	1 year	60 ECTS
#j	Italy	Politecnico di Milano Master in Product-Service System Design	2 years	120 ECTS
#k	Italy	Politecnico di Milano Master in Service Design	1 year	60 ECTS
#l	Ireland	The National College of Art and Design M.A. in Service Design	1 year	90 ECTS
#m	Norway	The Oslo School of Architecture and Design (AHO) Master of Design* *(specialisation in service design)*	2 years	120 ECTS
#n	South Korea	Hongik University Master in Service Design	2 years	120 ECTS
#o	Spain	Mondragon University Master's Degree in Strategic Design of Products and Services	2 years	120 ECTS
#p	Sweden	Halmstad University M.Sc. in Digital Service Innovation	2 years	120 ECTS
#q	Sweden	Linköping University Master's Programme in Design* *(track in service design)*	2 years	120 ECTS
#r	The United Kingdom	Brunel University London M.Sc. in Digital Service Design	1 year	90 ECTS
#s	The United Kingdom	London College of Communication M.A. in Service Design	1 year 3 months	90 ECTS
#t	The United Kingdom	Ravensbourne University London M.Des. in Service Design Innovation	1 year	90 ECTS
#u	The United Kingdom	Royal College of Art M.A. in Service Design	2 years	120 ECTS
#v	The United Kingdom	The Glasgow School of Art M.Des. in Design Innovation & Service Design	1 year	90 ECTS
#w	The United Kingdom	The University of Warwick M.Sc. Service Management and Design	1 year	90 ECTS
#x	The United States of America	The Savannah College of Art and Design (SCAD) M.F.A in Service Design	2 years	90 hours*

Common educational threads
A common characteristic of these master's degrees is that they tend to combine 'hands-on' project work with lectures/seminars. This is often also accompanied by collaborations with external organisations and companies. The idea is to expose the students to a design thinking approach and make them practice their ability to develop a service design project

from research and analysis, up to problem definition, ideation and concept development, prototyping, and testing. Identifying user/stakeholder needs and improving their experience is one of the core principles of service design (Stickdorn & Schneider, 2010) that most of these master's programmes acknowledge. Gaining the mastery of service design tools and methods is the essential educational aims of all these programmes and programmes tend to offer supporting courses such as user-centred design for services, user experience design for service interaction, deep customer insights through ethnographic research. The business and management aspects of services and the creation of new value propositions are other common topics even though the intensity of focus on these aspects differs among the programmes.

Differences in educational approaches

Most of the master's degrees aim to create T-shaped people (Kelley & Littman, 2005), i.e. professional designers that combine design expertise with a broad understanding of other disciplines so that their capabilities can be applied in different sectors within multidisciplinary teams (Raijmakers, Thompson, & van de Garde-Perik, 2012). However, there are two master's degrees - Master of Hospitality Management, Leadership and Service Design (#f) and M.A. in Wellness and Spa Service Design and Management (#c) - that aim to teach service design thinking as anchored to a specific sector of application.

Depending on the faculty that hosts the education, there are certain differences among various typologies of degrees. M.B.A programmes put more emphasis on the business aspect of services and propose courses such as: introduction to leadership and service design, managing organisations, new service development and innovative business models, service logic-based strategic management, and also elective courses of service marketing and selling, management accounting and control in services, pricing in service business, change leadership and service culture, capital investment analysis, entrepreneurship in services. Some M.Sc. programmes tend to focus on the technological aspects of services, for example offering courses such as digital innovation, digital service applications, service support technologies, computing infrastructure management, programming for services, intelligent services, services in the digital society. In some cases, programmes combine the business and management aspects with an attention toward technologies by offering courses such as leading change, business model generation, reputation and relationship management, service support technologies, financial analysis and control systems. The third category is a cluster of M.Des., M.F.A., and M.A. programmes. These programmes occur within design and art schools and offer curricula that more strictly focus on design practice and methods and tools for creative arts (e.g., offering courses such as visualisation, storytelling and storyboarding, visual communication, and graphic design).

Recurrent areas of focus

In addition to the faculty or the school in which they are located, some of the curricula of the master's programmes are also informed by broad and recurrent areas of focus. One of them is social innovation, which is often directly mentioned as one of the key aspects of the education in the main study website or is taught through dedicated courses such as social innovation and user participation or social innovation and social responsibility. Since the value of services is co-produced with other service systems (Spohrer, Maglio, Bailey, & Gruhl, 2007), "system" is yet another term emphasised in a substantial amount of these educations. Two of the analysed master's degrees contain the term systems in their title (#a and #j) and offer courses such as systems project management, systems design, general system theory, services as systems and product service system design studio.

Less common topics
A few programmes propose courses or specialisations that are not consistently offered in service design education. Examples are:

- Social aspect: policy innovation (#u), circular economy (#u), ethics and sustainability in digital service innovation (#p)
- Business aspect in consulting: professional practice in management and consulting (#t), design facilitation and leadership (#n)
- Business aspect in finance: pricing in service business (#e), financial analysis and control systems (#w), management accounting and control in services (#e)
- Technological aspect: programming for service design (#a)

5 Final remarks

This preliminary review of current master's degrees in service design raises some questions that are worth further exploration.

Why is service design education so scattered around different faculties and schools?

Service design as a multidisciplinary field aims to break silos and approach the problems holistically (Moritz, 2009; Stickdorn & Schneider, 2010), whereas the majority of academic institutions still tend to be structured and organised in silos of faculties and departments. These silos lead to the variation of the master's degrees in M.Des., M.Sc. M.B.A, M.A., M.F.A, and the consequent differentiation on their curricula. Depending on the faculty, the majority of the programmes are either design-led or management-led educations. This differentiation is not problematic per se and can possibly enrich the field. However, the lack of standards makes it also difficult to compare and assess service design programmes and raises the question of how to assure the quality of the master's degrees in service design.

Do the current curricula cover the skills required from service designers?

Our analysis shows that two sets of skills could be better developed by the current education in service design. First, when designing services, the active participation of multiple stakeholders is essential across all phases. As such, service designers should be trained to lead and facilitate the engagement of diverse stakeholders (Han, 2009). However, although communication and facilitation skills play such a crucial role in the service design practice, only a few programmes offer dedicated courses on these topics. Second, a particularly challenging aspect of service design is the implementation and evaluation phase (Raun, 2017; Ewerman & Persson, 2018). Most of the programmes here analysed offer hands-on project work that generally ends with testing some concept ideas, but there is little focus on the phases of service implementation and assessment. All these aspects - facilitation, communication, service implementation and evaluation - seem to be not fully covered by current education.

These questions remain here only outlined as to possibly inform future research. Hopefully, the (partial, limited and biased) snapshot of the current state of service design programmes provided by this paper can be a building block for further and more focused analyses.

6 References

Ali, H., Grimaldi, S., & Biagioli, M. (2017). Service Design pedagogy and effective student engagement: Generative Tools and Methods. *The Design Journal*, *20*(sup1), S1304–S1322.

Al-Yassini, R., Kim, M., & Selzer, S. (2011). Designing a Service Design Curriculum. *Touchpoint - the Journal of Service Design*, *3*(1), 66–71.

Blomkvist, J., Holmlid, S., & Segelström, F. (2011). Prototyping a Service Design Curriculum. *Touchpoint - the Journal of Service Design, 3*(1), 53–55.

de Götzen, A., Morelli, N., & Grani, F. (2014). Challenges and Perspectives in Service Design Curricula: The Case of the Service Systems Design Master of Aalborg University in Copenhagen. *ServDes. 2014 Service Future; Proceedings of the Fourth Service Design and Service Innovation Conference; Lancaster University; United Kingdom; 9-11 April 2014*, 394–400. Linköping University Electronic Press.

de Götzen, A., Simeone, L., Morelli, N., & Kun, P. (2018). Making sense of data in a service design education. *ServDes2018. Service Design Proof of Concept, Proceedings of the ServDes. 2018 Conference, 18-20 June, Milano, Italy*, 177–187. Linköping University Electronic Press.

Erlhoff, M., Mager, B., & Manzini, E. (1997). *Dienstleistung braucht Design: professioneller Produkt- und Marktauftritt für Serviceanbieter.* Luchterhand.

Ewerman, D., & Persson, S. (2018). How to Stay Relevant Moving from what we do to what we deliver. *Touchpoint - the Journal of Service Design, 10*(1), 12–15.

Faust, J. (2011). Using Service Design Education to Design University Services. *Touchpoint - the Journal of Service Design, 3*(1), 40–45.

Ferruzca, M., Tossavainen, P., Kaartti, V., & Santonen, T. (2016). A comparative study of service design programs in higher education. *INTED2016 Proceedings*, 6490–6498.

Guersenzvaig, A. (2011). Teaching Service Design to Design Students. Touchpoint - the Journal of Service Design, 3(1), 46–48.

Han, Q. (2009). Managing Stakeholder Involvement in Service Design: Insights from British service designers. *Conference Proceedings ServDes. 2009; DeThinking Service; ReThinking Design; Oslo Norway 24-26 November 2009*, 93–104. Linköping University Electronic Press.

Hollins, G., & Hollins, B. (1991). *Total Design: managing the design process in the service sector*. London: Pitman.

Howard, J. (2011). Teaching Co-Design. *Touchpoint - the Journal of Service Design, 3*(1), 56–57.

Kelley, T., & Littman, J. (2005). The 10 faces of innovation. *Fast Company*, *99*, 74.

Mager, B. (2008). Design Dictionary-Service Design. In M. Erlhoff & T. Marshall (Eds.), *Design Dictionary: Perspectives on Design Terminology* (pp. 354–357).

Mager, B. (2009). Service design as an emerging field. In S. Miettinen & M. Koivisto (Eds.), *Designing Service with Innovative Methods* (pp. 27–43). University of Art and Design, Helsinki.

Manzini, E. (1993). *Il Design dei Servizi. La Progettazione Del Prodotto-Servizio, in "Design Management*, 7.

Morelli, N., & de Götzen, A. (2014). Shaping a New Service Design Programme. *Touchpoint - the Journal of Service Design, 6*(2), 86–89.

Morello, A. (1991). *Design e Mercato dei Prodotti e dei Servizi* (Dottorato di Ricerca in Disegno Industriale). Politecnico di Milano, Milano.

Moritz, S. (2009). *Service design: Practical access to an evolving field.* Lulu. com.

Neale, J. (Ed.). (2008). *Research Methods for Health and Social Care*. Basingstoke; New York: Macmillan International Higher Education.

Ojasalo, K. (2012). Designing and implementing an innovative Master's degree programme: A case study. *International Journal on New Trends in Education and Their Implications, 3*(3), 136–147.

Ojasalo, K., & Ojasalo, J. (2009). Developing Service Design Education. In S. Miettinen & M. Koivisto (Eds.), *Designing Service with Innovative Methods* (pp. 98–123). University of Art and Design, Helsinki.

Pacenti, E. (2011). Better Services for Better Lives. *Touchpoint - the Journal of Service Design, 3*(1), 58–61.

Penin, L. (2011). A Critical Approach to Service Design Education. *Touchpoint - the Journal of Service Design, 3*(1), 62–65.

Polaine, A. (2011). Late to the Party? *Touchpoint - the Journal of Service Design, 3*(1), 50–52.

Raijmakers, B., Thompson, M., & van de Garde-Perik, E. (2012). New goals for design, new roles for designers. In *Cumulus Conference, Helsinki, 2012. Proceedings… Helsinki*(pp. 1-11).
Raun, L. (2017). *Designing for Service Change: A study on how designers address implementation during service design projects for hospitals* (PhD Thesis). Aalborg Universitetsforlag.
Sangiorgi, D., & Prendiville, D. (2014). A theoretical framework for studying service design practices: First steps to a mature field. *The 19th DMI International Design Management Research Conference*, 2422–2440. DMI.
Shostack, G. L. (1982). How to Design a Service. *European Journal of Marketing, 16*(1), 49–63.
Shostack, G. L. (1984). Designing services that deliver. *Harvard Business Review, 62*(1), 133–139.
Spohrer, J., Maglio, P. P., Bailey, J., & Gruhl, D. (2007). Steps toward a science of service systems. *Computer, 40*(1), 71–77.
Stickdorn, M., & Schneider, J. (2010). T*his is Service Design Thinking : basics - tools - cases.* Amsterdam: BIS Publishers.
White, H., & Holmlid, S. (2012). What Do Tomorrow's Service Designers Need to Know?, in *International ServDes conference. 2012*: Finland.

About the Authors:

Begüm Becermen: Begüm Becermen is a Research Assistant at Aalborg University Copenhagen and member of the Service Design Lab (https://servicedesignlab.aau.dk/). Her research activity focuses on service systems design and education.

Luca Simeone: Luca Simeone is an Assistant Professor at Aalborg University and a member of the Service Design Lab (https://servicedesignlab.aau.dk/). His work is situated at the intersection of research and entrepreneurship with a particular focus on strategic thinking.

FlipMe: A Tangible Approach to Communication in Online Learning

Jeong, Wondo; Self, James Andrew*; Oakley, Ian; Lee, Hui Sung
UNIST (Ulsan National Institute of Science & Technology), Ulsan, Republic of Korea
* jaself@unist.ac.kr

Online learning continues to see rapid growth with millions of students now engaging in online and remote courses as convenient alternatives to conventional classroom-based teaching. Despite these advantages, online courses suffer from high drop-out rates. Prior research has suggested the limited opportunities for social interaction between students may contribute to these undesirable outcomes. In order to address this challenge, we developed FlipMe, an Internet of Things companion augmenting peer-to-peer interaction in real time. We then conducted a pilot user study to explore the potential of FlipMe as design intervention to increase peer-to-peer learning while watching online video content. Initial findings indicate FlipMe's tangible interface and feedback have the potential to promote peer interaction in online learning. We close by discussing directions for future work.

Keywords: Online Learning; Tangible Interface; Product Design; Communication

1 Introduction

Online learning services, defined as any form of learning conducted partly or wholly over the internet (Shah 2017), are growing in use and popularity. These include both MOOC (Massive Open Online Courses) learning platforms and independent sites and tutorials that are ubiquitously available through social media sharing venues. However, online learning, and its associated platforms for communication, face many crucial challenges. Notably, dropout rates in online learning far exceed traditional, classroom based equivalents. Approximately 90% of all students do not complete their online course. This is largely due to low student engagement and the challenges of self-motivated learning activity (Lu et al. 2007). Moreover, students studying in online learning environments, such as Udacity (Udacity Inc. 2019), Coursera (Coursera Inc. 2019) and Khan Academy (Khan Academy, 2019) suffer from a lack of communication with peers because the individual online learners in a peer group are remote from one another. In addition, compared to a traditional classroom context, most online learning platforms provide dramatically lower student to instructor ratios. Both communication with peers and receiving feedback from instructors benefit students' learning experiences (Hong Lu 2007); the lack of these features in otherwise accessible and convenient online learning systems contributes to high dropout rates.

Peer learning activities, described as any learning that involves multiple students studying from and with each other to attain educational goals (O'Donnell 1999) can improve students' engagement and the quality of the overall learning experience (Ahn et al. 2013). Likewise, previous studies reveal social factors influence students' expectations of peer learning (Boud et al. 2014). Thus, social interaction with peers appears fundamental to achieve higher completion rates in online education programmes (Cercone, 2008). Research has suggested that online social activities, such as discussion in forums, are far less effective than the more personal and interactive communication provided in traditional classroom contexts (Thomas, 2002).

The tangibility of real world objects, experiences and social interactions may contribute to the effectiveness of classroom learning. Tangibility plays an important role in people recognizing and affecting their environment (Johnson, M, 1987). It is also an effective channel though which to convey information to and between people in memorable and intuitive ways via physicalized data (Zhao, 2006). As Zhao (ibid) argues, these more impactful representations of information can directly change user behaviours. Based on these observations, the current study explores how interaction with a tangible product representing the activities of a peer, online learner can improve opportunities for social interaction to motivate students to engage with their peers during online learning.

2 Interpersonal Communication through Tangible Interaction

The current study aimed to physicalize learning activities through *data physicalization* (Jansen 2015). *Data physicalization* is beneficial for leveraging our perceptual exploration skills, facilitating understanding and learning, bringing data into the real world and fostering public engagement in the number of favourable situations (Yvonne Jansen, 2015).

For example, an early study by Ishii (2001) used 40 computer-controlled pinwheels to present ambient information of human's activities, such as physical movement: walking or online activity like emailing. If the system detects an email containing a large volume of attached files, several pinwheels spin, while only a few pinwheels spinning indicated smaller sized emails. Likewise, CalmStation (Kim 2017, Figure 1, left) allows users to remain focused while conducting desk work. While LOOP (Sauvé et al. 2017) introduces a physical artefact that changes its shape according to the activity data of the owner (Figure 1, right).

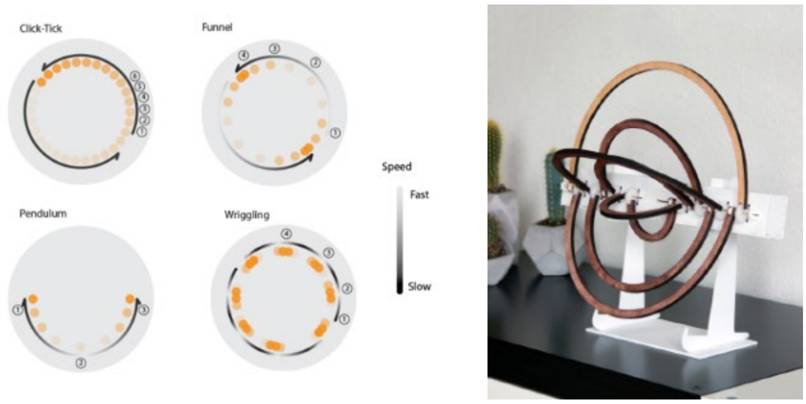


Figure 1. Examples of abstract and reflective information through not disturbing interaction methods. Calm Station (left) and Loop (right)

Both examples provide abstract information with simple product compositions. CalmStation (op cit) demonstrates various types of mobile phone notification through the speed and pattern of the rolling ball, while LOOP provides activity data gathered by trackers, such as smart watches.

Further early work by Strong & Gaver (1996) describe three experiments in designing in support of implicit, personal and expressive communication. Feather (Figure 2, left), is constrained by a transparent plastic cylinder, lifting and falling by air pressure as the paired partner touches an interactive picture frame. More recently, the Indoor Weather Station (Gaver et al. 2013, Figure 2, right), consists of a tiny 'forest', made of paper, enclosed by a transparent, miniature pavilion. Once the station detects wind, it controls a small fan inside the forest's enclosure, which amplifies the gusts to create miniature storms that visibly blow the 'trees'. While not concerned with communication, Gaver et al.'s (ibid) forest concept exemplifies the ways in which tangibility may be used to express a change or feedback (trees moving) related to an action (wind).

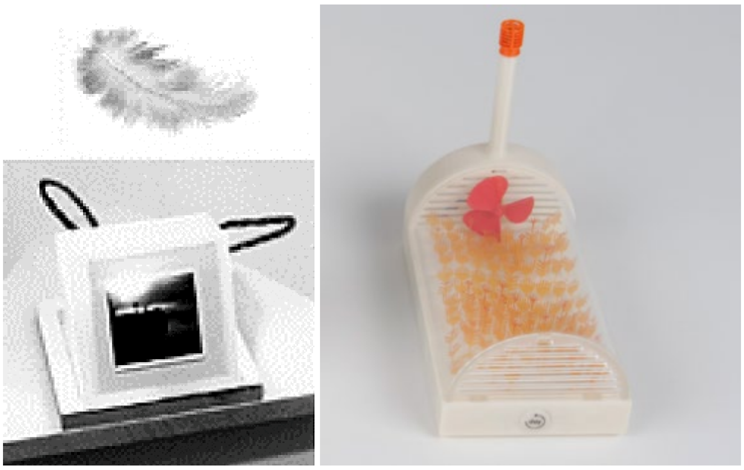


Figure 1. Feather(left) and Wind Tunnel(right)

In terms communication more specifically, InTouch (Brave & Dahley 1997) provides a physical communication channel between people in remote locations. Two geographically distant people may cooperatively move, fight over the rollers or feel the other person's manipulation of the roller (Figure 3).

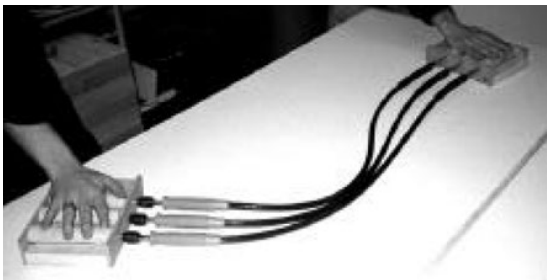


Figure 2. Prototype of InTouch design

Tactile communication appears beneficial for expressing emption. In addition, interpersonal communication through tangible interfaces has been shown to convey enjoyable experiences (Jones & Yarbrough 1985).

3 Preliminary User Interview Study

The purpose of an initial user interview study was to explore how students study in online courses and affect each other through communication and discussion online. These insights were then used to drive the definition of design requirements.

For this research purpose, we conducted semi-structured interviews with 3 graduate students aged from 26 to 28 years old (2 female, 1 male), two university tutors and one high school tutor aged from 32 to 33 years old (2 female, 1 male). Although the complete interview process, analysis and results are not reported here, Table 1 provides an indication of example interviewee responses, insights gained and application as design requirements to drive the design and development of a tangible product design concept we term FlipMe (Table 1).

Table 1. Design requirements derived from preliminary interview study

Participants' verbatim	Insight	Design requirements
I feel uncomfortable… some responsibility if I don't watch video lectures because I may affect negatively my team member.	Social responsibility plays important role in motivating video content watching watch	1. Design must provide feedback on progress of group members
We pin our works on the wall. At that moment, I care a lot not only about their (peers) comments but also micro things such as whispers, Wow sounds and so on. This helps me to evaluate my own work.	Micro/non-verbal interaction (with peers) stimulates student reflection on own works	2. Design to provide micro interaction opportunities. i.e. nudge, whisper, body language
I feel I'm the only one spending my time in front of the computer to watch the lecture. In contrast, I feel better if surrounded by my colleagues, taking lectures together.	Peers motivates peers to engage more in online lectures. Presence of colleagues in same time/space motivates learning	3. Design must accommodate peer-to-peer motivation through simulation of working in same time and/or space
Group work is significant but there is no answer to make a perfect group…always mixing members up if some show poor performance may help. It's because individual students learning styles are all different.	Learning styles affects teamwork and potential cohesion of teams	4. Design needs to provide opportunity for matching learning style to improve collaborative learning

4 FlipMe Design & Development

4.1 Design Features

FlipMe is an IoT (Internet of Things) concept, aimed at augmenting peer-to-peer interaction to promote more active online learning (Figure 4).

Figure 4. FlipMe online learning companion

We designed FlipMe through metaphors, with the objective of at reminding users of learning activities familiar with student (Casakin & Hernan 2007). In this we aimed to provide the predictability of the novel interactions. For example, flipping book pages and sharpening a pencil in a learning context (rotating handle design). A flipping-top provides real-time feedback on peer study activities through its *reading-a-book* like motion (Figure 5).

Figure 5. Peer-to-Peer communication promoted through FlipMe's tangible approach to interaction and data physicalization

Group study activity is expressed through a *rolling-ball* feedback to the product's front (Figure 6). A rotating handle provides a peer-to-peer nudging function. All three features were designed to motivate students' social interaction, which was identified as of significant importance in online learning (Nisbet 2004).

Figure 6. Rolling-ball indicates group (class) study activities towards online class works

4.1.1 Real-time Feedback on Peer Learning Activity

Through FlipMe's book-flipping metaphor, students inform peers of online learning activity. When a paired colleague begins to view video content the personal learning companion starts to flip. This design feature was derived from the requirement to motivate working together.

4.1.2 Tactile Interpersonal Communication

FlipMe provides an opportunity to communicate between peers. A user may rotate the handle when (s)he wishes to start learning together and/or discuss educational contents. As a user rotates the handle, FlipMe transmits the same number of spins to the friend's flipping top, thereby indicating to peers that they are studying (Figure 7).

Figure 7. Rotation handle (bottom-left), inner mechanism for flipping top (top-left)

4.1.3 A Common Goal Indicator

A ball placed in the front face of FlipMe moves to indicate when one or more class peers are viewing video content. The goal-oriented visual presentation also meets goal setting theory proposed by Locke & Yarbrough (2001) that indicates the importance of evaluating progress towards learning objectives. When the deadline of certain course sections ends, the ball moves back to its starting position and the collaborative race will begin again.

4.2 Design Prototyping & Implementation

All parts of FlipMe were designed using CAD (Computer Aided Design) modelling subsequent to ideation through sketching and illustration. Based on material and/or complexity of shapes, we utilized different fabrication techniques in the production of a high-fidelity prototype that aimed to approximate, in detail, aesthetic and functional characteristics.

A 3D printer (Objet Eden 260) was utilized for complex shapes or parts, which were subsequently finished in colour spray paint. FlipMe's plate type components were fabricated by laser cutter (Universal laser system), while CNC (Computer Numerical Control) was utilized for the manufacturing of FlipMe's wooden base and leg parts (Figure 8).

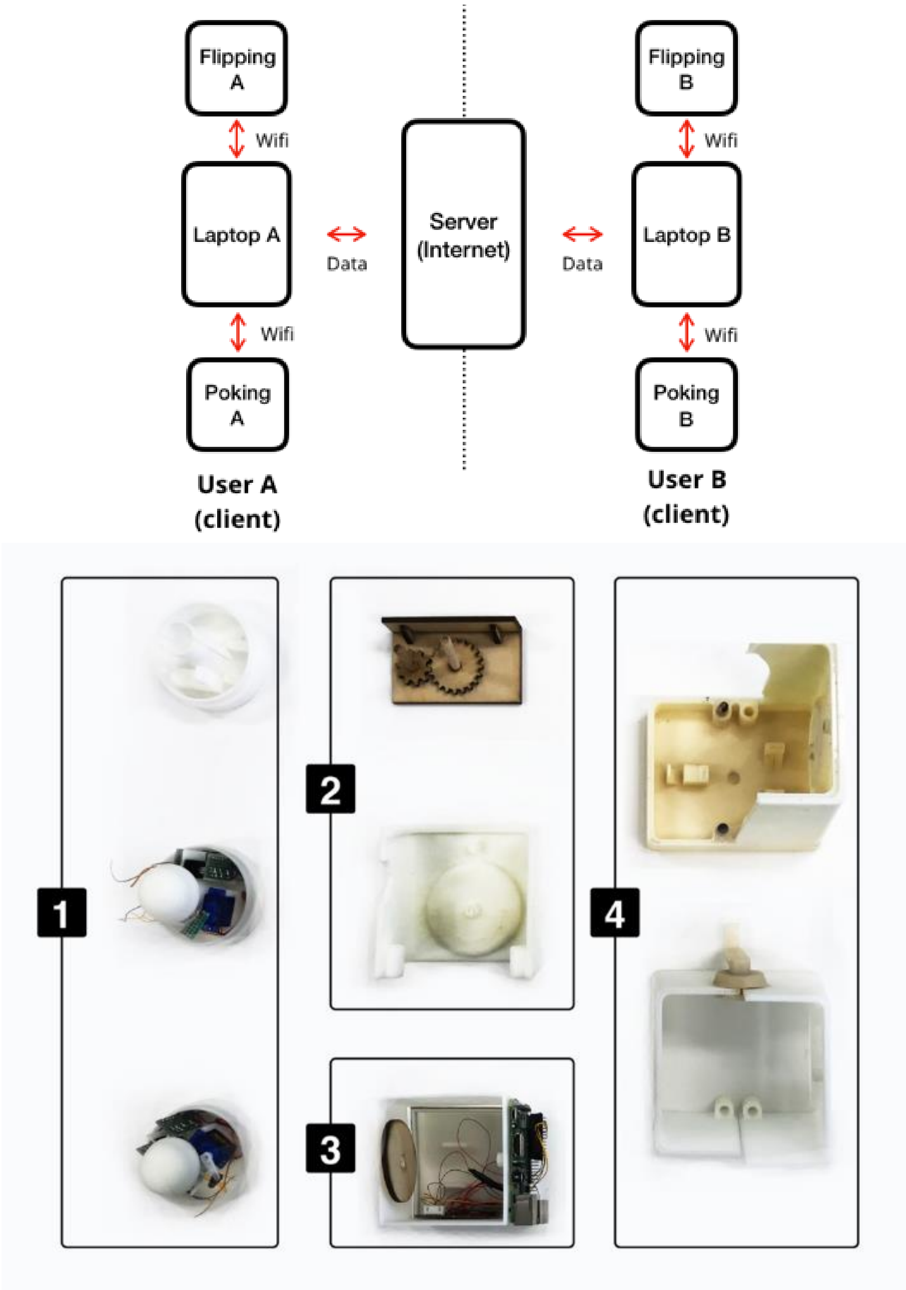


Figure 8. Initial system communication design. Iterative prototyping process: product divided into each interface type. 0)'Poking' prototyping, 1)Common goal indicator prototyping, 2)'FlipMe' 1st generation and 3) Housing structure of FlipMe 2nd generation.

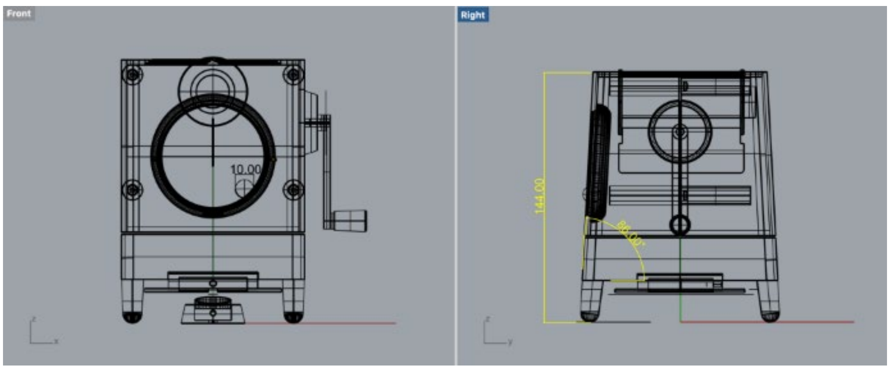


Figure 9. Front and side view of CAD modelling of FlipMe 2nd generation

The main body was designed with a height (144mm, including legs) and an inclination (86°) (Figure 9) so that a user could more easily observe the main interfaces on top and in front. he parts were painted through surface air spray (TESTROS enamel spray, Figure 10).

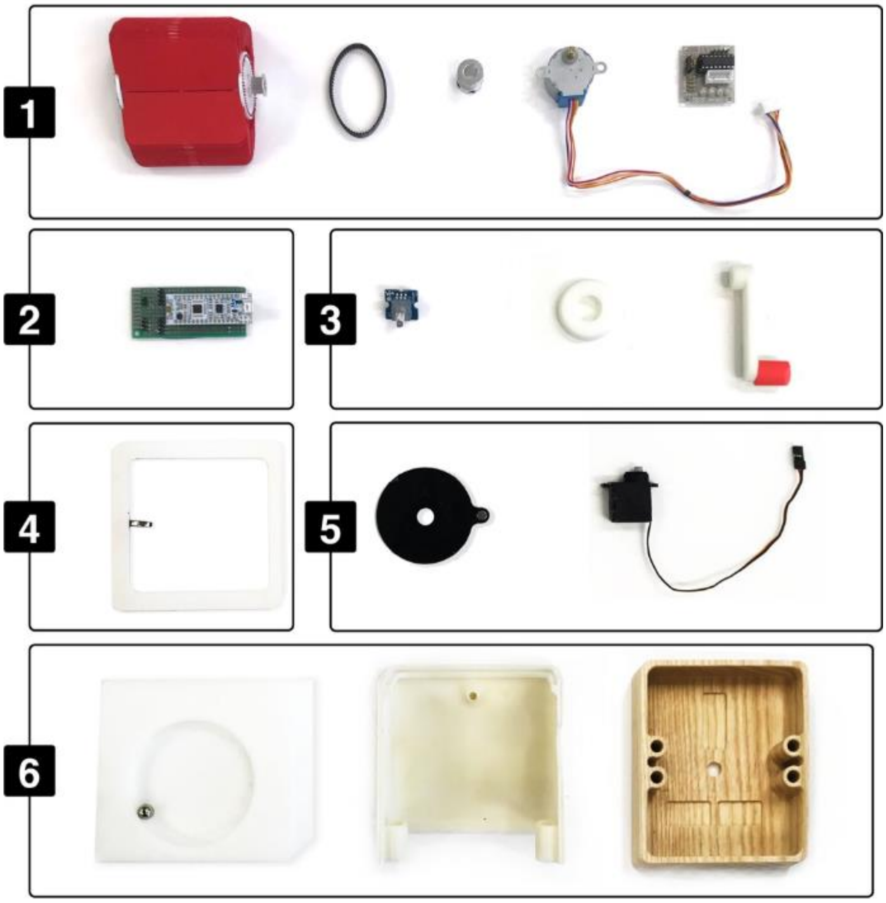


Figure 10. Components of FlipMe prototype: 1) flip cards, timing belt, pulley, step motor and step motor driver, 2) MCU with Wi-Fi module, 3) Handle components with rotary encoder, 4) Rid with a flipping card holder, 5) a magnet holding plate for common goal indicator and a servo motor, 6) Front housing and wooden body

A neodymium magnet with a diameter of 8mm was used to provide information on the progress of the common goal to the front side of the body (roller-ball feedback, Figure 7 above). The neodymium magnet was installed to roll along a circular embossing area of 64mm in diameter. In order to implement the movement of the ball type magnet, two gears with a gear ratio of 1:1 and diameter of 32mm were laser cut and plugged with 180 ° servo motor. A plate with cylindrical magnets was installed on the backside of the circular embossing area. As the servomotor starts to turn, the plugged gear turns, transmitting the rotation to another gear installed with the plate on the back side of the circular embossing area. Consequently, the cylindrical magnet on the backside of the body rotates the ball-shaped neodymium magnet.

To design FlipMe's flipping card feedback feature; a flip clock's mechanism was used as a reference. 1mm polycarbonate sheet was selected and cut by laser cutting (5% power 5%, speed 4%, PPI (500), 1.00mm). A mat red finish was finally applied to the flipping card parts (Figure 11). A small aluminium needle (0.3mm diameter) was designed to hold and release the flipping card. In total, 48 finished cards were used to provide information on peer's learning activity. Finally, to rotate the cards, a timing belt (130mm) and pulley (15cogs, ⌀5mm) was used as power-train from a stepper motor.

Figure 11. Flipping cards' color variation trials and cards holding mechanism

The interior design of the handle was considered to install a 360° rotary encoder module (Grove-Encoder) which senses the number of rotations of the handle through the digital control board (Nucleo L432KC). This provided the same pattern/number of rotating to a paired FlipMe product. Ash was selected to provide the natural beauty of the grain. In order to prevent the breakage during CNC machining, a minimum thickness of 6mm was maintained. FlipMe's wooden legs were inclined to 82°. A 3D printed cable holder also was installed to FlipMe's wooden base. The most basic task was to send data to the server, that existed on the internet, and the real-time transmission and reception of information between paired FlipMe prototypes. The server thus communicates with the internet server at intervals of at least 2~4 secs. In the case of the handle, its rotating pattern is divided into 10 levels and recorded by the user's input as one rotation per second. The data is immediately reported to the Internet (*'rotation angle' per 1sec.* Rotation index ≡ $\left\lfloor \frac{\text{degree}}{36} \right\rfloor + 1$, 0~17 degrees= 1,18~35 degrees= 2 ...342 degrees~359 degrees= 10).

The server was built on Node.js Express. It supports the hosting two websites (one for each peer) and also communicates with each peer's FlipMe device, providing the appropriate commands to the device or website according to the experimental environment.

5 Pilot Validation Study

Through a pre-set learning environment and a given learning task, we conducted an initial in-lab validation study to assess the value of FlipMe as an intervention for increasing peer-to-peer interaction during online learning. Although we report the results of a relatively limited pilot study here, the findings provide initial validation of FlipMe's potential. Specifically, the pilot aimed to explore the extent to which subjects were provided increased awareness of a peer's study activities (viewing video content), and to what extent this may result in behavioural change in terms viewing of video content. Would the spinning handle interaction/flipping-book/roller-ball feedback result in increased collaboration between peers?

5.1 Participants

The experiment was conducted with 22 student participants (*n=22, 22-32 years old, 8 female & 14 male*). All subjects were full-time, undergraduate students studying at the authors' specialised research institution in the Republic of Korea. All had experience in online education and were asked to complete Kolb's (2005) learning style questionnaire. We measured participants against Kolb's (ibid) learning styles to explore how learning style may implicate communication between peers (Neese, 2016). Since the experiment was designed to observe peer-to-peer interaction, participants were asked to choose a peer and to participate in the experiment as a pair. Four pairs were assessed as exhibiting the same learning styles, while six possessed different styles (Table 2).

Table 2. Participants' learning styles

Participants	Learning Styles	Learning Style Correspondence
P1 – P2	Assimilator – Assimilator	Same
P3 – P4	Diverger - Diverger	Same
P5 – P6	Assimilator - Converger	Different
P7 – P8	Accomodator - Assimilator	Different
P9 – P10	Assimilator – Assimilator	Same
P11 – P12	Converger - Diverger	Different
P13 – P14	Assimilator – Accomodator	Different
P15 – P16	Diverger – Assimilator	Different
P17 – P18	Diverger - Converger	Different
P19 – P20	Accomodator – Accomodator	Same

5.2 Study Design

Two fully functional FlipMe prototypes were connected through an internet server. The pilot study was conducted between two independent spaces to provide an opportunity for participant pairs to remotely interact (Figure 12). The independent space assigned to each individual was a cube-shaped booth, with a whiteboard wall for recording notes. Each cube contained a FlipMe prototype, a desk, a chair, a personal computer (MacBook Pro, Apple), A4 writing paper, a pen, pencil and highlighter, post-it notes and a multi-plug. A camera was installed on the ceiling of the cube (Figure 13).

Figure 12. In-lab experiment setting

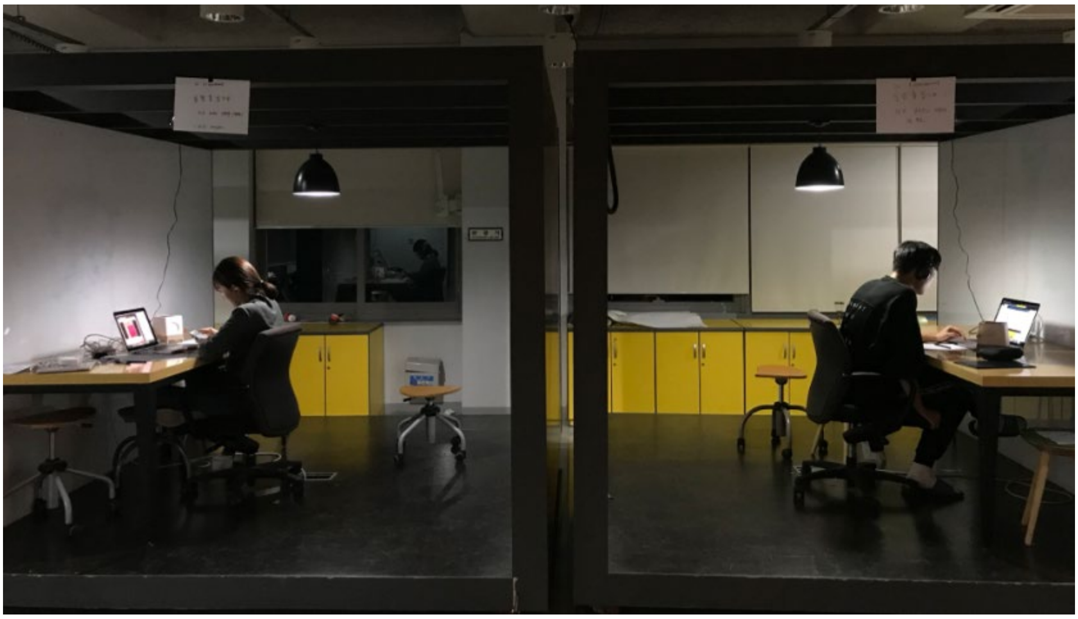


Figure 13. Independent participant booths

After an explanation of experiment aims, we provided participants the results of their learning style survey (Figure 14). At the same time, subjects were given time to share stories related to the task for 5 minutes.

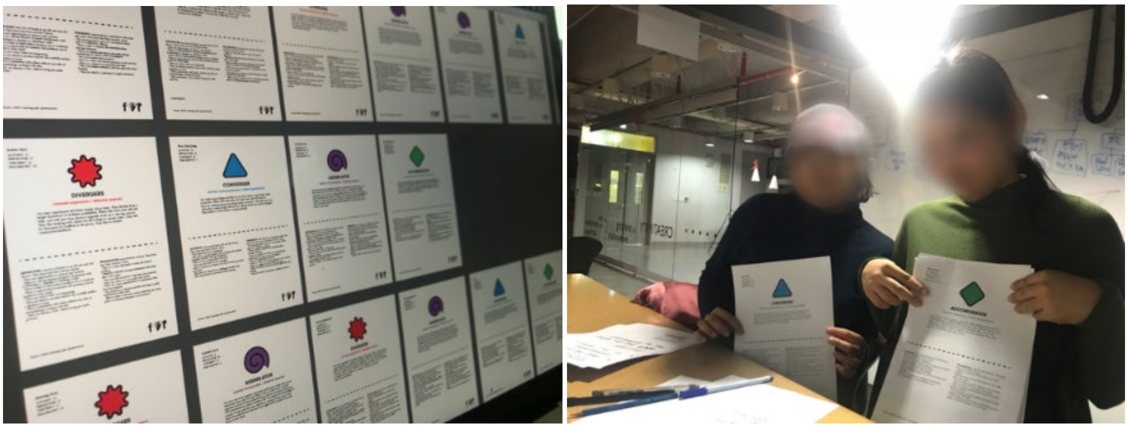


Figure 14. Learning style results for team building and for ice breaking at the beginning of the interviewing

Participants then entered their respective booths and were given 60 minutes to complete the assigned task. A 24-minute video (Norman, Simsarian & Glasson 2019) was provided as a source to help subjects address the provided questions. Questions were open-ended, essay type questions designed to stimulate discussion between peers. The length of the video content was set to be similar to the length of Pope's (2015) previous study exploring the dropout rate of students during video viewing. Although provided, watching video content was not prescribed as a condition or rule. A post-session debriefing was run at the end of the sessions. In this final section of the study, participants were asked to share their responses to the given questions, their use of FlipMe and any challenges and/or opportunities experienced in terms of communication. Interview questions are presented in Table 3.

Table 3. Retrospective interview question design

Questions	Follow-up Questions (indicative)
Q01Do you have recent experience watching online educational content?	What was good or bad?
Q02 How do you normally watch/read given content?	Why do you…? Any issues faced?
Q03 How do you normally communicate/discuss regarding the course with your friends on/offline?	Why do you prefer…? With what purpose do you normally? Any inconvenience in online discussion?
Q03 Can you tell me any particular behaviour to watch (educational) video content?	Why do you prefer this…?
Q04 What activities did you engage to resolve the problem at the beginning of the task?	Why? Was it effective?
Q05 Did you complete the provided video?	From when? In what context did you start? Can you describe at that moment?
Q06 Have you used the handle?	Can you describe the moment you used the handle? Why you want to use? What have you felt? Any suggestion?
Q07 Can you describe when the ball started to move?	What was your reaction? Why? Any suggestion?
Can you rank among three main motions: flipping when the peer is watching, flipping with pattern when the peer is spinning and the ball location?	Why it was the best for you? With that, what have you done/felt? Why it was the least satisfying? Any suggestion?

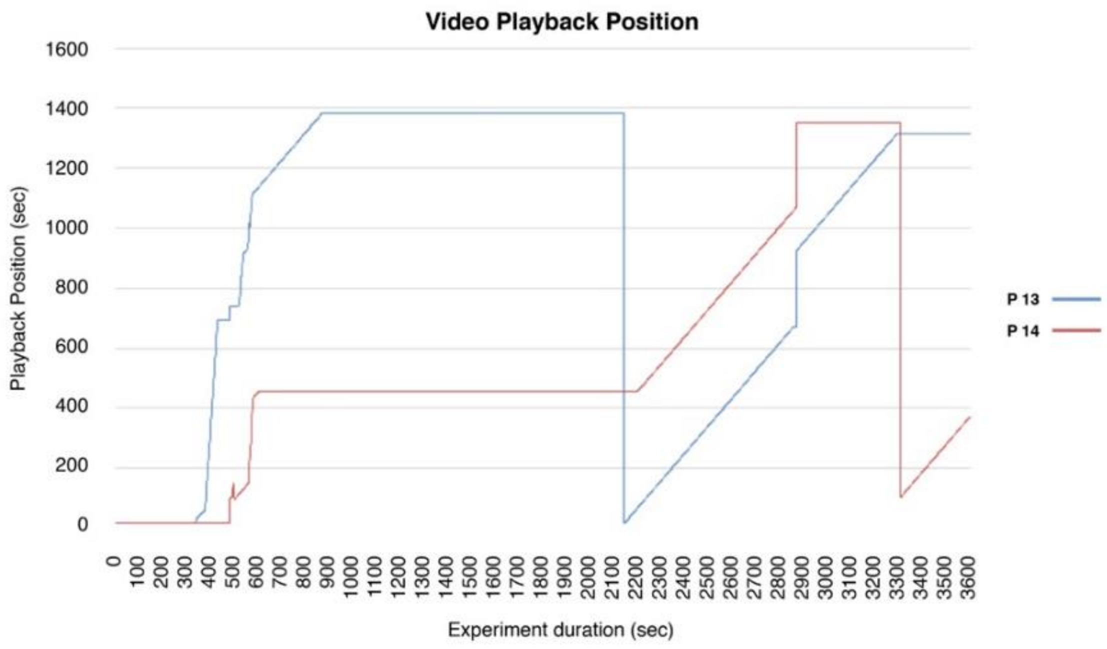
5.3 Product Interaction data logging

Data was logged from two sources for about 1200 minutes. Both types of data were logged to AWS (Amazon Web Service). The source of the data logging was the YouTube player link connected to the internet server and the rotary encoder of FlipMe's handle. The data log gathered from FlipMe was sent to the digital control board and, through the Wi-Fi module, delivered to an online server.

The raw data logged by a single user included: the number of connected users (1, 2), the user ID (*User1, User2*), the current video playback interval (*0-1440 seconds, total 24 mins*) video play status (*during playback, stop*), the spin frequency (*f*) and message frequency (*f*). All data types were reported every second based on KST. In addition, text message frequencies (participants using own PC and/or device) were logged in Slack (Slack.com), a professional communication platform's chatting room. Quantitative, interview response data was also collected through voice recording, followed by transcription and analysis.

6 Results

To explore if physicalizing peers' learning activities through the tangible interface (handle turns, flipping-book/rolling-ball feedback) motivated participants towards increased communication while engaging the provided video content, we compared handle spin frequencies (*f*) and video playback time (sec.) between paired peers. Figure 15 illustrates relations between video content playback and handle spin frequencies for a pair of participants (P13 & P14).



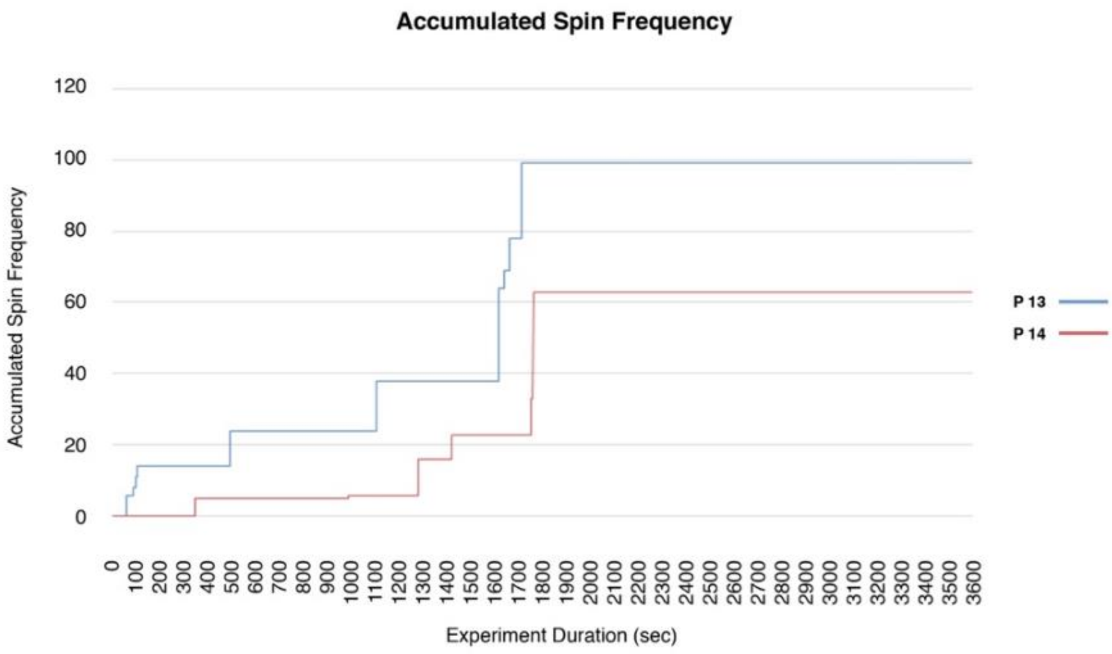


Figure 15. Line charts illustrating video playback timing and durations (above), and Spin frequencies (below) for participant pair P13 and P14.

The line graph above (Figure 15) indicates video playback position (vertical axis) and the session time in seconds (horizontal axis). The graph below shows accumilated spin frequencies (*f*), vertical axis, and session timing (horizontal axis).

As indicated the graphic expression of video playback position, at 350 seconds into the session P13 starts to view video content (Figure 16). P13 also starts to rotate FlipMe's handle just after the start of the session (see Figure 17 below, blue-line, 50 sec.). P14 starts to play video content shortly after P13 at 500 seconds (Figure 16). P14 also starts to spin FlipMe's handle later than P13 (see Figure 17 below, red-line, 350 sec.) and at a slower rate (3 spins). It may be that P14 responded to the flipping-book feedback with a handle spin of his own, before commencing video watching. This indicates that the flipping-book feedback as a nudge for a paired peer resulted in a return nudge followed by the commencement of video watching.

From 350 to 850 seconds of the session time P13 watches 0=1400 seconds of video content (Figure 16). The speed at which the content is viewed indicates P13 increased the speed of video playback, and/or scrubbed through the content. From 850 to 2150 seconds P13's video remains of 1400 seconds of playback.

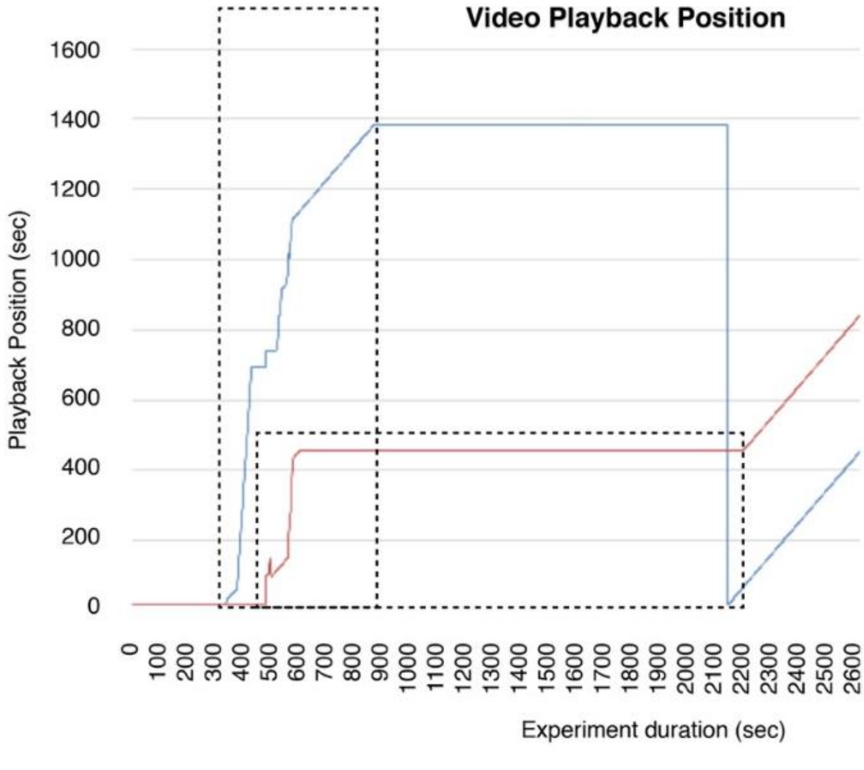


Figure 16. Playback of P13, 330-770sec and P14, 440-550sec.

In contrast, from 500 to 650 of the session P14 views up to 430 seconds of video content and pauses the video until 2250 of the session time (Figure 16, red-line). In the same period, both P13 and P14 give three further spins of FlipMe's handle, following a pattern of P13 spinning first, followed by P14 (Figure 17).

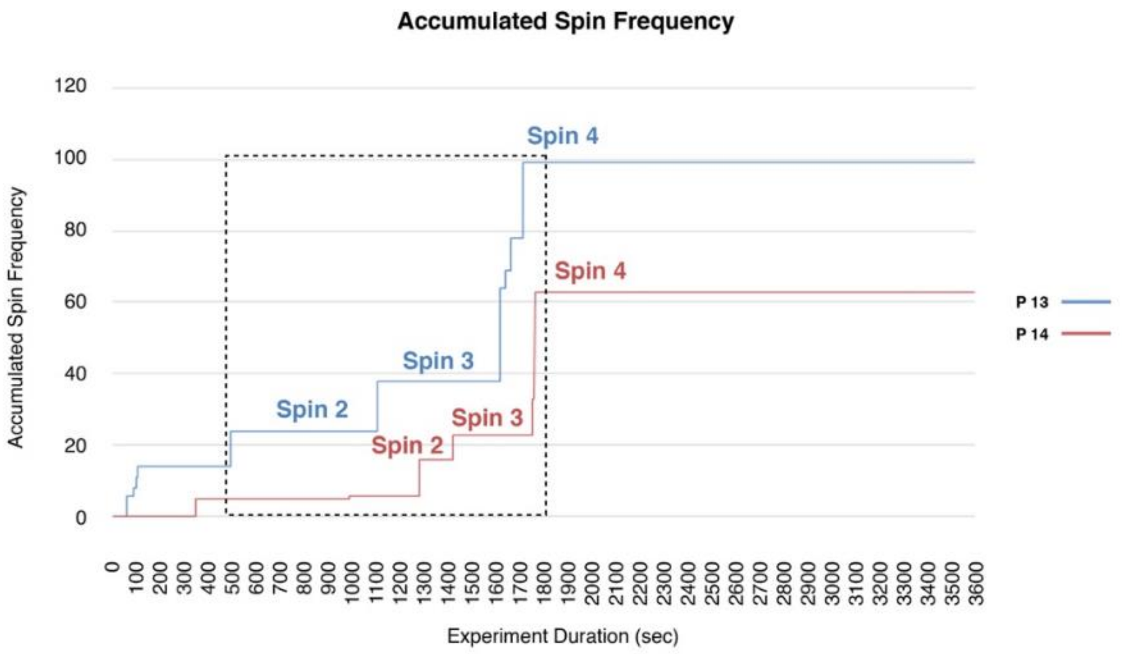


Figure 17. Handle spin frequencies

Despite the intensity of spinning frequencies by both P13 and P14 between 350 and 1800 seconds of the session, both P13 and P14 remain on 1400 second and 430 seconds of video content respectively until, at 2200 seconds, P13 re-starts playback from the video's beginning (Figure 18).

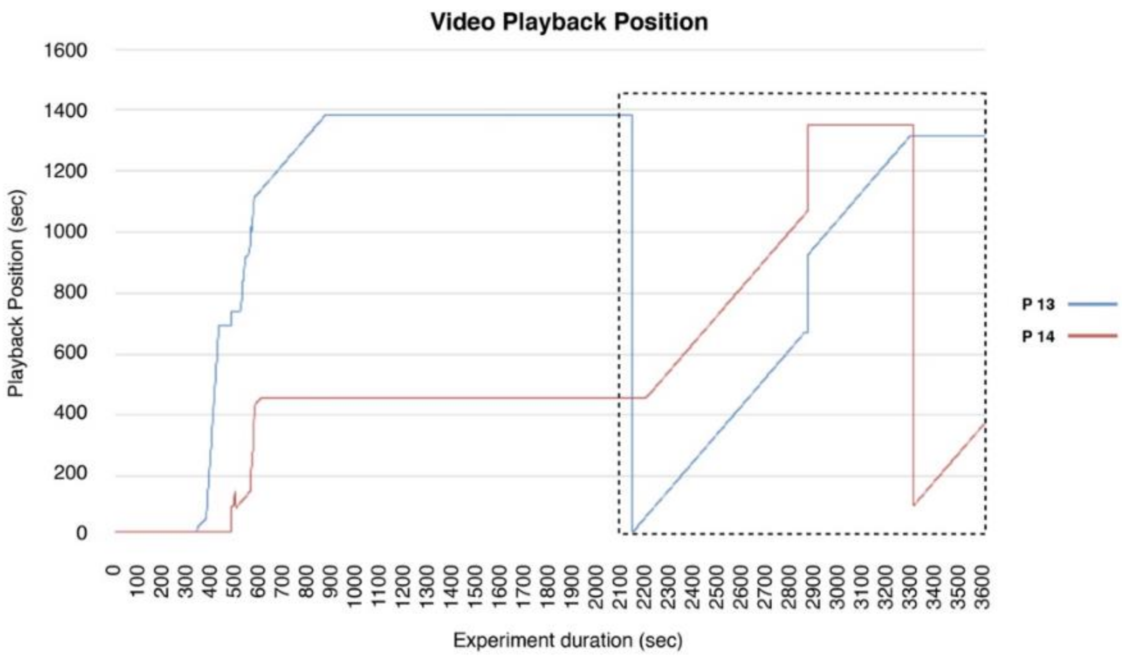


Figure 18. Re-commencement of video playback. P13 at 2150 sec. P14 at 2200 sec.

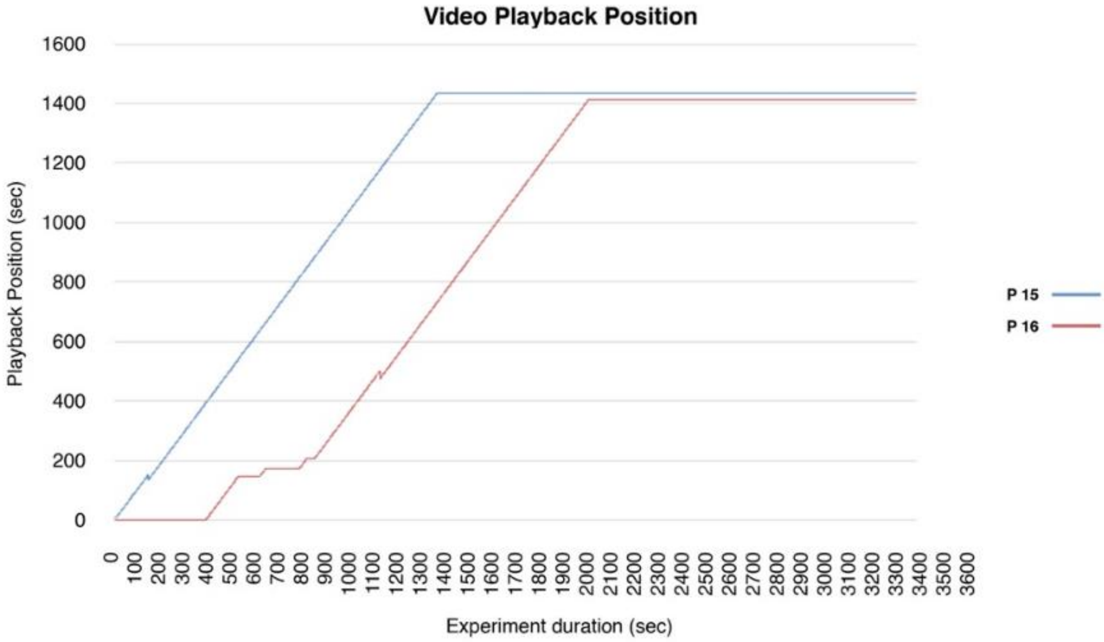
This is followed by P14, who commences video watching again at 2200 seconds of the session time (50 seconds later than P13). P14 continues to watch video content up to reaching 1070 second of the video, before scrubbing through to 1380 of playback at the 2900 second of the session (Figure 18, red-line). At 2900 seconds, the same time as P14 scrubs forward through the video, P13 also scrubs through to a similar playback position (Figure 18, blue-line, 970 sec. playback position). P13 then continues to watch video content up until 3300 second of the session and the 1350 second of playback (Figure 18, blue-line). At the same time in the session (3300 sec), P14 scrubs back to the start of the video and commences playback again from the beginning (Figure 18, red-line, 3300 sec.)

An analysis of post-experiment interview data indicated how the use of FlipMe's spinning handle nudge feature and associated flipping-book feedback may have stimulated P14 to engage video content under pressure from P13, '*At the beginning of the experiment, I, actually, was watching 'YouTube' game channel. But I felt that I also need to study once I realise my friend is studying.' (P14).* The use of social media (messaging) was also found in communication between the pair. For example, P13 explained, *"I spun the handle first then my friend sent a message to ask the reason for spinning. Then we started to chat about the product first and then about the video.'*

Taken together with the analysis of video watching and spin frequencies in relation to time in the session, these results illustrate the ways in which FlipMe worked as stimulation to engage in the video content. However, the subjects' interest appeared first focused on the novelty of the interaction/feedback (possibly explaining the appearance of spinning in the session's first half). In particular, the tangible interaction and flipping book feedback were appreciated by P13, '*The feeling of passing through the book through analog way added sensitivity.'* Likewise, P14 indicated a positive emotional response to the product, *'I do like the chewy sound as cards were flipping, it was white noise for me'.* For P13, feedback on the benefit of communication through FlipMe, resulted in increased efforts to interact through the FlipMe product, '*When my friend replied that my handle action worked on him, I continuously rotate handle to see my friend reaction.'*

However, 6 participants remarked on the distracting sounds from the device. Any future version needs be carefully designed to minimize noise production. In addition, it is not clear to what extent communication through FlipMe was related to the novelty of tangible interaction. The initial interaction through FlipMe did, however, facilitate further discussion towards the video content, resulting in some peer pressure to engage in both discussion of the materials and its viewing, '*I sent a message about our task to her (P13) then turned the handle, or turned the handle then sent a message.' (P14).*

On the other hand, such mutual communication between peers did not always occur in all subject pairs. For example, Figure 19 indicates no attempt to engage a peer through the FlipMe interaction (P18, red-line, below, spin frequency).



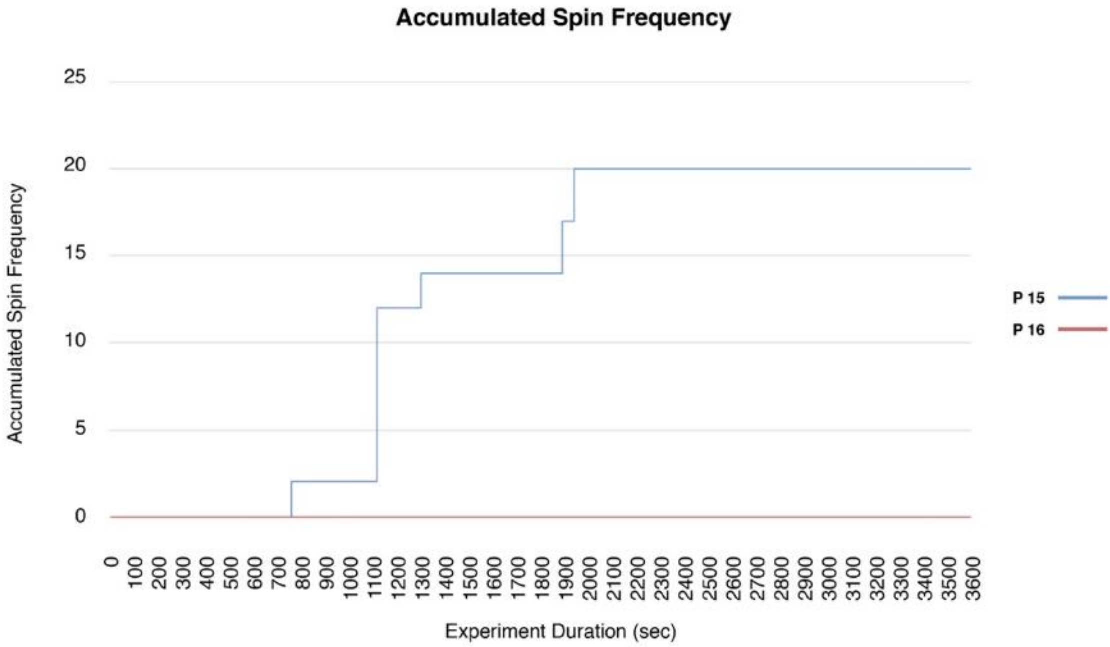


Figure 19. Line charts illustrating video playback timing and durations (above), and Spin frequencies (below) for participant pair P15 and P16.

In this session, unlike that of P13 and P14 illustrated in Figure 15 above, video watching commences for P16 at 400 seconds of the session and continued until 1200 seconds, whereupon the video's end was reached at approximately 2000 seconds. (Figure 19, above, red-line). P15 did attempt to communicate with P16 five times over the course of the session (Figure 16, below, blue-line stepping). P16 confirmed an aversion to interaction through the FlipMe product when stating, '*I do not care what others do. I have my own watching pattern.'* While for some subject pairs, FlipMe appeared to stimulate more communication than others, across the sample group a statistically significant correlation was identified between handle spin frequency and the number of messages exchanged (Pearson's r = 0.81, Table 4).

Table 4. Spin and message frequencies among participants (N=20)

Participants	Spin frequency	Message frequency
P1 (Assimilator, paired with P2)	0	25
P2 (Assimilator)	9	53
P3 (Diverger, paired with P4)	24	0
P4 (Diverger)	11	0
P5 (Assimilator, paired with P6)	46	49
P6 (Converger)	25	43
P7 (Accommodator, paired with P8)	4	8
P8 (Assimilator)	0	2
P9 (Assimilator, paired with P10)	0	0
P10 (Assimilator)	0	0
P11 (Converger, paired with P12)	0	2
P12 (Diverger,)	2	4
P13 (Assimilator, paired with P14)	97	162
P14 (Accommodator)	58	150
P15 (Diverger, paired with P16)	20	94
P16 (Assimilator)	0	61
P17 (Diverger, paired with P18)	30	8
P18 (Converger)	3	10
P19 (Accomodator, paired with P20)	1	0
P20 (Accomodator)	5	0

This result indicated a significant relation between the use of FlipMe and the number of messages exchanged. However, it is unclear from this result to what extent the paired peers themselves influenced communication and use of FlipMe, as indicated in the differences between pairs illustrated in Figures 15 and 16 above.

To explore the potential influence of differences between paired peers, we examined if learning style may be an influence upon the frequency of handle spins and messaging between pairs (Table 5). The data of group 5 (P9-P10, min), group 7 (P13-14, max) are excluded as outliers. Results indicated the mean (x) value of spin frequency (f) for *Diverger style* learners was highest. Message frequency in the same learning style showed the second highest mean value ($x=21.2$). In contrast, the *Assimilator* recorded the highest mean messaging frequency ($x=38$).

Table 5 Spin and message frequencies by learning styles

Learning styles	Spin frequency (avg.)	Message frequency (avg.)
Divergers	17.4	21.2
Convergers	9.3	18.3
Accomodators	3.3	2.6
Assimilators	11.0	38.0

This initial result may indicate FlipMe's appropriateness for *Diverger* users, described as learners comfortable with exploration and trial in their learning styles. Interestingly P13 was profiled as Assimilator, while P14 was an *Accomodator*. In contrast, P15 was, in fact, classified as *Diverger*, with P16 as *Assimilator*. The two assimilators received the greatest (*f=97*), and least (*f=0*) spin frequency counts. While Table 5 indicates *Assimilators* as making the most use of FlipMe, there was a wide deviation across the sample group. As such, results in the influence of learning style upon communication through FlipMe are inconclusive.

From the above analysis, we tentatively posit three broad insights towards FlipMe's potential to stimulate peer-to-peer interaction during online learning. First, FlipMe did provide an opportunity for interaction, supported by conventional communication platforms (i.e. social media). Second, FlipMe, and its tangible interaction (*spinning handle*), and feedback characteristics (*book-flipping feedback, rolling-ball*) received positive response in terms of the novelty of FlipMe as stimulation for interaction. For example, P8 suggests, *'I realized that my friend was studying. So I wanted to share what I found. I wanted to rush before my friend finished studying before the card stopped flipping'.* Third, a significant correlation between frequencies of handle spins and messaging indicated FlipMe's use coincided with increased use of other forms of communication (i.e. messaging). These findings are further discussed below, together with implications for tangible approaches to product interaction as means to stimulate communication in online learning.

7 Discussion & Conclusions

An initial interview study of experts in and users of online learning platforms derived a set of design requirements aimed at improving communication/collaboration between peers during online learning. These design requirements drove the design, development, and implementation (as a high-fidelity prototype) of FlipMe, an IoT (Internet of Things) product intervention with tangible interaction (rotating handle for nudge feature) and feedback characteristics (flipping book metaphor, rolling ball). An initial pilot study to validate FlipMe's potential indicated the concept's ability to facilitate interaction between peers online, albeit from a user study that is small in scope.

Our pilot validation study indicated FlipMe's ability to provide an opportunity for interaction, supported by conventional communication platforms (i.e. social media). That is, the use of FlipMe appeared to depend upon and be associated with the use of other online means of communication, in particular messaging through social media platforms. However, an identified significant relationship between rotation frequency of FlipMe's handle and messaging across the sample group did not indicate the direction of effect. That is, we cannot say if the increased use of FlipMe resulted in more messaging or vice versa.

The post-session interview did, however, suggest the potential of FlipMe to stimulate learning activity (video watching). For example, *P14* stated in a post-session interview, *'At the beginning of the experiment, I was watching 'YouTube' game clip. But I felt I also needed to study, once I realized my friend was studying.'* Likewise, post-session qualitative responses indicated how FlipMe's use appeared to stimulate interaction suggestive of work-in-progress (video watching). *P13* stated, *'I spun the handle first, then my friend sent a message to ask the reason for spinning. Then we started to chat about the video'.* We interpret these findings as evidence of FlipMe's potential derived from opportunities for tangible, more implicit communication (*flipping book*) to facilitate the explicit communication afforded through text messaging and social applications.

Related to the above, findings also indicated FlipMe's tangible interaction opportunities (*spinning handle*), and feedback characteristics (*book-flipping feedback, rolling-ball*) were positively received by most (but not all) participants. This result indicated FlipMe's value as a catalyst for communication during online learning may depend upon the characteristics of the online learner. An analysis of learning styles through the application of Kolb's (2005) taxonomy was inconclusive in identifying a particular learning type(s) most likely to benefit from FlipMe as means of communication.

Although our pilot validation study has indicated FlipMe's potential as means to facilitate communication in online learning, caution is required in any generalisation or interpretation of these results. First, our initial user study lacks scope in the implementation of the design. From these findings alone, it is not possible to verify the potential of tangible interaction as means to foster increased peer-to-peer communication in online learning. Further studies are required to better account for differences in learning attitudes, styles and expectation as an influence on the appropriateness of FlipMe's tangible approach.

Likewise, to what extent the type of learning material, its content, aim and learning objectives implicated FlipMe's beneficial qualities as stimulation for communication was not measured. Future studies may wish to examine the role of tangible interaction and embodied feedback in relation to different types of learning content (i.e. video, quiz, assignment, audio).

Our initial validation study approximated the geographical dislocation of learners. However, we did not account for time-zone differences, cultural influences or contextual requirements (working at home, in the office, in transit), and so implications for FlipMe's tangible communication approach. Other studies may wish to explore how, for example, changing modes, activities and habits of learning may influence the approach to communication in online learning.

FlipMe's physical flipping feedback approach indicated enhanced engagement in video content. However, future studies may also wish to explore how different types of physical interaction (i.e. press, push, pull) may implicate peer-to-peer communication within the online learning space.

These limitations aside, the current study has indicated tangible interaction has the potential for enhanced communication in online learning. This was achieved through our research through design approach in the design, development, and implementation of the FlipMe concept. Further studies are now required to identify and expand the potential of tangible product interactions to provide more connected learning experiences in the online space.

8 References

Ahn, J., Weng, C. & Butler. B., S. (2013) The dynamics of open, peer-to-peer learning: what factors influence participation in the P2P University? *System Sciences (HICSS)*, 3098–3107.

Boud, D., Cohen, R. & Sampson, J. (1999) Peer learning and assessment. *Assessment and Evaluation in Higher Education*, 24(4): 413–426.

Brave, S. & Dahley. A. (1997) inTouch: A Medium for Haptic Interpersonal Communication. *In* CHI '97 Extended Abstracts on Human Factors in Computing Systems *(CHI EA '97)*. ACM, New York, NY, USA, 363-364. DOI: https://doi.org/10.1145/1120212.1120435

Cercone, K. (2008) Characteristics of Adult Learners With Implications for Online Learning Design. *AACE Journal*, 16(2): 137-159.

Coursera Inc. (2019) Accessed 11.04.19. https://www.coursera.org/

Gaver, W. W., Bowers, J., Boehner, K., Boucher, A., Cameron, D. W., Hauenstein, M., & Pennington, S. (2013) Indoor weather stations: investigating a ludic approach to environmental HCI through batch prototyping. *In Proceedings of the ACM SIGCHI Conference on Human Factors in Computing Systems*, 3451-3460.

Ishii, H., Wisneski, C., Brave, S., Dahley, A., Gorbet, M., Ullmer, B. and Yarin, P. (1998) ambientROOM: integrating ambient media with architectural space. *In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '98)*, 173-174. http://doi.acm.org/10.1145/286498.286652

Jansen, Y., Dragicevic, P., Isenberg, P., Alexander, J., Karnik, A., Kildal, J., Subramanian, S. & Kasper H. (2016) Opportunities and Challenges for Data Physicalization. *Proceedings of the 2015 annual conference on Human factors in computing systems (CHI'15)*. 3227-3236.

Johnson, M (1987) *The body in the mind: The bodily basis of meaning, imagination, and reason*. Chicago, IL, US: University of Chicago Press.

Jones, S. E., & Yarbrough, A. E. (1985). A naturalistic study of the meanings of touch. *Communications Monographs*, 52(1), 19-56.

Khan Academy (2019) Accessed 11.04.19. https://www.khanacademy.org/

Kim, T., Park, Y., W., Hong, H. (2017) Calm Station: An Interactive Perpetual Desk Object that Reduces Digital Distractions. *DIS'17 Demo*, ACM Press, Edinburgh, UK, June 10-14.

Kolb, A. Y. (2005) The Kolb learning style inventory-version 3.1, *2005 technical specifications*. Boston, MA: Hay Resource Direct, 200, 72.

Locke, E.A. & Latham, G.P. (2002) Building a Practically Useful Theory of Goal Setting and Task Motivation: A 35-Year Odyssey," *Amer Psych*, 57(9): 705-17.

Lu, H., Jia, L., Gong, S.H., & Clark, B. (2007) The Relationship of Kolb Learning Styles, Online Learning Behaviors and Learning Outcomes. *Educational Technology & Society*, 10 (4): 187-196.

Neese, B. (2016) Different Learning Styles and Effective Communication. *Husson University Online*. Accessed, 11.04.19, https://online.husson.edu/different-learning-styles/

Nisbet, D. (2004) Measuring the quantity and quality of online discussion group interaction. *Journal of eLiteracy*, 1(2): 122-139.

Norman, D., Simsarian, K. & Glasson, C (2019) Lesson 1: Affordance and Signifiers. Intro to the Design of Everyday things, *Udacity Inc*. New York, USA. Accessed 11.04.19,https://www.udacity.com/course/intro-to-the-design-of-everyday-things--design101

O'Donnell, A. M., & King, A. (1999) The Rutgers Invitational Symposium On Education Series. *Cognitive perspectives on Peer Learning*. (Eds.).Mahwah, NJ, US: Lawrence Erlbaum Associates Publishers.

Pope, J. (2015) What are MOOCs good for? *Technology Review*, 118(1): 69–71.

Sauvé, K., Houben, S., Marquardt, N., Bakker, S., Hengeveld, B., Gallacher, S., & Rogers, Y. (2017) LOOP: A Physical Artifact to Facilitate Seamless Interaction with Personal Data in Everyday Life. *In* Proceedings of the 2017 ACM Conference Companion Publication on Designing Interactive Systems *(DIS '17 Companion)*. ACM, New York, NY, USA, 285-288. DOI: https://doi.org/10.1145/3064857.3079175

Shah. D. (2017) A Product at Every Price: A Review of MOOC Stats and Trends in 2017. In Class Central Mooc report, *Class Central*. Accessed 11.04.2019. https://www.classcentral.com/report/moocs-stats-and-trends-2017/

Strong, R., & Gaver, W., W. (1996). Feather, scent, and shaker: Supporting simple intimacy. *Proceedings of CSCW'96,* Nov. 16 - 20, Boston, USA.
Thomas, L. (2002) Student retention in higher education: The role of institutional habitus, *Journal of Education Policy*, 17(4): 423–442. doi: 10.1080/02680930210140257
Udacity. Inc. (2019). Accessed 11.04.19. https://www.udacity.com/
Zhao, J. & Vande Moere., A. (2008) Embodiment in Data Sculpture: A Model of the Physical Visualization of Information. *Proceedings of the Third International Conference on Digital Interactive Media in Entertainment and Arts, DIMEA 2008*, 10-12 September 2008, Athens, Greece.
Casakin, Hernan. (2007). Metaphors in Design Problem-Solving: Implications for Creativity. International Journal of Design. 1. 23-35.

About the Authors:

Wondo Jeong: Wondo Jeong is a freelance UX designer specialized in digital and tangible interface design. Most recently, he graduated from the Design Practice Research Lab at UNIST, specializing in interaction design and engineering. He previously delivered works ranged from mobile application to IoT products for companies from various industries such as IKEA, Hyundai Motor Company, LG, L'Oreal and Azimut Yacht as an interaction designer in Italy and South Korea.

James Andrew Self: Dr. James Self is associate professor of industrial design and Director of the Design Practice Research Lab (dpr.Lab), UNIST, School of Design & Human Engineering. Prof. Self holds a doctorate in industrial design and, before switching to academia, worked for several years within the design industry, both in his native London and Sydney, Australia. He holds Associate Editorships and committee positions for a number of international journal and conference publications. Design works and research contributions include international design awards, patents, articles, exhibitions, seminars, workshops and numerous publications. Design project and research works are focused around three core interests: design practice, interdisciplinary design education and design-driven innovation.

Ian Oakley: Ian Oakley is an associate professor at the School of Design and Human Engineering at UNIST in South Korea. He holds a BSc (Joint Honours First Class) in Computing Science and Psychology and a PhD in Computer Science from the University of Glasgow, UK. He has worked in Ireland (MIT MediaLab Europe), Korea (GIST and ETRI) and Portugal (University of Madeira) and spent time as a visiting professor in Korea (KAIST) and the USA (Carnegie Mellon HCII). His research focuses on the design, development and evaluation of multi-modal interfaces and social technologies. He has published on this topic in both leading conferences (such as ACM CHI, ACM TEI and ACM CSCW) and journals (such as the IJHCS and IEEE Computer).

Hui Sung Lee: Hui Sung Lee is an assistant professor of School of Creative Design Engineering at UNIST(Ulsan National Institute of Science and Technology), directing the Design and Electronic Convergent System. My lab creates novel sensing and interface technologies that foster powerful and delightful interactions between humans and machines. This research often lies in emerging use modalities, such as touch/gestural interaction, voice interaction, and emotional interaction.

Acknowledgement: This work is supported by the Promotion of Special Design-Technology Convergence Graduate School of Korea Institute of Design Promotion (N0001436) with a grant from Ministry of Trade, Industry & Energy of the Republic of Korea.

Fostering Creativity Through Fast Paced, Quick, Down-and-Dirty Ideation

Paepcke-Hjeltness, Verena *[a]; Barnhart, Betsy[b]; Cyamani, Aziza[c], Walters, Kellie[d]

[a] University of Texas at Austin, United States of America
[b] University of Kansas, Lawrence, United States of America
[c] Iowa State University, Ames, United States of America
[d] Garmin Ltd., Olathe, United States of America
* vpaepcke@gmail.com

In educational and professional design environments, where the focus is often set on high quality outcomes, it is easy to get blinded by beauty and perfection. The "hot design sketch", photo-realistic rendering or fully fleshed out aesthetic prototype, despite not always being the better choices, win in many, if not all cases. This research is set to explore the validity of fast paced, iterative, low fidelity ideation in both 2D and 3D during the design concept development phase. Two avenues were explored to prepare students for industry realities, one focused on providing students with a sequence of methodologies to develop creative, robust and diverse ideas quickly on paper. The other focused on implementing fast iterative 3D physical mock up explorations using non-precious materials. This research follows the hypothesis that if students focus on low fidelity processes, they would be able to overcome fixation, create more innovative ideas and develop their skillsets as industrial designers. Therefore, the goals are to explore repeatable and systematic approaches to enhance learning experiences by nurturing creativity. As well as to challenge traditional educational design studio practices in an effort to efficiently ideate for meaningful outcomes.

Keywords: messy front end; low fidelity ideation; fast paced design process; fostering creativity

1 Introduction

Industrial Design education is largely driven by project based studio work where students ‘learn by doing’. The process is often labour intensive, repetitive in nature and if structured too loose, can result in project fatigue and overall inefficiency. In addition, this project-based approach to teaching design makes it foreign to traditional academic disciplines that are based on hard data and facts since it is not always clear how to measure success and what the students have actually learned (Dorst & Reyman, 2004).

One way to measure success is to focus on high fidelity outputs throughout the development process in the form of detailed renderings and high-quality mock-ups. Students are taught to sketch and render to high fidelity, whether it is on paper with pen and marker, or digital relying on tablets and software. These high-quality outputs provide a more measurable deliverable in the otherwise nebulous sphere of how to evaluate the acquired knowledge.

However, there is a danger within this focus on high fidelity early on in the design process, as such that the sketch often manifests itself as the outcome, instead of as a vehicle to explore various ideas. Similarly, physical low-fidelity mock-ups are frequently frowned upon due to their lack of quality, rather than seen as an opportunity to conduct research through design with fast paced iterations without the designer becoming too attached to the concept. The industry's daily realities, however, are based on cost and efficiency - having streamlined workflows, staying within budget and tight timeframes. Failing early, quickly, and often is crucial to avoid long-term monetary repercussions (Rudd, Stern, Isensee, 1996). Incorporating this approach in an educational setting is easier said than done. Students are not encouraged to fail, neither early nor often. On the other hand, professionals may not have the time or bandwidth to spend a large portion of their timeline on intense mass ideation at the front end of a project, they may only have a day to ideate and develop a solution (Buchenau, Suri, 2000) (Rudd, Stern, Isensee, 1996) (Sio, Kotovsky, 2015).

Graduates who were taught a process that focused on the high-fidelity nature of process steps are not prepared to adapt to the industry's procedures of fast explorations and researching through design. Sharing early ideas, being able to communicate ideas efficiently in diverse team settings, and building meaningful mock-ups quickly and abundantly are methods able to be learned. In addition, the focus on high fidelity outputs at an early stage can bias the process and end in fixation on the 'wrong' idea. The hot design sketch has the tendency to win, if the audience cannot see beyond its shiny surface (Rudd, Stern, Isensee, 1996).

Recent interviews with professionals revealed that applicants' portfolios lack the actual "down-and-dirty" process work that is the backbone of an efficient streamlined development process of so many design studios. Work sharing sites such as Béhance.com and Coroflot.com entice designers to mainly share their 'candy' shots and final outcomes, very little is seen on the actual design and decision-making process. As a result, some design students we interviewed frequently concluded that the design process operates always on this high-level fidelity. In return, they did not see the value in quick iterative sketches, are reluctant to present sketches that were not highly refined, or altogether avoid to include process work in their portfolios. This research team, situated at an Industrial Design program at a Midwestern University, asked how could design education become a better catalyst in preparing graduates for seamless entry into the fast-paced realities of the industry? In addressing this question two avenues are being discussed in this paper, which were explored in a 3rd year and a 4th year level course.

1. Explorations into 2D idea generation methods to become more efficient in both input and output in an effort to provide students with a fast, yet meaningful approach to concept explorations. (3rd year level course, focusing on design methodology)
2. Modifying 3D prototyping processes inspired by current industry practices to teach students hands-on research through problem exploration via a series of actual physical mock-ups. (4th year level course, focusing on market ready innovations)

2 Literature Explorations

The following literature review frames three key areas pertinent to this research, idea generation, sketching, and model making.

2.1 Idea generation

Among the primary processes employed in the initial phase of a product design is idea generation, which takes place in the conceptual design phase. The goal of conceptual design is to establish a core technical concept around which the entire design will be built (Jansson and Smith, 1989). According to studies, it is estimated that nearly 70% of the life cycle cost of a product is determined during the conceptual design phase. Therefore, to ensure innovative and efficient solutions in this crucial stage, designers employ different techniques to construct concepts that meet their design criteria. Among such techniques are the commonly known idea generation techniques such as Brainstorming, C-Sketching, Method 6-3-5, Fishbone diagrams, Storyboarding, and many more. Different studies of design suggest that designers proceed through the process of problem solving by cycles of seeing-moving-seeing (Schön and Wiggins 1992) - frequently alternating between internal, mental procedures and external materializing actions (Römer et al, 2001). Through internal cycles, a designer is able to imagine the entire set of possible solutions that result from the exhaustive combination of all imaginable features and externalize them through images and ideas using sketches and physical models (Römer et al, 2001).

2.2 Sketching in the design process

According to Garner (1990), although the styles of sketches may differ between different disciplines, the purpose of sketching is broadly similar. As an integral part of the design process, sketching is used by designers to rapidly shift between design tasks (Atman et al., 2007; Cross, 2004), including thinking through problems (Buxton, 2007; Cross, 1999), enabling problem scoping and solution archiving by enhancing collaboration and communication, and supporting the designers' own dialogs with ideas and their evaluation of imagined solutions (Crismond and Adams 2012). Though additional means of communication such as verbal communication, hand gestures, annotations, and others can be used to illustrate concepts in the idea generation phase (Booth, Taborda, Ramani & Reid, 2016), sketching (pen on paper) is suggested to be the most important media for ideation therefore, as a result, most proposed ideation techniques are built solely on the principle of sketching (van der Lugt, 2002). Thurlow and Ford (2018) quote the early work of Barthes (1967) who denoted a sketch to carry the same structure as a spoken sentence where the abstract form conveyed by the literal illustration is explained through the symbolic image it represents. In this case, sketching can be perceived as a both a method and process of communication (Barthes, 1967). When dealing with innovation in the form of new products, many researchers agree that evaluation is based on a number of attributes, but creativity is an important criterion (Amabile, 1982; Besemer, 1998; Christiaans, 2002; Horn & Salvendy, 2009). Thus, because of their intervening role as the principal media through which mental concepts are converted into external elements, sketches have unexpectedly taken on the role of assessment criteria. It is reported that ideas communicated with high-quality sketches are much more likely to be perceived as creative compared to similar ideas presented with low-quality sketches (Kudrowitz, Te, & Wallace, 2012). Thus, the correlation between good sketchers and creative abilities is not uncommon (Chan & Chan, 2007). In their study, Kudrowitz, Te & Wallace (2012) explained that sketches done during idea generation are exploratory in rationale, executed quickly, with no detail or depth, and using loosely constructed lines and according to Rudd, Stern and Isensee (1996), high-fidelity sketches generated during the early phases of design can have a major influence on fixation and therefore affect the rest of the design process as well as the final outcome. Booth et al.

(2016) discussed a similar concern in engineering design schools were students' early use of Computer Aided Design (CAD) tools in the design process led to premature fixation.

2.3 The importance of model making

In design work, modeling can involve building a physical prototype – "an approximation of the product along one or more dimensions of interest" (Ulrich & Eppinger, 1995) – using easy-to-fabricate modeling materials, like cardboard and duct tape. These approaches can help students visualize their product ideas more easily, especially those with modest drawing skills (Lemons, Carberry, Swan, & Rogers, 2010). Cognitively, according to Viswanathan and Linsey (2011), working with physical models such as prototypes can reduce cognitive workload, support visualizing solutions for complex problems, and identifying flaws in concepts; therefore, leading to more feasible ideas. During the initial phases of problem exploration, applying prototypes to an experience for the user to test is highly effective to demonstrate context and identify issues and design opportunities where multiple disciplines are needed to solve design problems (Buchenau & Suri 2000). Additionally, in his observation, Youmans (2011b) states that building models and testing the solution against its requirements (i.e. validating an early-stage design) increased the chances of producing many solutions that are both original and more useful, which can reduce fixation, and thus improve innovative thinking. Alternatively, negative effects of prototyping as mentioned by Viswanathan and Linsey (2011) describe how students can fixate on their own initial solutions due to a phenomenon called the sunk cost effect (Arkes & Blumer, 1985), i.e. attachment that stems from investing effort and time in developing a physical model. Low fidelity prototypes as described by Rudd, Stern, and Insensee (1996) are not intended to show in detail how the design solution operates, but are rather quick and dirty; their purpose is to allow the designer to work through different solutions with low investment both in time and finances (Rudd, Stern & Isensee, 1996). By using low-fidelity prototypes in the beginning of the design process, it becomes possible to generate a perspective that the design problem being faced is what's important and not necessarily the tools and techniques that were used to get to that point (Buchenau & Suri, 2000) through a quick and inexpensive design method (Youmans, 2011b).

This paper follows the thought that if students early on in their design education are able to gain experience in areas that they have less aptitude for, such as sketching - by guiding them through low fidelity processes and slowly increasing fidelity, they would be able to learn to create more innovative and robust ideas. As mentioned above, this research investigates methods for idea generation in both 2D and 3D concept development, with the goal to provide students with repeatable systematic methodologies that increase speed and improve quality of outcomes. The investigations were situated in two different industrial design course settings at a Midwest University, a third-year studio course with a focus on design methodology and a fourth-year studio focusing on performance based sporting goods with an emphasis on market ready innovative solutions to understand their individual effects on learning outcomes.

3 Preparing students better for fast paced industry realities

Students in a third-year industrial design studio course lacked in innovative idea development and avoided exploring concept variations. Post project interviews with the students revealed an inability to constructively and successfully think on paper was a major inhibitor. Equipping these students with alternative ways to systematically foster creative confidence, develop and explore ideas quickly, while preparing them for the fast-paced work environment, three ideation methodologies were combined strategically to break up the ideation process into smaller steps. The goal of this process was to provide the students with a structured, repeatable, yet low barrier approach to conceptualization, getting them past initial reluctance to put pen on paper and providing them with means to avoid the inherent bias of a high-fidelity output early on in the design process.

Questions that drove this exploration were: How can the process steps be broken down into smaller, less intimidating chunks? What ideation methodologies could be combined to result in more robust, creative ideas being produced faster? How can the depth of the concepts increase, going beyond the immediate solutions? How will the students respond to this process?

3.1 Ideation Process, Low Fidelity High Quantities Outputs

In an effort to lower barriers for sketch ideation and thinking on paper, speeding up the ideation process, while increasing the output and quality of ideas the following methods were combined.

The Idea Box: In his book *Thinkertoys*, Michael Michalko (Michalko, 2010) describes the concept of the ‘idea box’, which is inspired by the morphological box originated by Dr. Fritz Zwicky. The ‘idea box’ lists various parameters of a challenge in the top row of a matrix first, then variations for each parameter are being generated by listing them below the original parameter in each column. By using this step, students first think about solving smaller problems, one at a time by verbally describing possible solutions.

The Lotus Blossom: According to Robert Riley, Yasua Matsuma originated the Lotus Blossom technique in an effort to add focus and power to general brainstorming. The process is as follows. The main idea or theme is placed in the middle. Around this centre eight solutions or related themes are developed on 3x3 cards. Moved outward from the centre, these new eight themes become new centres for the next higher level of brainstorming, visually resembling the growth of a lotus blossom (Riley). In a variation to the original lotus blossom, students now visualize each previously described solution on a purposely-kept small piece of paper.

Concept Sketches: In the design process, concept sketches serve different purposes at different stages. These usually range in fidelity from napkin style sketches, depicting high level ideas and concepts, to more photo-realistic renderings, detailing the design to its manufacturing specifications. Situated on the lower end of the fidelity scale concept sketches can serve as ‘talk’ and ‘think sketches’ for multiple stakeholders involved, as opposed to the more detailed and time consuming ‘make’ and ‘prototype sketches’ (Paepcke-Hjeltness, V., Henry, K., 2017). During this step students are now combining previously visualized individual solutions into comprehensive concepts.

3.1.1 Step 1: The idea box applied

Based on the original idea box, for this purpose of rapid ideation students were asked to list the previously developed design criteria in the top column of the matrix and possible solutions for each individual design criteria underneath in the columns. Students were supposed to develop as many as 24 different possibilities directed towards the specific design criteria only using words (figure 1).

Rearrangeable	Good organization	Implement into current home	Looks handmade	Place for Notes/ coupons	Mail Organizer	Multi-purpose	Avoid things getting lost	Personal connection	Easy to clean	Organize cords	Holds pens/pencils
detachable parts	drawers	match colors of house	wood material	cork board	horizontal filing	control temp of home	top angled slots	draw pictures on the side	incorporate glass	hidden inside	fabric pouch attachment
re-stack in different ways	stackable shelves	small enough for any counter	rustic metal	white board	vertical filing	charging box	angled slots for side access	plays music	wood with gloss coating on it	entire piece encases an outlet	drawer
slide together in different ways	lots of compartments	can include family photo	fabric added to wood	digital screen-text notes to family/self	separate slots per person	calender with events	binder tabs	rearrangeable	plastic that looks like wood	phone charging port	jar
build it yourself in multiple ways	labels for where things go	neutral colors	build it yourself	Chalk board	private slot to hide mail	grocery list	large slots	calender built in	washable fabric liners	built in power box	fold out accordion
dowels hold parts together	slots rearrange to fit products	portable	incorporates family pictures	attached sticky note pad	accordion slots	holds notes	pop out shelves	chalk board with message/date	rounded edges	holes for cords to go through	box
hinges separate 2 parts	file folders	built ins	ceramic pieces	control from phone when completed	side loading	holds coupons	folds open	plant in the center	no tight corners	peg to wrap around	foam block
adjustable height	slots for each family member	magnet onto fridge	painted	syncs to cloud	packs flat when no mail	organizes mail per person	every slot is open on a different side	photos featured in the middle	no cracks or crevices	drawer for misc cords	box crate look
adjustable width	dividers in each box	fits in standard size drawer	nice joinery	dowel for fabric bags to hang on	ranked on urgency	holds pens	Not too much stuff in it	screen with changing photos	pieces come apart	USB slots	peg board
stackable or sit next to each other	pictures to show what goes into it	flips down from cabinet door	hardware	labeled shelves per person	mail slot	notebook holder	proper sized slots	birthday alerts	stainless steel	boxes with cords and phone below	fabric on dowels
removable shelves	sensors track what is inside - app	attaches to cabinet door	re-purposed	categories for mail	separate for bills paid and not paid	has tv screen on side	beeps when untouched for 1hr	user assembles	removable liners	built in surge protector	string where they clip on
box dividers	good organization for pens	amazon alexa - ia	pallet wood	box for notes	separate per person	daily schedule	turns red when basked is too full	everyone has their own slot	liners go in washing machine	retractable cords	detachable pencil case for on the go
velcro together	nothing falls out	on line customization	antique drawer pulls	mail slot, open when needed	by date received	key hook	tracking device on products	made of materials from old home	smooth material	wrap for headphones	elastic
snap together	no huge pockets	tall or long	inside connections visible	magnetic board	by date event takes place (weddings)	notifies about laundry	tiles that notify when piece gone	name engraving	colors don't show dirt	cord tray below	magnetic
button on compartments	keeps track of what is inside it	joinery can be seen	flat-pack	everyone has a box for notes to check	notifies when you get mail	connects to phone, beeps when rings	no huge compartment	___ family est. 1992	fabric parts are washable	iHome for phones	hook onto a cloth sheet
all connected to a belt	clear walls to see inside contents	changes colors	un-sanded	organize coupons for each store	fabric pouch on side	clock built in	magnetic pieces to box	logos of favorite things	can be put in dishwasher	2 inch cords for each electronic	side loading horizontal tube
boxes velcro onto sides	access in different ways	different material options	visible joinery	tablet attaches to side	hanging folders	timer built in	stacked by importance	stickers/patches	pieces come apart for cleaning inside	stuff box for cords	wire basket on side
add more shelves on top of others	inside drawers to hide things	different size options	visible hardware (screws and nails)	clip board	stacking shelves	alarm clock		tickets (travel, sport, music)		whole piece plugs into wall	fabric pouch as side wall
expand with hidden center				pins into the wood	multiple slots to organize	says what for dinner		sign into who visited			two bands to slide pens into
cloth baskets can go on shelves				fold open drawers for coupons	able to hide mail inside	organizes kids activities		in the shape of family last name			holds scissors
				sends grocery list to phone		reminds you to walk the dog					velcro onto sides
						makes ice					angle loading tube
						holds medicine					jar with lid
						distributes drugs for each day					fabric with individual slots
						charges laptop/ tablet					

Figure 1 Idea Box: Exploring solutions for each design criteria (top row) at a time (Idea Box: K. Guerin).

3.1.2 Step 2: The lotus blossom applied

This step focused on visualizing the individual solution listed in the columns under the design criteria. To visually show connections the criteria served as the heart of each 'blossom'. Eight select solutions from the idea box were then supposed to be visualized on a 3x3 cards around the 'heart'. Due to the small size of the cards (or sticky notes) the initial sketches were more abstract and low fidelity in terms of detailing. The reason was to not get focused on one idea yet, but to start thinking about broader visual solutions. This step mainly used the visualization of the lotus blossom not necessarily its focus on additional iterations. (figure 2).

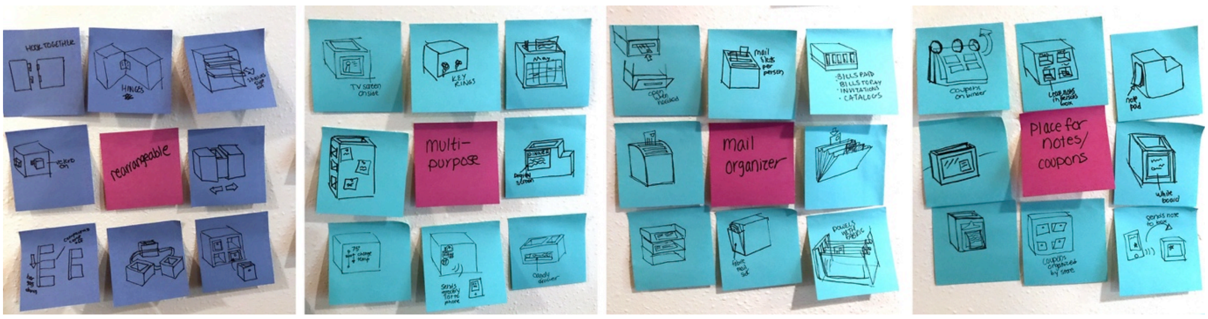


Figure 2 Lotus Blossom: Visualization of previously described solutions in low fidelity (Sketches: K. Guerin).

3.1.3 Step 3: Concept sketch development

Once the lotus blossoms were completed the individual solution ideas were combined into a complete concept addressing all design criteria. Students were asked to explore different approaches for combining ideas. Randomly choose 3x3 sticky notes from each criteria blossom, choose ideas that flow together well, and choose extreme opposites to create an unexpected intersection of ideas (Johansson, 2017). The 3x3 sketches were placed on an

11x17 paper. The overall concept was summarized in words first and then visually explored in higher fidelity and to more detail.

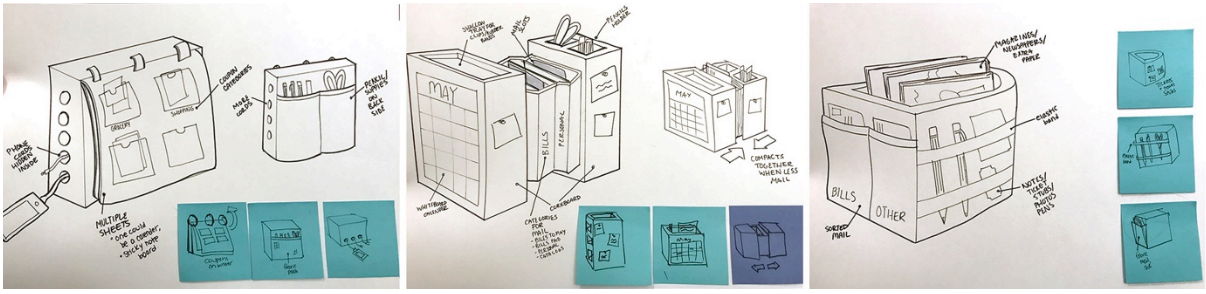


Figure 3 Concept Refinement: Visualization of previously described solutions in low fidelity (Sketches: K. Guerin).

3.2 Research set up and focus

The students were tasked to follow this ideation sequence to explore ideas focusing on topics ranging from storage and organization, to pet products, to cleaning products, to small kitchen appliances. A total of 76 students applied this sequencing of methodologies. Each student was supposed to apply this process individually over the course of three days.

3.2.1 Driving hypothesis

Through the step-by-step approach to ideating the first round of concepts the students could focus on each element independently and not get overwhelmed by the complexity of the problem. In addition, the high-level concept visualization allows for random or specific combinations and can result in almost infinite concept ideas. The latter can aid in resolving roadblocks if they occur since the student can refer back to the high level individual ideas for further inspiration and exploration.

3.2.2 Research Analysis Methods

Analysis methods were geared towards comparing the actual student work as well as towards interviewing select students (n= 10) and sending out a questionnaire to all students in four different studio sections (n= 76). Questions were comprised of:

- How comfortable are you visualizing your ideas on paper?
- How efficient was this process to you?
- What part did you like or not like about this process?
- Please describe in your own words what worked well and what didn't. Or if you have any suggestions.

In addition, during the interviews students were asked to elaborate on the idea box process and how it influenced the next step of high fidelity visualization, as well as how they were able to derive complete concepts from this.

3.3 Observations and Findings from research investigation

3.3.1 Interview analysis (n=10)

The interviews revealed in-depth insight into how the students perceived the process. Student responses can be generally broken up into two directions, the ones who appreciated the process and the ones who had trouble with it or did not like it.

Students who like the process voiced the following:

- It took a while to put together the idea box, however, this seemed to take off the stress of having to try to visualize while figuring out how problem could be solved
- Once the idea box was compiled sketching simple visuals of the descriptions was fairly easy, since the hard 'labour' was already done.
- Combining ideas into a more detailed concept sketch based on the lotus blossom was very fluid and fast.
- The idea box was challenging, but a lot of unique ideas were gained from it, which the student would return to when getting stuck.

Students who had issues with the Idea Box:

- Thinking in words seemed to have complicated the process, however, it was mainly the struggle of thinking about many different ways to find solutions.
- This process was counterintuitive for some students who are very literate in visualization. These students avoided the process and in fact reverse engineered it to show they 'did it'.
- Other students who are literate in visualization followed through with the process, but did not enjoy it and stated that they found it to be a waste of time.

3.3.2 Survey responses (n=19)

Students responding to the survey had a much broader response to the process. The data showed that there was no obvious correlation between students' comfort with sketching and their response to this process, which was an outcome of the interviews. Some students completely embraced this process and felt very comfortable with it. It allowed them to break down the ideation process into smaller steps, which they appreciated. Whereas others thought it added unnecessary time to the process and did not reveal any additional advantage.

It was clear from the responses that the quantity of 24 variations asked for in the idea box was too much, which added bias to the perception of the usefulness of this process. However, this was anticipated since the number was high and mainly asked for students to think beyond the first obvious solutions. The majority of students, however, did comment on how easy it was to combine the single ideas into more comprehensive concepts.

3.3.3 Discussion of overall deliverables and suggestions for improvement

Not all students followed the entire process as assigned. None of them verbally described the third step in the concept sketches. All of them, however, selected several ideas from the lotus blossom to combine into a whole concept. The quality in content varied from lotus blossom to lotus blossom. The students who struggled through the process did not explore many visual variations and stuck with sketching similar solutions over and over.

Revisions for the next round of testing will include providing visual templates and prompts for each phase. Constraining the design criteria to six from twelve, in addition to clearly defining the criteria to avoid two word descriptions. Reducing the amount of written solutions for each of the criteria to ten from 24. Emphasising the written summary of combined ideas.

4 Bringing fast paced industry practices to education

Moving on to 3D idea generation, this industrial design fourth-year studio applied the fast-paced industry process of using low-fidelity mock-ups by moving through a process of extremely low to high-fidelity 3D process work. The goal of the course was to instruct students how to effectively innovate, take risks, and move past fixation, ridding bias through user testing throughout the design process. Questions that drove this initial exploration were: How can ideation methodologies be simplified in order to get quality concept testing feedback and full participation from primarily inexperienced undergraduates? How can the depth of the concepts surpass functional fixedness? How can students get past fixation early on in the design process? How can students think beyond the existing product and innovate within the same product category? How will the students respond to this process?

Methods that were adapted from practice are as follows:

Scaffold Prototypes: A prototyping method to quickly see where there are opportunities worth investigating further. The materials used are deliberately non-precious, duct tape and zip lock bags, so there is no sense of finality to concepts, only exploration to see if they merit further exploration.

Model Modification: The purpose of this type of making is to focus on specific aspects of the design problem at a time. Only focusing on minor functions of the product and specific affordances. (Norman, 2013) Existing products are the baseline structure of the mock-up, but deconstructed and reconstructed with duct tape and staples to innovate while decreasing the intimidation of innovating all aspects of a complex product.

Execution Prototypes: Still rough, but more refined mock-ups are generated to test and represent function. Materials that closely depict performance material are used, but still at a non-precious state to keep bias away from communicating product completion for manufacture.

4.1 Research set up

The following analysis of implementing this 3D Ideation from practice to education method of making was introduced in a design studio comprising a range of students including: 10 fourth year industrial design undergraduate students, 1 first year Industrial Design Graduate student, 1 fourth year Kinesiology student, 1 third year Apparel Technical Design students, 2 fourth year Apparel Technical Design students, 2 fourth year Apparel Product Development and Sourcing. A total of 17 students applied this sequencing of methodologies.

The design brief was framed around a group project designing a hydration backpack and students were given the design question: "Where is it best to carry hydration on the body and in what quantities?"

4.1.1 Driving hypothesis

Similar to the 2D approach students are able to focus on elements of concepts independently so they do not initially become attached to concepts and are able to move forward and avoid fixation. Moving from extreme low fidelity with a gradual increase throughout the ideation process avoids fixation and bias from students, resulting in more robust ideas and a broader range of initial concepts.

4.2 Ideation Process of a hydration backpack

4.2.1 Step 1: Scaffold Prototypes

Students used duct tape and zip lock bags filled with water to tape to individuals for user testing. This proved an efficient process and allowed for adjustments to validate, assess, and adjust their concepts mid-test. Students were able to efficiently test their concepts and assess which had potential to move forward based off of data from testing rather than what they assumed would be best.

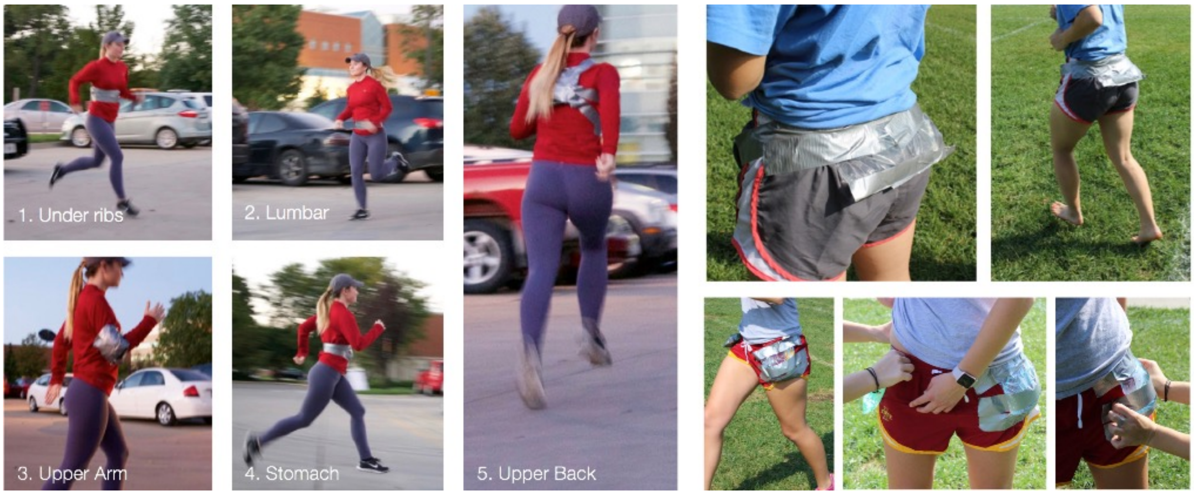


Figure 4 Scaffold Prototypes

4.2.2 Step 2: Model Modification:

Students used existing products- shirts, backpacks, vests - as a base to work from and explore ways of carrying hydration in areas explored in initial investigation. Six to eight options were built and validated through user testing, with three to four rounds of reiterating specific aspects of the product occurring in this phase. Each round would result in a higher fidelity mock-up based off of user feedback with concepts becoming more refined throughout the process. The goal was not to find a solution yet, but to investigate as many opportunities as efficiently as possible through user testing.

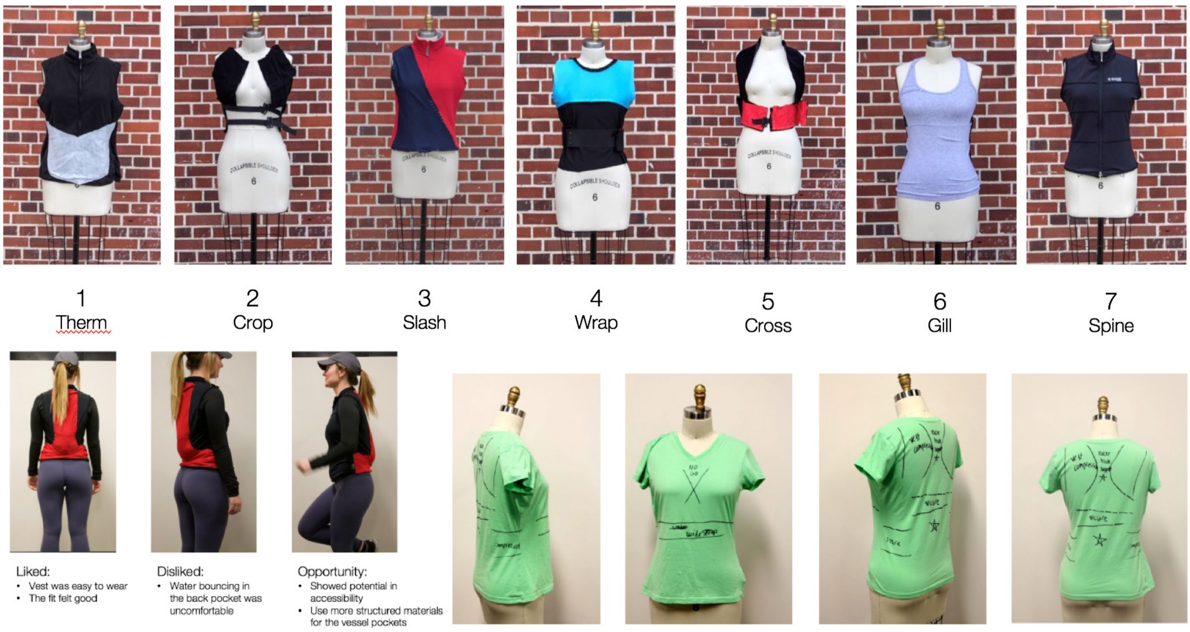


Figure 5 Model Modification

4.2.3 Step 3: Execution Prototypes:

At this point in the process, the skillsets of the group have grown through steps 1 and 2 and students show more confidence and understanding of how to manipulate the materials to test and gain insight. Teams now create multiple versions of performance mock-ups, fairly refined but still not exact materials are used to confirm overall performance of a product to test in its entirety. The goal for this phase is to end with three viable concepts, which were achieved through iterative user testing

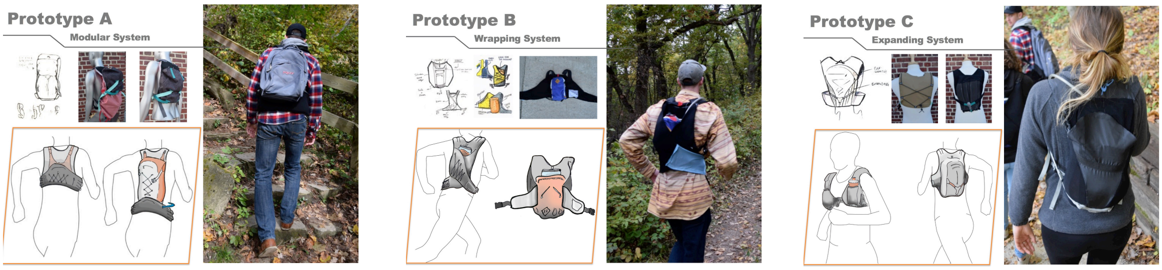


Figure 6 Execution Prototypes

4.3 Observations and Findings

To validate whether this studio methodology was effective for low-fidelity modelling to assist students in moving past fixation, we collected information from 10 students enrolled in the class through a Semi-Structured Interview framework.

Questions that were asked:

- How confident are you in your sewing skills?
- Did the process help engage all team members?
- Did you find yourself getting stuck on an idea? Were you able to move past it? Elaborate on how you moved forward.
- What part did you like or not like about this process?
- Please describe in your own words what was effective and what wasn't.

4.3.1 Findings from interviews (n=10)

Students perspective on the process:

- The initial brief was overwhelming, specifically being tasked with creating a complex market ready innovative product, the process of starting with a simple task of investigating water placement using duct tape and bags of water made students less overwhelmed and able to start.
- By not completing mock-ups and only having portions of ideas students were able to quickly move forward and test without knowing if it would be successful.
- Using existing products and updating portions made testing ideas efficient and students felt less overwhelmed.
- This process helped students come up with a multitude of ideas and not apply multiple aesthetics to one functional product.
- The students drove what aspects of products moved forward through functional assessment, so they felt ownership and knew why they were making decisions instead of completing a pre-determined set number of concepts which felt contrived.
- Overall the students' responses were positive to embrace the merit of this iterative and reiterative process through means of splitting the product into different facets. They appreciated that they did not have to solve the entirety of the design problem at once and they could have different active elements in process at once in

each phase of Scaffold Prototypes, Model Modification, and Execution Prototypes, in which the low-fidelity process allowed for greater work past fixation.

5 Recap of both approaches

5.1 Developing idea generation processes to match fast paced industry realities

In summary, although students struggled with the idea box it turned out to be very useful. It felt counterintuitive for some. However, for others who describe themselves as being more analytic, it was a welcomed change of the ideation process. Despite the idea box taking up a long time nearly 80% of the interviewed students commented that it made the next step of visualizing the solutions a lot easier. In addition, combining those single ideas into a more comprehensive concept was a faster process than without it. Contrary to that, students who are very fluid in visualizing struggled with the overall process and felt inhibited in their idea finding. Those students who were more comfortable in sketching overall embraced this process less than students who are not as comfortable.

However, the work of the students who embraced the entire sequenced ideation process was overall more successful and more diverse compared to the outcomes of student works that did not follow it. The bias of the hot sketch skewed student's view of the process effectiveness even when it was visibly beneficial.

5.2 Adapting fast paced industry standards working through mock-ups

Students were highly responsive to the 3D ideation from practice to education method. On average there were 42 mock-ups per project. Since project progression was from evidence based user testing, there was clear movement towards a final concept, making the process not appear to be busy work. Responses from students informed us that students were initially overwhelmed by the thought of designing the whole product, but were eased by the focus on specific functions and affordances. Students reported that the continual iterations employed throughout the Scaffold Prototypes, Model Modifications, and Execution Prototypes were effective in forcing user validated responses and insisting continued making avoiding the bias of higher-fidelity process work. Students confirmed our hypothesis that when fixation occurred, the ability to focus their attention on another small functional aspect, begin user testing for analysis, and the focus on the functional strength of the product helped students move past those moments of fixation.

5.3 Conclusion:

There was a greater reluctance in embracing the 2D ideation process compared to the 3D ideation process. Based on the student responses the reasons lay within their existing skillset as well as within the course topics. The 2D ideation research was situated in a 3rd year studio course focusing on skill development and methodology (a required course). The 3D ideation research was situated in a 4th year course (an elective course). Students in the former course had varying skill levels pertaining to 2D ideation. Only a handful of students considered themselves as avid sketchers, while the majority were not as comfortable communicating visually on paper. Students in the latter course were more on par skill-wise and were exposed to the additional pressure to perform well to design for production, hence the more competitive studio environment. In addition the low fidelity focus of the mock-up development did not require any major model building skills.

The research team sees a merit in continuing this investigation by:

- Exploring the influence of different learning styles to idea development
- Adding a benchmark of the skill levels at the beginning of the study
- Testing the complete 2D/3D sequence in 3rd year studio environment
- Testing the complete 2D/3D sequence in a 4th year studio environment
- Surveying recent graduates regarding their seamless/non-seamless adaptation into the work environment

In summary, this study uncovered that there are more barriers in speeding up ideation processes in 2D compared to 3D developments. This can be related to inferior sketching skills and a greater divide between students who are very sketch confident and the ones who are not. In addition, the bias in education of allowing the increase in low fidelity concept development over high-fidelity outputs needs to be addressed. In an effort to prepare the students for the fast paced industry standards these barriers will be further explored.

6 References

Barthes R. Elements of semiology. London: Jonathan Cape; 1967.

Booth, J. W., Taborda, E. A., Ramani, K., & Reid, T. (2016). Interventions for teaching sketching skills and reducing inhibition for novice engineering designers. *Design Studies,* 43, 1-23.

Buchenau, M., & Suri, J. F. (2000). Experience prototyping. *Proceedings of the conference on Designing interactive systems processes, practices, methods, and techniques* - DIS 00.

Carmen, G. C. M., Mulet, E. E., & Aguilar, Z. J. (2007). *Analysis of Individual Styles of Problem Solving and Their Relation With The Representations in Design Process. Guidelines for a Decision Support Method Adapted to NPD Processes.*

Chan, D. W., & Chan, L.K. (2007). Creativity and drawing abilities of Chinese students in Hong Kong: is there a connection. *New Horizons in Education* 55(3), 77–94

Cross, Nigel. Design as a Discipline. (n.d.). *Designerly Ways of Knowing,* 95-103.

Crismond, D. P., & Adams, R. S. (2012). The informed design teaching and learning matrix*. Journal of Engineering Education*, 101(4), 738-797.

Dorst, K., & Reyman, I. (2004*).* Levels of Expertise in Design Education. *7th International Conference on Engineering and Product Design Education.* Delft

Garner, S. W. (1990). Drawing and designing: the case for reappraisal. *International Journal of Art & Design Education,* 9(1), 39-55.

Jansson, D. G., & Smith, S. M. (1991). Design fixation. *Design Studies*, 12(1), 3-11.

Johansson, F. (2017). The Medici Effect, With a New Preface and Discussion Guide: What Elephants and Epidemics Can Teach Us About Innovation. *Harvard Business Review Press*.

Kudrowitz, B., Te, P., & Wallace, D. (2012). The influence of sketch quality on perception on product-idea creativity. *AIEDAM*, 26, 267-279.

Luchins, A. S., Luchins, E. H., & Wertheimer, M. (1970). Wertheimer's seminars revisited: problem solving and thinking. *Faculty-Student Association, State University of New York at Albany, Incorporated.*

Norman, D. (2013). The design of everyday things: Revised and expanded edition. *Basic Books (AZ).*

Paepcke-Hjeltness, V., Henry, K. (2017). My other sketch is a Porsche. Changing the paradigm of visual thought processing through generative sketchnoting. *International Design Conference 2017. Industrial Designer Society of America.* https://www.idsa.org/educationpaper/my-other-sketch-porsche *(Retrieved July 01, 2019)*

Prats, M., Lim, S., Jowers, I., Garner, S. W., & Chase, S. (2009). Transforming shape in design: observations from studies of sketching. *Design studies*, 30(5), 503-520.

Riley, R. https://thoughtegg.com/lotus-blossom-creative-technique/ (last accessed 2/3/19)

Römer, A., Pache, M., Weißhahn, G., Lindemann, U., & Hacker, W. (2001). Effort-saving product representations in design—results of a questionnaire survey. *Design Studies*, 22(6), 473-491.

Rudd, J., Stern, K., & Isensee, S. (1996). Low vs. high-fidelity prototyping debate*. Interactions*, 3(1), 76-85.

Schön, D. A. (1984). Problems, frames and perspectives on designing. *Design Studies*, 5(3), 132-136.

Shah, J. J., Kulkarni, S. V., & Vargas-Hernandez, N. (2000). Evaluation of idea generation methods for conceptual design: effectiveness metrics and design of experiments. *Journal of mechanical design,* 122(4), 377-384.

Shah, J. J., Vargas- Hernandez, N. O. E., Summers, J. D., & Kulkarni, S. (2001). Collaborative Sketching (C- Sketch)—An idea generation technique for engineering design. *The Journal of Creative Behavior*, 35(3), 168-198.

Sio, U. N., Kotovsky, K., & Cagan, J. (2015). Fixation or inspiration? A meta-analytic review of the role of examples on design processes. *Design Studies*, 39, 70-99. doi:10.1016/j. destud.

Skaggs, P. T. (2002). Aptitudes for industrial design. *In The 2002 IDSA National Education Conference* (CD ROM).

Smith, S. (1995). *Creative cognition: Demystifying creativity. Thinking and literacy: The mind at work*, 31-46.

Thurlow, L., & Ford, P. B. (2018). An Analysis of Sketch Inhibition within Contemporary Design Education.

Zainol, A. S., Yusof, W. Z., Mastor, K. A., Sanusi, Z. M., & Ramli, N. M. (2012). Using Group Brainstorming in Industrial Design Context: Factors Inhibit and Exhibit. *Procedia - Social and Behavioral Sciences*, 49, 106-119.

About the Authors:

Verena Paepcke-Hjeltness: Associate Professor of Practice in Industrial Design is focusing her research on the diffusion of design thinking practices, with an emphasis on exploring visualization as a gateway to sketch and creative confidence as well as subject matter expertise and design-ability.

Betsy Barnhart: The Director of the Institute of Sports and Entertainment Design, providing connections between academic institutions and private practice tackling large-scale, complex design problems. She holds multiple patents from her work in professional practice for Nike Lacrosse, STX, and Newell Rubbermaid.

Aziza Cyamani: Is a graduate of the Masters of Industrial Design and soon to be graduate of the Masters of Sustainable Environments at Iowa State University. Her research focuses on exploring the intersection between sustainability, marginalized communities and design education

Kellie Walters: CMF Designer at Garmin International, previously a CMF designer at Newell Brands, focusing on home goods and outdoor and recreation products. Kellie also continues her research agenda investigating the relationship between academia and professional practice.

Learning and Sharing Creative Skills with Short Videos: A Case Study of User Behavior in TikTok and Bilibili

Qiyang, Zea*; Jung, Heekyoung

University of Cincinnati, Cincinnati, Ohio, USA.
* zhouqg@mail.uc.edu

SHORT VIDEOS, ranging from a few seconds to a few minutes, have become a popular form of learning and sharing creative skills such as cooking, drawing, and crafting. Short videos in social media platforms are reshaping the experience of learning creative skills with visually engaging materials and communication features to socialize with other users who have similar interest. However, regardless of their popularity and potential, user behaviors in short video platforms have been under investigated yet when it comes to learning and practice creative skills. This study analyzed 1) viewers' comments on selected drawing skill sharing videos (which resulted in four themes of viewer activities and three types of viewer attitudes) and 2) creators' activities (which resulted in frequent user models by regression analysis and dendrogram analysis) in Bilibili and TikTok. User interviews complement the findings from the quantitative user data to identify the gap between user behavior and expectation in practicing and sharing drawing skills in short-video sharing platforms. The multi-dimensional data about user behaviors and expectations are synthesized into five different personas and user journey maps, leading to the discussion of design recommendations to support creative practice in short video sharing platforms.

Keywords: short videos; social media; learning and sharing skills; user studies

1 Introduction: Creating and Sharing Knowledge in Short Video Platforms

Contemporary communication and media technologies have enabled learning and sharing various kinds of knowledge through online communities (Dron & Anderson, 2014). Social media is a group of Internet-based applications for the creation and exchange of user-generated content (UGC) (Kaplan & Haenlein, 2010). Also, it is defined as *"collaborative online applications and technologies which enable and encourage participation, conversation, openness, creation and socialization amongst a community of users"* (Bowley, 2009). As social interactions are important attributes to transfer knowledge among individuals (Polanyi, 1967), social media can facilitate creating and sharing knowledge among people with similar goals and attitudes (Wahlroos, 2010; Panahi et al., 2012), generating alternative views and new ideas in online communities (Eteläpelto & Lahti, 2008). People tend to hold a positive attitude to collaborative learning on social media because they provide a more interactive experience and motivation during their involvement in knowledge-related activities (Manca & Ranieri, 2016; Mao, 2014).

1.1 Short Video Sharing Platforms

Short video platforms have become a popular form of social media applications among millennials for sharing entertaining contents (Patrick, 2018). Most short video platforms are mobile applications, where users can create, edit, share, and view short videos. Short videos have a standardized short duration ranging from few seconds to few minutes; the relative convenience of content generation, rapid content transmission, and emphasis on sociality are the distinct attributes of short video platforms (Zhao & Wang, 2015).

TikTok is a popular short video platform, introduced in China and fast growing with over a half billion users from all around world (Zhong, 2018). The platform enables many short video specific features such as “Duet” (to create a duet video with another user) and “React” (to comment with a video) to encourage new collaborative and immersive user experiences. Bilibili is a Chinese video-sharing website, which was derived from a Japanese video-sharing website, Niconico, currently with more than 200 million users (Wang, 2016). Videos could last from few seconds to few hours in Bilibili. Besides short video specific platforms, other social media platforms also integrate short videos as one of the UGC sharing media forms. Instagram has released the “Instagram story” feature, which is a personal feed of photos and videos within Instagram and can only exist for 24 hours (Instagram, 2019). The duration of each story is limited to 15 seconds. The feature has reached a great success with more than 400 million active users out of its total 1 billion users (Ahmad, 2018).

1.2 Knowledge and Skill Sharing in Videos

Based on the success of entertainment-oriented short video sharing platforms, knowledge sharing has also become important part of their services. The categories of shared knowledge on TikTok vary from creative skills and personal experience to explicit knowledge such as science, technology, and culture (CBNData, 2017). Su (2018) found that users would have a positive attitude on TikTok because they can learn many skills beneficial in their daily lives. Learning in the form of shorter video will significantly encourage learners to take part in task-relevant activities and reduce task-irrelevant activities (Szpunar, 2013).

Videos have been broadly used in knowledge sharing from social media to Massive Online Open Class (MOOC) platforms. Studies show that viewers are more engaged with knowledge sharing videos shorter than 3 minutes on MOOC platforms (Guo et al., 2014); videos less than 5 minutes are likely to succeed in providing a better knowledge-obtaining experience for users by improving their learning attitude, effectiveness, and engagement (Hsin & Cigas, 2013). Other studies offered insights to improve users’ learning experience in video-based MOOC platforms: the ease of access to knowledge in the comment section will help viewers better understand the content of the video (Monserrat et al., 2014); users on collaborative video platforms are more willing to share their opinions and knowledge than on traditional forum platforms (Wu et al., 2018).

2 Research Questions and Methods

Previous studies affirm the potential of short videos as an effective medium for learning creative skills through social interactions and collaborative content creation and sharing. However, most of those studies are about video durations and knowledge sharing in MOOC platforms that have specific learning objectives. User behaviours in short video sharing platforms have been under-studied when it comes to their potential of creative skill sharing where the boundary between learning and playing is blurred. Also, there has been little discussion regarding user experience and interaction design opportunities in popular short video sharing platforms that serve a huge number of users with different goals and attitudes. This study is motivated to understand user behaviors specifically related to learning and practicing creative skills with the following research questions:

- What are user expectations from posting and watching skill-sharing short videos?
- How do they learn and practice creative skills in short video sharing platforms?
- What may be gaps between their expectations and actual experience in short video sharing platforms regarding learning and practicing creative skills?
- How can we understand user behaviors and improve their experiences of learning, practicing, and sharing creative skills in short video sharing platforms?

2.1 Data Collection and Analysis

There are numerous video contents and different kinds of user activity and profile data available in short video sharing platforms, and it is challenging to define the scope of data collection and analysis. Our research process has been exploratory by selecting specific video posts shared as public knowledge in popular short video platforms and sampling relevant user groups based on their reactions to those videos for further investigation. [Figure 1] overviews our research process that consists of different data collection and analysis methods.

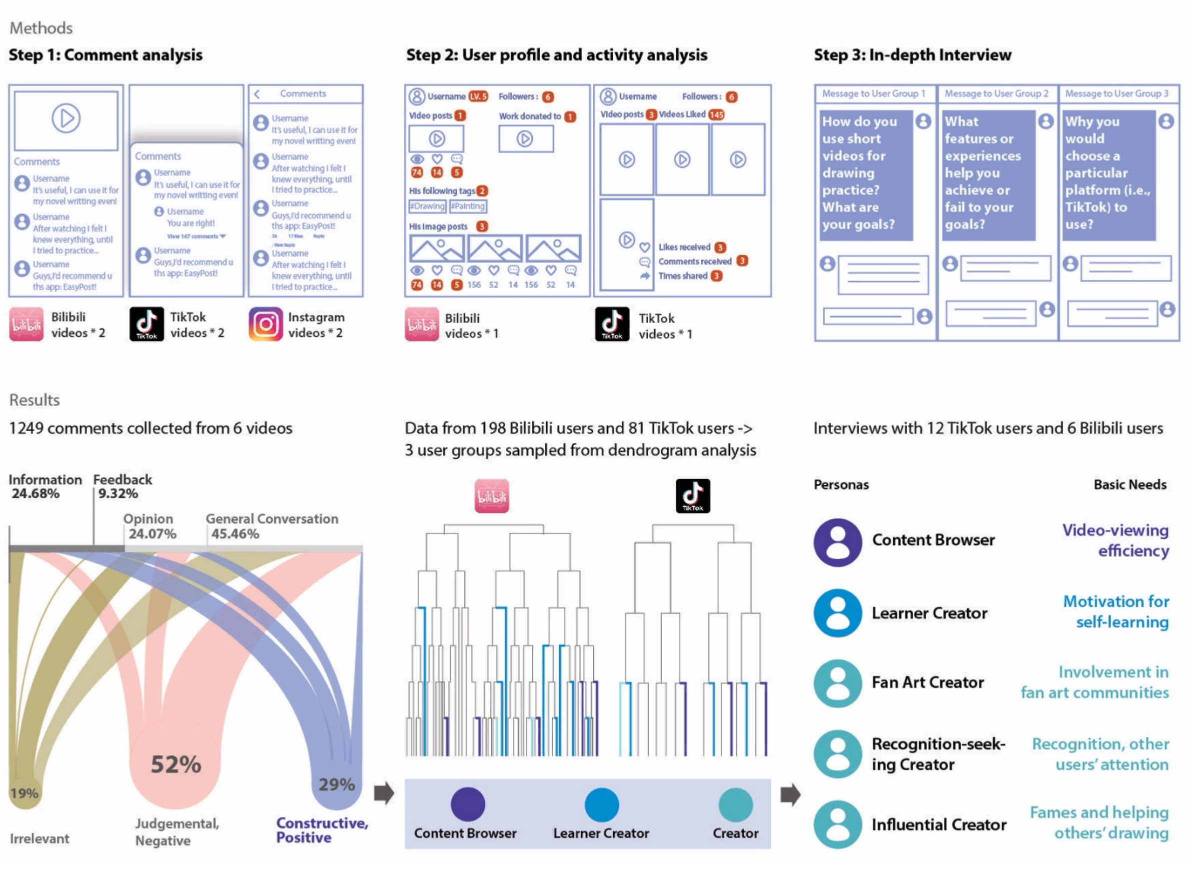


Figure 1. The Research Process.

1) **Platform and Video Selection:** We selected drawing videos from three popular platforms as a topic for this case study: TikTok, Bilibili, and Instagram. According to the search results we retrieved from each platform on April 2, 2019, the videos with a "drawing" hashtag ("画画" in Chinese) have been viewed 142 million times on Instagram and 6.9 billion times on TikTok. We selected highly ranked videos tagged with "drawing" and "drawing tutorial" in each platform: top 2 videos from Bilibili [1, 2], top 3 videos from TikTok [3, 4, 5], and top 3 videos from Instagram [6, 7, 8].

2) **Comment Analysis:** We collected 1,249 public comments in total from the 8 selected video posts and analyzed their contents and attitudes with a focus on user motivations for learning and sharing creative skills from the videos. We identified some users who are more actively participating in skill sharing and supporting based on their commenting contents and attitudes to the selected drawing videos.

3) **User Profile and Activity Analysis**: We traced the public profile and activity data of the users identified from the comment analysis. 13 kinds of user data were collected from 198 Bilibili users [Table 1] and 8 kinds of data from 81 TikTok users [Table 2]. No personal information was further collected or associated with the online public profile. With Tableau [9] and Excel formulas, we conducted *regression analysis* to find out any statistically significant relations between some user data and *dendrogram analysis* to identify influential factors (i.e., knot) and cluster distinct user groups with those knots as their main characteristics (Qu et al., 2015). The dendrogram was resulted in 52 clusters in Bilibili and 16 clusters in TikTok that divide distinct user groups according to their levels of participation in content creation and sharing.

4) **Pilot Interview:** We contacted 81 users who are grouped in the 16 primary clusters in TikTok for a pilot in-depth interview; 12 of them voluntarily responded back. They shared more details about their purposes of viewing and sharing drawing videos, experiences in TikTok, and expectations regarding their creative practice in short video platforms by direct messages in TikTok, not sharing any other personal information (In average 300 messages exchanged for 30 minutes per interview). Responders' ages range from 13 to 25 with their backgrounds from middle school student, to graduate student, to user experience designer, and to software developer.

5) **User Persona and Journey Map:** We conducted thematic analysis of the interview responses and generated five themes by highlighting worth-noted points from them inductively (Boyatzis, 1998). Each theme is developed into a persona and user journey map with specific experience phases in short video sharing platforms. Design recommendations are discussed to support various user expectations regarding creative practice in consideration of the users' broader life styles and goals.

[1] https://www.bilibili.com/video/av21462790?t=47
[2] https://www.bilibili.com/video/av33688833
[3] http://v.douyin.com/2W2KHH/
[4] http://v.douyin.com/2WAhEj/
[5] http://v.douyin.com/2WDGwN/
[6] https://www.instagram.com/p/BqkllsRl2ca/
[7] https://www.instagram.com/p/BqlRqofgaVQ/
[8] https://www.instagram.com/p/Bb-F36qAgVl/
[9] https://www.tableau.com/

*Table 1 Users' data category on Bilibili (*Top Three Knots)*

Data Category	User Data	Justification
User status on the Platform	User's membership level (LV)*	User's LV ranges from level 1 to level 6. LV is depended on the frequency of Bilibili usage and the amount of users' experiences, which can be earned by users' involvement on Bilibili.
	User's followers*	The number of a user's followers can represent the individual's social influences.
Knowledge-consuming activities.	Drawing-related posts user saved*	It reflects the knowledge-document behaviors of users.
	Drawing-related posts user paid	Users can earn the Bilibili coins through multiple involvements on Bilibili. User can use the coin to pay others' posts to show the payer's support and acknowledgment.
	Drawing-related tags user followed	On Bilibili, "tag" consists of a few words that represents a topic. It contains many related resources within the platform. Users use tags for efficient information-searching
Knowledge conversion, creation, and sharing activities.	Drawing-related image posts	N/A
	Drawing-related video posts	N/A

*Table 2 Users' data category on TikTok (*Top Three Knots)*

Data Category	User Data	Justification
User Status on the Platform	User's followers*	The number of a user's followers can represent the individual's social influences.
Knowledge-consuming activities	Drawing-related posts users liked (i.e., L) *	In TikTok, "like" is a function of saving. It reflects the knowledge-document behaviors of users.
	The ratio of the number of drawing-related posts that a user like to the number of all posts that a user liked (i.e., L/A) *	Like is a behavior that happened very often and random. It will be more accurate to apply L/A to prove if individual's knowledge sharing/learning intentions are stronger than others.
Knowledge conversion, creation, and sharing activities	Drawing-related posts	N/A

3 Research Findings

This section summarizes the findings from the comment analysis, user profile and activity analysis, and pilot in-depth interviews. In this course of multi-dimensional data analysis, primary user groups are specified to further investigate their behaviors related to learn, practice, and share drawing skills in short video sharing platforms.

3.1 Four Comment Categories and Three Commenting Attitudes

Madden et al. (2013) categorized YouTube comments into three categories based on their relevance to the videos: 1) comments related to video content, 2) comments related to video context, and 3) general comments that do not relate to video content or context. Building upon this general categorization scheme, we specified the three comment categories with a focus on user participation in learning and sharing drawing skills. Below are the reframed comment categories that represent four different types of comments:

- **Information type**: Comments elaborating on or requesting explicit information directly related to the posted video, providing an objective statement or point of view. (e.g., *"So, brows decide the styles of eyes."*)
- **Feedback type**: Comments asking for more information about how to apply the video to practice or feedback to the commenter's work created based on the instruction of the posted video. (e.g., *"I got stuck in drawing ellipse."*)
- **Opinion type**: Comments assessing the quality of the posted video, stating the commenter's subjective, often critical, point-of-view. (e.g., *"this is useless"*)
- **General conversation type**: Comments initiating or continuing conversations to interact with other viewers and share information, often not directly related to the video content. (e.g., *"Thank you for your tutorials"*)

Apart from the content types, the collected comments showed three different attitudes that reflect the commenter's engagement in learning and sharing drawing skills:

- **Constructive and positive attitude**: Comments showing interests and curiosity directly related to video content and context, generating questions and discussions to apply the video content to different contexts, share more information, and build knowledge about creative practice (Fosnot & Perry, 1996; Madden et al., 2013).
- **Judgmental and negative attitude**: Comments related to video content or context but not contributing to skill-sharing or knowledge construction nor acknowledging the shared content, mostly aiming to criticize and judge.
- **Irrelevant attitude**: Comments not related to video content or context and irrelevant to the subject or topic of the video, showing ambiguous or no learning intention.

Table 3 shows that the general conversation type of comment is most prevalent (mostly taking a judgmental and negative attitude), while the feedback type of comments is the least in most videos (mostly taking a constructive and positive attitude). The opinion type of comments often shows an irrelevant attitude to learning and practicing creative skills. The overall statistics imply that most comments are intended simply to start a conversation and interact with other users, not necessarily to learn and practice creative skills. Design opportunities lie in supporting this relatively small but highly motivated group of users by prioritizing to reveal and reward their constructive, content specific comments from the majority of irrelevant ones.

Table 3 The percentage data of the comments categorized by the two classification schemes.

	Total	Information	Feedback	Opinion	General Conversation
Constructive, Positive	29%	42.81%	29.94%	14.97%	28.14%
Judgemental, Negative	52%	15.56%	0.0%	19.70%	64.40%
Irrelevant	19%	20.81%	0.9%	54.75%	26.70%
Total	100%	24.68%	9.32%	24.07%	45.46%

3.2 Three User Groups: Content Browsers, Learner Creators, and Creators

We selected another drawing video respectively from TikTok[10] and Bilibili[11] and validated our comment classification scheme by applying it to analyze the comments from the two videos. We also identified active users who made information and feedback types of comments with a constructive and positive attitude to each video; tracked their public profile and activity data to investigate their behaviors related to drawing practice in each platform: 13 kinds of data from 198 Bilibili users [Table 1] and 8 kinds of data from 81 TikTok users [Table 2]. First, *regression analysis* revealed how the two platforms afford different user experiences of creative skill sharing:

- **In Bilibili,** the number of each user's video posts and the number of the user's image posts are highly associated with each other (with r > 0.7; R2 = 0.52; p<0.0001). Users who post work in one format is likely to post in another format. Meanwhile, the total number of image posts (1,257) significantly exceeds that of video posts (193). Also, the number of likes received per video post (i.e., L/P), comments received per video post (i.e., C/P), and view counts per video post (i.e., V/P) present a statistically significant correlation, while the number of users' video posts, L/P, C/P, and V/P are not statically associated. It indicates that users tend to show their appreciation to a video post through multiple reactions after viewing it. However, productive users do not necessarily receive prolific recognitions corresponding to their creative effort.
- **In TikTok,** the number of shares per post (i.e., S/P), L/P, and C/P present a statistically significant positive association. It indicates that viewers more likely reward the video uploader with multiple reactions than once. The number of each user's followers does not statistically associate with the user's L/P, C/P and S/P. This may be due to TikTok's decentralized video recommendation mechanism, which pushes to reveal more user-generated contents to other users, equally regardless of the number of followers. In this way, video posts of the users who comment to another post are more likely to receive as much recognition as influencers who have much more followers on TikTok than on other platforms.

Second, *dendrogram analysis* resulted in 52 clusters in Bilibili (1 – 29 users per cluster) and 16 in TikTok (1 – 17 users per cluster) that divide distinct user groups in each platform. The mean number of users in all clusters from both platforms is 3. Based on this mean value of 3, clusters that have more than 3 users are counted as primary user groups, which resulted

[10] https://www.bilibili.com/video/av40642497/
[11] http://v.douyin.com/jHaCWU/

in 15 primary user groups on Bilibili [Figure 2] and 7 primary groups on TikTok [Figure 3]. The top three knots that cluster primary user groups in each platform are marked in Table 1 and 2. We combined those primary clusters from both platforms into three user groups according to their browsing, reacting, and sharing patterns related to drawing practice [Table 4]: 1) Content Browsers, 2) Learner Creators, and 3) Creators.

Table 4 Data of percentages of the three user groups on Bilibili and TikTok.

Platform	Content Browser	Learner Creator	Creator	Total Number
Bilibili	30%	33%	5%	198
TikTok	36.7%	20.7%	19.5%	81

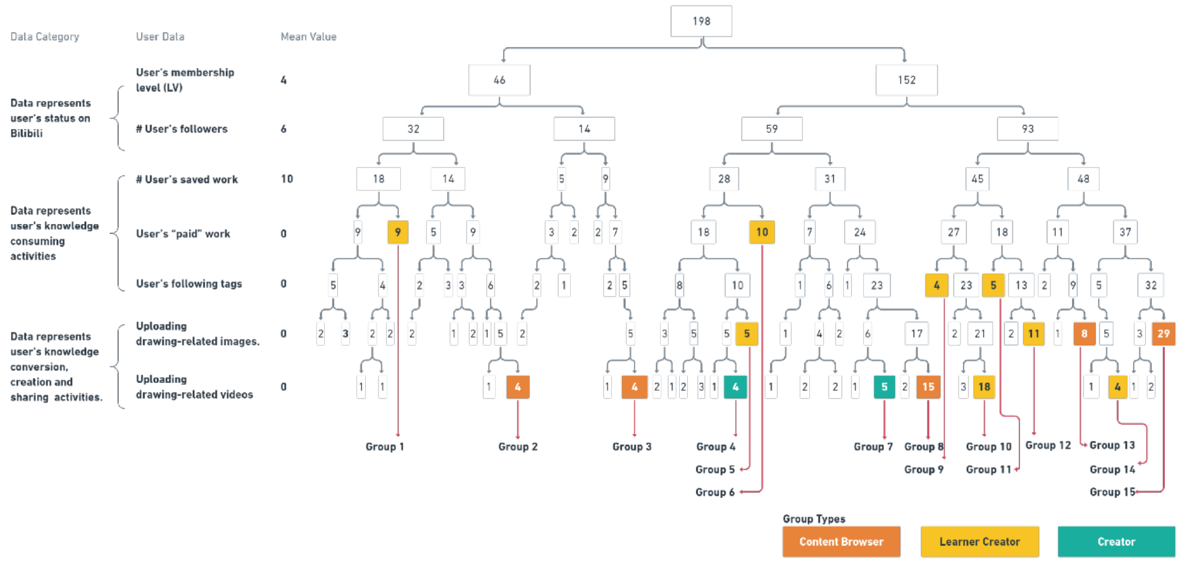


Figure 2. The dendrogram of Bilibili users.

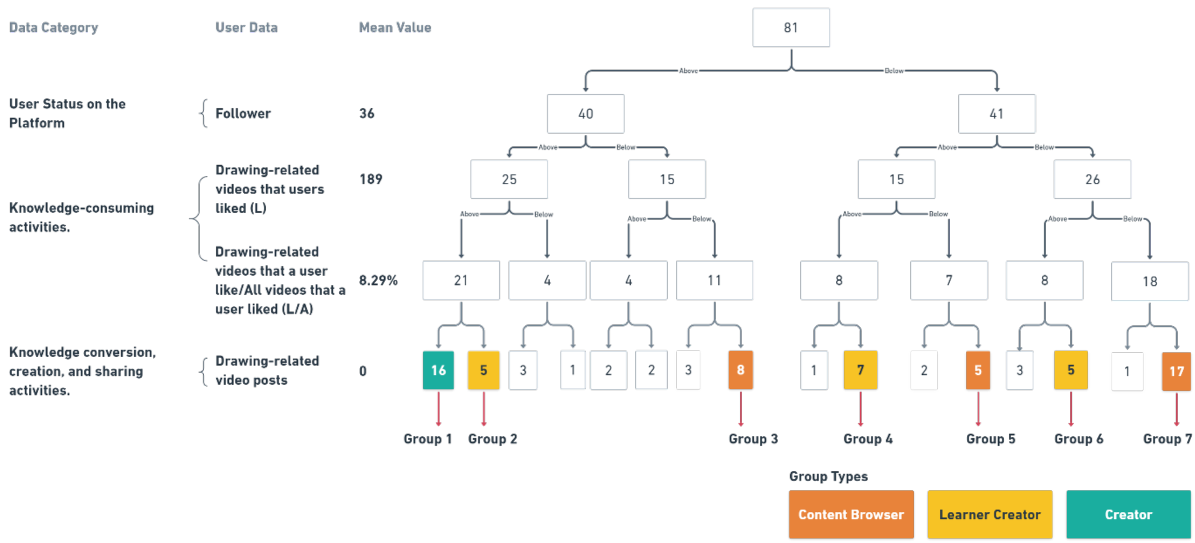


Figure 3. The dendrogram of TikTok users.

3.2.1 Content Browser Group:

This group of users takes up a large number of users in the primary clusters (30% in Bilibili; 36.7% in TikTok) but shows less activities related to drawing practice than the average users, rarely creating a drawing video post or reacting to others' work. Majority of users in this group have the value of LV (44 out of 60) and the number of followers (33 out of 60) below or equal to the mean value on Bilibili [Figure 2]. Similarly, all the TikTok users in this group show the number of L and the value of L/A below the mean [Figure 3]. They are involved in limited social activities such as searching or viewing drawing-specific videos, following other users, commenting, and liking, which require minimum commitments.

3.2.2 Learner Creator Group:

This group of users have knowledge learning goals and interests on specific topics such as figure drawing or landscape painting. The majority of users in this group have more than 10 (mean value) pieces of work saved on Bilibili and higher L/A or L than the mean value on TikTok. It implies that Learner Creator Group would like to view and archive certain types of videos according to their learning goals and interact with others by liking or commenting to other posts but rarely post their creative work.

3.2.3 Creator Group:

This group of users have posted their drawing videos in social platforms, active in creating, converting, and sharing skills [Figure 2 & 3]. Table 4 shows that on TikTok, the percentages of Learner Creator and Creator Groups in the primary clusters are similar, but that of Creator Group is significantly greater on TikTok than on Bilibili. Each Creator tends to have more followers than average on TikTok. This echoes to the results of user's behaviour patterns discussed in *regression analysis* above (in the section 3.2). Users tend to follow productive creators and (actively) react to their work in TikTok.

3.3 Pilot Interview with Selected Users from Each Group

As a pilot interview, we sent direct messages to the users from the three primary groups in TikTok (total of 81) for open-ended questions about their experience of learning and practicing creative skills through short videos. 12 of them voluntarily responded back: 2 out of 12 users are from the Content Browser Group; 4 out of 12 users are from the Learner Creator Group; 6 out of 12 users are from the Creator group. Their responses are summarized according to each group's purposes, experiences and expectations in learning and sharing their drawing practice in TikTok.

3.3.1 Main purposes in learning and sharing drawing videos

The Content Browser Group commonly express that they are busy and stressed in daily lives. They have interest in drawing but do not plan to practice. It is relaxing for them to just watch creative practice by others. They enjoy learning more about drawing skills and tips, through which they could also socialize with other users online. The Learner Creator Group are more committed to learn drawing skills by watching drawing videos for self-learning and collecting inspirations. The Creator Group mentioned that online friendship and social recognition are the drivers of their drawing practice; they actively create and share their work for seeking more social interactions and recognition from others.

3.3.2 User experiences and expectations in short video sharing platforms

The Content Browser Group think TikTok provided them with immersive and engaging watching experiences. In particular, they appreciate the short durations of videos, fitting in the limited free time of their busy life. However, they doubt the credibility of the contents posted by other users: Is it worth watching? Is this a right or better way of practicing drawing? Is this video appropriate to my drawing level?

The Learner Creator Group think learning by watching TikTok videos is efficient because of their short durations and rich contents. They are also satisfied with the video quality on TikTok and expect to discover more. They often apply what they watched and create their own drawings but rarely post because they are afraid of receiving negative and untrustworthy evaluation by public.

The Creator Group like the decentralized content distribution mechanism of TikTok as it exposes their work to more users. While it is easy to watch short videos, they often find it hard for them to create one because of its limited duration. A more guided process to plan and edit their drawing session in a short duration would be useful.

All three groups have complaints about current commenting and searching features in TikTok. They think the current comments section fail to provide an efficient way of retrieving and archiving key information from videos. Also, it was a common response that short video sharing platforms need practical and ethical guidance in posting and reacting to user generated contents to create quality contents and supportive online communities of practice.

4 User Personas, Journey Map, and Design Opportunities

Persona is a fictitious and concrete representation of target users, describing their characteristics and behavior patterns (Pruitt & Adlin, 2006). This chapter synthesizes the insights from the multi-dimensional user data into characteristic user behaviors and expectations based on thematic analysis. The insights are developed into five personas and corresponding user journey maps to illustrate their experience in short video platforms.

Through the thematic analysis, the coded themes of the interview data from the two respondents in the Content Brower Group participated are similar and merged to create user persona 1: **Content Browser**. Also, the coded themes of the interview data from the four users in the Learner Creator are similar and merged to create user persona 2: **Learner Creator**. Additionally, we found differences in the coded themes of the data from the six users in the Creator group; further categorized them to develop 3 personas: **Fan Art Creator** (N=3), **Recognition-Seeking Creator** (N=2), and **Influential Creator** (N=1).

Based on different behaviors of the five personas, we re-mapped the findings from the user profile and activity data to specify the phases that each user persona would experience in a short video sharing platform for their drawing practice. We also integrated the key phases of user journeys across the five personas and discussed the design recommendations for each phase in the integrated journey map [Figure 4]: 1) Creative Practice Through Social Interaction, 2) Video Previews and Comment Categories, 3) Personal Tracking, Assessment, and Guidance for Creative Practice.

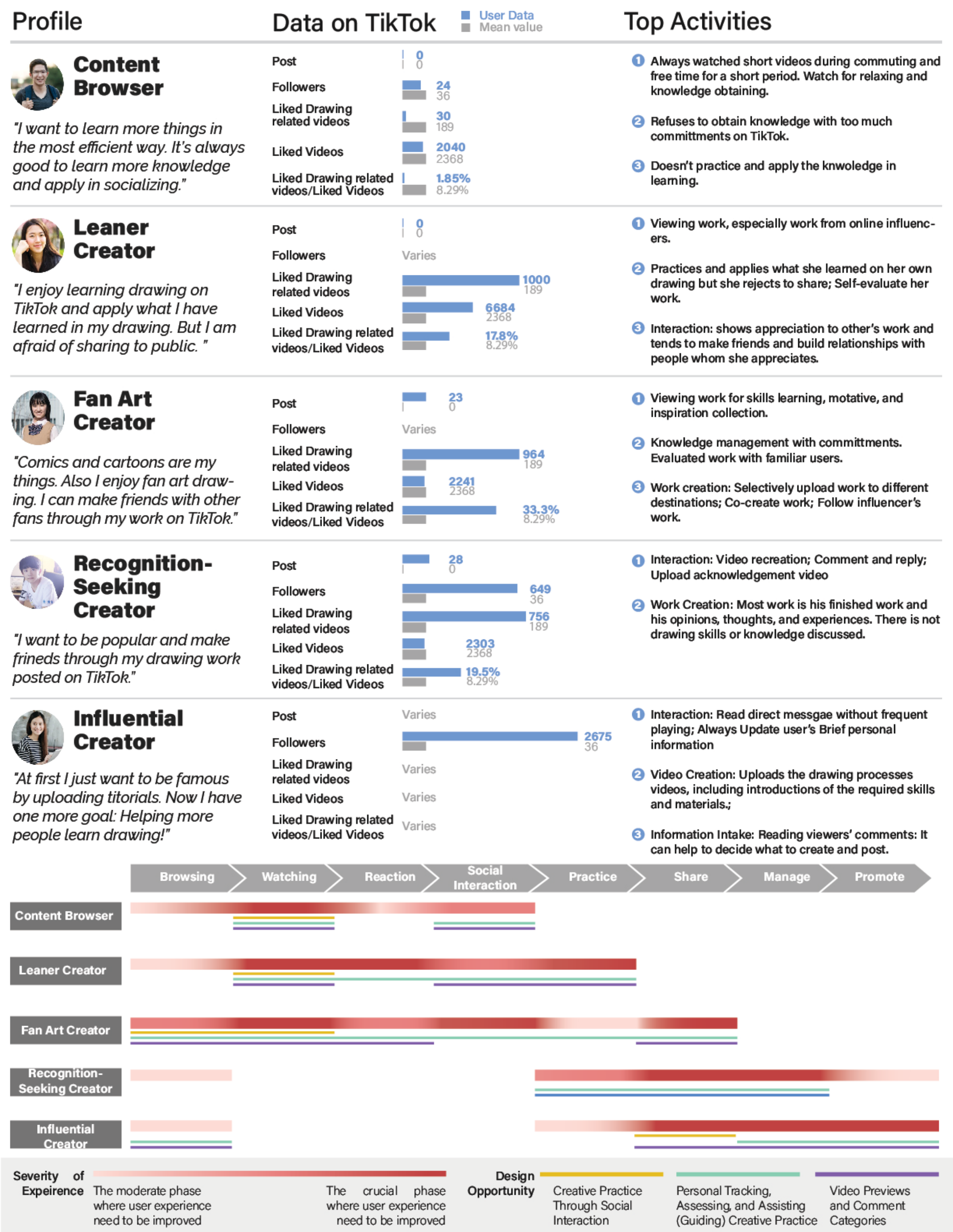


Figure 4. Five personas, user integrated journey map, and the implementation of the three design opportunities.

4.1. Creative Practice Through Social Interaction

While social recognition and responses from other users are vital elements of learning and sharing creative practice in short video platforms, Chapter 3.3 shows that users would not always receive enough recognition for their work. This study proposes three design considerations to encourage users to create and share work on short video platforms. First, platforms could assign deeper meanings to value video posts beyond clicking "Like", for example, by donating monetary currency. Bilibili users donate "Bilibili coin" to a video post to express their conscious appreciation compared to "Like". It meets their need to more tangibly contribution to the creators and the need of creators who eager for meaningful feedback. Second, platforms could nurture the community to admire and value others' practice and progresses so that more users, like the Learner Creator group would feel more comfortable and supportive to create and share content. For example, Facebook has enabled users to express varied reactions to a post in different emoji icons, which diversify their feedback beyond "Like" or "Dislike". Third, platforms could help creators discover trending challenges for creative practice in relation to their learning goals and connect to other users with similar interest. [Figure 4] shows that this strategy highly targets the problems of multiple user groups in Watching phase and Sharing phase.

4.2. Video Previews and Comment Categories

While short videos are engaging to watch, the research shows that there are opportunities to improve user experience of browsing and archiving video content. First, platforms can provide multiple media formats to describe the videos more accurately in the preview so that users could expect the content before viewing. Second, platforms can provide a rating system to guide skill level requirement of the videos. Third, Chapter 3.1 shows that users with different learning attitudes would preferred different types of comments. Platforms can thus provide a comment categorization and a key information-finding feature for viewers to browse specific types of comments based on their preferences. [Figure 4] shows that this strategy highly targets the problems of user groups with knowledge learning intentions, like the Content Browser, the Learner Creator, and the Fan Art Creator, as well as user group who are with knowledge sharing intentions, like the Influential Creator group.

4.3. Personal Tracking, Assessment, and Guidance for Creative Practice

The research also shows that users encounter many challenges in continuing their practice on short video platforms. Thus, we recommend a learning evaluation and situation prediction system, with which platforms can provide features to track user's activities, progress, and achievements in learning and practicing drawing skills. These strategies aim to build users' learning confidence and keep them motivated on the knowledge learning. Allow users to customize the categories of archiving or tagging videos beyond "like" so that users could easily organize and retrieve them according to their learning levels and goals. This custom categorization could further expand to an adaptive system that automatically generates appropriate category labels and recommends related video posts for archived videos. A template to guide which process to follow to complete a drawing tutorial video and preview the potential outcomes of the work they are planning to create can be useful for beginners. Also, assessing the quality of a drawing posted in a video can allow user to track their progress and for other viewers to consider the quality as their resource for learning. [Figure 4] shows that the users with needs of video watching—The Content Browser, the Learner Creator, and the Fan Art Creator—would be benefited from this strategy.

5. Discussion and Conclusion

This study was motivated to understand users' creative practice in short video sharing platforms and collected popular videos of drawing practice selected from each platform (3 from TikTok, 2 from Bilibili, and 3 from Instagram). Then this study collected viewers' public comments to selected short videos and developed two new classification schemes: **comment characteristics** (information, feedback, opinion, general conversation) and **commenters' attitudes** (constructive and positive, judgmental and negative, and irrelevant). The statistics show that that less users are actually participating knowledge-related activities (30%) while viewing drawing videos in these platforms by leaving information and feedback types of comments [Table 3]. We also found that those users are more likely to show a constructive and positive knowledge learning and sharing attitude and focused them as a main target group. While our design recommendation for comment categorization targets at this specific group of active users, there are far more passive users who browse and watch videos but rarely leave any comment (i.e., Content Browser). Personalized search and archival of videos and setting and tracking learning goals could lower the barrier of creating and sharing skill-practicing videos in these platforms.

This study further tracked and analyzed public data from Bilibili and TikTok users that can reflect knowledge-related activities. Using *regression analysis*, we uncovered that as Bilibili supports creating and uploading multi-media file formats, users who post more videos are more likely to post more images as well. Users prefer to post their drawing creations in image format versus video format since sharing drawings by images is easier. Another result showed that TikTok is a decentralized UGC community, where users receive reactions and feedback based on the quality and quantity of their work, regardless of the number of followers they have. These findings are further discussed above as design strategies to facilitate user creation and interaction in short-video platforms. This study also finds three major user groups through the patterns of users' data by *dendrogram*: **Content Browser** group, **Learner Creator** group and **Creator** group. The percentage of Creator group (19.5%) on TikTok is greater than on Bilibili (5%), showing that more TikTok users create and share their work as diverse posts are revealed to public regardless of the popularity of creators.

Based on the user group categories synthesized by the quantitative research, this study also conducted pilot interviews with 12 TikTok users via direct messages to further understand experience of knowledge learning and sharing through the platform. The results are synthesized into five distinct types of personas and user journey and experience phases for each persona, concluding with three design recommendations: **1) promote creative practice through social interaction**, **2) provide video previews and comment categories**, and **3) support for personal tracking, assessing, and guiding creative practice**. In summary, the findings of this study imply the potential of new learning models with short videos and social media platforms. The five personas and their user journey maps will provide a constructive foundation to design new platform services and experiences for collaborative learning of creative skills. The methods used for analyzing and identifying distinct user groups could be applied to other online user experience research in the future.

Still, this study has access to only public user data and it is hard to generalize the findings. Also, we do not have a concrete understanding about the expectations and behaviors of passive users who only watch videos for personal practice but do not engage in any online activities. Broader user recruiting and face-to-face interview could lead to in-depth conversations regarding users' expectations and suggestions for improving their learning experience in short video sharing platforms. In future work, the personas and user journey maps could be validated with more comprehensive data from a larger sample and also applied for ideating and developing new short video platform services to support creative practice.

6. References

Ahmad, S. (2018, June 30). Instagram Stories Crosses 400 Million Active Users. GuruFocus.com. Retrieved February 15, 2019, from https://www.gurufocus.com/news/702700/instagram-stories-crosses-400-million-active-users

Bowley, R. C. (2009). A comparative case study: *Examining the organizational use of social networking sites* (Doctoral dissertation, The University of Waikato).

Boyatzis, R. E. (1998). Transforming qualitative information: *Thematic analysis and code development*. sage.

CBNdata. (2017). *2017 duanshipin hangye dashuju dongcha [The insights of short video industries in 2017]*, 2017. Retrieved from https://cbndata.com/report/397/detail?isReading=report&page=1

Dron, J., & Anderson, T. (2014). *Teaching crowds: Learning and social media*. Athabasca University Press.

Eteläpelto, A., & Lahti, J. (2008). The resources and obstacles of creative collaboration in a long-term learning community. *Thinking skills and creativity*, 3(3), 226-240.

Fosnot, C. T., & Perry, R. S. (1996). Constructivism: A psychological theory of learning. *Constructivism: Theory, perspectives, and practice*, 2, 8-33.

Guo, P. J., Kim, J., & Rubin, R. (2014, March). How video production affects student engagement: An empirical study of MOOC videos. In *Proceedings of the first ACM conference on Learning@ scale conference* (pp. 41-50). ACM.

Hsin, W. J., & Cigas, J. (2013). Short videos improve student learning in online education. *Journal of Computing Sciences in Colleges*, 28(5), 253-259.

Instagram (2019). Instagram Help Center: Stories. Retrieved March 21 2019, from: help.instagram.com/1660923094227526.

Kaplan, A. M., & Haenlein, M. (2010). Users of the world, unite! The challenges and opportunities of Social Media. *Business horizons,* 53(1), 59-68.

Madden, A., Ruthven, I., & McMenemy, D. (2013). A classification scheme for content analyses of YouTube video comments. *Journal of documentation*, 69(5), 693-714.

Manca, S., & Ranieri, M. (2016). Facebook and the others. Potentials and obstacles of social media for teaching in higher education. *Computers & Education*, 95, 216-230.

Mao, J. (2014). Social media for learning: A mixed methods study on high school students' technology affordances and perspectives. *Computers in Human Behavior*, 33, 213-223.

Monserrat, T. J. K. P., Li, Y., Zhao, S., & Cao, X. (2014, April). L. IVE: an integrated interactive video-based learning environment. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 3399-3402). ACM.

Panahi, S., Watson, J., & Partridge, H. (2012). Social media and tacit knowledge sharing: Developing a conceptual model. *World academy of science, engineering and technology*, (64), 1095-1102.

Patrick, M. S. (2018, August 25). TikTok video app has become a petri dish for youth culture. *The Japan Times*, p.1. Retrieved from https://www.japantimes.co.jp/news/2018/08/25/national/media-national/tiktok-video-app-become-petri-dish-youth-culture/#.XIda5ohKjid

Polanyi, M. (2009). *The tacit dimension*. University of Chicago press.

Pruitt, J., & Adlin, T. (2010). *The persona lifecycle: keeping people in mind throughout product design*. Elsevier.

Qu, X., Jain, A., Rajput, N. N., Cheng, L., Zhang, Y., Ong, S. P., ... & Persson, K. A. (2015). The Electrolyte Genome project: A big data approach in battery materials discovery. *Computational Materials Science*, 103, 56-67.

Richardson, A. (2010). Using customer journey maps to improve customer experience. *Harvard Business Review, 15*(1), 2-5.

Su, T., (2018). *Research on influencing factors of the new generation user's behavior intention toward mobile short video App*. (Master's thesis, Jinan University)

Szpunar, K. K., Khan, N. Y., & Schacter, D. L. (2013). Interpolated memory tests reduce mind wandering and improve learning of online lectures. *Proceedings of the National Academy of Sciences*, 110(16), 6313-6317.

Wahlroos, J. K. (2010). Social media as a form of organizational knowledge sharing. A case study on employee participation at Wärtsilä. *Master, Department of Social Research, Faculty of Social Sciences, University of Helsinki, Helsinki*.

Wang Y (2016, May 25). China is obsessed with Japanese anime, and investors are paying attention. Forbes.com. Retrieved December 14 2018, from

https://www.forbes.com/sites/ywang/2016/05/25/china-is-obsessed-with-japanese-anime-and-investors-are-paying-attention-2/#3c5341f52947
Wu, Q., Sang, Y., Zhang, S., & Huang, Y. (2018, January). Danmaku vs. forum comments: understanding user participation and knowledge sharing in online videos. In *Proceedings of the 2018 ACM Conference on Supporting Groupwork* (pp. 209-218). ACM.
Zhao, Y., & Wang, Y. (2015). Duanshipin de chuanbo xianzhuang fenxi [The research on the dissemination of short videos]. *Research on Digital Media*, 32(3), 54-58.
Zhong, R. (2018, October 29). China's King of Internet Fluff Wants to Conquer the World. *The New York Times*, p.1. Retrieved from https://www.nytimes.com/2018/10/29/technology/bytedance-app-funding-china.html

Learning and Teaching in the Three Environments of Drawing in Design: Evaluating a New Model

Schenk, Pam

Heriot-Watt University, Scottish Borders Campus Galashiels, Scotland
P.M.Schenk@hw.ac.uk

The Three Environments Model of Drawing in Design has been devised from the complex findings of an extensive and long-term investigation of the role that paper-based drawing has and still plays both in the design industry and in design education, even in the digital studios of today. Part of the presentation of these findings for publication involved a detailed taxonomy which, while accurately reflecting the conclusions of the investigation, did not evoke the experience of drawing in design and of developing drawing competence. However, the categories of drawing competence formulated for the taxonomy are used as a basis for the model, where areas of intellectual, practical and technical competence represent overlapping environments through which designers may be seen to move in their increasingly effective use of drawing. Evaluation of the model is provided by accounts of two practice-based projects conducted by the author, both of which involve seeking inspiration from visual sources through various drawing-based copying techniques. Through the design of motifs for digital weave, the experience of both using and learning about drawing in all three environments of drawing competence was noted and verified through subsequent analysis of the drawn record of the project. Similarly, a workshop for students to encourage reassessment of their established drawing practice, particularly with regard to copying, was informed by the model and proved successful, prompting recommendations of its use in planning drawing studies.

Keywords: learning through drawing; teaching drawing competence; three environments of drawing; drawing-based copying; design education;

1 Introduction and context

Concern has been expressed about the increasing tendency for design students to exploit downloaded images with little or no adaptation and without any understanding of their historical context. The employment of paper-based drawing remains an ideal method of responding to visual sources in ways that inform visual literacy, inspire creative reinterpretation, and facilitate innovation. This paper explores the potential for promoting learning about designerly drawing and supporting the teaching of designerly drawing abilities based on the interrelationship of the intellectual, practical and technical drawing competences that are represented in a new model of drawing in the design process.

The long-term investigation from which the model was developed began in what was then the Manchester Polytechnique in the mid-1980s. It was, from the beginning, twofold in intention, the twin aims being to explore the role of drawing in design not only in industrial but also in higher educational contexts in order to see how drawing studies in design education could be informed by promoting better understanding of drawing activity in industry. Later, from the 1990s, what began as an analysis of paper-based design procedures became a monitoring of the changes in design practice brought about by the introduction of computer-aided technology to the design studio, and particularly of the new convergent and hybrid forms of designerly drawing emerging in the intervening years. The duration of the research which spanned a timeframe of over thirty years, the size of the sample of designers and academics interviewed (over 300), and the fact that many hundreds, indeed thousands, of drawings were analysed during the investigation, makes it an important, and, perhaps, unique contribution to both drawing and design research, leading not only to a better understanding of the complexity of drawing for design but also to a clarification of the competences required, both of which are captured in a new model, termed the *Three Environments Model of Drawing in Design* (Schenk, 2016).

Evidently, the role of drawing in design is extremely multifaceted, necessitating an intricate meld of drawing abilities to be productive, and it was towards the end of the long-term investigation into the changing role of drawing in design that a model of the use of drawing in the design process and of the drawing abilities necessary to support that use was devised. The model is based on two significant features of these findings. Firstly, that even in today's digital studio environments, three kinds of drawing competences are advantageous in the performance of many of the procedures involved in the design process, and that these comprise intellectual competence, practical skills and technical expertise. Secondly, that the performance and progression of drawing-supported tasks in the design process is not linear but requires movement through, and back through, these areas of competence. This movement through interlinking areas of expertise implies a model with spatial and temporal characteristics, and hence the adoption of the term 'environment'. It has now been possible to test this model in a number of practical projects, two of which are described below.

In 2010 a Drawing Research Group (DRG) was set up in the School of Textiles and Design, Heriot-Watt University, and members of the group were encouraged to engage in various practice-based research projects surveying the nature of drawing in design and in design education. Through cooperation with a DRG colleague in an exploratory drawing-based textile design project, the author studied some of the intellectual, practical and technical aspects of design for digital weave, in particular the reproduction of drawn images in woven fabric. Several extensive sets of drawings were produced in order, firstly, to seek inspiration, then to initiate and synthesize concepts and, finally, to refine motifs in preparation for actual weave. In this way, the three areas of drawing competence defined in the model could be explored experientially. Again, through working with another colleague from the DRG, what has been termed a Constructive Copying Workshop was planned, delivered and evaluated based on the model.

2 Drawing in design education

There exists today a very different educational environment on design courses than when the long-term investigation began in the mid-1980s. At that time evidence of established drawing ability was a prerequisite for student acceptance but now, even on textile design courses, some students with little previous experience of drawing can be recruited.

Therefore, it cannot be assumed that all students will choose to draw to support their design activities, even when this would be advantageous to them, so it becomes necessary to provide targeted educational provision to introduce them to the benefits or reconfirm the advantages of paper-based drawing. It is also essential to encourage them to achieve the knowledge and understanding to be able to actively choose the forms of drawing they adopt, instead of just turning to a digital application as a default, which is often the norm. For example, hand-drawn forms of copying are seen to be of value in promoting learning, and their re-evaluation is recommended (Cain, 2010 102; Camp, 1981; Drew & Harrison, 1987; Irvin, 2005 123; Paine 2000). By encouraging students to use drawing for their copying tasks, active and intelligent engagement with the visual source may be inspired (Imperatore, 2012 37). Although some young student designers may feel that the use of digital technology supersedes the need to develop drawing skills, discussions with new recruits (and even established designers in industry) have revealed that they can eventually feel the need to teach themselves drawing after leaving their university design course, not believing themselves to be fully effective without it. Indeed, exponents of other areas of expertise like, for example, anthropologists, provide evidence of the effective use of drawing for contemporary challenges, when the physical act of drawing can provide great flexibility (Ingold 2007 7). Taussig describes the rich opportunity facilitated by an anthropologist's fieldwork drawings that can be read and reread to find 'unexpected meanings and pairings' (2011 47), and Kuschnir (2016 105) describes a number of benefits in using drawing in fieldwork including the recording and expression of 'memory, temporality, spatiality, [and] visual perception.'

Many design courses, particularly textile design courses, continue to encourage students to enhance their drawing abilities, indeed many design projects begin with a collection of visual refences in a sketchbook. However, a renewed interest in achieving more inclusive and sustainable systems of learning, and the development of creative thinking in all areas of education, requires the construction of learning experiences that generate not only creative products but also involve creative processes (Gustina & Sweet, 2014 46; Hargreaves, 2016 37). The promotion of formal training workshops has been recommended as a way of improving student problem-solving and creativity (Karpova, Marcketti & Kamm, 2013), but drawing classes can be fragmented and short-lived so it is important to make the most of well-planned and accurately focussed workshops. The benefits for drawing studies that the three-environment model proposes is to encourage the intelligent and deliberate use of drawing, facilitate a multidisciplinary approach and help students to manage and use complex data (Ritchie, Tinker & Power, 2015). It also recognizes the importance of the type of proficiency acquisition defined in Kolb's Experiential Learning Model (Manolis, David, Rashmi & Ravi, 2012).

Historically speaking, from the setting up of the schools of design, the extent to which life drawing (as opposed to copying) should be a basis for training has been controversial, the copying of patterns being seen as more appropriate to the needs of artisans, as design students were then regarded (Macdonald 1970; Strand 1987). Indeed, different approaches to copying formed the basis of the influential South Kensington System of instruction (Kantawala & Daichendt, 2017), with little regard to the development of aesthetic or imaginative sensibilities (Bell, 1963 261). Today, with their increasing use of digital copying techniques, encouraging students to draw to interrogate visual sources has become very difficult. In response to this challenge, the three-environments model is being tested in an educational context and is forming the basis for trial workshops designed to encourage students, specifically, in the case described below, printed textile design students, to re-examine their attitudes to copying from found imagery and to reassess the potential role of drawing. Indeed, it has been found that the drawing activities associated with paper-based copying are particularly conducive to the identification and reinforcement of intellectual, practical and technical drawing competences.

3 The Long-term investigation and the Taxonomy of Drawing in Design

In the long-term investigation, structured interviews with designers and educators were conducted in their place of work, complemented by further discussions to facilitate analysis of the respondents' drawings. In this way, the activity of drawing in the completion of design tasks was identified throughout the design process and findings compiled in a taxonomy (Schenk, 2016 179-189). Throughout the investigation it was found that at any given time the terminology for different types of drawings or drawing activities was not consistently applied, either across the design profession or, indeed, on design courses, and consequently, one of the most exacting aspects of analysis, was achieving a consistent definition of terms in the presentation of findings. Perry recognizes similar problems (1992), and Love (2000, 295) cites confused and imprecise terminology as one of his criticisms of design research. The author endeavoured to achieve consistent use of terminology for the content of the taxonomy and has used or modified these terms as appropriate in the two projects described below.

It is evident that the broad nature of designerly activity changes as the design process progresses and it is apparent that the use made of drawing is correspondingly different. As the design process moves through distinct stages that mark key changes in both designing and drawing activity, a wide range of drawing competences can be inferred. The taxonomy presented a linear model of the design process with design procedures like, for example 'Preparation and Inspiration', and 'Briefing' and Ideation' given in the form of a progression, and with the tasks employed in the performance of these procedures described in detail. However, while the tabular format accommodated a comprehensive presentation of tasks together with the roles that drawing and drawing competences play in their execution, the taxonomy failed to embody the actual experience of drawing for design. Therefore, the model has been proposed as an adjunct to the taxonomy, as an alternative way of interpreting the findings of the long-term study in a more reflexive and expressive manner.

4 Three environments model of drawing in design

As part of the analysis of findings, design tasks and the associated drawing competences were categorized into three areas of activity namely, *intellectual, practical* and *technical*, and it is these areas that form the basis of the three environments model. The term *environment* was chosen because it denotes a setting for activity and a milieu through which to move, with activity and movement being significant characteristics represented by the model. However, while the categorization of design tasks was readily achievable, categorising drawing competences in three areas was more complicated in that many forms of competence were derived from a meld of abilities and, therefore, intermediary or overlapping areas were deemed necessary in the new model. Figure 1. shows the areas and intermediary areas of drawing competence, and Figure 2. demonstrates the spatial and overlapping environments of the three-environments model.

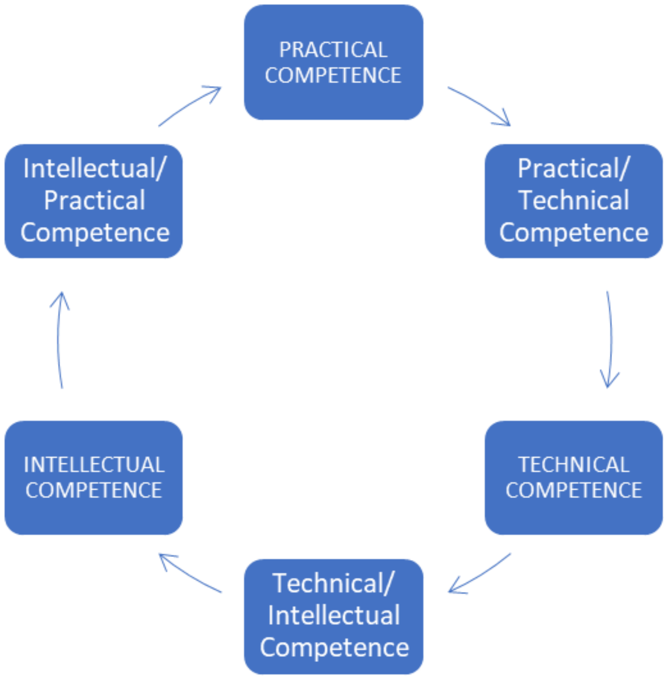


Figure 1. The areas and intermediary areas of drawing competence.

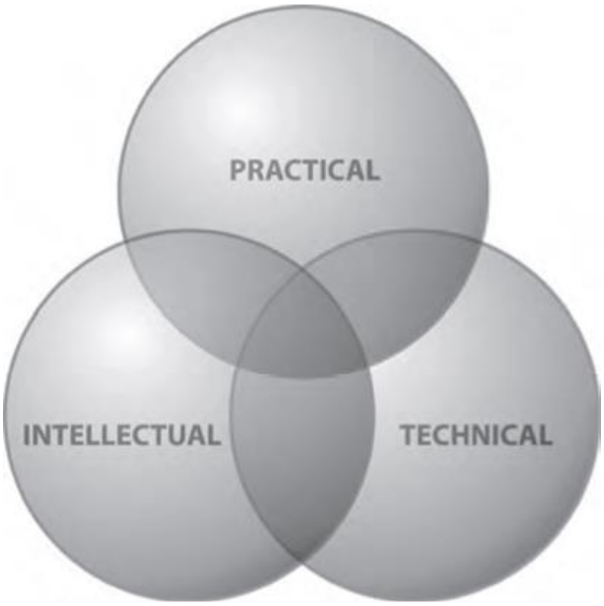


Figure 2. The Three Environments of Drawing in Design.

Whereas the core of the taxonomy was the design task, in the three-environments model it is drawing competence that is the core and, as such, the model offers a basis for planning the content of drawing studies. Of the three environments, the *intellectual environment* is what might be described as the cognitive domain of knowledge, understanding, conjecture, memory and imagination. The *practical environment* may be seen to represent studio-based creative practice, including drawing in various forms, and the *technical environment* may be seen as the setting for the employment of specialist skills, digital skills, drawing techniques and technical drawing. While design tasks are being performed, designers visit and revisit areas of drawing activity that are supported by intellectual, practical or technical abilities, or meld or combination of these abilities, and this ‘revisiting’ may support a view that the design process is reiterative (Zimmerman, 2003 176). However, where the process is moving through areas of competence, it can be claimed that ‘reiteration’ is not an accurate or, indeed, a comprehensive description of that activity because the experience gained by design activity enhances the designer’s drawing competence through learning. While design activities require designers to revisit areas of their competence, the competence will have changed. Therefore, while ‘going back’ may be a characteristic of design behaviour, it is never to the same place. Figure 3. represents a designer’s movement through and back through the environments of drawing competence.

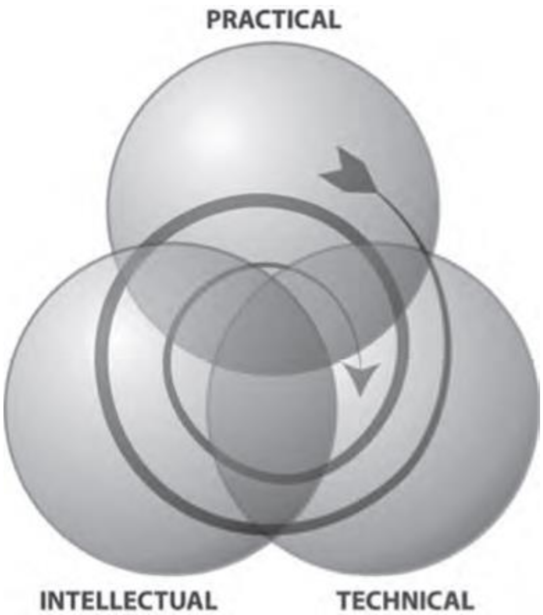


Figure 3. Movement through the three environments.

While there have been numerous attempts to provide models of the design process that capture all aspects accurately (Dubberly, 2004), there is still a lack of a single all-encompassing theoretical model of designing (Green, Southee & Boult, 2014 515). Unquestionably, design is highly complex, and it can be difficult to provide meaningful comparisons between different design disciplines. Design researchers invariably conduct their actual inquiries within their own specific design discipline, even if they later generalize their findings and extrapolate conclusions about the nature of design itself. Dorst (2008 7) claims that while the emphasis on the process of design has been extensive, ‘design research has a blind spot for issues to do with the designer, the content of the design activity and the context in which that activity takes place’. It is proposed that the three-environment model takes cognisance of the designer, particularly the competence of the designer, in the key design activity of drawing.

5 Drawing for Weave

As mentioned above, during the time when the author was revising the taxonomy and conceptualizing the three environments model, a practice-based project was also being carried out with a colleague who was a textile design academic and expert weaver. In an early pilot study for the DRG, the author undertook to produce various motifs that could be translated into digital weave by this colleague so that, together, they could explore the capability of the digital production process to represent the subtle graphic and pictorial qualities of drawings in the form of a weave. The reflective notes, email correspondence and, above all, the extensive portfolio of preliminary and developmental drawings produced for the project, entitled ‘Drawing for Weave’, have now been analysed, and the findings employed in an evaluation of the model.

Given that the investigation began primarily as a piece of drawing research, each design step could be pursued in far greater depth and over a much longer time period than would be possible in industry, thereby providing an opportunity to concentrate on the types of drawing competence being required to complete each task. Thus, deliberately ‘slow’ in execution, this practice-based project facilitated dwelling on the creation of several sets of drawings as the design process progressed, focussing on the intellectual aspects of finding and interrogating visual sources, then on practical exploration and experimentation with media and visual form as concepts developed, and, ultimately, on the technical development and refinement needed for presentation and production. The relative slowness of paper-based drawing provided time and opportunity for ideas to be fully absorbed and transformed in the mind (de Freitas, 2010 2). The drawing-facilitated design steps were both reflective and reflexive in execution (Silverman, 2013 146), while the author explored the potential synthesis between the drawn line and woven forms (Collette 2010, 13). Subsequent analysis of the drawn record was revealing, and it was clear that learning took place and improved competence achieved during the design process.

The study of the decorative qualities of natural forms is well established as a source of inspiration in the decorative arts (Grasset, 2004) and it was decided that acer leaf shapes would provide a good subject on which the designs of the motifs to be woven would be based. The acer was chosen for a number of reasons including the availability of historical imagery, particularly Japanese examples, and the opportunity to draw these plants from observation. Pictures and photographs of acers were collected from various books, catalogues etc., scanned and printed in black and white, and from these a diverse ‘bank’ of images was categorized in large sketchbooks to act as a systematic set of references and visual resources. Preliminary investigation assessed the pictorial potential of each of these categories through adjacent sketches rapidly drawn in a range of black and white media, and many such spreads were composed and annotated. Predominantly intellectual competences were a prerequisite in these procedures of preparation and interrogation, with the need for visual literacy and visual awareness, perceptiveness and observational skills informing the search and initial analysis. The importance of interpretive ability and visual literacy should not be underestimated and an iterative relationship with source material is an important part of the practice of designers who incorporate elements and ideas from visual sources into their work (Petre, Sharp and Johnson 2006: 189). However, the ability to plan and draw quickly in a range of media is also essential in responding to a wide range of found imagery, as was the case here. Figure 4. shows two double page spreads with adjacent sketches.

Figure 4. Two double page spreads from sketchbooks: Pam Schenk mixed media 2011

From the initial analysis, several key planning decisions were made in discussion with the weaver. It was decided that the visual characteristics of black and white drawings to be conveyed in five motifs, would be linear, tonal, textured and decorative, and that motifs would be of increasing complexity and abstraction. For example, Motif One would be linear and naturalistic and Motif Two tonal and naturalistic, Motif Three was to explore decorative linear effects, and Motif Four was to exhibit the gestural qualities evocative of spontaneous drawings. It was intended that Motive Five would be decorative and abstract, but this work was not taken to completion because of time constraints. Another decision was that the motifs would be designed in grey and black utilizing the white substrate to represent the paper on which the motif was to appear ‘as though drawn’ in the final weave. Moreover, it was agreed that by utilizing differing white, grey and black sections in both warpwise and weftwise directions, several variations in the woven motifs would be produced and, thereby, extend the inquiry.

The ideation and concept development phase produced an extensive range and type of drawing activity, with many working drawings being created and improved drawing confidence and competence achieved. A wide variety of free, experimental drawings responding to the potential of the collected imagery and using a wide range of media and substrates was produced, and even simple printing and stencil techniques were employed to yield as diverse a set of drawings as possible. Figure 5. Shows examples of these drawings.

Figure 5. Drawings exploring line, tone and texture: Pam Schenk mixed media 2011

The development and synthesis of the early concepts into the final designs for the motifs were conducted through a process of re-visiting earlier visualizations, revision, and more careful rendering and control of technique, thereby unravelling complexity and replacing it with clarity, with drawing playing an important part in these intellectual and technical exercises. Practical competences had prevailed in providing the fluent, spontaneous and playful image-making essential for early ideation, but more technical skills were entailed as accurate rendering became necessary. In order to clarify the concept for each motif, precision was necessitated and, while learning occurred throughout the project, the phase of the synthesis and development of the motifs was most challenging, and new skills acquisition was essential.

The designs of various images were then presented to the weaver and, through a process of feedback and modification, four 'weavable' images were achieved that fulfilled the previously specified visual characteristics. As proposals for motifs were presented to the weaver, expert feedback had to be interpreted through improved understanding of the technical constraints of digital weave, adding another technical/intellectual skill attainment to the author's growing list of new drawing competences, with practical/technical drawing skills being developed to manipulate the images in accordance with feedback. Of the Motifs that were finally selected, Figure 6. shows Motifs One and Two and Figure 7 shows Motifs Three and Four.

Figure 6. Motif One and Motif Two: Pam Schenk mixed media 2011

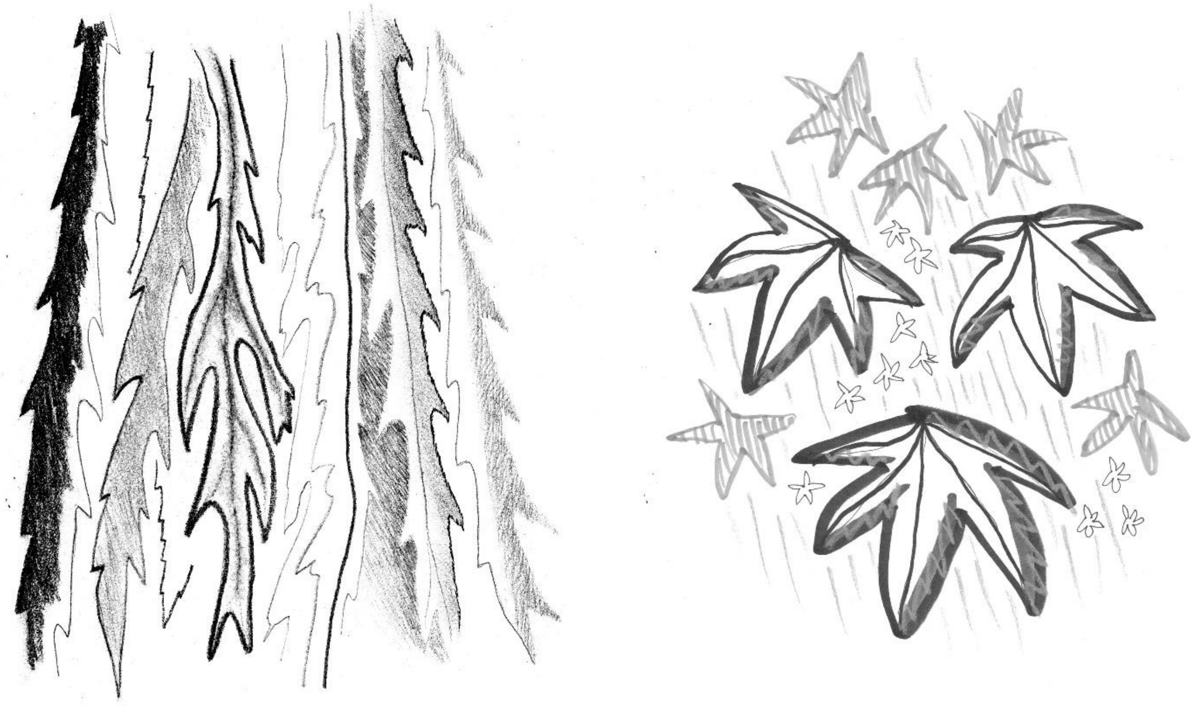


Figure 7. Motif Three and Motif Four: Pam Schenk mixed media 2011

Table 1. shows the drawing competences identified in the review of the drawing for weave project. Competences and intermediary competences are combined in columns, e.g. 'Intellectual' and 'Intellectual/Practical' because it is often difficult to precisely categorize some terms, e.g. to 'visualize' implies both intellectual and practical ability. Both technical drawings and drawing techniques are situated in the final column.

Table 1 Drawing competences identified in the drawn record of Drawing for Weave

Design procedure	Intellectual and Intellectual/Practical	Practical and Practical/Technical	Technical and Technical/Intellectual
Collecting visual source material	Strategy; Oversight; Visual literacy	Observation; Recording; Sketching	Search techniques; Digital scanning and printing
Categorizing visual source materials	Perception Interrogation; Recall	Cropping; Composing; Sequencing	Recording; Image editing; Creating layout
Initial interpretation of sources	Observation; Translation; Visual awareness	Fluency; Rapidity; Spontaneity	Copying; Tracing; Indicating
Agreeing plan of project	Conjecturing; Interpreting; Communication	Diagrammatic; Visualizing; Composing	Digital weave-savvy; Drafting
Ideation and concept development of motifs	Conceptualization; Analysis; Inspiration	Assurance; Expressiveness; Playfulness	Technical drawing; Tracing, Stencilling
Synthesis and resolution of motifs	Synthesis; Resolution; Revision	Precision; Accuracy; Dexterity	Rendering; Control of media and drawing instruments
Presentation and response to feedback	Communication; Persuasion, Clarity	Refinement; Reinterpretation; Manipulation	Responding to Instruction and Specification

While by no means comprehensive in presenting the full range of competences implicit in the drawn record, the table demonstrates movement across the three-environments of drawing competence while also depicting movement down through the design process. For example, ideation, or creative thinking, requires both the intellectual capacities to analyse and be inspired by visual sources, but also relies on the practical ability or assurance to play around with emerging concepts through drawing, and then the application of techniques to give more concrete form to these sketchy concepts.

6 The Constructive Copying Workshop

Encouragement of the type of movement through intellectual, practical and technical competences identified in the project described above, formed the basis of a DRG project to investigate drawing-based copying techniques. A workshop was conducted with two groups of 2nd year printed textile design students and, through discussions with the students' course director, a *copying vocabulary matrix* was put together to define terms for drawing activities and for a range of copying techniques. The specific aims of the workshop were also defined as 'to enhance awareness of the stylistic characteristics of visual sources, to encourage a reflective practice of drawing for design, and to enhance awareness of effective copying techniques'. Media were deliberately limited, and students were asked to use only black pencil and A4 tracing and cartridge paper. This was to not only to get them to concentrate on the copying tasks and not on textile design, but also to maximise comparability in the drawn outcomes. Students were all given the same textile-based image to copy from, e.g. a section from a Liberty print, and asked to draw in response to the terms in the matrix. They were also encouraged to use online reference to a thesaurus and asked to make reflective notes on the meanings of the terms and their experience of working with them. The terms comprised 'trace', 'reproduce', i.e. to produce some form of facsimile or direct reference to the original; 'investigate' and 'deconstruct', i.e. to interrogate the original for innovative potential; and 'memorize' and 'reinterpret', i.e. to seek inspiration from the original. During each workshop the author conducted short opportunist interviews, small group discussions and observations of drawing practice in the studio as the students worked, with more structured interviews being conducted after the students had had opportunity to reflect on their practice. By analysis of findings from these interviews, the students' drawings, and their reflective notes made during the workshop, it was evident that they all had perceptive and informed comments to make about their experience of drawing-based copying.

For example, starting with the term 'trace' the students soon found that they were made to look more carefully at an image in order to trace it and so notice features they would not have otherwise, and they found that to 'reproduce' involved a completely different set of practical skills than was typically required of them. While 'investigate' and 'deconstruct' prompted them to try inventive and imaginative techniques that they would not have undertaken otherwise, or, that they may have already been using but with only tacit understanding of that use. Drawing to 'memorize' was particularly mentally taxing, and, interestingly, their responding to the term 'reinterpret' prompted in many cases an in-depth questioning of their usual methods when working from found imagery. In the reflective notebooks kept by the students for the workshop, they noted their difficulties and what they regarded as their successes, and, in most cases, they articulated their drawing strategies well, even including, in some cases, personal reflections on their own established drawing practice. Indeed, in some cases, this led students to consider reassessment of these drawing practices particularly with regard to copying techniques. It was also interesting to note that is was not just the students who were known to be interested in drawing that responded well to the workshop. There were some who, while acknowledging that they generally preferred working on screen, nevertheless became intrigued by the intellectual tasks of deciphering the technical terms in the matrix and of differentiating between them, and so were able to put aside their inhibition about drawing on paper. Further details of the workshops and the results of the study are described elsewhere in the literature (Schenk & Parker 2019).

7 Conclusions

The experience gained when the weave project was conducted had an implicit influence on the development of the three-environments model. The motifs were designed consecutively and, as the design of each motif commenced, analysis returned to the bank of images collected and to the initial interrogation of these visual sources. It was evident that, in the design of the second and then, increasingly, with the third and fourth motifs, understanding of the potential of the imagery employed, the practical handling of media to aid ideation, and the knowhow relating to technical constraints all saw significant improvement. A more recent review of the drawn record of the project has shown that a wide range of different types of intellectual, practical and technical drawing competences combine differently through each stage of the design process. Therefore, as indicated in the three-environments model, it can be concluded that not only is there a need for the association of intellectual, practical and technical competences in the application of drawing to design activities, but also that the experience of the designer is one of movement through, and back through, the environments of competence, and that pertinent learning occurs and accumulates on the way.

How could drawing studies be provided in a way so as to introduce and enhance this form of pertinent learning, a kind of cognition that not only improves perception of, and response to the features of a particular design project but also intrinsically enhances drawing competence? The Constructive Copying Workshop was predicated on the three-environments model, using a matrix of copying terms to unite intellectual and technical knowhow and thus prompt practical responses. It was found to be successful in encouraging an enquiring approach in students' use of drawing and a profound reassessment of their own established drawing practices. It also stimulated a rethink of the pivotal act of copying in seeking inspiration for innovative solutions. When the practical work of twelve students from the workshop, each creating six copies from the same source, was assessed at the end of the project, of the seventy-two drawings produced, none of them were the same and all were inspiringly original.

It is particularly relevant that in both the weave and workshop projects, inquiry was concentrated on the early stages of the design process, particularly on the search for inspiration from visual sources and the initiation of design concepts, and both sought to exploit paper-based drawing in these endeavours. Indeed, they demonstrated the effectiveness of such drawing in the range of tasks performed. It is undeniable that, increasingly, in the progression of design projects, designers adopt digital means to solve technical problems and that the laborious drafting and rendering aspects of the specifications and technical drawings that form the completion of a design project are no longer done by hand. However, it is apparent that many designers in industry still draw on paper in the early stages described above. We owe it to our students to make sure they can use drawing in the most appropriate ways possible when they too join the design industry.

This opportunity should include not only those students that have already established their drawing practice, but also those that have not. Indeed, there are many students on design courses that have either not had the opportunity or, alternatively, have not seen the need to learn what might be thought of as old fashioned and outdated paper-based drawing methods. With the complex challenges that come from knowingly working in the three-environments of drawing as defined in the model and mirrored in the workshop described above, they may be convinced it is worth their effort, and so the model may help bring about new approaches to the teaching of drawing in design.

8 References

Bell, Q. (1963). The Schools of Design. London: Routledge and Kegan Paul.

Cain, P. (2010). Drawing: The Enactive Evolution of the Practitioner. Bristol: Intellect Books.
Camp, J. (1981). Draw: How to Master the Art. London: Andre Deutsch.
Cross, N. (2011). Design Thinking: Understanding How Designers Think and Work. Oxford and New York: Berg.
Collette, C. (2010). Found in translation; The transformative role of drawing in the realization of tapestry. Studies in Material Thinking, 4. http://www.materialthinking.org/sites/default/files/papers/CressideCollette Accessed 21 July 2018.
Dorst, K. (2008). Design research: A revolution-waiting-to-happen. Design Studies, 29 (1), 4–11.
Drew, J. & Harrison, M. (1987). Past and Present: Contemporary Artists Drawing from the Masters. Exhibition catalogue. London: South Bank Centre
Dubberly, H. (2004). How Do You Design? A Compendium of Design Models. San Francisco: Dubberly Design Office. www.dubberly.com/wpcontent/uploads/2008/06/ddo_designprocess. Accessed 15 September 2017.
de Freitas, N. (2010). Materiality of drawing/thinking. Studies in Material Thinking, 4. http:// www.materialthinking.org/papers/9. Accessed 3 July .2019
Grasset, E. (2004). Plants and Their Application to Ornament: A Nineteenth-Century Design Primer. Becker, P. (In Introduction). San Francisco: Chronicle Books.
Green, S., Southee, D. & Boult, J. (2014). Towards a design process ontology, The Design Journal, 17 (4), 515–537.
Gustina, S. & Sweet, R. (2014). Creatives Teaching Creativity, International Journal of Art and Design Education, 33 (1), 46-54.
Hargreaves, A. (2016). Blooming Teachers. Royal Society of Arts Journal, 162 (1), 34–9.
Imperatore, L. (2016). See for yourself: Drawing (out) the interiors of vision. Drawing: Research, Theory, Practice, 1 (1), 37-57.
Ingold, T. (2007). Lines: A Brief History. London: Routledge.
Irvin, S. (2005). Appropriation and authorship in contemporary art. British Journal of Aesthetics, 45 (2), 123–137.
Kantawala, A. & Daichendt, G., J. (2017). George Wallis (1811–1891) and Ernest Beinfeld Havell (1861–1934): Juxtaposing Historical Perspectives on Nineteenth-Century Drawing Books in England and India. International Journal of Art and Design Education, 36 (1), 71-81.
Karpova, E., Marcketti, S. & Kamm, C. (2013). Fashion industry professionals’ viewpoint on creative traits and, strategies for creative development. Thinking Skills and Creativity, 10, 150-167.
Kuschnir, K. (2016). Ethnographic Drawing: Eleven Benefits of Using a Sketchbook for Fieldwork. Visual Ethnography, 5 (1), 103-134.
Lee, J. (2014). The Integrated Design Process from the Facilitator’s Perspective. International Journal of Art and Design Education, 33 (1), 141-156.
Love, T. (2000). Philosophy of design: A meta-theoretical structure for design theory. Design Studies, 21 (3), 293–313.
MacDonald, S. (1970). The History and Philosophy of Art Education. London: University of London Press.
Manolis, C., Burns, D. J., Assudani, R., & Chinta R. (2013). Assessing experiential learning styles: A methodological reconstruction and validation of the Kolb Learning Style Inventory. Learning and Individual Differences, 23, 44-52
Paine, S. (2000). Artists Emerging: Sustaining Expression Through Drawing. Aldershot: Ashgate.
Perry, L. (1992). Towards a definition of drawing, in D. Thistlewood, S. Paine and E. Court (Eds), Drawing: Research and Development, (pp 89–97). Essex: Longman Group.
Petre, M., Sharp, H. & Johnson, J. (2006). Complexity through combination: An account of knitwear design. Design Studies, 27 (2), 183–222.
Ritchie, J., Tinker, A. & Power J. (2015). The effectiveness of design thinking techniques to enhance undergraduate student learning, in the Association of Fashion and Textiles Conference Proceedings Futurescan 3: Intersecting Identities. 11- 12 November Glasgow: Creative and Print Services, Loughborough University, 10-20.
Schenk, P. (2016). Drawing in the Design Process: Characterizing Industrial and Educational Practice. Bristol UK/Chicago USA: Intellect.
Schenk P., & Parker M., (2019). Constructive copying: exploring the vocabulary. International Journal of Art and Design Education, 38 (2), 524-538.
Silverman, D. (2013). Doing Qualitative Research (Fourth Edition). London: Sage Publications Ltd.
Strand, R. (1984). The art schools’ progress, in K. Baynes (Ed.), Young Blood, Britain’s Design Schools Today and Tomorrow. London: Design into Industry Ltd/Lund Humphries, 72–79.

Taussig, M. (2011), I Swear I Saw This: Drawings in Fieldwork Notebooks. Chicago: University of Chicago Press.

Zimmerman, E. (2003). Play as research, in B. Laurel (ed.), Design Research; Methods and Perspectives, (pp 176–184). Cambridge: MIT Press,

About the Author:

Dr Pam Schenk is a Professor at Heriot-Watt University and leader of the Drawing Research Group in the School of Textiles and Design. She has published widely on the role of drawing in design and is a Fellow of the Design Research Society.

Acknowledgement: I would like to acknowledge the expert contributions to the digital weave project of my colleague Ruth Walker, and to the Constructive Copying Workshop of my colleague Mark Parker.

IASDR 2019

International Association of Societies of
Design Research Conference 2019
DESIGN REVOLUTIONS

Manchester School of Art
Manchester Metropolitan University
02-05 September 2019

Lenses of Care – revisiting interconnectedness in service design

Hakio, Kirsi*; Mattelmäki, Tuuli; Veselova, Emilija

Aalto University, Espoo, Finland
* kirsi.hakio@aalto.fi

This paper focuses on the connections and resonances between an ethical and philosophical concept of care and service design. The paper contributes, on one hand, to discussions on service design seen as a dynamic discipline that addresses relations and responsibilities when shaping our futures. On the other, it highlights the concept of care in our everyday choices, and how it matters in learning context. We first frame our take on service design and our motivation to recalibrate the focus on human-centred design by enhancing, with the concept of care, the understanding of interconnectedness. Then, we introduce, based on literature, three lenses to view the everyday manifestations of care through different perspectives and horizontal depths. We also introduce an experiment within a university course on service design where we included an additional, value-based layer, on 'care'. The three lenses are then used in discussing and students' learning reflections and design outcomes, as well as the potential and challenges of the experiment as a transformative experience. Based on our observations, we propose that care as a concept can support in bringing deeper understanding on interrelatedness to service design education.

Keywords: service design; care; education; relations

1 Introduction

Service design is dynamically emerging field (Sangiorgi and Prendeville, 2017). It seeks to understand and coordinate what is meaningful for people and organisations, and a skilled practice to deliver and co-create valuable outcomes. The focus and competence development in service design have shifted from mainly working for outputs (e.g. interfaces and interaction), to increasingly considering three interconnected elements: a) a change-oriented, people-centred, creative and systematic process; b) a transformational, people-centred, collaborative, exploratory mindset; and c) an approach that fosters learning and, through that, change (ibid, p.28). Rachel Cooper (2011, xii) has stated that as services focus "in interactions, relations and activities rather than on objects" they deal with sustainability and human-centred approaches. Service design thus could increasingly be a vehicle for small scale and wider societal transformations.

To address sustainability and long-term societal change, the conceptions on human-centred design and empathy, the two crucial building blocks in service design, need to be revisited. Manzini (2011, p. 4) suggests that the "most common approach is to see the user as an individual, bringing needs, desires and knowledge to be listened to and integrated into the design stage and the assessment of proposals and end results.” In this scenario, a user is active in stating needs, but passive in action (Ibid). The concept of ‘designing for services’ however, widens perspectives on the role of individuals and communities. Manzini, by following the thinking of Nussbaum and Sen (1993), proposes that assigning value to users’ abilities and competencies these users can become more active participants, blurring “the roles of the service provider and receiver” (Ibid).

To follow this line of thinking we, the authors of this paper, set up a course named Designing for Services (hereinafter referred to as DfS-course). For seven years we have strived to educate design students to explore, collaborate and facilitate learning of the participating stakeholders, while taking into account human competences and responsibilities. This pursuit was supported through selection of course partners. We have extensively worked with public sector, with City of Espoo as a returning partner for the past three years. In the latest edition of the course, the teaching team wanted to underline the relational nature of designing for services by introducing an overarching theme 'Fostering Care'.

The introduction of the theme served three purposes. First, it was an attempt to emphasize the shift from a narrow way of seeing human-centred and empathic design, as requirements of fulfilling individual ‘needs’, to a more comprehensive and relational view. As designing for services, fundamentally, is about orchestration of elements that together create holistic service experience (Ostrom et al., 2010), it extensively engages with relationships. *“To care about something, or for somebody is inevitably to create a relation”* (Puig de la Bellacasa, 2012, p. 198). The ‘Fostering Care’ theme was envisioned as a way to foster service culture that can be understood as acting for the benefit of others, taking responsibility, participation and co-creation of sustainable ways of co-existing.

Second, it sought to trigger students to reflect on designer’s responsibility when considering wider social and environmental impacts. We introduced caring as a mindset and practice for training designers as custodians of care, who “*create spaces for others to reflect, make mistakes, learn and debate” and “support people in caring and changing their environment as they might wish”* (Light and Akama, 2014, p. 160). The theme aimed at shining an additional light on the philosophical choices, for example varied dimensions of participation in inclusion, that designers have when encountering others, co-creating and making.

Third, the theme served as a lens for reflecting on potential pedagogical questions. In Donna Haraway’s words: *“It matters what matters we use to think other matters with, it matters what stories we tell to tell other stories with... it matters what thoughts think thoughts... It matters what stories make worlds, what worlds make stories”* (Haraway, 2016, p.12). In line with Haraway, Puig de la Bellacasa (2012, p.199) points out that “*creating knowledge is a relational practice with important consequences in the shaping of possible worlds”.* We used these metaphors to reflect upon the impact and responsibility of an educational setting. Thus, we assigned highlighted importance to whose ‘stories’, and in what ways, are told to the students, as these affect not only the students but also their project outcomes, the client and, ultimately the society. The DfS-course with the theme “Fostering Care” served as an experimental setting to learn about potential of introducing the lenses of care in a design project with a partner. This paper presents the insights which surfaced during and after this experiment.

2 Care is visible in our daily choices

In order to understand what care could mean in the context of DfS-course and its themes, broader definitions of care are introduced. Moving beyond the common associations of care being a nurturing, caregiving, person-to-person event, we aim to explore the more complex meanings and occurrences of care.

2.1 The myth of the autonomous individual

Joan Tronto (2013) emphasizes that care is not a theory but a concept. This concept becomes vividly embodied and visible through daily behaviour, choices, activities and encounters with others. When we, humans, care for something, we create relations that are highly personal and individual, but also easily unnoticeable and sometimes automatic. Yeandle et al. (2017, p.8) argue that care might be ubiquitous as it is typically mundane and taken for granted; therefore, it often remains forgotten, marginalized or excluded. The well-established, broad concept of care by Joan Tronto defines the essentiality of care quite comprehensively. "*On the most general level, we suggest that caring be viewed as a species activity that includes everything that we do to maintain, continue, and repair our 'world' so that we can live in it as well as possible. That world includes our bodies, ourselves, and our environment, all of which we seek to interweave in a complex, life-sustaining web"* (Tronto, 1993, p. 103). Care stems from the premise that everything exists in relation to other things; it is, thus, relational and assumes that people, other beings and the environment are interdependent (Tronto, 2017, p.32).

In the modern Western societies, we conceive the world as centred around humans, thus not perceiving or, perhaps, forgetting that we are all parts of a large life system. As Annemarie Mol (2008) points out, in the Western culture, people often think they are autonomous, independent individuals. However, many Westerners no longer cultivate their own food, sew their own clothes nor bury their own dead (Mol 2008, p.4). Thus, we are always, inherently connected to other humans. Moreover, we cannot generate substances needed for our physiological survival, e.g. fresh water and oxygen, and all materials without natural systems and the elements they are comprised of. Currently, our societies and lifestyles are built in a way that masks the interconnectedness and dependency on nonhumans. These perspectives have developed over centuries due to many, interrelates reasons (Zylstra et al., 2014). Puig de la Bellacasa (2012, p.197) argues that a changing perspective about nonhumans is a vital requisite of collective thinking in interdependent worlds and demands thick vision of caring. It requires de-centering the human, acknowledging that nonhumans are not servants of humankind; they are here to live with (Puig de la Bellacasa, 2010, p.161). A species, including humans is not going to survive alone, and care should be extended to nonhumans. Thus, it is important to realize that humans are extensively dependent on and connected to other humans and to the supporting structure of different relationships, communities and ecosystems.

Additionally, there seems to be an underlying, hidden division how personal lives and public lives are seen in the society, in relation to care and human dependency on others. According to Hankivsky (2004), a liberal model of citizenship too, assumes that people are autonomous, independent individuals who are able to take care of their own basic needs. This is a "narrow and incorrect view of the human condition" and the "reliance on family and friends in the private sphere is acceptable, but individuals are expected to transcend dependency once they enter the public realm" (Ibid., p.6). It seems that care and dependency are accepted as being a natural part of human life in the private, close family relations, but dependency on society or the state is seen as an exception for only the weak and underprivileged, not as a norm (Ibid., p.6). This further strengthens a distorted myth of an autonomous individual which is deeply rooted in the structures and ways we have built our society.

It is fundamental to understand that, in essence, we all are givers of care and also receivers of care. It is easy to picture this when people are infants, infirm, and frail in old age, but as Tronto (2013, p.146) points out, all people have needs, all of the time. When people recognize their own needs, they more likely recognize the needs of others as well. This recognition of care and its relations as well as the amount of the time devoted to caring others as for themselves (Ibid., p.146), helps to highlight the, sometimes, silent meanings and value care has in our daily lives. *"Until we recognize that we are care receivers, all, there can be no change in the ways that we think about care or in the fact that it is undervalued" (Ibid., p.150).* In this paper, we see that this is in line, and further elaborates on how Manzini, Cooper and others above frame service design, and turn our attention to the interconnected nature of service, and highlight the potential of care in service design education. In the following, we will further elaborate caring as a transformative theme.

2.2 Tansformation of values with the new ethos of caring

According to Tronto's (1993, 2013) well established work on care ethics, care has always been embedded in all types of communities and societies, regardless of how these communities were organized. Every society, based on democracy or not, has had to resolve the question of responsibility of care and how the responsibilities should be distributed (Tronto 2013, 148-149). Several authors (e.g. Yeandle et al., 2017; Hankivsky, 2004; Tronto, 1993, 2013; Puig de la Bellacasa, 2017; Tsing et al., 2017; Haraway, 2016) have emphasized that, drawing from the feminist thought of equality, such as equal rights, equal voice, the ethics of care have sought to bring care (in its broadest environmental, life-sustaining meaning) into the light of public debate. They have aimed at highlighting the equal importance of care related to societal, political and environmental issues, as care can be treated as a distraction from the 'really important' issues.

However, care should not be ignored or demoted out of the way for the 'really important' societal and political matters. Care simply exists, as Puig de la Bellacasa (2012, p.198) notes "care holds the peculiar significance of being a 'non-normative obligation': it is concomitant to life – not something forced upon living beings by a moral order; yet it obliges in that for life to be liveable it needs being fostered. This means that care is somehow unavoidable". Inevitably this points to the question of dominant cultural values, around which societies are centred. Tronto (2014, 2018) contributes to this question by arguing for transformational turn to what we have emphasized and what has been considered important cornerstones and values in our Western society.

Such radical changes require collective mental transformation, intent and skills, a new way of perceiving and relating oneself amongst the others as an interconnected state of being. As our current ways of thinking reflect what matters the most to us, we need to focus on our underlying moral and ethical values. In a five-phase process of care, with corresponding ethical qualities, Tronto (2013, p. 34-35) brings forth the aspect of solidarity called caring with. She notes that the ethos of caring with is not the same as judging one's self-interest, instead it has to do with both, the collective and self-interests in the long run. *"To do so requires a change in the values of citizens. It requires that citizens care enough about caring—both in their own lives and in the lives of their fellow citizens"* (Ibid., p.34-35). Thus, from a city or a state perspective, caring democratically requires a democratic process by which citizens are able to care with their fellow citizens (Ibid., p. 13), meaning supporting and enabling structure in line with the ethos of caring.

Mol (2008) reflects through the context of diabetes the logic of care in our society and the role of a collective, e.g. a City, when it comes to responsibilities and enabling or hindering factors of care. According to her, it is central to think whether a public administration should ask individuals to change their ways of living, or should we focus on changing the conditions and environment around them instead (Ibid). This is a question of caring - taking the responsibility and the burden of change on collective shoulders instead of making recommendations, guidelines and campaigns about the ideal life styles.

Sharing responsibility is a collective action, not an abstract, scientific or legal endeavour (Tronto 2017, p.32). The ethos of caring is not regulated or limited by the markets, economy or money per se, instead, it is our value system and what is commonly held meaningful in life that restrict care and its full potential occurring in our world. As Tronto (Ibid.) sums up, caring with occurs when a group of people is able to rely on an ongoing cycle of care to continue to meet their caring needs. When such patterns become established and reliable, they produce the virtues of trust and solidarity (Ibid.) thus fostering the ethos of caring becoming mainstream in the society.

2.3 Three lenses of care

The review on care surfaced different perspectives on how care can be interpreted and perceived. The everyday manifestations of the concept of care can be seen through different perspectives and horizontal depths. They can be summarized into three lenses:

- Lens 1: Care as an act - to care for, to care about. Care is an object or an act - I'm going to give my care to someone. This lens could be seen as a rather 'superficial' lens of care.
- Lens 2: Care rooted in the mindset of interconnectedness. An individual acknowledges that they are part of a system and are in relationship with and dependent upon others, both humans and nonhumans, in this system. They view themselves both as a giver and receiver of care and have a mindset paying it forward.
- Lens 3: Care is omnipresent, care simply exits. Care is present everywhere where there is life: in every action, in every breath, in every interaction; the planet wouldn't exist without care. This could be viewed as a strongly philosophical lens and, potentially, as a paradigm of future.

These lenses are not mutually exclusive and overlap in some aspect and differ in other. Collectively, they highlight that the same event and appearance of care can be seen through different lenses simultaneously. However, we argue that the thick understanding of care requires ability to be present, listen and sense the ongoing, constant everyday unfolding of care.

3 An Experiment – everyday unfolding of care

To explore the concept of care in everyday context of learning environment, and see how, and if, it's influence can be tracked, the authors set up an open-ended experiment. A university course, Designing for services (DfS), gave a frame to our experiment and data collection; in other words, this university course had its set of learning objectives dealing with service design that were only partly overlapping with the concept of care.

DfS-course is a Master's level, intensive, 6-week-long teaching module at during which approximately 25 students, the majority having background in design, and a few in engineering or in business, learn about designing for services. The course includes readings, lectures and in-class workshops. The students read fundamental and latest literature on designing for services, co-creation, and design tools; through in-class workshops, they also apply this knowing to their project work. The course also includes project work with a real partner on a commissioned brief. Each year a partner, lately a local municipality, proposes one or several briefs that address current needs of the city and its citizens. Teams of approximately five students work with these briefs: together with the partner and stakeholders they build an understanding of the problem arena, co-design potential solutions and, finally, outline a solution proposal. As explained above, the course focuses on not only building students' skills and capacities of making sense of complex service structures, participation and application of service design approaches, but also aims to educate responsible, empathic, reflective designers. Adding the care theme created an opportunity (and necessity) to include additional, care-related content to the course.

Hence, rather than carefully planning every instance of the course through the perspective of care, we focused on a few key interventions, and allowed the theme to evolve naturally and reflexively following the flow of the course. This learning by doing approach included four key types of data collection. Throughout the course, we collected literature, written instructions, announcements and lecture slides given to the students. We followed the lectures and workshops given and organised by the teaching team and guest lecturers, and the presentations given by the students, and documented whenever possible, the instances when care was addressed. We followed students' weekly learning diaries, a mandatory course assignment, to gather insights about their individual reflections on care. Finally, we analysed student teams' final written reports and presentation. In addition, before, during and after the course, we deepened our own understanding of care through literature. This literature review and its key insights - the three lenses of care introduced above - lead to the development of an analytical framework through which we retrospectively and iteratively analysed the effect of the "Fostering Care" theme on the DfS-course. Findings of this analysis are presented in the next sections.

Retrospectively, we, the teaching team studied the course contents through the three lenses of care. We mapped the content of the student briefs, weekly readings, lectures, announcements and our input during the mid-term presentations and the dress rehearsals of the final presentation. We concluded that notions, stories, examples about care were related to the students through at least eight instances: (1) project briefs; (2) week one and five readings; (3) an introductory lecture on care and a following care-related discussion; (4) feedback on the first team presentations; (5) a fostering care workshop; (6) a lecture and workshop on interconnectedness, systems thinking and sustainability; (7) a more-than-human care workshop; and, finally, (8) an introduction of a 'Care Statement' assignment for the teams. Twice we also nudged the teams to address care in their teamwork presentations - before the midterm and the final presentations. This overview, however, presents only the perspectives and the 'stories' about care that we delivered to the students through the official course materials and events. It does not review all the interactions that the students might have had with the topic. Nevertheless, it provides an opportunity to extract examples of learning by getting a glimpse into students' insights on care and the course overall.

4 Care as transformative theme for individuals

During and after the course, we were able to track explicit signs of transformational insights. The theme and the course overall urged several of the students to recalibrate their perspectives about their own design work, projects and role in the society. Care surfaced as a transformative topic that urged the students to reflect on their previous work and projects, and their overall approach to design. For example, a student reflected *"somehow this topic [of care] made me reflect my previous designs, did I offer the care to the users through the new launch function? Would users feel the care from the services?"* Another student wrote that the interaction between the designing for services approach and topic of care transformed her designer identity. Moreover, this interrelation fostered students to reflect on their responsibilities. For example, a student revealed that during the course she began to pay more attention to problems related to society and surroundings affecting life equality and the whole ecosystem. Another student wrote that the course opened up the topic of responsibility of a designer without providing definite answers, guidelines of rules and how she attempts to be more conscious of these issues in the future.

The topic of care in the context of the DfS-course seems to have been a transformative experience to a few students. However, the majority of the students did not explicitly reflect on care not responsibility in their learning diaries, but focused more on the more fundamental components of the course. Based on our observations and analysis, we are able to distract elements that potentially impacted these students' abilities.

The placement of this additional experimental component and its interrelation to course's main content. In the first week, about a third of the students reflected on the concept of care by referring to the weekly reading: Light and Akama (2014) paper, and only a few students reflected on the introductory lecture on care. One student's outburst in his learning diary well describes the situation: *"Even though the discussion on design was interesting, I just don't have the capacity to take it all in and start poking around my existing conceptions of design, designers and service design. It feels like just when I think I'm starting to do quite good in understanding what this service-oriented design culture means in the first place, Manzini comes in and says it's not sufficient anymore – we're already moving to the next evolution. Then Light and Akama throw in the concept of care and now I can honestly say I'm not completely sure what's going on anymore."*

The engagement with the topic seems to have decreased during the weeks that did not include specific care-related content and increased when the topic was explicitly address in the workshops, readings and lectures of the week. The instances of care-related content might have triggered more reflections as a whole rather than on their own. Later during the course, after the workshops on systems thinking and on more-than-human care, about one third of the students brought up 'the concept interconnectedness' and how humans and their actions affect the systems, other humans and non-humans. It seems that the systems thinking element was needed to tangibly demonstrate how people's decisions and actions affect the overall system.

The ambitious objectives and the intensity of the course seems to have affected the engagement with the topic, too. By the end of the course, a student revealed that the fast pace of the course hindered their ability to engage with the topic, as they were immersed into learning service design and working on the team project. The dynamic, active setting of the classroom dynamics boosted the ability of some of the students to engage with care. For example, a student proposed that the dynamic workshops throughout the course helped him to better engage with themes like care and empathy on design. He referred them as “*things that I thought about but never got to really put on or apply on my actual thinking.*”

Finally, students' backgrounds, previous skills and knowledge seemed to affect the extent of interaction with the topic of care. Those who had more previous experience with the design tools were more able to add this additional layer of care to their learning outcomes. For example, during the two specifically care related workshops, it seems that those who already were able to reflect on the notions of interconnectedness, had more experience of designing or were more used to reflexivity and expressing feelings, were more able to adopt and digest the care topic.

5 Manifestations of care in the design outcomes

“Fostering care” care theme was included in the project briefs yet it was more explicit in three of the project briefs. In the final concepts, the teams both included and excluded care. Three out of five teams implemented notions of ‘interconnected care’ in the core principles of their solutions. For example, one team created an overall concept and guiding principles for development of a mindset of care within the City. Another team focused on caring for one stakeholder group of their project to boost their ability to provide care and foster care within the system. A third team proposed that the city officials should foster care for the immigrant population by increasing focus on citizen participation in their structural processes, e.g., decision-making. However, while some were able to reach more strategic level, along their care-centred concepts these teams proposed rather traditional designing for services elements and tools, such as a workshop concept, a design game to facilitate collaboration, or a website (see figures 1 and 2). Meanwhile, one of the teams used certain notions care for - care about (lens 1.) as an element in their solution, yet did not seem to incorporate the “interconnected care” into their concept. Finally, in one team’s project care was addressed with a small remark stating that the concept aims to care for a stakeholder group which was not directly involved in the process or addressed with the solutions.

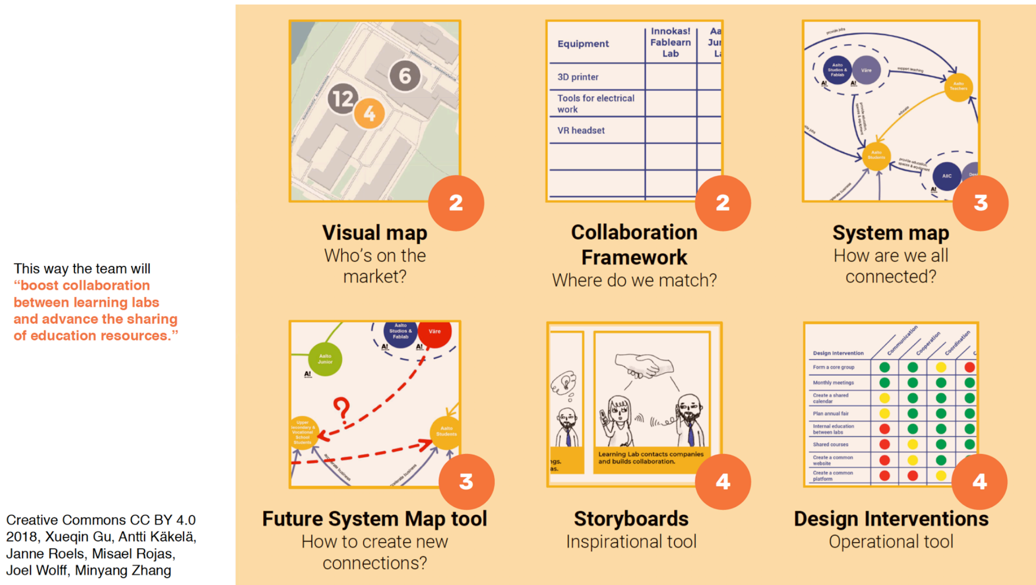


Figure 1 A team that focused on finding ways to support collaboration for sharing resources between university and municipality proposed several tools that help in mapping out how different people and units are connected, and how to create new connections on personal and more systemic level.

Figure 2. A team that focused on supporting start-ups at the city proposed three guiding principles to their concept titled 'Total care'. The guidelines reflect their findings on individual, processes and connections levels.

Reflective analysis of team communication about the projects yielded two insights. First, the reports did not necessarily reflect the extent to which teams engaged with the topic, thus establishing relationship between the concept and "Fostering Care" theme require a focused, reflective analysis of the project outcomes through the lenses of care. This was especially visible when contrasting two teams. While one team successfully conveyed care in their report through the soft, caring language they used and the stories they told; the presence of care in this project was indisputable from the first glance. Meanwhile, another team was not as sharp in communicating their findings and core elements of their solution in their final presentation and report. At an initial glance, the project did not seem to reflect on care; however, after a more thorough reading, the team had actually engaged deeply with the topic and embedded it into the solution extensively by focusing on communities and responsibilities. Second, the stories about care from the care-related course content, shaped the content of the project reports. In these reports, almost all teams used the quotes about care presented in the first lecture and course reading material. Teams were repeating stories they had heard – the terms, argumentation and the definitions of care. Therefore, the stories told by the teaching team had shaped the students' stories, and we hope, further have the potential to shape the stories of, and the reality within the municipality and society.

6 Discussion

Service design education focuses on how to make sense of and propose solutions for change. Literature on care acknowledges and embraces the necessity for societal change, however, yet very little is proposed on how to tackle the issues. With the spirit of Tronto's (2013, 2014, 2018) argument on transforming what is held meaningful in our society, we experimented with what happens when philosophical and ethical concept of care is bridged with educational setting and laid over an existing service design course structure. Thus, this experiment is a contribution to discussion of connecting care and service design (e.g. Light and Akama, 2014). More precisely, we were interested in how the values of care, responsibility and mutual respect can be addressed, cultivated and fostered in design student education, within a context of a municipality by applying the skills and capabilities of service design.

There seems to be more profound relations between service design and care, than what it seems at first glance. The three lenses of care presented here give both structure and frame to explore and analyse these connections. Interestingly, there is a resonance how the mindset of systemic thinking within service design links to features of care as a mindset of interconnectedness, the lens 2. in our frame. Both approaches carry similar essence and mentality of paying it forward. More precisely, both emphasize seeing a whole as a sum of its parts, where the parts are in relation, sharing connections, dependencies and purpose, and where an individual understands herself as both the giver and the receiver.

Puig de la Bellacasa (2010, p.162) reflects that working with ethical issues of care changes the person. Naturally, educational context has always short-term and long-term impacts, some of which only surface months or years later and some might never be explicitly voiced. We became aware how the concept of care as an additional layer in a service design course, was able influence the way the some of the students view and understand designers' role within these contexts and society in general. In this paper, we can only share the insights of those students that recognized and documented the implications in the learning diaries. As only few students directly reported their transformative learning experiences and change of mindset as result of working with care, the implications of the experiment might (or might not) only surface in the future, while the students continuing the stories of care they learned in working life. Thus, we can only assume some the long-term implication.

Design for service has gained attention as one of the vehicles to foster and support societal change (e.g. Meroni & Sangiorgi, 2011, Sangiorgi & Prendeville, 2017). In such context, the building blocks of service design - human-centred design and empathy - need to be revisited and expanded with other relevant notions. One of such notions is care and caring as part of everyday design choices. Design education admittedly serves as a one of the 'nudge agents' in our society, contributing to shaping societal futures. However, further research is needed to trace the potential implications of these studies on their partners.

7 Conclusions

In service design education, we need thinking tools to recalibrate the focus of service design from customer needs as a driving force to a more relational and responsible world view. This paper contributes to service design by studying the concept of care as a potential frame for emphasising interconnectedness. We have introduced three lenses on care as tools to investigate learning in a service design course. We looked at how the concept of care can be addressed, cultivated and fostered within an educational context by applying the skills and capabilities of service design. The paper also seeks potential connections between design for service and the concept of care. In addition, to study this connection in a learning context, we have extracted how the concept of care represented itself in student project design outcomes and individual students' reflections.

The open-ended experiment yielded three sets of results. First, through a literature we were able to articulate three lenses of care: care as an act, care rooted in interconnectedness and omnipresent care. These lenses have served as a reflective and analytical tool for analysing course content, student learning and outcomes of the course project course. Second, the addition of care and the interplay of this theme with other course content urged several DfS-course students to recalibrate their perspectives on care and role of the designers in society as well as in relation to care. We also uncovered that the impact on students, that the theme might have had, was influenced by placement of the care-related content; its interrelation with other course content; high intensity of the course; active, workshop-like setting of the classroom and backgrounds of each student.

Moreover, analysis of the solutions proposed by students showcased that the care-related content and workshops introduced by the teaching team resurfaced in student solutions, presentations and final report. These results highlight the potential of incorporating care as an extension of the current designing for services approach as a vehicle for sustainable societal change and lay foundations for the necessary further research on the topic.

8 REFERENCES

Cooper, R. (2011) Preface. In Meroni, A., & Sangiorgi, D. Design for Services. Aldershot, Gower.
Haraway, D. J. (2016) Staying with the trouble: Making kin in the Chthulucene. Durham and London: Duke University Press.
Haraway, D. J. (2016) Staying with the trouble: Making kin in the Chthulucene. Durham and London: Duke University Press.
Hankivsky, O. (2004) Social policy and the ethic of care. Vancouver: UBC Press.
Light, A., & Akama, Y. (2014) Structuring future social relations: the politics of care in participatory practice. Proceedings of PDC, pp.151-160.
Meroni, A., & Sangiorgi, D. (2011) Design for Services. Aldershot, Gower.
Manzini, E. (2011). Introduction. In: Meroni, A., & Sangiorgi, D. Design for Services. Aldershot, Gower, (pp. 1-6).
Mol, A. (2008) The Logic of Care: Health and the problem of patient choice. London & New York: Routledge.
Nussbaum, M., & Sen, A. (1993) The Quality of Life. New York: Oxford University Press.
Ostrom, A. L., Bitner, M. J., Brown, S., Burkhard, K. A., Goul, M., Smith-Daniels, V., Demirkan, H., & Rabinovich, E. (2010) Moving Forward and Making a Difference: Research Priorities for the Science of Service. Journal of Service Research, 13, pp. 4-36.
Puig de la Bellacasa, M. (2017) Matters of Care: Speculative Ethics in More Than Human Worlds. Minneapolis: University of Minnesota Press.
Puig de la Bellacasa, M. (2012) Nothing comes without its world: thinking with care. The Sociological Review, 60(2), pp. 197-216.
Puig de la Bellacasa, M. (2010) Ethical doings in naturecultures. Ethics, Place and Environment, 13(2), pp. 151-169.
Sangiorgi, D., & Prendeville, A. (eds) (2017) *Designing for Service: Key Issues and New Directions.* Bloomsbury, London.
Tsing, A., Swanson, H., Gan, E., & Bubandt, N. eds. (2017) Arts of Living on a Damaged Planet. Minneapolis: University of Minnesota Press.
Tronto, J. (1993) Moral boundaries: A political argument for an ethic of care, New York, NY: Routledge.
Tronto, J. (2013) Caring democracy: Markets, equality and justice, New York, NY: NYU Press.
Tronto, J. (2014) Lecture. The 25th Anniversary Conference. A Meaningful Life in a Just Society: Investigating Well-being and Democratic Caring. 30th of January. [Online] Available from: https://www.youtube.com/watch?v=VAbJ4aVpbEg [Accessed 20 November 2018]
Tronto, J. (2017) There is an alternative: homines curans and the limits of neoliberalism, International Journal of Care and Caring, 1(1), pp. 27–43.
Tronto, J. (2018) Interview. The inaugural CERC conference: Care Ethics and Precarity. Care Ethics Research Consortium, 27th and 28th of September, Portland. [Online] Available from: https://www.youtube.com/watch?v=nKZNMln5tsI [Accessed 20 November 2018]
Yeandle, S., Chou, Y-C., Fine, M., Larkin M., & Milne, A. (2017) Care and caring: interdisciplinary perspectives on a societal issue of global significance. International Journal of Care and Caring. 1(1), pp. 3–25.
Zylstra, M.J., Knight, A.T., Esler, K.J., and Le Grange, L.L., 2014. Connectedness as a core conservation concern: An interdisciplinary review of theory and a call for practice. Springer Science Reviews, 2(1-2), pp.119-143.

About the Authors:

Kirsi Hakio: Kirsi is design researcher and doctoral student at Department of Design in Aalto University School of Arts Design and Architecture. Her work relates to service design as relational practice and she is passionate about awareness-based co-creation for sustainable design.

Tuuli Mattelmäki: Tuuli is associate professor at Department of Design in Aalto University School of Arts Design and Architecture. Her research focuses on empathic and co-design. She is interested in understanding the relationship with human-centred design and relational systemic design challenges.

Emilija Vesselova: Emilija is design researcher and doctoral student at Department of Design in Aalto University School of Arts Design and Architecture. Her research focuses questions on sustainable design and she is passionate about the role of co-design in more than human-centred futures.

Acknowledgement: We warmly thank our talented students at Aalto ARTS and City of Espoo as an enthusiastic forward-looking partner.

MUGEN: Teaching code to design students through game-making

James, Brian

St. John's University, New York City, United States

* hellobrianjames@gmail.com

Teaching computer coding to students of design presents a unique context, with its own set of challenges, from affective factors like motivation and stress, to the cognitive load of coding itself. But design students also bring unique strengths to the table, ripe to be magnified through code. This in-progress study introduces the Mini UnGame ENgine (MUGEN), a custom made software tool with associated pedagogical materials, in an attempt to bridge the gap between computer science research involving the pedagogical applications of game-making, with the the instructional needs of contemporary design classrooms.

Keywords: pedagogy, game, code, computation, digital, interaction, web

1 Introduction

Teaching computer coding to students of design presents a unique context, with its own set of challenges, from affective factors like motivation and stress, to the cognitive load of coding itself. Such challenges can make even small projects daunting to learners and instructors. But design students also bring unique strengths to the table. They are often highly motivated to learn tools that expand their creative powers, and they have invaluable productive skills such as illustration, photography, and even project management, ripe to be magnified through code.

This case study describes the in-progress development of one pedagogical response to these challenges and opportunities, informed by a strand of game-based education research in the constructionist tradition. The heart of the response is MUGEN: The Mini UnGame ENgine, a simple JavaScript library that allows novice coders to create small game-like experiences. MUGEN offers a flexible learning tool that can support an instructional approach focused on visual design, or an approach focused on coding, or on an approach that balances the two. The present study aims to use this tool and the pedagogical materials developed in conjunction with it to bridge the gap between computer science research involving the pedagogical applications of game-making, with the instructional needs of contemporary design classrooms.

2 Review of the literature

The educational potential of video games has been investigated, touted, and commodified for decades. The Minnesota Educational Computing Consortium, for example, began in the

1970s to produce iconic computer games like *Oregon Trail* and *Number Munchers*, which would become cultural touchstones for countless elementary school students in Generation X and the Millennial Generation (Jancer 2016). These types of educational video games follow what can be called an “instructionist” pedagogical model, wherein students learn by *playing* video games whose content imparts information or skills (Kafai 2006). While this has been a popular approach, there is another model of game-centric pedagogy: a “constructionist” approach of learning by *making* games (Kafai 2006). This approach has been explored by researchers of Human–Computer Interaction, Computer Science pedagogy, and related domains. Following a similar path, the present study in design education also adopts a constructionist approach in relation to teaching code.

In their 2016 study, Batista, Connolly, and Angotti conducted a broad review of studies on teaching code through game-making. The dozen papers they selected for discussion reflected a variety of programming languages, and a variety of learning objectives, all falling under the umbrella of text-based programming languages. Moreover, the studies varied by scale: while many were designed around a semester-long intervention, at least one (Sung et al. 2011) focused on much shorter instructional modules. Despite the diversity of these studies’ particulars, Batista, Connolly, and Agnotti noted that the overall body of research indicates that game-making code pedagogy is “a promising strategy to arouse the interest of young students” (2016).

Two of the papers included in that review stand out as particularly relevant to the present study. The first, by Lewis and Massingill (2006), addressed game-making pedagogy in a university-level, second-semester computer science course using the Java language. They created a custom software tool to simplify game programming to a course-appropriate level, and deployed it in a semester-long program of study, designed by the researchers to meet the course’s existing learning outcomes and broader departmental curriculum through a game-making approach. Lewis and Massingill (2006) note that their software tool was created in such a way as to force students to learn how to study software documentation—an intentional design decision to teach this vital skill, and one which the present study was informed by.

The results of their study indicated that the game-making approach tested by the authors was as educationally effective as the standard non-game-making approach, and furthermore that students found the game projects to be more engaging and rewarding than traditional assignments. Moreover, the researchers noted that the programming tool promoted acquisition of the aforementioned documentation-related skills more effectively than other teaching methods they have tried.

The second study, by Sung et al. (2011), described a related but distinct approach to integrating game-making into programming courses. Like the above study, this one also involved a custom software tool, this time in the C# language. As before, the tool was aimed at simplifying programming for students. But in this case, the authors note that the tool was also intended to assist faculty who are interested in game-making pedagogy, but who lack specific game programming expertise. Such explicit consideration of faculty needs sets their study apart from many others.

Another crucial faculty-related consideration was the timescale of the pedagogical interventions: Instead of a semester-long program, this paper tested a series oif seven short, independent assignment modules, which could be integrated piecemeal into traditional curriculum. This was intended to make the benefits of game-making pedagogy more accessible to faculty who, for institutional or other reasons, could not reorient their entire curriculum around games. Additionally, the researchers developed a series of workshops and materials to teach instructors how to use the software tool, as well as how to deploy the game-making modules alongside traditional classroom instruction.

Note that, due to certain pedagogical factors—and perhaps also the short timeframe of the modules—the games created in this study were quite simple. They were also not particularly entertaining, as the authors themselves note. For these reasons, Sung et al. describe the products of these assignments as “game-themed,” and “real-time interactive graphics programs,” rather than as proper “games” (2011). For the purposes of the present study, that distinction is important. We may observe that Sung et al. did not propose a course in game design, but rather they used video games as a point of departure from which to frame their assignments. That gesture will return in the present study’s method as well.

Sung et al. (2011) deployed the tool and modules into standard computer science courses, mixing them into the established curricula. Although post-test surveys revealed some student dissatisfaction with the limited nature of the games, compared to students in control courses, students in the game-making groups exhibited higher rates of course completion, and higher assignment scores, even while spending less time on some assignments. Returning to the faculty considerations mentioned above, the post-test confirmed that the modules did not require more effort to implement than did traditional assignments, despite the test instructor’s lack of experience with game-making or graphics programming.

3 Research gap and question

The aforementioned pedagogical theory of constructionism, which touts the importance of making tangible artifacts during the learning process, seems like a natural fit for design education. Previous studies on constructionist pedagogical approaches of learning code through making games also seems highly relevant to design educators.

A major limitation in the research, however, is the overwhelming focus on computer science as the disciplinary context of learning to code. While programming may once have been rarely taught outside of computer science courses, in recent years coding has become a mainstream tool in other disciplines, including design. Thus, the review of the literature presents exciting pedagogical possibilities for design educators who engage with code, however it also reveals a dearth of related research performed in the context of the design classroom. That gap offers a potentially fruitful and transformative area to build upon the findings of previous research, but in the novel context of design education.

This paper presents an in-progress report on an exploratory case study that attempts to fill the current research gap by developing a constructionist, game-making pedagogical package that can be used to teach coding in the context of a design curriculum. The current phase of the study is addressing the questions: What shall be the requirements and components of such a package? How can its effectiveness be tested?

4 Methods

4.1 Development context

The design of the pedagogical package is informed not only by the research precedents described above, but also by the unique context posed by the design classroom as a site of learning code. Inasmuch as this project is in its initial stages, development has begun in response to conditions in one particular design program, with the intent to abstract and adjust various elements of the package as additional field tests are completed in other locations.

This project is being developed alongside a web design course with an enrolment of eight students, offered in the Graphic Design program at a large private university in the Eastern United States. It is the second in a two-semester sequence of web design classes, and enrolled students had achieved intermediate levels proficiency in HTML and CSS, and very cursory familiarity with JavaScript.

4.2 Design

The design of the pedagogical package will be described in terms of (a) its requirements and (b) its components. These requirements and components were chosen as important design considerations based upon the precedents covered in the review of the literature, as well as the novel design context of the present study.

The following requirements were identified based upon the review of the literature:

- produces a functional, publishable design artifact
- supports short-term, low-stakes projects that are suitable for testing in a variety of classes
- usable by instructors with varying levels of coding expertise
- produces simple game-like works, not oriented around game design per se

Several additional requirements were formulated in response to the design context:

- offers meaningful engagement for coders of various skill levels
- allows learners to apply visually creative skills
- uses web languages (JavaScript, CSS), which are easier and commonly used by designers

The following package components were proposed, based on the requirements identified above, as well as the research precedents:

- software tool to simplify coding (MUGEN)
- robust documentation for learners to gain experience using
- game demonstration with functioning code and visual assets
- lesson planning materials for instructors

A final component was resolved upon based on the unique design context: an Adobe Illustrator file to act as a template for designing visual assets like characters and a background scene.

4.3 Early development

Inasmuch as the software tool would enable the rest of the package to function, development began from there. The author created a small JavaScript library called MUGEN (Mini UnGame ENgine), which enables users to quickly produce a single-screen, interactive, game-like experience. Note: The terms “UnGame” and “game-like” acknowledge the simple nature of the pieces produced, in the spirit of Sung et al. Hereafter, however, these pieces will simply be referred to as games for the sake of convenience. Each game consists of three visual elements: a player-controlled character, a computer-controlled character, and a background scene. Structurally, the game is in platform format, where characters are viewed from the side. Players can move their character left or right, jump, or perform a key action.

In functional terms, MUGEN handles advanced coding tasks like handling player input such as clicks and button presses, and interactively applies visual styles and animations—designed by the learners through their visual assets and with relatively simple CSS code. Optional features allow advanced learners to attempt more complex tasks, such as programming custom functions triggered by certain in-game events.

A fully functioning demonstration game is distributed with the library. This demo not only shows how to use MUGEN, and how the visual assets are to be organized, but also provides a hackable starting point for novice coders. Beginners might try tasks as simple as replacing the demo’s visual assets for characters and backgrounds with ones of their own design, and/or tweaking settings like character speed, or jump height, in the existing code.

A GitHub repository was then created from which to publish the package. GitHub is a web platform that supports collaboration on software development and distribution, as well as publication of documentation. Along with the tool and demonstration, software documentation was posted for learners to reference as they learned how to use the tool. The platform also allows users to report bugs, and to request new features.

The package was developed to the point described above, and was deployed in the researcher’s class as an early pilot test, the results of which will guide further development. The test was conducted as a two-week project to create a simple game to the specifications described above. Once again, it is important to note that the assignment was not an exercise in game design, but rather an opportunity for students to practice code by simplifying complex tasks and allowing them to integrate their visual skills into an interactive project, while building peripheral skills like using documentation.

5 Tentative findings

While formal pre- and post-test impact assessments are forthcoming in a subsequent phase of the study, initial student response to this pilot phase seemed positive. Students filed multiple feature requests for the software tool, indicating a degree of motivation and interest in the project. One student verbally reported satisfaction at the opportunity to practice a new kind of illustration for the first time while making visual assets for the game. From the instructor’s perspective, students seemed to spend more time on visual making for this assignment compared to other assignments in the same class.

Significant limitations, however, also exist. Some students expressed dissatisfaction with the small scale of the game, and with the lack of ability to create different kinds of games. Also, the interaction between the player character and the computer character was framed in terms of player–hero versus computer–monster in the assignment brief, which although a convenient shorthand, tended to limit designs to this simplistic and combat-oriented metaphor. While not necessarily a fatal flaw, it was realized in retrospect that this framing is both limiting to the students' design thinking as well as potentially off-putting to some students. This was truly a missed opportunity, as the MUGEN tool itself could likely support many other kinds of interactions. This realization underscores the importance of the next phase of the package's development: lesson planning and support materials.

6 Conclusions

The above findings revealed two key points that serve as a conclusion to this initial phase, and as feedback to inform future development of this study. First, student responses to and perceived engagement with the MUGEN tool indicate the value of continuing to develop this approach to teaching computer coding in the context of design. These responses also suggest several areas of focus for testing impact assessment in the next phase, where the researcher plans to compare student experience of "typical" (non-game-related web design projects) to the game-based project of this study. Namely, tests will assess: degree of motivation to complete the assignment, degree of satisfaction with the completed assignment, acquisition of intended code learning outcomes, and—perhaps unique to the present study's context of design pedagogy instead of computer science—proportion of student work time devoted to design versus coding, and acquisition of intended *design* learning outcomes. If, as initial observations suggest, students were able to spend more time on design thinking for this project than on their typical projects, the approach explored by this study may allow students to place more emphasis on practicing their visual design skills while still learning the coding objectives.

A second key finding is the limiting nature of the game scenarios supported by the MUGEN tool as presently constructed and administered. If possible, future rounds of development will aim to increase both the flexibility of game scenarios, and the scale or complexity of those scenarios. Regarding flexibility, as noted above, the project brief could probably be modified with minimal or no technical change to the MUGEN tool itself in order to promote other concepts of interaction aside from combat. Increasing the scale and/or complexity of scenarios may also increase student motivation, and it could support additional learning objectives around constructing visual narratives, interaction design, and so on. However, this would require great consideration so as not to undercut the simplicity and ease of use which the students and instructor experienced in the initial test phase, and which Sung et al. foregrounded in their aforementioned study (2011). As such, the scale/complexity aspect of development may best be left for later stages.

7 Next steps

The next step of MUGEN's development will focus on completion of the final component specified in the package design: lesson planning materials for instructors who want to use MUGEN in their classes. Toward that end, the following materials are currently in development or contemplation:

- Clear, brief written documentation of all the components of the package
- Brief tutorials/workshop plans for the instructor to learn MUGEN, especially for instructors with little or even no coding experience
- Lesson plans for a variety of coding levels, and ideas for emphasizing different aspects of design through MUGEN, ranging from character design and animations to more advanced JavaScript programming
- Suggestions for instructors on maximizing the flexibility of MUGEN, given its simple parameters and functionality

Further pilot testing will continue in design classes taught by the author in subsequent semesters. Additionally, design professors at multiple institutions have expressed interest in participating in further field testing once those lesson planning materials are complete. These future pilot tests will measure student response with pre- and post-test surveys of the students as well as the faculty, modeled after those of the studies discussed in the review, but informed by the insights discussed in the Conclusions section of this study. Quantitative measures of hard coding skill and design outcomes is under consideration for those tests, however this may be more difficult to meaningfully assess in the relatively subjective environment of the design classroom compared to that of computer science.

8 References

Batista, A., Angotti, J.A.P., & Connolly, T. (2016, October 6, 7). *A Framework for Games-Based Construction Learning: A Text-Based Programming Languages Approach*. Paper presented at 10th European Conference on Games Based Learning. Paisley, Scotland: Academic Conferences and Publishing International Ltd.

Jancer, M. (2016, July 22). How You Wound Up Playing The Oregon Trail in Computer Class. *Smithsonianmag.com*. Retrieved from smithsonianmag.com/innovation/how-you-wound-playing-em-oregon-trailem-computer-class-180959851

Kafai, Y. B. (2006). Playing and Making Games for Learning. *Games and Culture, 1*(1), 36-40. doi:10.1177/1555412005281767

Lewis, M. C., & Massingill, B. (2006). Graphical game development in CS2. *Proceedings of the 37th SIGCSE Technical Symposium on Computer Science Education - SIGCSE 06*. doi:10.1145/1121341.1121499

Sung, K., Hillyard, C., Angotti, R. L., Panitz, M. W., Goldstein, D. S., & Nordlinger, J. (2011). Game-Themed Programming Assignment Modules: A Pathway for Gradual Integration of Gaming Context into Existing Introductory Programming Courses. *IEEE Transactions on Education, 54*(3), 416-427. doi:10.1109/te.2010.2064315

About the Authors:

Brian James is a design educator with industry experience ranging from local institutions to global brands. His academic work aims to enrich the language of graphic design by building bridges of dialogue to adjacent domains through technology.

Novice facilitators as creative catalysts in innovation support

Lampitt Adey, Kate; Bailey, Mark; Carrion-Weiss, Justine*; Gibbons, Frederick

Northumbria University, Newcastle-upon-Tyne, Great-Britain
* justine.c.carrion-weiss@northumbria.ac.uk

This article explores the value that students, acting as novice facilitators, bring in supporting professionals to innovate. This empirical research took a grounded theory and action research influenced approach to investigate a series of innovation support workshops with sole traders and SMEs delivered by Northumbria University. These workshops were part of a wider regional research project entitled Creative Fuse North East. The research found that there was trust and rapport between the expert facilitators, novice facilitators and enterprises participating which supported co-creation. In this safe environment, novice facilitators and enterprises worked together to learn and grow. It is argued that this enabled both parties to build their creative confidence. Thus, this approach offers a route to stimulating innovation in the region through supporting small scale enterprises and sole traders, and by developing strong creative graduates to participate in future workforces.

Keywords: creative confidence, novice facilitators, innovation support, creative catalysts, innovation readiness.

1 Introduction

This paper explores the role that students play in supporting professionals to innovate. The paper suggests that when students act as novice facilitators, they are able to have a significant impact on the creative confidence of the enterprises supported. Additionally, the students themselves benefit from cooperative learning and co-creation and their creative confidence is also enhanced. These findings have been reached through empirical research influenced by grounded theory and participatory action research. A series of data collection and analysis activities were embedded within a design-led context. The findings in this paper have a dual benefit by way of contributing to innovation in the region through business support and through nurturing creative graduates.

The North East is attractive to businesses due to the quality of life achievable, however they can find it difficult to attract talent (CFNE, 2017). Although the region has good educational establishments, innovation is low and, across the country, there are calls to support ‘everyday entrepreneurs’ and SMEs to enhance their leadership skills, possibly through collaborating with universities (HM Government and Transport for the North, 2015; Department for Business, Energy and Industrial Strategy, 2017). This challenge is addressed here, to enable people to continue to build successful businesses in the area they want to live in through supporting the creative confidence of professionals and future graduates.

In this paper we are using the term ‘creative’ to mean an ‘expression of self’, therefore open to all (Phelan and Young, 2003; Hegarty, 2014). ‘Creative confidence’ refers to people’s belief in their ability to change the world around them through courageously trying out new ideas (Kelley and Kelley, 2012). This is closely related to the concept of self-efficacy, an individual's belief in their own capabilities “to mobilise the motivation, cognitive resources and course of action”, required to reach their goals (Bandura and Jourdan, 1991: 952). Kelley and Kelley (2012:4) describe creative confidence as lying “at the heart of innovation” as it requires us to face challenges and take risks (Phelan and Young, 2003). We are referring here to a personal rather than organisational creative confidence.

The paper will first set out the research environment and methodology. It then describes the research findings that the students built trust and rapport with the enterprises so that they could co-create and learn together, thus potentially generating a stronger understanding of the innovation readiness of the enterprise. The paper closes by considering how this co-creative learning stimulated creative confidence.

2 Research environment

The research was conducted during the design and delivery of ‘Get Ready to Innovate’ (GRTI), a series of workshops delivered as part of Creative Fuse North East (CFNE). CFNE is a European Regional Development Fund, Arts and Humanities Research Council and Arts Council England funded project involving 5 regionally linked universities. This project sought to explore the potential for the creative, digital and IT sectors to drive innovation and growth across the North East (CFNE, 2019)

Get Ready to Innovate (GRTI) was a program where enterprises were aided in assessing their innovation readiness. GRTI consisted of 12 hours of funded support for regional enterprises. Funding dictated the duration - but not the format - of support, which had 2 strands:

1. GRTI one-to-one: an enterprise attended sessions with expert facilitators (see Gribbin, Bailey & Spencer (2018)).
2. GRTI one-to-many: 2-4 enterprises all attended sessions, each facilitated by 2-3 students.
3. 3 sets of ‘one-to-many’ GRTI workshops were delivered with enterprises from sectors such as music and textiles. Enterprises were predominantly sole traders, with some micro SMEs (less than 10 employees) and one SME who had 38 employees.

Multidisciplinary Innovation (MDI) Masters students at Northumbria University acted as ‘creative catalysts’ in the planning and delivery of GRTI. MDI students are from any undergraduate discipline and professional horizon, and an Integrated Academic Practice model is employed by way of a pedagogical approach, where students engage in design-thinking projects with external partners (Bailey and Smith, 2016). To emphasise their ‘professional-in-training’ role, students will be referred to as ‘novice facilitators’ (NFs). A staff team of academics and researchers, ‘expert facilitators’ (EFs), also participated.

Each enterprise attended 3 workshops of 3 hours over several weeks, and a 3-hour review session following these broad themes:

1. Current business/future opportunities (Figure 1);
2. Modelling the opportunity (Figure 2);
3. Realising the opportunity (Figure 3);
4. Reviewing innovation readiness (review session with EFs only).

A series of design-led activities were developed and then personalised to each enterprise's needs.

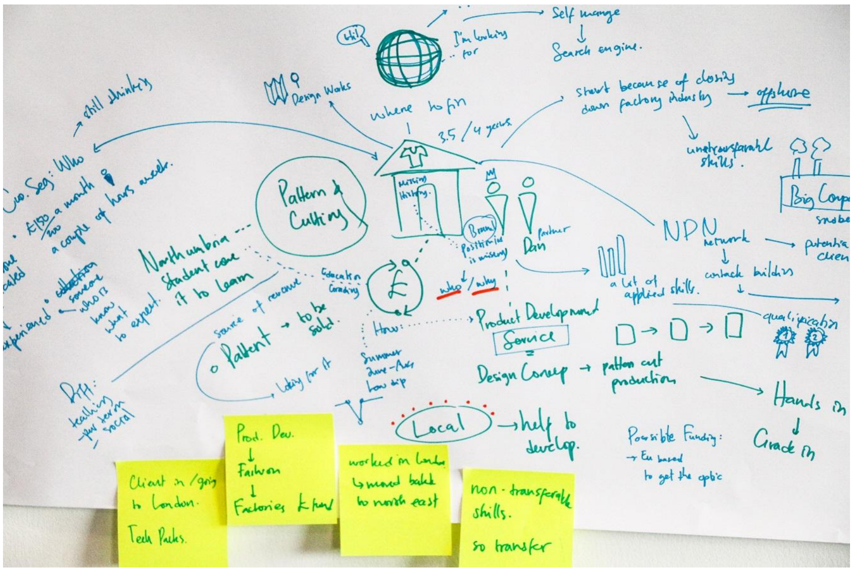


Figure 1: Mapping the enterprise

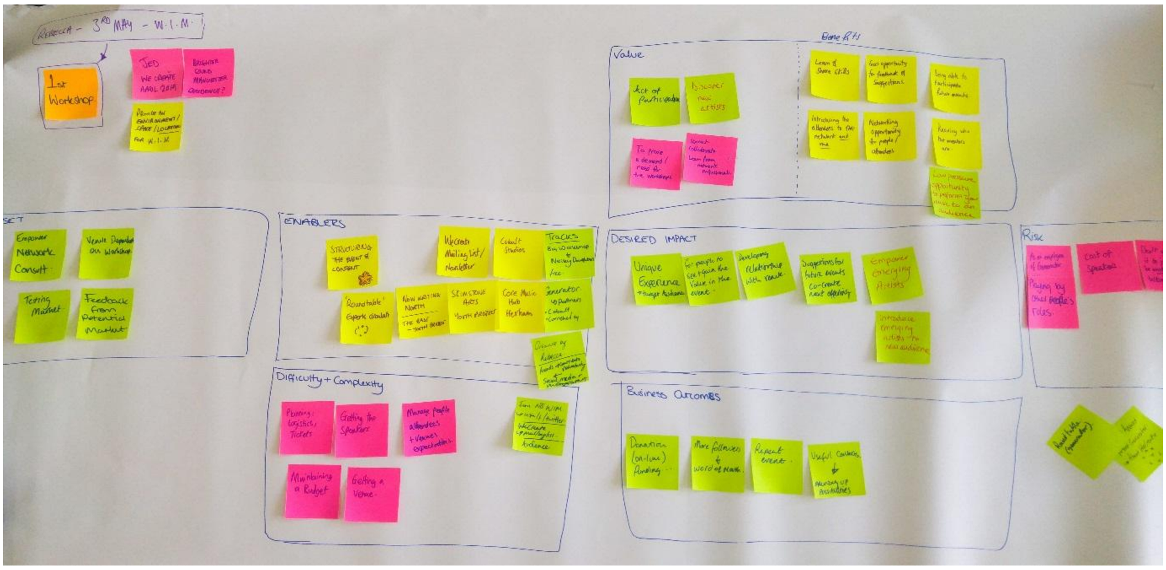


Figure 2: Modelling the opportunity space

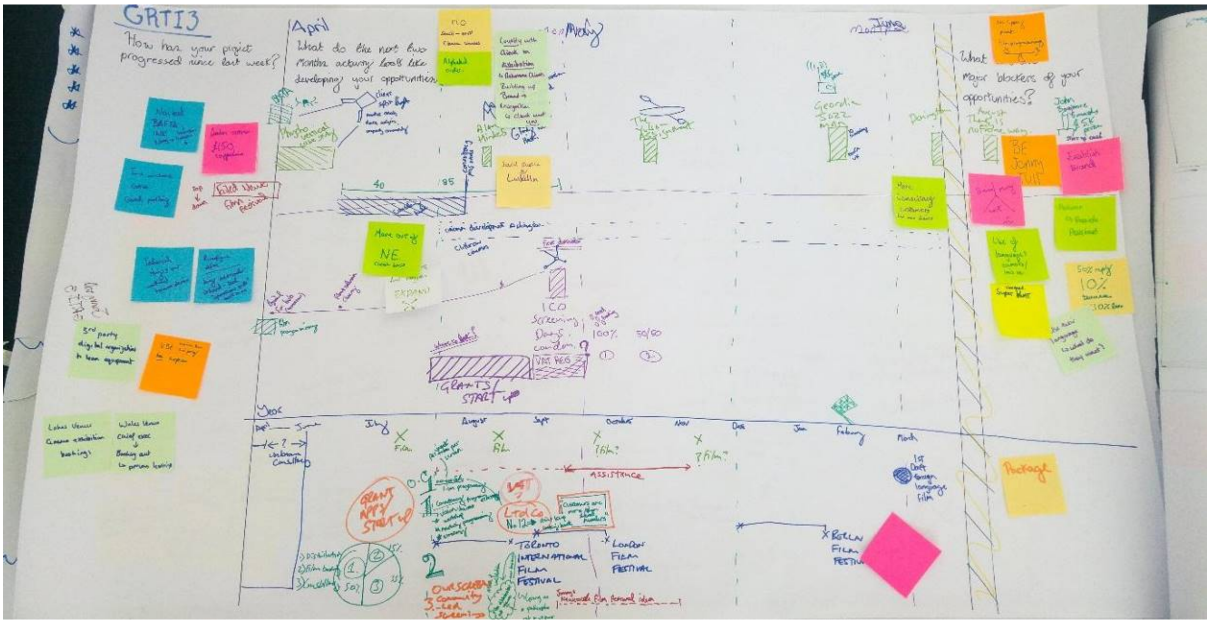


Figure 3: Strategising around the opportunity

Facilitation is taken to mean supporting others to reach a shared aim (Kolfschoten et al., 2007). In GRTI, the facilitator is integral to the group work, and activities are co-creative and design-led. A design-led approach to solving complex and ill-defined problems involves using the tools and mindset of a designer and requires the creative confidence to act decisively and take risks (Rauth, Koppen, Jobst & Meinel, 2010; Kelley and Kelley, 2012; Ulibarri, Cravens, Cornelius, Royalty & Nabergoj, 2014). The design-led facilitator does not act as consultant but works in multidisciplinary teams with diverse people as the route to solving complex problems (Baer, Greg, Costa Jacobson & Holingshead, 2008: 255). This paper focuses on the role that the students played as novice facilitators. We can speculate that, were the business to be supported only by EFs, we might have observed different techniques and results, as will be explored in future research.

3 Methodology: Design-led, participatory and grounded in data

The research design was influenced by grounded theory and participatory approaches undertaken within a design-led context, aimed at trustworthiness and authenticity. The largely early-career research team were conscious that they were working within an experienced team and saw an opportunity to take a fresh approach to an under-researched aspect of the departmental practice, that of student involvement in innovation support. This research design offered a way to make use of existing knowledge to sensitise the team to what was going on but also to navigate the body of expertise.

A grounded theory approach was taken which aimed to generate findings that were 'grounded' in the data, and therefore there were no pre-existing hypothesis. The effect of the researcher's prior or emerging assumptions was minimised using an iterative refinement of data collection methods in response to emerging themes and a systematic and transparent coding process (Charmaz, 2006). An analytical leap from data straight to theory was avoided using a progressive content analysis procedure involving first descriptive then analytical themes (Saldana, 2009). Facilitation and visualisation techniques from a design-led approach were used to aid reflection and communication between research participants and researchers (Ward, Runcie and Morris, 2009).

Key research stages (each data collection stage was followed by coding in QSR*NVivo):

1. Scoping literature and departmental practice to develop initial ‘sensitising concepts’. A broad initial question ‘what is going on here?’ guided scoping so that themes could emerge in response to what was observed (Charmaz, 2006).
2. Observation of five GRTI workshops, initially observing all enterprises before focusing on one enterprise to gain a deeper understanding. This enterprise was selected to generate rich, rather than representative, data as they were working with strong NFs (Charmaz, 2006). The paper here refers to insights drawn from all workshops, totalling 12 enterprises.
3. Sense-checking interview to explore emerging themes with an EF.
4. Data collection workshop with 3 NFs and 2 researchers.
5. Descriptive and analytical (re)coding of all data collected (Saldana, 2009).
6. Analysis workshop with 4 researchers to generate analytical framework.
7. Identification of relevant theoretical frameworks helped make sense of the analytical conclusions thereby ensuring, as much as possible, literature did not shape the conclusions, but aided interpretation of themes that had already emerged.

A core researcher was joined by co-researchers embedded in the planning and delivery of GRTI as EFs, thus enabling a participatory action research approach and allowing multiple-perspective validation. The research was situated within the departmental community of practice (Kemmis, McTaggart & Nixon, 2014) and benefitted from the enhanced trustworthiness and transparency of a grounded theory approach to research design and analysis (Charmaz, 2006). The research team had 5 members with varying roles, as can be seen in Table 1.

Table 1: Changing team roles during GRTI planning, delivery and research activity

<table>
<tr><th></th><th>GRTI Planning</th><th colspan="2">GRTI Delivery</th><th>Post-delivery research activity</th></tr>
<tr><td>RA 1</td><td colspan="4">Researcher</td></tr>
<tr><td rowspan="2">RA 2</td><td colspan="3">EF</td><td></td></tr>
<tr><td></td><td>Participant</td><td>Researcher</td><td></td></tr>
<tr><td>IiR 1</td><td colspan="3">EF</td><td>Researcher</td></tr>
<tr><td>IiR 2</td><td colspan="3">EF</td><td>Researcher</td></tr>
<tr><td>Senior staff member</td><td colspan="3">EF</td><td>Researcher</td></tr>
</table>

4 Findings and analysis: Creating a space for growth

Analysis identified three core interrelated themes. Firstly, trust was built and nurtured between all activists. Secondly, supported by the EFs, NFs worked to gather and make sense of information about the enterprise and context. Thirdly, and perhaps acting on a higher analytical level than the previous themes, a 'safe' environment was created that supported both NFs and the enterprises to grow together though exploration, reflection and learnings.

4.1 Building trust

GRTI required "trust across hierarchy", as the EFs and NFs worked together on workshop planning and delivery, "you established a level of trust with myself" (EF). NFs were encouraged to try different approaches and to operate without constant supervision. Trust was recognised by one NF who described a family-like structure,

> it's a bit like parents giving trust to their children … you're like 'OK someone gave me a huge chunk of trust to do this on my own so let's not screw up'.

The NFs did take on this responsibility, contributing their own time to preparation between sessions.

It was also evident that the NFs trusted EFs to support them if necessary. They asked for advice and sought feedback between workshops. One EF reflected on his position relative to NFs, "I am credible amongst them...they know I'm rigorous". There was also the need for the NFs to trust each other to prepare for and participate in sessions.

Enterprises needed to trust the students in order to expose their fears and dreams to scrutiny by people they had only recently met, as one NF reflected,

> it's like someone telling a story about themselves and we were surrounding ourselves with information about her and she felt safe and that these people want to know me.

This may be helped by a 'fit' between enterprise and facilitators, "we got really good people to work with who were from a similar background to us ... I suppose otherwise we would have maybe taken a little longer to get to that honesty" (NF).

4.2 Developing rapport

Closely related to trust, to create a non-confrontational climate for questioning and collect authentic information, rapport between facilitator and facilitated was vital. The NFs seemed to achieve this through emphasising that they had a shared goal. Observational notes provide an example of this, "[the EF] comes over to the table, the business is talking to one of the students, but one student shows him the business' new business card design, really chuffed and positive, like she is siding with the business". The EF described here later commended how the NFs put their enterprise at ease,

> [the NF] was brilliant at establishing and re-establishing that relationship ... every single time he came in [to the workshop] he was great at 'how've you been', 'what's it been like' … establishing the comfort level so the business knows 'ah it's [student's name], we're familiar with him, he's good.

NFs also developed a rapport by employing empathy, attempting to look at the world through the enterprise's eyes, "you're able to relate to and understand who is sat in front of you" (EF).

We will go on to speculate that because the NFs were in a position of having to learn and take risks as well as the enterprises, the enterprises were perhaps better able to open their business up to scrutiny than they might have been were they faced only with an EF or with an industry expert, although personality of the NF may have an impact.

The length of GRTI, with the NFs and enterprises having 9 hours of intensive interaction, provided the time for NFs to have both light-hearted and focused conversation, "getting to know them as a person rather than as a whole business" (NF). The NFs recognised that to do this required establishing a shared goal and a shared language, "it's a bit like knowing what's your enterprise's language" (NF). Rapport was perhaps especially important as the NFs were predominantly working with sole-traders whose working and personal selves were often indistinguishable and therefore conversation inevitably strayed into private lives and heartfelt dreams. One NF described being aware of this,

> when you're working with people with things that are close to them ... and then all of a sudden they have met you for the first time and this is what we're doing, so you have to be personable, you have to be a good actor.

The ability of the NF to do this and their personality type may affect the degree to which this can be achieved.

4.3 Approaching the topic

To gather comprehensive information and to explore the business in new ways, the facilitators approached topics from different angles, probing to understand factual and emotional sides of the business. They also had to navigate conversational 'dead-ends'. One NF reflected on his developing understanding of the need to avoid meeting resistance with resistance, "I learned... don't be as resistant as them...you won't get anything back and we'll just sit there in awkward silence". GRTI was not intended to be an easy process for the enterprises, and several reflected that it was gruelling, and forced them to think about things they might rather not, requiring great skill and persistence on the part of the facilitators.

The NFs strove to use questions which kept the space open for conversation, for example they encouraged deeper discussion by 'playing back' what the enterprise was saying, echoing Wegerif's (2005) creative space for conversation. NFs engaged in 'active listening' (Rogers and Farson, 2015); taking in both the content of what enterprises were saying and the underlying feelings or attitudes that were shaping their communication. In this way they were prepared to see the world from the enterprise's perspective. Co-creating a deep understanding

The NFs came from diverse backgrounds and therefore provided a fresh perspective, as suggested by one enterprise,

> this is how people see my business, people who don't know me, not my family, not my friends, but they are willing to help me ... I am rather stuck in a vacuum so it's nice to see things from another person's perspective".

There seemed to be a generative effect when NFs and the enterprise contributed different ideas to co-creation, a kind of "social or collective creativity" (Reilly, 2008). In the context of ill-defined problem spaces it follows that a multidisciplinary approach might be beneficial. Reilly (2008: 72) describes observing similar co-creation amongst novice facilitators outside of a design-led context, where participants worked with each other's ideas to clarify a patchwork of perspectives, novices “simultaneously hold and use a multidimensional perspective lens … generating creative open solutions”.

However, a lack of experience or conflicting personalities may have prevented the co-creation of understanding at times, for example one NF commented that “the people that you work with sometimes encouraged the work output or ... restricted the work output” (NF).

We could speculate that this was a consequence of the NFs and EFs misjudging the support this enterprise required by framing the problem as idea generation, rather than how to prioritise.

4.4 Sense-making & sense-checking

The NFs recognised the importance of working with the enterprise to develop an understanding of what was really going on. For example, re-framing for one enterprise, a desire to buy new software as a need to maximise profitability. One NF described this situation; “sometimes they [the enterprise] would say this, and they actually meant something different, it needed translating”.

NFs achieved varying degrees of sophistication with regards to ‘translating’ what they heard. For example, one enterprise revealed she did not chase customers for payment which was interpreted by the NFs as a time management issue. However, with EF intervention it became evident that a more insightful interpretation was to read her comments as a lack of confidence. There was other evidence of NFs lacking in ‘active listening’ skills (Rogers and Farson, 2015), for example after the first GRTI workshop session an EF commented “I think they had lost sight of why they were there and they had begun to project their own points of view”. The NFs had shaped a strategy around sales growth through craft-fair attendance, when the enterprise, as a full-time worker and mother, saw growth as achieving enough online sales to fund her evening creative occupation.

If we frame attributes, such as empathy, as acquired rather than inherent, these moments of not actively listening present learning opportunities for the NFs. An EF discussed the different approach she took to the NFs when working with an enterprise who had big dreams but no strategies to reach them. She said she had to actively encourage the NFs to introduce criticality by encouraging the enterprise to prioritise his ideas. In this example it again seems the EF was encouraging the NFs to engage in active listening by considering not only the content of what was said, but the underlying emotions and values behind what the enterprise was saying and encourage the enterprise to do the same (Rogers and Farson, 2015).

By developing a rapport with the enterprises, the NFs created a climate of confidence where trust and honesty were the norm. This later enabled them to co-create a deep understanding of the enterprise's situation,

> [w]e had 3 students all with their own unique strengths who worked well as a team to come up with excellent ideas and solutions - they were the value (enterprise).

Gathering information throughout the GRTI programme allowed both NFs and enterprises to discover each other’s values and skills on a personal and professional level.

4.5 Growing Together

The GRTI co-creative experience shook up the enterprises’ and MDI students’ working habits which forced them to step out of their comfort zones. The trust the EFs placed in the

NFs and the rapport established between them and the enterprises gave each group a common purpose and drive to take up the challenge and exceed expectations, engaging in exploration, reflection and learning.

4.5.1 Exploration

The NFs are familiar with working on 'live' projects with external clients, however this usually involves receiving a brief from the client, working as a group without clients being present, and then presenting back to them. In GRTI the students and the enterprise were able to spend a much longer period of time working closely together. This activity could be framed as a space for exploration and upstream research before the development of a brief.

4.5.2 Reflection

Enterprises and NFs learnt through reflection 'in-action' during sessions and 'on-action' afterwards (Schon, 1984). For example, EFs prompted intermittent re-caps upon re-entering the group, and the visual nature of the activities allowed the group to engage in reflective practice by moving post-its between categories, moving around the table to explore diagrams from different perspectives and easily identifying knowledge gaps, "to make it real and to make it tangible and to do some of the processing" (EF). Space for reflection on-action was also created through 'homework' activities or questions to think further on between sessions,

> they have time to actually think about that question that we've asked them about, so they can rethink if that's [the answer they have given during the session] actually what it is (NF).

4.5.3 Learning

NFs were not marked on their involvement and they were encouraged to see failure as a learning opportunity without implications for course credit. The department removes the risk from experimentation as much as possible by encouraging failure with reflection in order to facilitate learning, consistent with a design-led approach (Author and Smith, 2010). Student learning during the iterations of GRTI is evidenced by their taking and being given, further input and control over the content of sessions. An EF described how, during early iterations, the students were more closely supervised than later ones,

> when we delivered to the first set of businesses we were very explicit in terms of what we wanted the students to do… we prepopulated the templates, we controlled everything.

Control was then handed over to "enable the student to be confident enough to come up with their own ways of working" (EF).

The workshops were also a learning space for the enterprises as they aimed to provide strategies that enterprises could use again in the future. The NFs acted as creative catalysts and a sense of adventure was encouraged, for example by using coloured pens and post its on big bits of paper (Figure 4). A sense of growth is suggested in this comment from an enterprise,

> I found the process to be exciting and energising… I was thrilled to be able to work with such enterprising and engaged young people and staff.

Their learning may have been enhanced through the face-to-face delivery of the support, allowing for the personal connections discussed above, and for NFs to make the most of their social skills such as leadership and trust-building, both factors that are necessary for a cooperative learning environment (Johnson and Johnson, 1999).

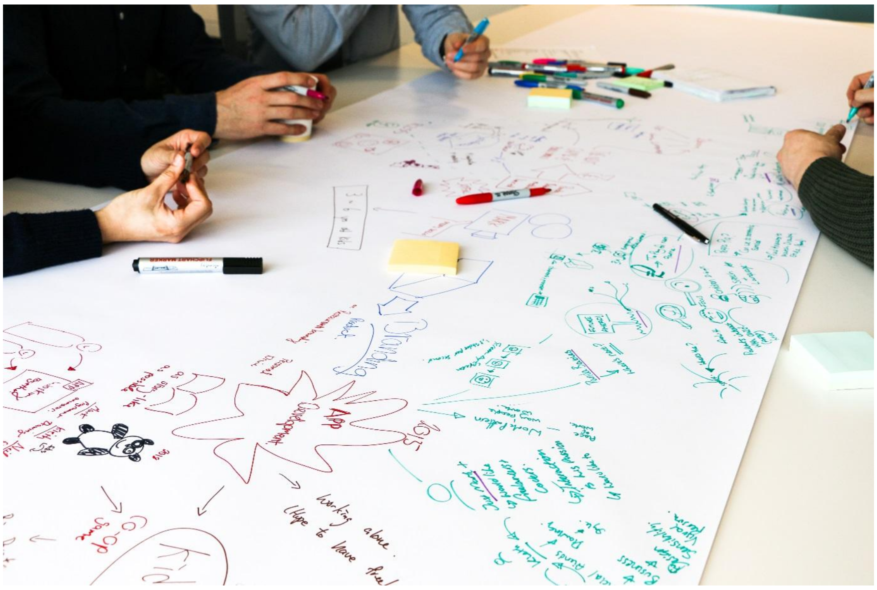


Figure 4: An enterprise and facilitators map ideas

4.5.4 Support

NFs are familiar with working alongside and being supported by staff in the presence of external partners during their MDI course. EF involvement during the GRTI workshops varied depending on the NF's and enterprise's needs. EFs often emphasised to enterprises that they were present to support NFs rather than lead the session as suggested in the statements they made such as, "I will hand the reins over" and "the students have come up with these ideas not me" (EF). At times the EFs subtly intervened to nudge conversation back on course, for example observational notes record that the EF "re-joins the group and directs them to bring conversation back to a higher-level strategy as they were getting bogged down in the details". There was a 'fluidity' as EFs moved in and out of groups, judging when interventions were necessary. This required an expertise on the part of the EF, to judge when to intervene, "I'm constantly reflecting on how I would approach it when I'm watching the table", and when not to, "I'd completely derail the session if I went [NF name] you should do this" (EF).

NF comments indicate that they felt supported where necessary to lend credibility to their work,

> we were getting a bit of onboarding from an academic perspective because sometimes we felt like the enterprise needed the reassurance from the academic.

EFs also provided some 'side talk', such as overall aims and timescales, and the 'theory' behind the activities, "my main role with that group was to help [the enterprise] understand what we were doing and why we were doing it" (EF). In contrast to GRTI one-to-one (Gribbin, Bailey and Spencer, 2018), enterprises may have felt supported by being able to see that other enterprises were having similar experiences and waves of conversation and quiet reflection.

The structure of the GRTI sessions and the reflective time between each of them allowed the enterprises and the NFs to grow as individuals and professionals and to develop a certain set of skills as well as building a relationship based on trust and understanding within a safe space (Bailey and Smith, 2010).

5 Discussion: Learning Creative Confidence

This research aimed to investigate the impact of student facilitated design-led innovation support workshops. It was found that the students, framed here as NFs, worked to build trust, gather information, and collaborate with the enterprises to make sense of what they learned. Despite at first surprising some of the enterprises, working with NFs was evaluated highly and no enterprises failed to attend the full (demanding) programme of support. Having NFs lead the delivery of this innovation support seemed to be significant. For example, when asked if there were any disadvantages of student involvement, one enterprise answered, "none, they were essential to the project". This section argues that student involvement in GRTI created a circumstance where facilitator and facilitated were learners together and authentic co-creation could take place. Further, it is suggested that this develops the creative confidence of those individuals involved.

The first key assertion this paper makes is that an environment was created that allowed the NFs and the enterprise to learn and grow. Acting as creative catalysts, the NFs created a rapport with the enterprise and took ownership of the growth 'work' that took place during the workshops. We can speculate that a sense of 'we' rather than 'us and them' was partly created by both parties being there to learn, take risks, perhaps fail, but ultimately both growing together. One NF had clearly learnt about the practice of facilitation in a way he felt would benefit is core course work, "some of the theory we were using in GRTI, it went over to MDI and vice versa, so we were kind of working through methods and kinds of theories then intertwining them". We could frame the student facilitators as 'expert novices' (Glaser, 1987), aware that they do not know everything, but confident that they can acquire the new knowledge they need . That NFs are able to take on the role of expert novices is arguably facilitated by the safe space and supportive network of relationships with EFs, some of which are previous MDI students themselves and therefore act as role models. The NFs seem to have been able to adopt the role of an expert novice with high self-efficacy - believing in their ability to acquire new knowledge. A cooperative learning environment may have been enhanced by the premise that facilitators and facilitated were both attending to learn and grow as it encouraged a sense of 'positive interdependence'; both parties were invested in each other's success as intertwined with their own (Johnson and Johnson, 1999). This has been noted in other models for enhancing creativity such as the 'micro-cultures' fostered in the 'Team Academy' model (Tosey, Dhaliwal and Hassinen, 2014).

It may seem a straightforward conclusion that delivering an intensive business support workshop would challenge NFs to develop their skills, however it is nonetheless a valuable learning point. The opportunity to learn from their peers and from working alongside the EFs offers a chance to raise an awareness of what can be achieved for the NFs. Information is now readily accessible at the touch of a button meaning that we arguably no longer require as may graduates to be information experts as previously. Instead, we need people who can solve complex challenges in multidisciplinary environments. McFall, Beacham, Burton & Dulaney (2013:125) argue that to adjust to this new working environment universities need to "help students … bridge academic life and professional expectation" by exposing them to professionals and faculty to work together to “address a real-world problem”. While these authors present vertical studios as one way to do this, this paper has explored innovation support delivered within a safe environment, and through an Integrated Academic Practice approach, as another.

The second key assertion this paper makes is that, by co-creating and growing together, students and enterprises developed their creative confidence. This was identified by one of the NFs in relation to the enterprise, and we could perhaps speculate that the developing awareness in this student of the enterprise’s development demonstrates their increasing emotional intelligence, “the workshop doesn’t just profit their business it actually builds their own creative confidence while they’re doing it”.

Creative confidence might have been developed through the opportunity to repeatedly try out activities, “like a muscle - it can be strengthened and nurtured through effort and experience” (Kelley and Kelley, 2012: 4). It has been argued that self-efficacy is developed through repeated opportunities to achieve one’s targets or by learning when targets aren’t achieved (Bandura and Jourden, 1991). Similarly, Rauth et al. (2010: 6) found that through repeatedly engaging in design thinking a particular mindset was developed that built creative confidence,

> [C]reative mindsets are fostered by repetitively experiencing and applying the process as well as tools according to given problems or developing behavioural patterns in certain situations. These mindsets can be seen as the establishment of a bias towards creative behaviour in situations where students are facing situations in which they are uncertain or problems where there is no solution at hand.

Attempting new things requires a tolerance to risk, failure and uncertainty, and a confidence in one’s capability that these challenges can be overcome (Hsu, Hou & Fan, 2011). As people engage in design thinking they are more able to trust their abilities to cope when faced with the next challenge (Rauth et al., 2010). This increasing competence was recognised within the students in this research as they were awarded more control over their interactions with enterprises.

Kelley and Kelley (2012) suggest that creative confidence is progressive, adding to and enhancing what we do rather than meaning we must abandon existing work practices. Further, lack of creative confidence can hold people back from achieving their potential. This is exemplified in the example of a pattern cutting and sewing enterprise that participated in GRTI. They began GRTI with identifying that their biggest challenge was being able to afford new software they thought would lead to increased revenue. Through working with their NFs that uncovered the tangible problem spaces behind this goal, and adapted (rather than abandoned) their current working practices to address them. The NFs quickly saw that their lack of confidence in their own ability was holding them back when pricing work and choosing what work to accept, as noted by an EF “you picked up on that very quickly, on how to boost her confidence and when I came back her confidence was 20, 30% higher”. This was even dealt with directly by the NFs during the session, with one commenting to the enterprise that “you’ve already started building your creative confidence”. The enterprise quoted here gained the confidence to change aspects of their work that were less profitable and use their new confidence to get a great deal on the new software they wanted, thus they have the creative confidence to “pursue a line of action” (Lucas, Cooper, Ward & Cave, 2009: 740). This was summarised by the enterprise,

> recognising that the skills we have are valuable and giving us the confidence to go after bigger jobs and gain a deal ... for software essential to our growth … They have taught us better ways to evaluate the business and have improved our self-confidence which has resulted in larger fees from enterprises and us being more selective about who we work with.

Trust must exist for group members to venture new ideas and feel they can co-create, creating a kind of ‘contract’ between members who see each other as having the potential to have a positive impact on their environment (Carmeli and Spreitzer, 2009). Trust between NF and enterprise seemed to be built through social skills such as being personable and understanding, echoing Ulibarri et al.’s (2010: 263) finding that treating people as “human beings” (with fears, values and emotions) was vital if seeking to build their creative confidence, congruent with a design-led approach (Ghassan and Bohemia, 2013:526). We could speculate that within co-creative environments where a ‘contract’ of trust and honesty is created, a creative confidence in each other as well as oneself is fostered. Baer et al. (2008) refer to ‘team creative confidence’ and ‘collective efficacy’ when this confidence is directed towards a shared goal. It is suggested that because NFs may have seemed more approachable than experienced staff or industry experts, and because they were also learners and risk-takers, they may have been able to more readily establish rapport and collective creative confidence.

GRTI aimed to enhance the innovation readiness of sole-traders and SMEs in the region. We have argued here that students proved invaluable in achieving this aim through building the creative confidence of the enterprises who participated. An environment was created where these students could act as (expert) novice facilitators in that they acted with support from expert facilitators, were presented to enterprises as activity leaders with ownership over the activities, and built the cooperative learning skills necessary to acquire the information they required. Enhancing creative confidence is highly valuable if we consider that those with higher levels of belief in their own ability to change their environment, to grow, and to recover from failure in a positive way, are more able to reach for, and achieve, higher goals. The more we achieve these goals, the more our creative confidence flourishes. Therefore, this approach offers a way to stimulate innovation in the region through equipping enterprises and graduates with the seeds of creative confidence and some tools to build this mind-set further. Further research will reflect upon the strengths and limitations of taking this dual focus, and will seek to assess the innovation readiness of the SMEs involved.

6 References

Bailey and Smith, N. (2010) Safe environments for innovation: developing a new multidisciplinary masters programme. In: C. Boks, C. McMahon, W. Ion & B. Parkinson (Eds.), *When Design Education and Design Research Meet: proceedings of the 12th International Conference on Engineering and Product Design Education E&PDE10* (pp. 60-65). The Design Society.

Bailey & Smith, N. (2016). Making it Work; Integrated Academic Practice. In: *20th DMI: Academic Design Management Conference Inflection Point: Design Research Meets Design Practice* (pp. 2346-2363). Boston: DMI.

Baer, M., Greg, O., Costa Jacobson, G. & Hollingshead, A. (2008). The personality composition of teams and creativity: The moderating role of team creative confidence. *The Journal of Creative Behaviour,* 42(4), pp. 255-282.

Bandura, A. & Jourden, F. (1991). Self-regulatory mechanisms for governing the impact of social comparison on complex decision making. Journal of Personality and Social Psychology, 60(6), pp. 941-951.

Carmeli, A. & Spreitzer, G. (2009). Trust, connectivity and thriving: Implications for innovative behaviours at work. *The Journal of Creative Behaviour*, 43(3), pp. 169-191.

CFNE (2017). *Initial report.* Retrieved from http://www.creativefusene.org.uk/wp-content/uploads/2017/06/Creative-Fuse-North-East-Initial-Report-22062017.pdf.

CFNE (2019). *Project report.* Retrieved from http://www.creativefusene.org.uk.

Charmaz, K. (2006). *Constructing grounded theory.* London: Sage.

Department for Business, Energy and Industrial Strategy, (2017). *Building our industrial strategy.* Retrieved from https://beisgovuk.citizenspace.com/strategy/industrial-strategy/supporting_documents/buildingourindustrialstrategygreenpaper.pdf.

Ghassan, A., & Bohemia, E. (2013). From Tutor-led to Student-led design education: the Global Studio. In J. Beate Reitan, P. Lloyd, E. Bohemia, L. Merete Nielsen, I. Digranes, & E. Lutnæs (Eds.), *Proceedings of the 2nd International Conference for Design Education Researchers: Design Learning for Tomorrow – Design Education from Kindergarten to PhD* (Vol. 1, pp. 524–536). Oslo, Norway: ABmedia.

Gribbin, J., Author, Spencer, N. (2018). A rapid design-led approach to innovation readiness: advantages and disadvantages. In *21st DMI: Academic Design Management.* 1-2 August 2018, London, UK.

Glaser, R. (1987). Teaching expert novices. *Educational Researcher,* 16(9), p5.

Hegarty, J. (2014). *Hegarty on creativity there are no rules*. London: Thames & Hudson.

HM Government and Transport for the North. (2015). *The Northern Powerhouse: One agenda, one economy, one north*. London: HMSO.

Hsu, M., Hou, S. & Fan, H. (2011). Creative self-efficacy and innovative behaviour in a service setting: optimism as a moderator. *Journal of Creative Behaviour*, 45(4), pp. 258-272.

Johnson, D. & Johnson, R. (1999). Making cooperative learning work. *Theory into Practice,* 38(2), pp. 67-73.

Kelley, T. & Kelley, D. (2012). *Reclaim your creative confidence.* Harvard Business Review, 90(12), pp. 115-118.

Kemmis, S., McTaggart, R. & Nixon, R. (2014). *The action research planner: Doing critical participatory action research.* New York: Springer.

Kolfschoten, G., Hengst-Burggeling, M. & Vreede, G. (2007). Issues in the design of facilitated collaboration processes. *Group decision making and negotiation,* 16, pp 347-36.

Lucas, W., Cooper, S., Ward, T. & Cave, F. (2009). *Industry placement, authentic experience and the development of venturing and technology self-efficacy*. Technovation, 29(11), pp. 738-752.

McFall, B., Beacham, C., Burton, K., Dulaney JR, R. (2013). How can we make it better? Translating an innovative medical model into cutting edge design curriculum. In J. Beate Reitan, P. Lloyd, E. Bohemia, L. Merete Nielsen, I. Digranes, & E. Lutnæs (Eds.), *Proceedings of the 2nd International Conference for Design Education Researchers: Design Learning for Tomorrow – Design Education from Kindergarten to PhD* (Vol. 1, pp. 524–536). Oslo, Norway: ABmedia.

Phelan, S. & Young, A. (2003). Understanding creativity in the workplace: An examination of individual styles and training in relation to creative confidence and creative self-leadership. *The Journal of Creative Behaviour*, 37(4), pp. 266-281.

Rauth, I., Koppen, E., Jobst, B. & Meinel, C. (2010). Design thinking: an educational model towards creative confidence. *First International Conference on Design Creativity, ICDC*, 29th November - 1st December, Kobe, Japan.

Reilly, R. (2008). Is expertise a necessary precondition for creativity? A case of four novice learning group facilitators. *Thinking skills and creativity*, 3, pp.59-76.

Rogers, C. & Farson, R. (2015). *Active Listening*. USA: Martino Publishing.

Saldana, J. (2009). *The coding manual for qualitative researchers.* London: Sage.

Schon, D. (1984). *Reflective Practitioner*. Basic Books: USA.

Tosey, P., Dhaliwal, S. and Hassinen, J. (2014). *The Finnish Team Academy model: implications for management education. Management Learning.* 46 (2), pp. 175-194

Ulibarri, N., Cravens, A., Cornelius, M., Royalty, A. & Nabergoj, A. (2014). Research as design: Developing creative confidence in doctoral students through design thinking. *International Journal of Doctoral Studies*, 9, pp. 249-270.

Ward, A., Runcie, E. & Morris, L. (2009). Embedded innovation: design thinking for small enterprises. *Journal of Business Strategy*, 30(2/3), pp. 78-84.

Wegerif, R. (2005). Reason and creativity in classroom dialogues. *Language and Education*, 19, pp. 223–237.

About the Authors:

Dr Kate Lampitt Adey: Dr Kate Lampitt Adey is part of the Creative Fuse North East team at Northumbria University. Kate has a background in researching the benefits of creativity and designs and delivers design-led innovation workshops.

Mark Bailey: Mark Bailey is Director of International Development: Design at Northumbria University. He is Northumbria's Institutional Lead for the Creative Fuse North East programme and he leads research into Design-led Responsible Innovation Practice and Education.

Justine Carrion-Weiss: Justine Carrion-Weiss is Innovator in Residence at Northumbria University, where she graduated from the MDI master's degree in 2016. Justine's interest and focus sits on the long-term impact of rapid-led interventions, its key indicators and how it can be measured.

Freddie Gibbons: Freddie Gibbons has a master's degree in Multidisciplinary Innovation. After graduating in 201, he has been working as an Innovator in Residence for Northumbria University. Freddie's research interest lies in the use of design-led innovation techniques within workshop environments.

Acknowledgement: We would like to acknowledge the staff and students of MA/MSc Multidisciplinary Innovation at Northumbria University, the various enterprises who engaged in the Get Ready to Innovate programme and wide Creative Fuse North East team of academics, researchers and support staff who made the programme possible.

Possession Tool: Design Preferable Future with Humane Assistant and Diegetic Prototype

Fu, Zhiyong*; Xia, Qing

Tsinghua University, Beijing, China
* fuzhiyong@tsinghua.edu.cn

This paper presents a design tool to support future-oriented design of humanized product or service. With the development of technologies such as artificial intelligence (AI), people are increasingly eager for the active and emotional products and services. In order to add social and human features to the future goods, we try to generate a design approach based on the theory of design fiction, which can predict the preferable future, and back to the present to develop the current prototype. This new approach was used to empower student's creativity in design research project and practical courses, and it also iterated and refined through the feedback of students.

This paper proposes a design approach, namely Possession Tool, which focuses on the ideation process, including four stages, i.e., decomposing the problem, envisioning humane assistant to solve the problem, extracting the humane assistant features into a diegetic prototype, and transforming the diegetic prototype into a realistic solution. And a four-staged modular tool sheet has been built for the further research. The Possession Tool emphasizes reflection on the design output to ensure that the future development meets the designers expect. With the support of the tool, young designers can expand their creative thinking, re-establish relationship between the present and the future, and design the present by imagining the future.

In the field of design research and education, this paper contributes an approach that focuses on social and cultural perspective of product and service. It is hoped that this kind of experiment can open up a new field of design humanized artefact to speculatively building the preferable future.

Keywords: Possession tool; design tool; design fiction; diegetic prototype;

Demand for a tool to create humanized products

As the products become more intelligent, people have put forward further requirements for designing humanized products. The traditional design regards things as objects, media, the extension of human beings, which are lifeless and passive, executing the designed program to serve people. In recent years, with the matureness of intelligence technologies, people begin to dialogue with things directly, instead of looking them as the media between humans. For us, future is the time to symbiosis with intelligent artificialities. There will be more interaction between human and machine on function and emotional level. As a result, things are going to be human partners, which provides new space for design. We can design intelligent partners without hardware, focusing on their software, the world view, the character, and the way of completing tasks. If we look the software and hardware of machines as the spirit and flesh of lives, we used to pay more attention the flesh, but now we can design the spirit.

On the other hand, for the learning ability of machines is getting stronger, they can output design schemes by inputting excellent design samples. To some extent, the work of functional design will transfer to machines from designers, and the original field of human designers will be captured. As a response, designers will lay emphasis on mining opportunities at the social and human fields. Designing emotionalization and humanization products is on the way.

Table 1 The functional product and the humanized product

	The functional product	**The humanized product**
Background	Industrialization, informatization	Intellectualization
Field	The fiction of science	The fiction of society
Characteristics	Passive	Active
Essence	Medium	Noumenon
Manifestation	Functional, useful	Emotional, humanized

We want to build a tool that can be applied universally to the creation of humanized products. The tool will clarify the process of generating ideas. With this tool, not only designers, but also innovators of other disciplines can imagine products for the future. At the same time, we hope that this tool can be used both to envision the future, and to solve existing problems.

Method of generating new design tool

With the requirement of creating humane products, we turned to literature analysis for existing methods and tools which can stimulate humanized and social thinking on future products. In the literature of Design Fiction, we found the convergence of the concept with us, that is, to discover the preferable future through the product. We first set the tool with a working principle, to design future for good. But different from laying eyes on the discovery and speculation of problems advocated by Design Fiction, we hope the tool can solve problems to improve the present situation.

Then, by the method of Research through design, we gradually completed the tool through one research project and two courses. In each project or course, we collected feedbacks from tool users through questionnaires and interviews, and iterated the tool with the important revision suggestions. It can be said that the Possession tool is an approach that has grown up in the practical application of the project and courses. After two iterations, a procedural, modular tool has been formed. At the same time, we sought the company as a partner to ensure the design is connected to the real application.

Table 2 The experiment of research project/course and the development of Possession tool

	Name of research project/course	**Characteristics of project/course**	**User of the tool**	**The development of Possession Tool**

Experiment 1	AI city	Master student research project Non-directional	Design background graduate student	Forming basic process
Experiment 2	Future retail	Cooperative courses with company JD directional	Design background undergraduate student	Adding humanized features
Experiment 3	Future life	2-week concentrated development course directional	Multi-background undergraduate student	Completing modular tool

In the study of Ai city in Experiment 1, the tool was still in its infancy. The users of the tools were graduate students with the interactive design background. Through the experiment in this research project, the tool has determined the basic idea of searching the solution in the hypothetical future and then returning the solution to reality. In the interactive design course of Experiment 2, the entire process of the tool has been basically confirmed, forming a process of ideation by decomposing the problem, envisioning humane assistant to solve the problem, extracting the humane assistant features into a diegetic prototype, and transforming the diegetic prototype into a realistic solution. In the Experiment 3 Future Life, a design and the technology entrepreneurship laboratory course, the form of a modular tool has been finally generated through the verification by multi-background students. With the reference to the Design Fiction concept, and the practice of Research Through Design in research project and courses, a tool has appeared for promoting humanized product design.

From design fiction, to Possession Tool

Design fiction is a concept created by science fiction author Bruce Sterling, to suspend suspicion of change by intentionally use story prototypes. Anthony Dunne and Fiona Raby developed the concept, focusing on the speculative nature of the design, and reducing the “guessing” component of the fiction, which magnifies the impact of the product from a critical perspective. It implements a “prefigurative criticism” strategy that presents future possibilities to the audience and allows the audience to make choices. Just as Anthony's value proposition for Design fiction, our expectations for the new tool is to help people discover and identify the future they want. But at the same time, we also hope that the tool can give feedback to the present on the basis of speculation, and stimulate designers to influence the future by changing from now. If Design fiction is the radar scanning the future, we want to design a tool by which the feedback signal can be responded.

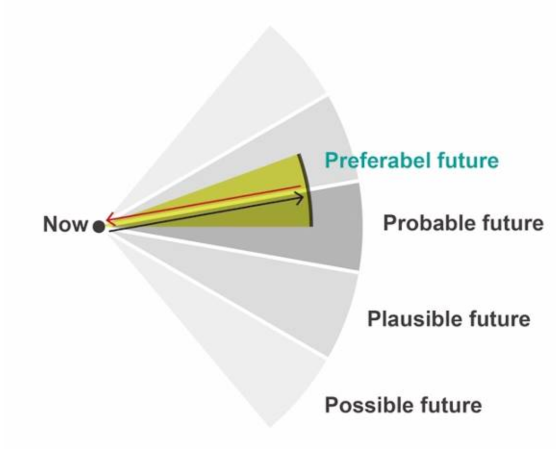


Figure 1. The radar of Design Fiction and the evolution by Possession Tool

In terms of controlling the humanized characteristics of the design results, we envision the ultimate intelligence of the product, which will eventually think like a human being, like a spirit. There are many similar myths and legends in China and the West, such as the spirit of wood and stone named Chimei in The Analects of Confucius, the magic mirror in Snow White, and so on. These legends are imagining the maximization of the objects' function, that they can do something by themselves and even with their unique way, so they are humanoid. Moreover, these super-energy objects have emotions, and hold their own principles of life. For example, Chimei like to live in the mountains, the magic mirror is quite stubborn. Meanwhile, their character features will also be reflected in their actual functions and images. It is the object that we want to create by controlling the design process with the design tool. Therefore, at the beginning of innovation with the tool, we set up a humane assistant, and it (Use it to refer not because it is an object, but because we are not sure what the gender it is) can solve the problem. By this, the way to solve the problem will be inherently humanized.

Next, by narrative way, the characteristics of the humane assistant will be shown in a designed object which is called the Diegetic prototype. The Diegetic prototype is derived from the science fiction movies, and is often used to display the possibilities of future technology through the design of objects. Here we can look it as a prototype that can express ideas. Diegetic prototype is suitable for describing the characteristics and usage of a future product through a story. It can be rough to leave room for imagination. With the diegetic prototype, innovators can express the concept of the solution which have the characteristics of the humane assistant. In other words, we can extract the spirit of humane assistant and inject it into the diegetic prototype. This process is much like the plot of spirit possession in stories, so we named this tool Possession Tool.

Combined with the above, we list several important keywords in the development of the concept of the tool, the preferable future, the humane assistant, and the diegetic prototype. By materializing these keywords with the design tool, we designed the main content and core process. Experimented in research and education, finally the Possession Tool has been iterated into a modular sheet.

Possession Tool

The Possession Tool is an approach for design ideation. It helps to export humane products to achieve the preferable future by seeking the solution of the existing problem in a future scene and bring the solution back to the reality. The approach divides the process of ideation into four stages, decomposing the problem, envisioning humane assistant to solve the problem, extracting the humane assistant features into a diegetic prototype, and transforming the diegetic prototype into a realistic solution. The approach emphasizes solving problems through a humane role, and then injects the role's characteristics and its method of solution into prototype to create a humanized product.

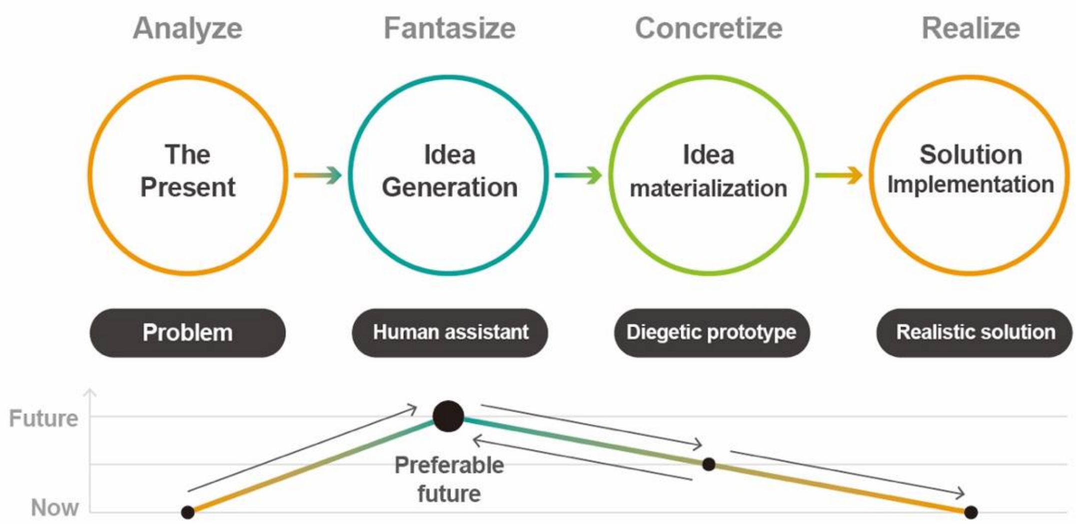


Figure 2. The stages of Possession Tool

The Possession tool pushes the search of solution into an extreme condition, exploring for broader ideas with fewer constraints, and then incorporating social, economic, and technical contexts into considerations, to bring out ideas with realistic considerations. In this way, we can envision the preferable future in the early stage of design. In the middle and later stage, we will check the conformance between the future we want and the future design product brings. By this way, the speculative factors will be throughout the overall process of idea creating.

Meanwhile, for the requirement of emotional products, we have introduced the role of humane assistant as a medium to solve problems. In the current design process, we often consider the hard support part before the soft support part, which makes products cold and inactive. We hope to reverse this order. While taking the function design into account, the spirit of the product can be considered as well. Or even the characteristics of the spirit go prioritized. When envisioning the future, innovators are asked to solve problems through roles that have human characteristics. The humanized role can be a super-smart creature or robot, such as Superman and Doraemon, or a sophisticated animal or item, such as Nekomata in Japanese mythology. They must have their own principles of behaviour and unique problem-solving techniques, which will be concretized as a diegetic prototype, to form the characteristics of the product.

On the final stage, the approach of Possession Tool guides designers to turn the diegetic prototype into a ground-breaking solution with the existing technologies. If the technology develops smoothly, the realistic solution will likely grow into the humane assistant we have envisioned.

Above, we realized the creation process with visible Possession Tool sheet. Corresponding to the four stages of the approach, the tool sheet includes four modules, the problem, the humane assistant, the diegetic prototype and the realistic solution. In the diegetic prototype module, we have left a space for reflecting the use of the diegetic prototype, on fields of social, economic, technical, and so on. The tool sheet can drive users into fully understand on each design stage and the design goal. It is more conducive to the ideation and reflection of ideas than linear step-by-step guidance.

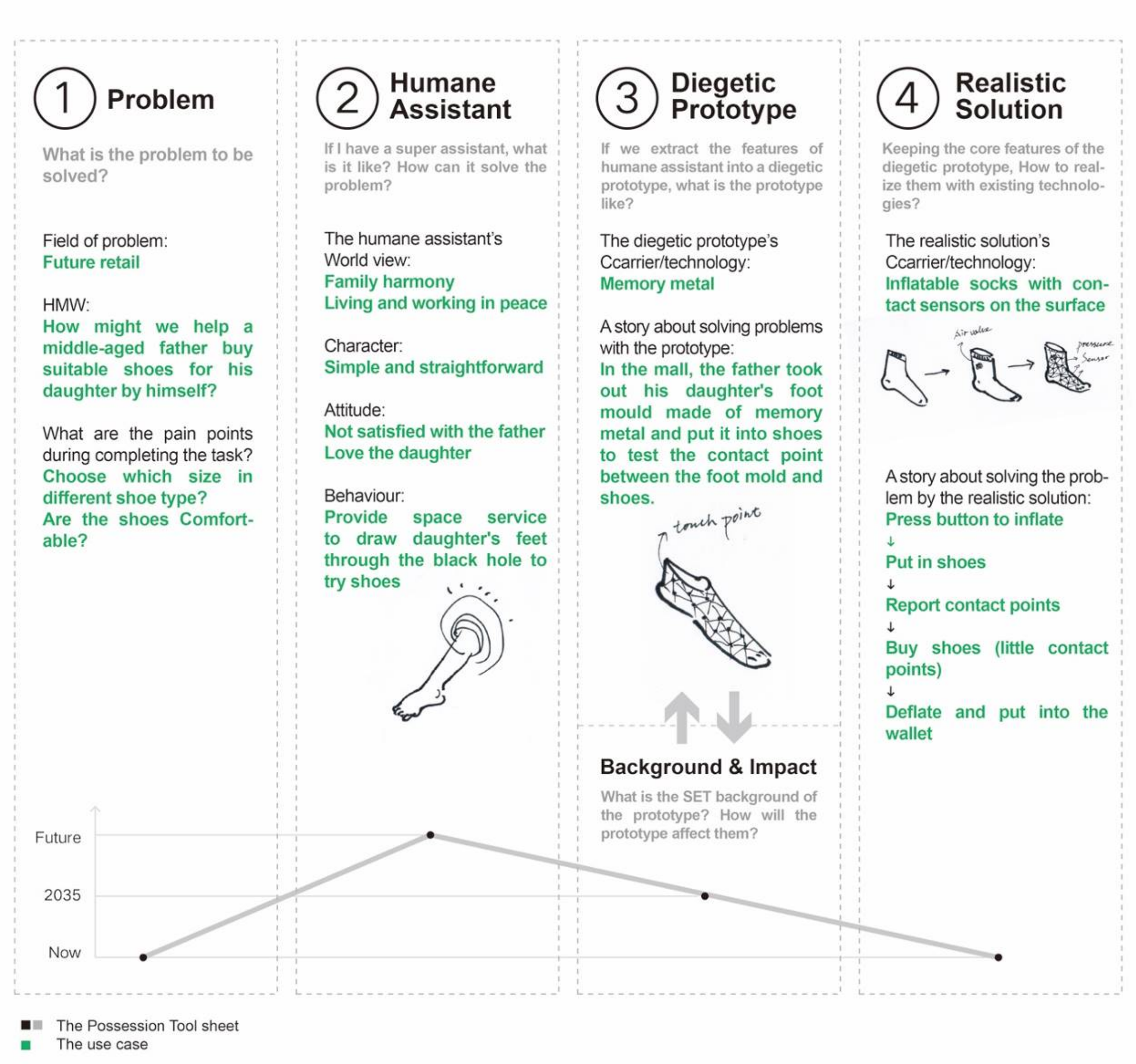


Figure 3. The Possession Tool sheet and use case

According to the process showed by Possession Tool sheet, product designers can smoothly design fiction and achieve the process of ideation. In addition to the modular stages, the tool sheet also provides a reference to the time axis to remind the user to pay attention to the background context when brainstorming. In actual use, the conventional approach is to deduct from the Problem in numerical order, but when it's blocked with thinking, the creator can break the order to rethink and reverse, so as to ensure the activeness of the process and the innovation of solution.

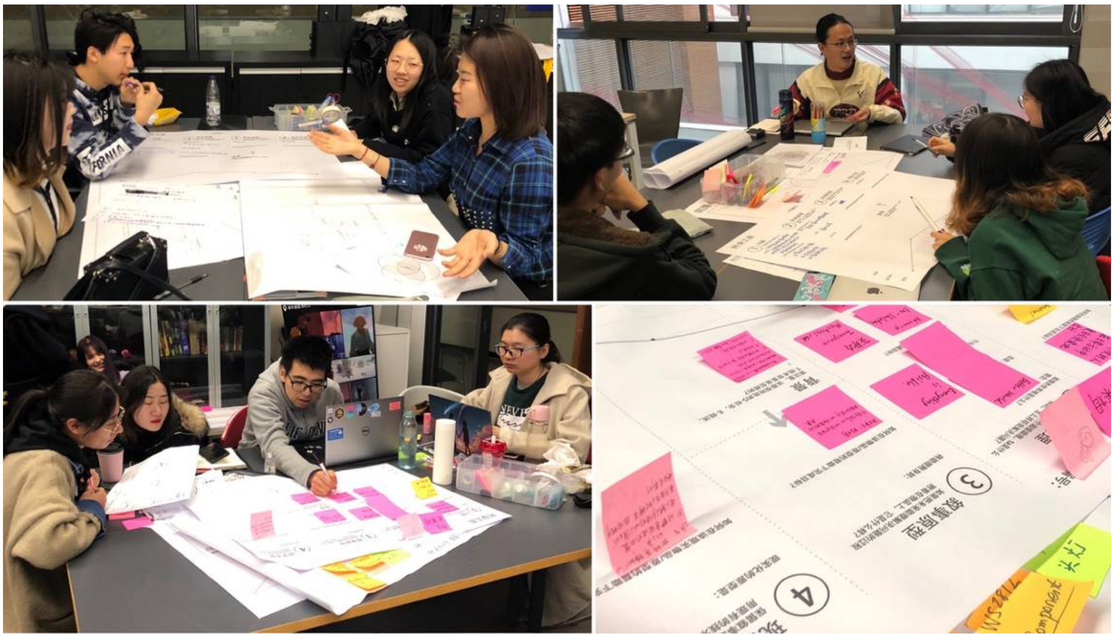


Figure 4. The scene of using Possession Tool

Decomposing the problem

As the beginning of ideation, we must first determine what the problem is to be solved. The problem is not an abstract phenomenon, but a most painful point for a specific person in completing a particular task. Since we are not the user, we usually cannot pick up the problem directly, so we use the step-by-step approach to dig out it.

Table 3 The process of decomposing the problem

	Process	Tools	Purpose
Coarse	Field of problem	Territory map, AEIOU	Circle the scope of the research
Middle	Task to be completed	How might we (HMW)	Guide the actual research
Fine	The pain point of the task	Persona, Empathy map, Journey map, Stakeholder	Discover the problem that can be turned into

As shown in the use case of Possession Tool sheet, in the field of retail scenarios, the task is to help a middle-aged father buy a pair of suitable shoes for his daughter by himself. Through research, we found that the most painful point for is the inability to determine the accuracy of the size and the uncertainty of the comfortableness due to different shoe types. These will be the findings to be turned into design in the next step. Then, we are going to imagine a humane character with special abilities to solve the problem in its unique way.

Go to the future: envisioning humane assistant to solve the problem

Based on the consideration of the humane characteristics of the product, after obtaining the pain points that the user wants to improve, we suggest the creator envision a humane assistant with personality to solve the problem in a unique way. The point is, the way must be preferable to all beings of the future. When envisioning the humane assistant, the creator can be as bold as possible for a distant future. It can be a intelligent creature of any kind with powerful capabilities to help you achieve your goals. But at the same time, it is limited by its own characteristics. Just as a person's way of solving problems is limited by his world view, personality, attitude and his own basic conditions, we also designed these features for the humane assistant to make it seem human. These humanized settings will evolve into personalized problem solutions.

Table 4 The characteristics of humane assistant

Characteristic	Content	Purpose
World view	What does the future assistant think of the world? Usually similar to the preferable future set by the creator	Ensure the final product leads to preferable future
Character	What is the inherent personality? Lively, steady, agile, delayed…	Affect product characteristics
Attitude	Attitudes and opinions on the problem to be solved	Affect the way a product solves the problem
Behaviour	Way of solving the problem	Determine the way a product solves the problem

Setting the assistant's worldview helps the creator choose the preferable future. Creators need to be clear that all products will have an impact on the development of society. The maximization of this impact should be benign, in line with what creators and the public expect.

The setting of the humane assistant character can provide designers with a basic reference for product characteristics. William Odom of Simon Fraser University in Canada participated in the design of a game called Slow Game which draws on the practice of playing Chess. The spirit of this game has a stable character, a complete chronic. When embodied the spirit in a specific function, the design only allows the user to play one move every day. Odom hopes that the personality of the game will make the user feel "slow life", only participate in a little bit each day, but participate for a long time.

The attitude of the humane assistant to the problem will affect its behaviour, that is, the method that the product present to solve the problem. In the case of the father choosing shoes for her daughter, we set a special attitude for the future space assistant. The space assistant is not completely positive about the father, which stems from the family relationship hidden behind the task. For the father has been not well involved in the growth of the daughter (a common problem in China's social, most of fathers tend to focus more on career), the assistant looks not very active for the father. But, it likes the daughter very much, so it chose to provide space service to draw daughter's feet through the black hole, to try shoes. It hopes that the daughter can be happy by feeling her father's heart, instead of taking a more convenient approach by directly matching the feet data model of the daughter and the scan model of shoes. After completing the task, the space assistant also has his own "selfishness", which expects the product derived from it to become a carry-on item to remind the father to pay attention to the family.

Before the future assistants had features, the solution was divergent, but afterwards they are contracted and concentrated. In the following, only by injecting these features into the prototype, it is possible to produce a functional thing with emotion and attitude.

Extracting the humane assistant features into a diegetic prototype
In this stage we begin to materialize the ideation of humane assistant into a diegetic prototype. In the conversion, we do not have to retain all the characteristics of the character, only the important part that has a decisive influence on the product characteristics. After materialization, we must reflect on the reaction of the product (on social, economic, technical, etc.). The designer should specifically examine the variants of the prototype in the next 2, 5, 10, 20 or even further years. The impact of using it on the future should eventually evolve into the preferable one we have chosen. In the impact of the deduction, we can use the Future Board tool to mark the development of the product on the given time axis, as well as the positive and negative effects on society, economy, technology, etc., as a reference to the value and necessity of the design.

Table 5 The process form humane assistant to diegetic prototype

Step	Content	Operation
1	Highlight key point of humane assistant characteristics	Select parts of humane assistant characteristics to be converted
2	Choose a point-in-time of future	The background of the era determines the level of technology that can be used
3	Selection carrier/technology	Choose carriers or technologies that properly represent future assistant features
4	Tell a story about solving problems with the prototype	Design an prototype with humane assistant features and describe how to solve the problem with it
5	Rethinking the impact of the prototype	Deriving the long-term impact of the product with the future board

In the case of the father choosing shoes for him daughter, we have identified some key attributes of the space assistant: moving the feet, sensing the contact between shoes and feet, and as the father's belongings. We chose 2035 as the time background of materialization. The reason for determining 2035 as the background of imagination is that it will not be unpredictable for the development of technology for it is too far away, and it will provide a 15-year period of scientific and technological developing, leaving us room for future design. In the consideration of the carrier, we have selected the memory metal to introduce the characteristics of the space assistant. This material has some obvious advantages, can be deformed, can record the shape, and can be electrically conductive as a metal. These features can be concatenated with the characteristics of the humane assistant, to form a diegetic prototype that can be transformed into a daughter's foot and can detect the contacts with shoes. Meanwhile, when it is folded, it can be placed in the wallet like an Omamori. The Omamori is a kind of amulet in Japanese culture that can be carried, like which, the folded memory metal foot mould will also remind the father to pay attention to the family and guard the family happiness.

From the humane assistant to the diegetic prototype, the process of soul possession is completed. This is the core part of Possession Tool.

Back to the reality: transforming the diegetic prototype into a realistic solution
After we have a solution in the form of things, the next step is to land it as a prototype that can be presented in the real world to respond to the questions asked in the first stage. When designing the realistic prototype, it must be noted that it is able to inherit all the important features of the diegetic prototype, that is, the character, attitude, and behavioural characteristics of the humane assistant, to ensure the continuity of ideation thinking.

Once the shape of the realistic solution is determined, the creators can demonstrate its service flow through a variety of design tools, and express the usage scenarios, usage methods, usage results and impacts of the solution in a narrative manner. At this point, we used the Possession Tool to help complete the entire ideation process.

Table 6 The process form the diegetic prototype to a realistic solution

Step	Process	Content	Tool
1	Find alternative materials/techniques	Find existing materials/technologies that can inherit the characteristics of diegetic prototype	
2	Design realistic prototype	Use existing materials/technical simulation solutions	Wizard of Oz
3	Use tools to describe realistic solutions	(product name) provided (product or service) with (feature highlights) to help (target user) solve (problem description)	Persona, Storyboard, Tomorrow headlines, Concept video
4	Display service	World view, operational rules, relationship diagram	Journey map, Experience of the ring

In the case of buying shoes for the daughter, we finally converted the foot mould made of memory metal into inflatable socks with pressure sensors on the surface. The transformed solution can be used in existing laboratory conditions to express the core concepts of design. Inflatable socks can simulate the shape of the foot and report the contact with the shoe by pressure sensors. At the same time, when the sock is deflated, it can be folded very small and placed in the father’s wallet. Moving the feet, sensing the contact between shoes and feet, and as the father's belongings, the realistic grass model as a variant of the diegetic prototype, also continues the important features of the humane assistant.

From decomposing the problem, envisioning humane assistant to solve the problem, extracting the humane assistant features into a diegetic prototype, to transforming the diegetic prototype into a realistic solution, the Possession Tool is unconstrained on ideation by imagining in the future scene and then draw the solution back to the existing conditions. The tool helps creators to achieve the idea in a broader context. At the same time, the tool introduced a humane role in the earlier creative stage targeting the problem, ensuring the humanized factors of the subsequent prototype, so that creators can integrate the world view and the future expectations into the product. In the design, to produce things with more emotional characteristics.

Feedback and reflection

After the one-and-a-half year experiment, the Possession Tool has been used in three courses to help students advance the process of ideation. In fact, this tool has been developed in the validation and feedback of these courses.

Table 7 The development of Possession Tool

	Course	The version of tool	Imagining in the future	Humane assistant	Drawing the solution to reality	Feedback of creators
1	AI CITY	Conversion between the future and reality in process (step-by-step)	√		√	The tool can help divergent ideas, but lacks uniqueness The outputs lack features
2	Future retail	Add humane assistant into imagining (step-by-step)	√	√	√	It's better to show the entire process, in order to master the staged goals
3	Future life	modular Possession Tool sheet	√	√	√	The tool can help design humanized products/services more effectively

For the purpose of creating a preferable future, Possession Tool was originally designed to help design future-oriented products or services. It has initially had the current process, to directly imagine a prototype in future to solve existing problems and then land it in reality, but lacks the setting of the humane assistant. After the verification of research AI CITY, we analysed the design direction of future products. Compared with machines, human designers are better at bringing emotional characteristics to products from the perspective of society and humanities. Therefore, we have added the role of humanoids into the approach (the development of technologies such as AI also provides the possibility of realization of this kind of imagination). In the second tool application of course Future Retail, Possession Tool continues the initial step-by-step approach to help creators with ideation. Users of this course have given important feedback suggestions, and hope to know the full picture of the tool in advance before using the it, to help master the stage goals and rethink across stages. As a result, the Possession Tool eventually grew into a modular tool sheet with four step-by-step stages.

Table 8 The evaluation of Possession Tool (PT) users

Course/Research	AI CITY	FUTURE RETAIL	FUTURE LIFE
Total number of student	8	16	22
Willing to use PT again	6 students	12 students	20 students
Got unexpected results with using tools	7 students	9 students	20 students
Recognized PT to help develop ideas	7 students	13 students	20 students

Thought there was a gap between method and practice	2 students	6 students	5 students
Main help for design thinking	Helps jump the thinking restrictions	Helps generate interesting and unexpected ideas Helps build critical thinking ability	Helps stimulate creativity within the group Combining characteristics of humane assistant with reality, the solution becomes special
Main help for design process	Helps determine design positioning Helps develop prototype	Helps express design concepts Helps list and sort out design ideas Helps concrete function and image of design	Helps divergent creative thinking Helps locate design scenarios Helps improve functions

Before ending the three research/courses, we issued a questionnaire to each student to know how the Possession Tool was used. We are gratified that Most users expressed their appreciation for this method and would continue using it in future designs. Moreover, respondents generally indicated that the Possession Tool method helped users develop critical thinking, jump out of thinking constraints, and create unique solutions. In the design process, it could help show design concepts, determine design positioning, and benefit prototype expression. Especially when the tool with four steps is integrated into paper sheet, it is more helpful for ideation than step-by-step procedural guidance.

In addition, on the innovation of the course results, we also interviewed the designers of corporate partner 7 Fresh offline store of JD (China's self-operated e-commerce). They showed their appreciation for the family and social relations mining in student works, and the way how to embed the relations into products and services, calling the results a new perspective of thinking independent from commercial design.

However, the design approach formed in this study has only experimented in the teaching and research of the college, so until now its application groups and scenarios have limitations. It is hoped that the tool could be tested in more practical projects in later research. In addition, there is a lack of long-term validation and feedback on the generation and use of tools. From the original intention of the tool design, we expect that the creators' ability and quality can be separated, that is, with the help of tools, non-design background creator can obtain design ability, and reach a certain level of design. As far as the observation of the use of Possession Tool, in fact, the background and quality of a tool user limit the use of tool. Design tools can help design advance, but they cannot substitute human thinking.

The next step of the study is going to collect the content filled out by users, analyse their thinking space and thinking mode, and the creative distribution characteristics, to promote the designer's comprehensive thinking. Another development direction of the research is to establish an related database to provide intelligent tips and help for tool users, and to help creators including designers and non-designers to ideate smoothly.

Conclusion

This research establishes an ideation approach from a humanized perspective. It helps innovators design present through exploring a preferable future. The rapid development of intelligent technologies enhances the active, emotional and humanized features of product. Smart technology will replace designers in functional design, and designers will play very important role in the field of humanized design. Under such a trend, this study attempts to set up a tool that adapts to the humane product creative process. The tool helps the innovators to draw a humanized solution by decomposing the problem, envisioning humane assistant to solve the problem, extracting the humane assistant features into a diegetic prototype, and transforming the diegetic prototype into a realistic solution.

In the paper, the Possession Tool was applied in the context of design for future. We conducted research and teaching experiments, which obtained good feedback from students and industry experts. There is a saying in Chinese that give a man a fish and you feed him for a day, teach a man to fish and you feed him for a lifetime. Design tools empower people the abilities to innovate, thus it has been becoming an important research direction and field in the future. It is hoped that this approach will provide a practical path in the application of new technologies for innovative design activities, and can inspire future-oriented, humanized and speculative tool development and form new research field. It is expected that more innovators can grasp the future-oriented design trends and produce more humanized results.

References

Marshall McLuhan. (1964). *Understanding Media: The Extension of Man.* New York: New American Library.

Dunne, A., Raby, F. (2013). *Speculative everything : design, fiction, and social dreaming.* London : The MIT Press.

Ozenc, KF., Brommer, JP., Jeong, BK., Shih, N., Au, K., Zimmerman, J. (2007). Reverse Alarm Clock: A Research Through Design Example of Designing for the Self. *Designing Pleasurable Products and Interfaces (22-25)*. Helsinki, Finland.

Zimmerman, J. (2009). *Designing for the Self:* Making Products that Help People Become the Person they Desire to Be. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (395-404)*. Boston, MA, USA.

Blythe, M., Encinas, E., Kaye, J., Avery, ML., McCabe, R., Andersen, K. (2018). Imaginary Design Workbooks: Constructive Criticism and Practical Provocations. *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems (paper No. 233)*. Montréal, QC, Canada.

Lindley, J. (2015). A Pragmatics Framework for Design Fiction. *Proceedings of the 11th European Academy of Design conference*. doi: 10.7190/ead/2015/69.

Jensen, T., Vistisen, P. (2017). Ethical Design Fiction. *Ethicomp Journal: Values in Emerging Science and Technology*. Doi: 10.29297/orbit.v1i2.56.

Flint, T. (2016). Fiction for Design: Appropriating Hollywood Techniques for Design Fictions. *Human–Computer Interaction Series (49-66)*. doi: 10.1007/978-3-319-29553-4_4

Blythe, M. (2014). Research Through Design Fiction: Narrative in Real and Imaginary Abstracts. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (703-712).* New York, NY, USA

Britta F. Schulte, Paul Marshall, Anna L Cox. (2016). Homes For Life: A Design Fiction Probe. *Proceedings of the 9th Nordic Conference on Human-Computer Interaction (article No. 80).* New York, NY, USA

Bella, F., Fletchera, G., Greenhillb, A., Griffithsa, M., McLeanc, R. (2013). Science fiction prototypes: Visionary technology narratives between futures. *Futures, 50*(6), 5-14. doi: 10.1016/j.futures.2013.04.004

Lindley, J., Coulton, P. (2015). Back to the Future: 10 Years of Design Fiction. *Proceedings of the 2015 British HCI Conference (210-211)*. New York, NY, USA

Skirpan, M., Fiesler, C. (2018). Ad Empathy: A Design Fiction. *Proceedings of the 2018 ACM Conference on Supporting Groupwork (267-273)*. New York, NY, USA

Kirby, DA. (2010). The Future Is Now: Diegetic Prototypes and the Role of Popular Films in Generating Real-World Technological Development. *Social Studies of Science, 40(1), 41–70*. doi: 10.1177/0306312709338325.

Odom, W., Wakkary, R., Bertran, I., Harkness, M., Hertz, G., Hol, J., Lin, H., Naus, B., Tan, P., Verburg, P. (2018). Attending to Slowness and Temporality with Olly and Slow Game: A Design Inquiry into Supporting Longer-Term Relations with Everyday Computational Objects. *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems (paper No. 77)*. Montréal, QC, Canada.

Grand, S., & Wiedmer, M. (2010). Design fiction: a method toolbox for design research in a complex world. *Proceedings of the DRS 2010 conference: Design and Complexity.* Montreal, Canada.

Markussen, T., & Knutz, E. (2013). The poetics of design fiction. *Proceedings of the 6th International Conference on Designing Pleasurable Products and Interfaces (231-240).* New York, NY, USA.

Sterling, B. (2009). Design fiction. *interactions, 16(3)*, 20-24. ISSN:1548-3320.

About the Authors:

Zhiyong Fu: Zhiyong Fu is doctoral advisor, associate Professor of Information Art and Design Department at Tsinghua University. His areas of expertise are information/interaction design, service design. He is committed to promote art & technology integration and interdisciplinary innovation education.

Qing Xia: Qing is a Ph.D. student at Academy of Arts & Design, Tsinghua University. Her research interests are in design methods and design tools.

Acknowledgement: This research is a phased achievement of "Smart R&D Design System for Professional Technology" project and supported by the Special Project of National Key R&D Program ——“Research and Application Demonstration of Full Chain Collaborative Innovation Incubation Service Platform Based on Internet+” (Question ID: 2017YFB1402000), "Study on the Construction of Incubation Service Platforms for Professional Technology Fields" sub-project (Subject No. 2017YFB1402004).

IASDR 2019

International Association of Societies of
Design Research Conference 2019
DESIGN REVOLUTIONS

Manchester School of Art
Manchester Metropolitan University
02-05 September 2019

Redesigning Children's Learning Experience Based on Persuasive Game：A Case Based on "Little Explorer of Hunan Embroidery"

Fu, Xuan; Zhang, Duoduo*

School of Design, Hunan University, Changsha, China
* zhang_duoduo@hnu.edu.cn

Nowadays, children are attaching more and more importance to the learning of various cultural heritages. However, It is the nature of children to play. They can't concentrate for long on the cultural knowledge they are not interested in. "Game" has become one of the effective ways to change this situation. Persuasive game design, as one of the methods of behavior change design, aims to create a user experience game world by using gamification, in order to change the user behavior in the real world. Based on the Hunan Embroidery Museum’s cultural leaning project, this study explored the possibility of persuasive game design to promote the positive change of children's learning behavior, and combined with profound experience design, redesigned the traditional cultural learning course - creating immersive learning experience for children through gamification. The results show that reasonable and interesting persuasive games can improve children's learning motivation, stimulate the flow, and promote them to achieve positive changes in learning behavior and enter into an immersive profound learning experience. This study verified the positive effects of persuasive game design and deep experience design on children's learning and personal development with practical projects, and provided some new ideas for the design practice of persuading children's behavior change.

Keywords: persuasive game design; flow; profound experience design; value

1 Introduction

In recent years, discussion and research on persuasive game design (PGD) have been growing. Many studies have shown that this method of using gamification to motivate users to achieve targeted behavioral changes is highly available. Therefore, PGD is applied in various fields, such as medical health (De la Hera, 2018), social interaction (Visch, 2017), education and learning (Alahäivälä, 2017), etc.. Among them, PGD is relatively rare in the field of education and learning, but it has great potential. Children are one of the major groups receiving education, and their early education will lay an important foundation for their future development and lifelong learning. However, children in the early school age (6-9 years old) are at the peak of their psychological and physical development. They are impulsive in learning, poor self-control, attention is difficult to focus for a long time and other problems, but at the same time they carry the "love to play" nature -- lively and active, strong curiosity, thirst for knowledge, strong performance, love to ask questions, love to imitate and so on. Children's learning motivation is easy to be induced in the rich and vivid life situation, and the plasticity is strong. It can be seen that the traditional formal learning style is not entirely suitable for children in the early school age, not only can not stimulate their interest in learning, but also stifle their imagination and creativity. On the contrary, game-based learning is a breakthrough that can effectively stimulate children's interest in learning and improve learning performance. Therefore, this paper explores the relationship between PGD and children's learning behavior, and verifies the possibility that persuasive games encourage children to learn positively. At the same time, we also combine PGD and profound experience design (PED) to explore the influence of immersive learning experience on children's future development.

This study is based on the Children's Hunan Embroidery Culture Learning Project of Hunan Embroidery Museum in Shaping Township. It aims to stimulate children's interest in traditional handicrafts through the study of Hunan embroidery, cultivate hand-brain coordination ability, improve concentration, and comprehend the spirit of Hunan embroidery contained in culture. However, as a national intangible cultural heritage, Hunan embroidery is very complicated and difficult to learn because of its profound culture and exquisite craftsmanship. At first, the museum adopted a more traditional teaching method. The museum's lecturer led the children to visit the museum. After briefly introducing some contents about the Hunan embroidery, they asked the children to complete the embroidery work that was distributed. According to the actual research data in the museum, we observe that this traditional method is very infeasible and cannot achieve the expected learning effect of the project. Therefore, the research team used the PGD and PED as the theoretical basis and methodology to redesign the Hunan Embroidery Culture Learning Project - "Little Explorer of Hunan Embroidery". Through the experiment, we found that PGD can transform the serious learning knowledge of the real world into various game elements of the game world through the gamification, which improves children's learning motivation and concentration, stimulates the flow, promotes the positive change of children's learning behavior, and makes them to enter a pleasant and immersive learning experience - the profound experience. At this time, on the one hand, children can effectively complete the learning (game) goal and carry out a series of good social interactions, thus generating a sense of achievement and happiness. On the other hand, children can absorb and comprehend the deep meaning (the spirit of Hunan embroidery) in the profound experience, and make these meanings transfer to the real world imperceptibly. The spirit they learned will strengthen and maintain children's positive learning behavior, and it is conducive to the shaping of children's values and the development of their personalities.

2 Related Work and Thories

2.1 Persuasive Game Design (PGD)

The theory of persuasion can be traced back to the ancient Greek rhetoric philosophy based on verbal persuasion (Bogost, 2007). After the rise of communication science in the 20th century, rhetoric began to be used in other fields, such as advertising, to persuade users to consume goods in television advertisements. With the development of interactive media such as games, Bogost (2007) put forward the theory of "procedural rhetoric" - running processes and executing rule-based symbolic operations. The theory is that games can make strong claims about how the world works - not just through words or vision, but through the processes they embody and the models they build. Bogost (2007) argues that it is this aspect of interaction found in games that provides users with the motivation to change, and thus forms the "persuasive game". Later, other researchers continued to develop the theory of persuasive games. Sicart (2011) proposed a new game theory to complement the existing concept of procedural rhetoric - persuasive games should engage with existing game rules, focus on instrumental game elements, or the way players choose. De la Hera (2013) adds a more convincing dimension to Bogost's procedural rhetoric, including narrative persuasion involving components such as stories and characters, and film-style persuasion involving components such as frames.

Valentijn Visch et al. (2013) officially proposed the persuasive game design and its general theoretical model in 2013 (Figure 1). Though “playing games”, users can transfer the experience of the real world to the experience of the game world, and the gameplay of the game world can promote and "persuade" users to achieve the target behavior change in the real world. In the real world and the game world, individuals are driven by the same motivational needs: the need for autonomy, ability, and social relationships controls their behavior (Ryan and Deci, 2000). In the real world, individuals must work very hard to meet the satisfaction of their needs, but the game world is clearly designed to meet these needs, which leads to a typical immersive and satisfying experience in the game world (Przbylski, Rigby and Ryan, 2010). Therefore, "persuasion" in persuasive games can be considered as the behavioral motivation designed for users in the interactive game world, which can promote users to conduct behavior change in the real world (Siriaraya et al., 2018). In the PGD model (Visch, 2013), this behavior change is called "transfer effect", which is defined as the change effect of users' expectation caused by gameplay, from changing users' attitude towards specific problems to changing users' lifestyle. Most of the existing research on PGD focuses on encouraging healthy lifestyle (De la Hera, 2018) and promoting social interaction (Visch, 2017), but relatively little on children's education and learning.

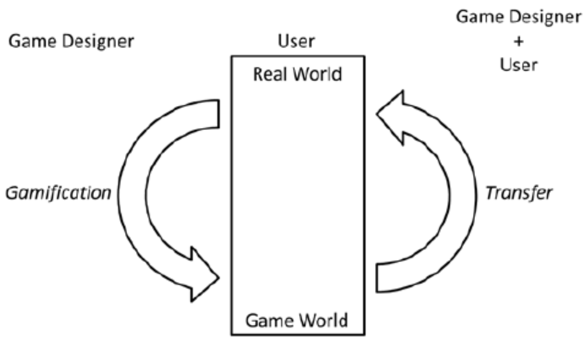


Figure 1. Persuasive Game Design (PGD) Model.

2.2 Profound Experience Design (PED)

Experience design (XD) is a solution that focuses on user experience and culture in the fields of designing products, processes, services, activities, marketing and environmental design. Experience design enables designers to gradually transform from designing users' lifestyle to designing the meaning of users' life. In the book Profound Experience Design (Jesper, 2014), Jesper (2014) proposes three dimensions that together form the integrity of the experience (Figure 2): instrumental dimension, use-experience dimension, and prodound dimension. The insrumental dimension focuses on products that facilitate other dimensions. It is tangible, often a physical creation. The use-experience dimension focuses on the processes and actions in the experience, that is, the process by which the user interacts with the product. The profound dimension is when the user is completely immersed in it - “At least that’s what you do if the use-experience is well designed, so the smooth and natural interaction allows you to forget all about the product and just ‘enjoy the experience’” (Jesper, 2014). Hassenzahl (2013) proposed a similar division, describing the three levels of design considerations when analyzing the experience of making coffee using a French filter coffee maker: why, what and how (Figure 2). These levels correspond to the concept of experience dimensions discussed above.

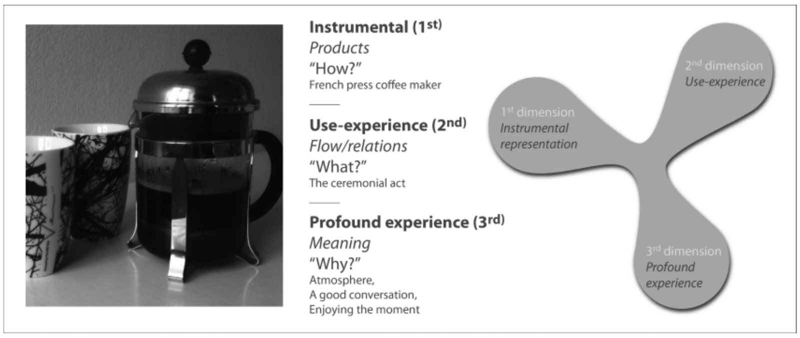


Figure 2. The three dimensions of an experience exemplified by a French Press Coffee Maker.

Jesper (2014) built an Experience Scope Framework (ESF) based on two basic orientations and two fundamental influences of profound experience. He portrays this deep dimension of the design framework as a two-by-two matrix that juxtapose omni and goal orientation along the one axis and the direct and derived effects along the other (Figure 3). The ESF is directly applicable in a design process, providing a structured way to explore a broader scope of the experience at a profound level. Making the orientations and effects of an experience more explicit - as well as working directly with the switch between them - improves the potential to start designing from a profound experiential level (Jesper, 2014).

Figure 3. ESF of Profound Experience Design.

However, the current study on PED is still related to product design, service design and so on. There is little or no study on children's learning experience and the combination with PGD. Therefore, while validating the effectiveness of PGD in promoting positive change of children's learning behavior, this study also explored the relationship between PGD and PED, and based on this, designed the "Little Explorer of Hunan Embroidery" manual activity.

3 Methods

Various studies show that children of different ages have different levels of physical function and cognitive development. The early school age is the most vigorous period for children's psychological and physical development, and also an important period for children to form their character and behavior habits. So, this study selected children aged 6-9 years old as primary subjects. The entire study is divided into two phases: preliminary research and PGD experiment. In the preliminary research stage, through field visits and surveys, we learned about the general situation of the Hunan Embroidery Museum, observed the learning behaviors of children using traditional learning methods, and found the design problems that need to be solved and improved. In the PGD experimental stage , through questionnaires, observations, semi-structured interviews, etc., we observed and recorded the learning behavior of children in a relaxed and joyful game situation, and analyzed and verified the expected experimental results.

When we conducted field visits and surveys, we participated in and observed a complete Hunan embroidery learning course with the assistance of the staff of the Hunan Embroidery Museum. The researchers were divided into two groups - the observation group and the interview group, each group assigned 2-3 people. The observation group recorded the specific situation of the Hunan embroidery learning course and the performance or behavior (language, expression, movement, etc.) of the children in the course by text and audio-visual images. The interview group randomly interviewed several children and the staff in the museum to know their views on the Hunan embroidery learning course and recorded them by means of recordings and texts.

The PGD experiment was carried out in Changsha Municipal Library, which launched a manual activity named "Little Explorer of Hunan Embroidery". Through a notice posted on the library's website, we invited 10 children to participate in the experiment. The children were randomly divided into three groups to play the game. Each group set up an observer, who accompanied and assisted the children to play all the time, and observed and recorded the children's performance and behavior. For better observation, we used a multi-scan method of tabular recording and video recording, which is a sampling method for children's social behavior research. In this experiment, each child had an independent record sheet. Each group’s observer needed to take turns to observe each child in the group and record the child's performance and behavior in the table. Observers recorded children's performance and behavior from four aspects: knowledge acquisition (learning) behavior, social interaction behavior, emotions and motivation, motor skills and attitudes. In addition, the researchers used the phone's camera to capture children's gestures, facial expressions and other nonverbal communication during activities, and set up a fixed-position camera to help record behaviors that might be overlooked. During and at the end of the activity, we conducted semi-structured interviews with several children and their parents to investigate their views and suggestions on the activity. Due to time and venue constraints, we decided to conduct an online questionnaire survey, and separately used the parent questionnaire and the child questionnaire to collect their feedback on the experience of this activity.

4 Research and Results

4.1 The preliminary research

In order to investigate the current situation and problems of the traditional Hunan embroidery learning course in Hunan Embroidery Museum, we we adopted the method of field visit and survey, and set observation group and interview group:

- Observation group: participated in and observed a complete learning course, and recorded the children's learning performance and behavior.
- Interview group: conducted informal interviews with some children and staff to investigate and record their views on Hunan embroidery learning course.

4.1.1 Current situation and problems of Hunan embroidery learning course

Hunan embroidery is a national intangible cultural heritage. In order to inherit, protect and revitalize the Hunan embroidery industry, the Hunan Embroidery Museum was established as a national cultural center and a scientific education practice base. Subsequently, the museum opened a series of Hunan embroidery learning courses for primary and secondary school students. The course is divided into six parts: Exploration, Visit, Research, Study, Perception and Practice. It aims to let children feel the charm of hunan embroidery culture, and at the same time, cultivate their spirit of struggle, perseverance and excellence.

Researchers made an appointment in advance to conduct a field survey of the Hunan Embroidery Museum. We followed the primary school team that visited that day and participated in a complete Hunan embroidery learning course. The museum has four floors: Hunan Embroidery Introduction Area (1st Floor), Collection Exhibit Area and Embroidered Mother′s Handicraft Workshop (2nd Floor), Hunan Embroidery Sales Area (3rd Floor), and Learning Experience Area (4th Floor). Under the guidance of the museum's lecturers, the children officially started their learning course. We show some photos taken in the museum in Figure 4.

(a) (b) (c) (d)

Figure 4. The photo of Watching the Hunan embroidery's video (a). The photo of visiting the musuem on the 1st floor (b). The embroidery mother's workshop (c). An already completed embroidery work by a student (d).

Through observation and interviews, we found several major problems:

1. A large number of students visiting the museum at the same time. It is too crowded and difficult to manage.

2. The propaganda films played in the hall were dull and did not quite fit the learning course.
3. Traditional teaching model can not stimulate students' interest in learning. Their learning focus and learning efficiency are low.
4. The route of the museum is haphazard and there is no clear learning goal.
5. The pattern of the manual experience is too old-fashioned, the color is monotonous, and the students are not interested.
6. The time allocation for the entire learning course is unreasonable.

In addition, the Hunan Embroidery Museum itself has problems in terms of geographical location, reservation mode, site layout, staff arrangement and so on.

4.1.2 Characteristics of children's learning performance and behavior in traditional learning course

Hunan embroidery learning course is mainly composed of traditional museum visit and manual practice experience. The museum visit is led by the lecturer. The students mainly understand the general situation of Hunan embroidery from the posters and explanations on the wall. Some related objects and Hunan embroidery works are displayed in the museum for students to watch and take pictures. Thevmanual practice experience part is taught by embroidered mothers. Subsequently, the students were divided into groups and each group was given a set of embroidery kits. They are required to finish the Hunan embroidery work within a certain time. Through observation and some informal interviews, we can roughly understand the learning performance and behavioral characteristics of children in each link of the traditional Hunan embroidery manual learning course, and record some dialogues (table 1):

Table 1 Record of children's learning performance/behavior in each link of Hunan embroidery learning course.

	Learning Performanc & Behavior	Dialogues
Exploration (Video)	Small part: listen and take notes Most: daze, chat, play cell phone...	"It's so boring, what are you doing?" "Checking Weibo, have you seen today's news..."
Visit (1st Floor)	Small part: active participation and interaction Most: wander aimlessly, take selfies, do other things...	"Hey, come over! Let's take a selfie together!" "OH! They are so old-fashioned!"
Research (2nd Floor)	Form a small group to wander around	"It's so boring, how long will it take?"
Study (2nd Floor)	Show a certain interest and closely observe the embroidered mother	"How long do you need to embroider this? Can you let me see how it is embroidered?"
Perception (3rd Floor)	Compete with friends for the price of Hunan embroidery products and find higher-priced products	"You look at it! This is actually more than ten thousand!" "I am looking for this more expensive than yours!"
Practice (4th Florr)	Feel difficult and don't want to embroider after embroidering for a while	"I didn't understand, I could not finish it." "How do you do this..." "Time is running out. I don't want to embroider."

According to Table 1, in the learning course, only a small number of students will actively participate in it, while most of them will find the course "a little boring", unable to learn or even unwilling to learn. In short, the traditional teaching methods adopted by the Hunan embroidery learning course cannot stimulate children's interest in learning. At the same time, the visiting route of the museum is chaotic and there is no clear learning goal for children, which makes the learning atmosphere very loose and blind. As a result, children's learning participation and learning efficiency are very low.

4.2 PGD experiment: "Little Explorer of Hunan Embroidery"

According to the problems found in the museum research, in order to improve the learning experience of children and improve their learning participation and efficiency, we have redesigned the Hunan embroidery learning course by means of gamification. We launched the "Little Explorer of Hunan Embroidery" manual activity in Changsha Municipal Library, let the children learn the hunan embroidery culture in the relaxed and joyful game situation, and observe their learning performance and behavior. The activity was initiated online by the library and consisted of 30 participants, including 10 children (6-9 years old, 2 boys, 8 girls), 10 parents (1 father, 9 mothers), 2 teachers, 5 observers, 2 organizers and a young Hunan embroidered mother. Ten children were randomly divided into three groups (A, B, and C) by lottery, and each group was set up with an observer for observation and assistance.

4.2.1 Experiment Procedure

The persuasive game in the manual activity of "Little Explorer of Hunan Embroidery" is set in the story of Grandma Hu, a Hunan embroidered mother in the qing dynasty, who travels through time to find memories. The children in each group need to go through the five game levels set by us to obtain "memory embroidery fragments", synthesize "time stones", send Grandma Hu "back to qing dynasty" and win prizes/gifts. The specific game settings and processes are shown in Figure 5.

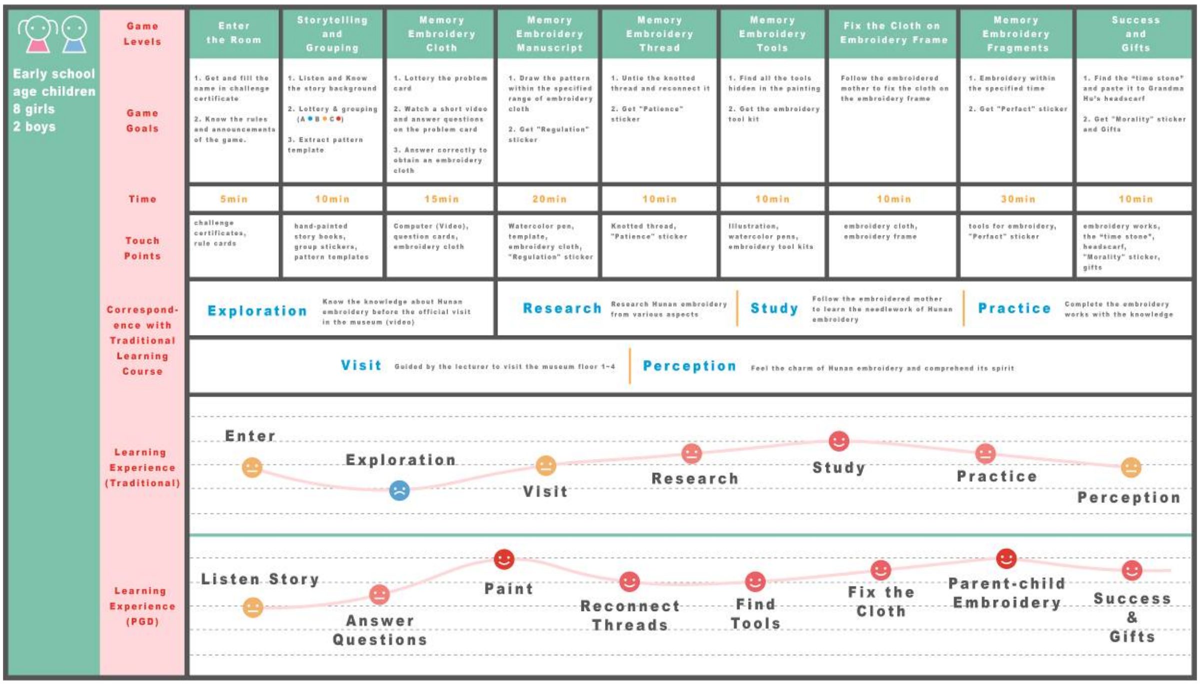


Figure 5. The specific game settings and processes of "Little Explorer of Hunan Embroidery".

Data of this experiment will be collected during and after the activity. During the activity, the observer of each group took turns to observe each child according to the four aspects of the observation record sheet, and recorded their learning performance and behavior. When necessary, the observers need to take photos and recordings with their mobile phones to capture the subtle gestures, expressions and verbal communication of the children during the activitie. In addition, a fixed camera was placed at the back of the field to record the whole process, so as not to miss some unobserved behavior. At the end of the activity, each child's work was photographed. We will show a part of the embroidery works by chirldren and the photos of the activity in Figure 6.

(a) (b) (c)

(d) (e) (f)

Figure 6. The embroidery works by a boy (a) and a girl (b). The photo of the completed challenge certificate and embroidery work by a cute girl (c). The photos of the activity (d)(e)(f).

After the activity, parents and children need to fill in a questionnaire to let us know their feelings and suggestions about the activity -- to verify the expected experimental results.

4.2.2 Experimental results

4.2.2.1 Persuasive game can improve children's learning motivation and efficiency.

Learning motivation is a series of learning challenges and learning objectives to guide, stimulate and maintain the learning activities of the internal process or internal motivation. Keller(1987)'s motivation model (ARCS) proposes four elements of learning motivation: attention, relevance, self-confidence, and satisfaction. Relevance refers to the fact that when the learning content is closely related to the learner, they usually show greater interest. Self-confidence is the third element that motivates and sustains learning motivation. Satisfaction is an important condition for learners to generate continuous learning motivation.

The traditional Hunan embroidery learning course, on the one hand, does not provide children with clear learning challenges and goals, and uses a boring teaching method that does not cause children's interest in learning. On the other hand, the learning content provided by the museum is too difficult for children. It is difficult for children to understand, and it is easy to make them lose self-confidence and satisfaction. However, "Little Explorer of Hunan Embroidery" activitie, through the gamification of PGD, transforms the real world's learning content into various game elements of the game world - bizarre storyline, mysterious rewards and gifts, difficult and different Challenge tasks, team cooperation, etc., in order to attract and guide children, stimulate their interest in learning, let them actively learn and explore new knowledge. In addition, this game is designed according to children's cognitive and physical skills, with moderate difficulty and high playability, so that children will have self-confidence and satisfaction when finishing the game.

Persuasive games make serious learning as easy and fun as playing games. The boring and tedious knowledge becomes vivid and interesting - more easily absorbed and mastered by children.

4.2.2.2 Gamification will stimulate the flow and promote a positive change in children's behavior.

When proposing persuasion techniques, Fogg (2009) pointed out that motivation, ability and triggers are indispensable for changing a target behavior. The various game elements of persuasive game enhance the internal and external motivations of children's learning. At the same time, in the design of the game level, the designer simplifies and clarifies the children's learning tasks, improving the children's learning ability and the possibility of completion. In addition, gamification as an incentive mechanism acts as a trigger in behavioral change, guiding people to produce purposeful behavioral changes. In the activity of "Little Explorer of Hunan Embroidery", the main target behavior change is to guide children to change from distracted learning state to immersive learning state. The flow is the state of mind that occurs when a person concentrates on an activity (Mihaly, 1990). Therefore, motivating children to enter an immersive learning state requires arousing the flow (Figure 7).

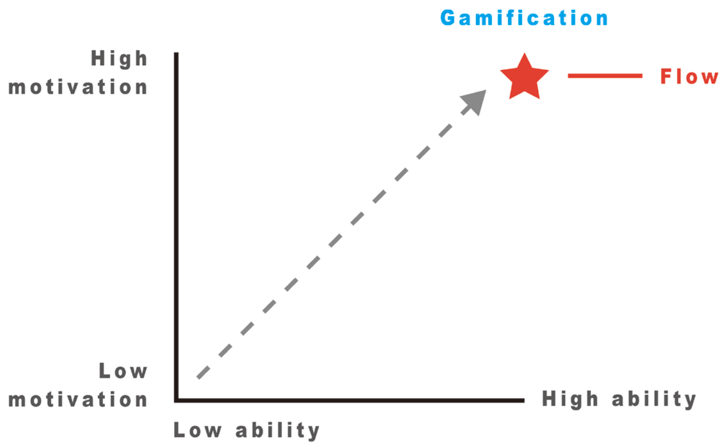


Figure 7. The relationship of Motivation, Ability, Trigger (Gamification), Flow.

The flow is a sense of accomplishment achieved through a perfect balance between challenge and skill (Mihaly, 1990). Wang Ning (2017) studied the stage of motivation formation and divided the relationship between individual motivation and cognitive development into four stages (Figure 8). He believed that individuals will reach the state of flow after experiencing the four stages of activity.

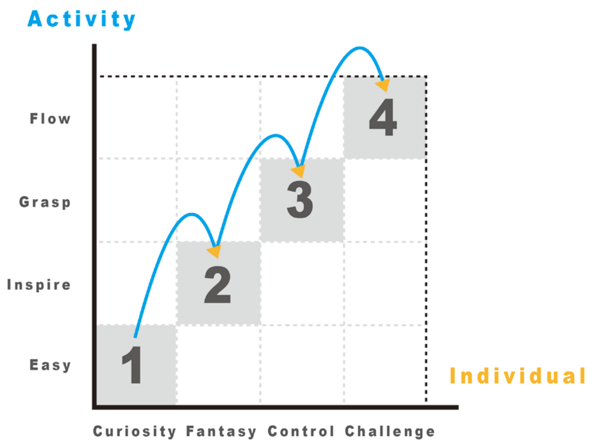


Figure 8. The four stages of motivation.

In the Hunan embroidery PDG experiment's first stage, children are introduced into the game situation of "grandma hu crossing" by means of storytelling to stimulate their curiosity. In the second stage, open learning environment is given to children, allowing them to explore, try and create freely in the game world, stimulating their fantasy of learning. The third stage is to guide children to "learn by doing", and let them learn and practice the knowledge and skills in the game levels. In the fourth stage, children use the knowledge they have acquired before to complete the embroidery work with the help of their parents and teachers, and obtain a sense of accomplishment.

Through four stages of motivation formation, children's psychological activities start from "easy" at the beginning, continue to "inspire" to gradually "grasp", and finally reach "flow" -- the perfect balance of learning challenges and skills. Children enter a state of immersive learning.

4.2.2.3 Persuasive games allow children to enter profound experience and generate happiness, which is conducive to shaping their values and personalities.
According to the relevant theories of PGD and PED, we found that designer's purposeful persuasive game design can guide people into profound experience and transfer the behavior change and deep meaning in experience to the real world. Based on the experience scope framework (ESF) and the PGD model, we made a specific analysis of the PGD experiment of Hunan embroidery (Figure 9). First, we found that the gamification of persuasive games is significant for the two basic orientations of deep experience:

- Gamification provides specific learning goals, improves learning motivation, promotes children to work hard to achieve goals, and finally enables them to obtain rewards and a sense of achievement.
- Gamification builds a relaxed and pleasant learning environment, allowing children to explore in the game world openly, freely interacting with others, and let them feel happy and joy.

Secondly, through field observation and questionnaire results, we found that the direct impact of persuasive games is to promote the positive change of children's learning behavior, so that they can enter into an immersive learning state and generate happiness. On the other hand, in the process of activities, children imperceptibly feel and absorb the deep meaning contained in the experience - "Hunan embroidery spirit". This will play a positive guiding role in shaping its future values and personality. Although, at this moment, they are not able to understand what it means, but in the future one day, a certain scene, they will have "insight" to these "spirit" and use it for their own.

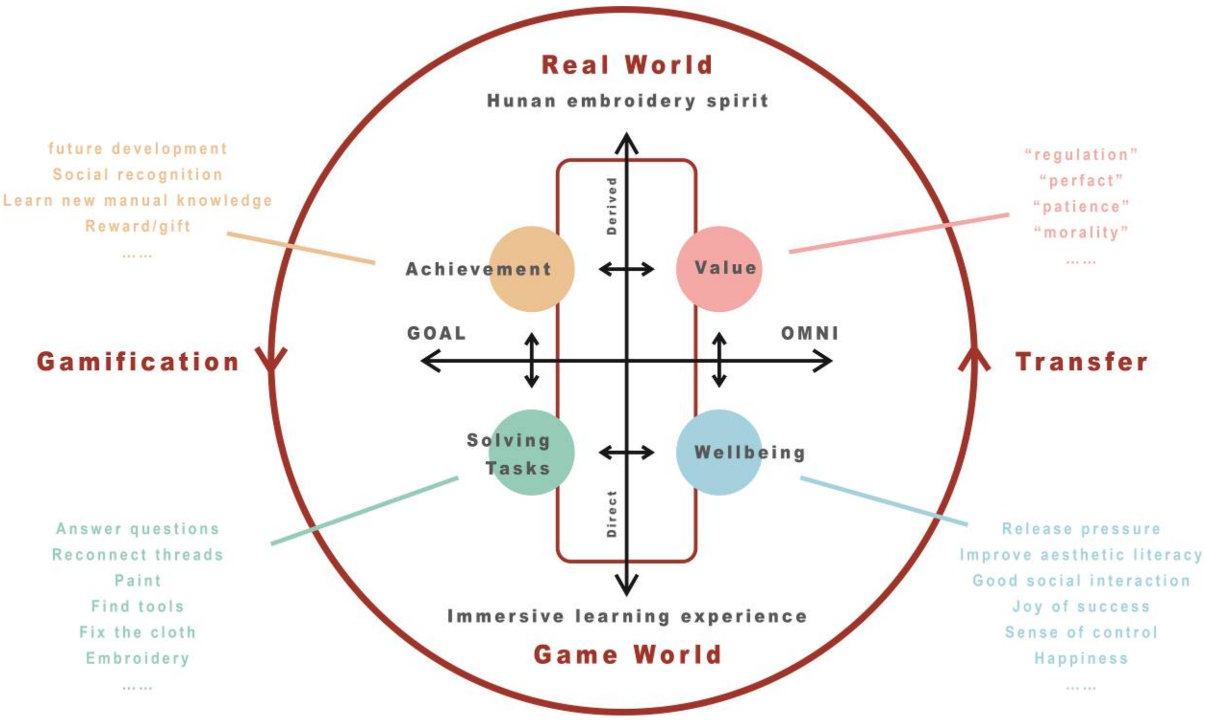


Figure 9. The relationship of the PGD model and the PED's ESF.

In short, in the Hunan embroidery PGD experiment, the designers use gamification to transform the knowledge of the real world into various game elements of the game world. The design of the game level is difficult and moderate, so that children can learn the embroidery skills and manual skills step by step and modularity. At this time, children's concentration is high, which stimulates the flow. This will allow them to ignore the existence of time and space, and completely immerse themselves in the experience of the game world - into the deep experience of learning. In addition, the experience in the game world not only promotes the positive change of children's learning behavior, but also enables them to absorb and comprehend the deep meaning in the experience, and make these meanings transfer to the real world imperceptibly, which plays a positive role in children's future development and growth.

5 Conclusion

This study uses gamification as a starting point to explore the connection between PGD and PED. The game elements that can trigger the change of children's learning behavior are associated with the needs and abilities of children in the learning experience of cultural heritage, and the traditional learning course is redesigned and practiced. When designing a persuasive game, the designer should consider the child's learning motivation, learning ability, learning style, learning content and game genre, and adjust according to the implementation scene and the actual situation of the object. Finally, this study verifies the promotion effect of persuasive games on children's learning. Gamification can stimulate flow, guide children into immersive learning experience, let them feel the sense of achievement and happiness while acquiring knowledge and skills, and have a positive impact on the shaping of their values and personality.

Persuasive games make full use of children's "playful" nature, making children "addicted" to learning in the process of "playing games". Designers should focus on designing more open and interesting learning scenarios, reasonable and appropriate challenges and feedback, more opportunities for competition and cooperation, and time for children to internalize and reflect. This will encourage children to actively learn knowledge and skills at the same time, imperceptibly absorb and comprehend the spiritual connotation of learning experience.

This study was limited in the aspects of venue, time and personnel arrangement. There is a lack of rigor in the design of experimental activities and data collection. In addition, the derivative effect of learning deep experience needs to be observed for a long time, and the current research results still need to be further verified.

6 References

De la Hera Conde-Pumpido, T. (2018). The persuasive roles of digital games: The case of cancer games. *Media and Communication, 6*(2), 103-111.

Visch, V. (2017). Warm-up your audience before dancing with them: Applying persuasive game design to enhance audience participation during a dance performance. *Empirical Studies of the Arts, 35*(1), 47-66.

Alahäivälä, T. (2017). *Designing a persuasive game for children's safety awareness* (Master's thesis, University of Tampere).

Wright, W., & Bogost, I. (2007). *Persuasive games: The expressive power of videogames.* Cambridge, MA: Mit Press.

Sicart, M. (2011). Against procedurality. *Game Studies, 11*(3), 209.

De la Hera Conde-Pumpido, T. (2013). A Conceptual model for the study of persuasive games. In *Digital games research association conference* (vol. 7). Digital Games Research Association, Atlanta, GA.

Visch, V. T., Vegt, N. J. H., Anderiesen, H., & Van der Kooij, K. (2013). Persuasive Game Design: A model and its definitions. In *CHI 2013: Workshop Designing Gamification: Creating Gameful and Playful Experiences*. ACM, New York, NY.

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist, 55*(1), 68-78.

Przybylski, A. K., Rigby, C. S., & Ryan, R. M. (2010). A motivational model of video game engagement. *Review of General Psychology, 14*(2), 154-166.

Siriaraya, P., Visch, V., Vermeeren, A., & Bas, M. (2018). A cookbook method for Persuasive Game Design. *International Journal of Serious Games, 5*(1), 37-71.

Jensen, J. L. (2014). Profound experiences. Cambridge, MA: Mit Press.

Hassenzahl, M. (2013). User experience and experience design. In M. Soegaard, & R. F. Dam (Eds.), *The encyclopedia of human-computer interaction* (2th ed.). Aarhus, Denmark: The Interaction Design Foundation.

Keller, J. M. (1987). Development and use of the ARCS model of instructional design. *Journal of Instructional Development, 10*(3), 2-14.

Fogg, B. J. (2009, April). A behavior model for persuasive design. In *Proceedings of the 4th international Conference on Persuasive Technology* (p. 40). ACM, New York, NY.

Bose, D. K. (1990). Mihalyi csikszentmihalyi. flow: The psychology of optimal experience. *Information Design Journal, 16*(1), 75-77.

Wang, N., & Deng, P. (2017). A study on motivation balance of educational games. *Course Education Research*, (33), 234-235.

About the Authors:

Xuan Fu: this paper’s first author, a graduate student of the School of Design, Hunan University. Her main research areas are persuasive design, educational games design, children's design, regional cultural innovation and digital design theory and practice.

Duoduo Zhang: this paper’s correspondence author, a PhD, associate professor and master's supervisor at the School of Design, Hunan University. Her main research areas are design anthropology, regional cultural innovation and digital design theory and practice, design management and design criticism.

Acknowledgement: The project is jointly funded by the Hunan Embroidery Museum, the School of Design of Hunan University and the Changsha Municipal Library. We would like to thank Changchang Shi and other students of the Hunan University for their assistance in the study, and 20 parents and children for their participation in the experiment.

Research on remote learning in multimodal interaction

Fu, Zhiyong*; Zhou, Yuyaio

Department of Information Art and Design, Tsinghua University, Beijing
* fuzhiyong@tsinghua.edu.cn

With the rapid development of the Internet, many new human-computer interaction methods have emerged in the education field to meet the increasing learning needs of people. This paper studies the teaching interaction of the learning maker course in the remote learning scenario, mainly observes the effectiveness of multimodal interaction in the process of distance learning and the changes in body characteristics (language, gestures and feedback). The experimental research allows the teachers and students to complete the hardware programming learning task. We set up three kinds of learning scenes that face-to-face and remote learning, and gradually increase the interactive mode to conduct experimental comparisons. According to the video, we explore the teacher-student interactions that occur in the real-time scenes, and investigate the learning effects through user interviews. The results show that multimodal interaction in the remote scene is beneficial to improve the efficiency of learning, and the picture presented is more three-dimensional, which promotes students' understanding of hands-on operation, and the sense of interaction between the two sides is more active. Finally, we analyse and summarize the multimodal interaction model of remote learning and its implications for design.

Keywords: Remote learning; Multimodal interaction; Maker Education

1 Introduction

Education innovation is the top priority of national development. The 2017 Horizon report[1] states that the educational technologies for mainstream applications in the next year are: maker space and robots; analytics technology and virtual reality in the next 2-3 years; artificial intelligence and the Internet of Things in the next 4-5 years. It shows that the country is paying more and more attention to the diversification of educational forms, the technology of educational equipment and students' practical ability. Different from the traditional single learning mode, the Maker classroom enables students to experience curriculum design and engineering more intuitively, integrate theory with practice, cultivate students' innovative consciousness and innovation ability, and stimulate learning enthusiasm.

Most people will choose offline institutions to learn Maker education. Face-to-face teaching is a traditional teaching mode, which is based on the teacher's lecture. The teacher demonstrates a point of view through explanations and examples until the students understand it. Remote learning is a cross-time, cross-regional, real-time or non-real-time interactive teaching format that is conducted online between teachers and students. With the increasingly close connection between people and computers, the human-computer interaction approach faces new challenges. From the traditional mouse and keyboard interaction methods to the current touch screen, gesture, voice and other interactive modes, the multimodal human-computer interaction technology that combines various interaction modes has been widely developed. At present, the medium of remote learning is to use mobile phones or computers for mobile learning to meet the needs of learners to obtain learning anytime and anywhere. It is characterized by openness, flexibility, sharing and management. However, there are still many problems in Online Learning, for example:

1. Students have a single learning model and do not have a variety of forms such as group collaboration, inquiry learning or heuristic learning.
2. Students have very few ways to get knowledge, only to hear each other's voice and get information from the screen.
3. The interaction is simple. The two sides mainly interact through sound, without using other non-verbal movements of the body, and cannot interact and collaborate.
4. The indication is not clear. Online Learning is difficult to clearly point out your problems with your fingers like offline, and it takes time to explain the problem.
5. After learning, students don't know if they have achieved the effect of learning.
6. Teachers tend to ignore the emotional changes of students

Multimodal knowledge transmission refers to the transmission and learning of knowledge through various channels of communication, mobilizing the senses of learners in many aspects. This paper focuses on the impact of remote learning quality in multimodal mode and exploring the effectiveness of body dynamics (language, gestures and feedback) for knowledge transfer and learning, and further considers the help of multimodal interaction to remote learning, so as to provide inspiration for the product design of remote learning. We selected 8 groups of teachers and students to complete the hardware programming teaching tasks, set face-to-face and distance learning, and gradually increase the three learning scenarios for experimental comparison. According to the video shooting, we explore the teacher-student interactions that occur in the real-life scene of remote learning, and investigate the learning effect of the course through user interviews. We have found that the time and learning efficiency of using multimodal remote learning can reach a level consistent with face-to-face learning. Thus, we observed the knowledge transfer of eight groups of users through body language in three learning scenarios, focused on the analysis of the teaching interaction between teachers and students, and finally we summarized the multimodal interaction model of remote learning and its implications for design.

2 Related work

2.1 Multimodal interaction

Bill defines Interaction Design（Figure.1）as a question threefolded: How do you do? How do you feel? How do you know? [2] Physics says that interaction is an encounter of two elements that transform each other mutually. Verplank's definition shows that the human feels the world, reflect upon it from what they know and act on the world accordingly. After the interaction, both human and world are not the same, so interaction can stimulate more collisions of inspiration and bring about self-improvement. The early human-computer interaction interface is Command-Line Interface (CLI), which can only support users to input information through the keyboard. Its operation form is simple, but it requires users to remember a large number of operation commands, which is very unfriendly to users. The Graphical User Interface (GUI) has been improved both in aesthetics and operation. On the one hand, the GUI does not require users to memorize a lot of commands, on the other hand, it can show users more abundant visual and auditory information, and add mouse as a new interactive channel, but the user's hand is too heavy to operate. With the development of information technology, Multimodal systems can offer a flexible, efficient and usable environment allowing users to interact through input modalities, such as speech, handwriting, hand gesture and gaze, and to receive information by the system through output modalities, such as speech synthesis, smart graphics and other modalities, opportunely combined[3].

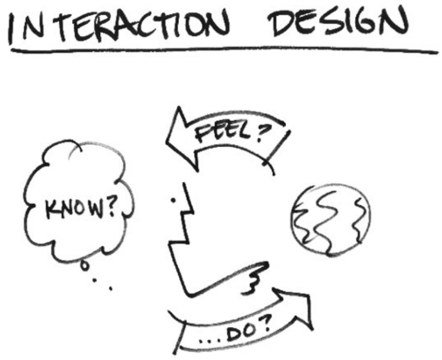


Figure 1. Bill Verplank's drawings about defining Interaction Design

2.2 Remote interactive learning

The traditional classroom learning is teacher-centered, and the teacher is the indoctrinator in the teaching process. The teaching medium mainly includes chalk, blackboard, model, etc. The students are mainly in a state of passive acceptance, and the teacher-to-student is a one-way interaction state[4]. The subjective status of students is neglected, which is not conducive to the creativity and divergent thinking of students. The increasing popularity of multimedia and network technology has begun to give students a leading position, no longer limited to traditional teaching materials, various resources are integrated and utilized, teaching content is enlarged, and learning mode appears mobile informal learning.[5] Therefore, interaction is an important factor in distance learning. The interaction in teaching can be understood as two-way communication between teachers and students. In 1989, Moore identified three types of interactions in distance education: interactions between learners and content, learners and teachers, learners and learners. Later, in 1994, Hillman et al. proposed the fourth type—the interaction between learners and interfaces[6]. The objects that learners interact with in these four kinds of interactions are content, teachers, other learners, and interfaces. So how to design the interaction between students and different objects is very important. In the process of remote learning, all kinds of knowledge and information are presented in a visual or auditory way. People receive and produce information mainly in five sensory spaces, namely vision, hearing, touch, smell and taste, of which the first three items account for 95.5% of the information. According to the research of educational psychology, the more senses involved in learning, the more neural connections between the outside world and the brain, and the better the effect of perception, understanding and memory[5].

Through literature research, we found that using Telepresence Robot[7,8] for remote learning, the participants' response is more efficient, the interaction is more positive, and the efficiency of the teacher's active teaching is correspondingly improved. The interaction of the Q&A forms increases the interaction of movement, gestures, object processing and so on.

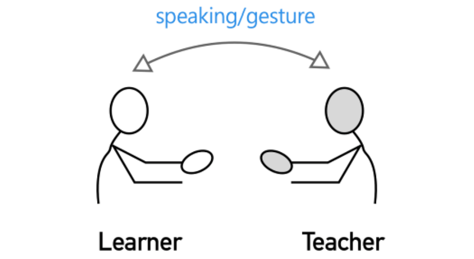
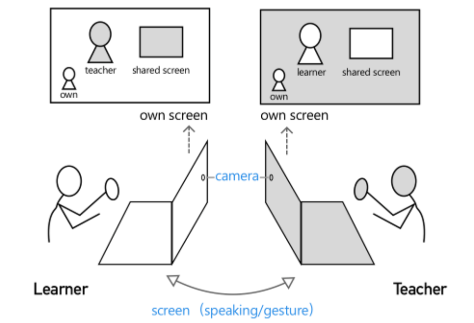
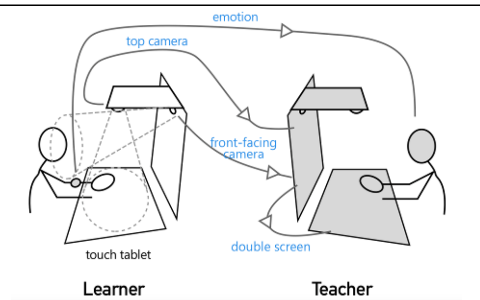
For the remote guidance of AR using head-wearing equipment, not only can the content be clearly positioned, but also can be immersed in teaching[9]. There are also studies that indicate that non-verbal behave is important, and visualization of multiple eye gaze can improve the interactive experience in multi-person remote learning. Depending on the learning task, eye movements and changes are very effective information for the teacher to observe the student's learning situation[10]. This is a form of instant feedback that allows the teacher to infer what the student is doing and understand their thinking process through the student's gaze path. If the student is looking for the wrong place, the teacher can also remind him in time. Group clustering makes it easy to manage multiple visualizations, and teachers can monitor the entire class while focusing on individuals[11].

3 Experience

3.1 Overview

This paper focuses on the impact of remote learning quality in multimodal mode and exploring the effectiveness of body dynamics (language, gestures and emotions) for knowledge transfer and learning. We conducted two progressive analyses of the experiment. The first analysis explores the learning efficiency of remote multimodal interactive learning. The interactive channel modes of the three scenarios are gradually increasing, mainly including face-to-face learning, computer video remote learning and multimodal remote learning, as shown in table 1.

Table 1 System composition of three scenarios

Learning scenario	System composition	Interactive channels
Face-to-face learning		Talking, Gesture
Computer video remote learning (Dell)		Screen (voice, gesture), Keyboard, Mouse
Multimodal remote learning (HP Sprout + Empatica's E4 wristbands)		Double screen (voice, gesture, touch screen), Double camera (different viewing angles, 3d recognition), Keyboard, Mouse, Emotion recognition

Face-to-face learning means that teachers and students are close to each other in the same space for teaching. Computer video distance learning is the way of remote learning for most people. Dell computer is selected for the experiment to complete the remote learning. Multimodal remote learning uses HP Sprout and Empatica's E4 wristbands. HP Sprout reinvents learning, authoring, collaboration and sharing by integrating PCs, projectors, 2D and 3D scanners into a cost-effective, all-in-one solution. It has a camera at the top that can project the contents of the desktop, and a second screen on the desktop touch pad. During the experiment, students wear Empatica's E4 wristbands to monitor the skin's electrocortical activity during the learning process. The skin electrical signal is an important physiological signal that has been proven to contain reliable emotional information. According to Rich Voithofer, an associate professor of Education Science and technology at Ohio State University, wearable devices are a way of interacting with us and the world. Computers and phones are what we choose to interact with, while wearable devices automatically collect our data[12].In the experiment, we added the expression recognition channel to pass the students' learning emotions to the teacher, then we observed the teacher's reaction after understanding the students' emotions. The second analysis explored the body dynamics in the learning process, comparing the interaction characteristics of multiple channels under three learning scenarios. We observed the differences, learning efficiency, clarity and interaction of students in different scenarios, and we analysed the body dynamics at each stage.

3.2 Participants and design

We selected 16 participants to participate in the experiment, 10 women and 6 men. 16 people are divided into 8 groups, one group has teachers and students. The teacher's age is 28 years old and has 3-4 years of programming teaching experience. The average age of students (undergraduates and graduates) is 20 years, and they all have certain Arduino learning background. Teachers and students are randomly assigned to a group. Teachers can teach according to their own style, but before the experiment, we will remind the teacher to pay attention to the students' emotions during the teaching process.

The study was conducted using a between-subjects independent-measures design[13]. We designed one independent variable, three different learning scenarios. Each group of teachers and students completes three learning scenarios. The teaching contents are different under the three learning scenarios, but the difficulty is the same, ensuring that the learning difficulty does not affect the experiment duration. In the three scenarios, the teacher and the student each have a computer and a microduino kit. In the distance learning scenario, it is carried out in two different rooms through networking. During the experiment, we use the video recorder to record the experiment process. We first analyse the students' learning efficiency and emotional changes through video observation, skin electricity data and questionnaires. Then we use video observation and user interviews to analyse the dynamic changes of teachers and students in three different learning scenarios.

3.3 Procedure

Before the experiment, according to the level of the students, the course contents of three learning scenarios were established: buzzer, steering gear and dot matrix screen. The learning difficulty is the same, and the learning time is about 15 minutes on average. Each group of teachers and students has the same course content and completes three learning scenarios. The learning process is divided into two parts: hardware teaching and software teaching. After experiment, the teachers and students need write the questionnaire. During the experiment, the camera records the time required to complete the hardware assembly and software operation. For the first analysis of the results, it is necessary to pre-process the electrical signals. In the multimodal remote learning, a total of 8 students' effective skin electrical signal data were collected. First, the original signal is sampled. The Nyquist sampling theorem proposes that when the sampling frequency is more than twice the maximum frequency of the original signal, the sampled signal can retain the effective information in the original signal without distortion, so the original signal at 1000 Hz is sampled down to 100 Hz. Subsequently, the sampled signal is denoised by wavelet transform threshold noise reduction. Finally, due to the large difference in the individual's basal skin electrical signals, the skin electrical signals between the different subjects were standardized to be comparable[14].

4 Results

4.1 The learning efficiency

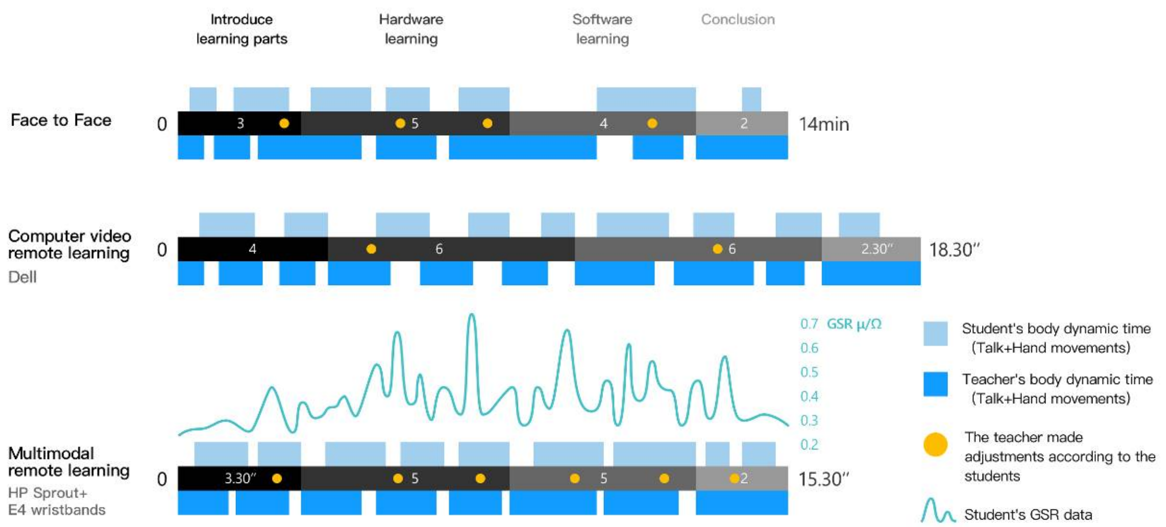


Figure 2. The average timeline of teacher-student learning in three scenarios

We use three indicators (time, learning gains, emotions) to judge learning efficiency. We calculated the average of the learning durations of the three groups of teachers and students, and Figure 2 shows the typical average timeline comparison. From the time point of view, face-to-face learning time is the shortest, multimodal learning is in the middle, and computer video remote learning time is the longest. We choose the length of interaction between the instructional language and the gestures. The face-to-face interaction between teachers and students is 3:1. Most teachers are hands-on and speaking, and students are prone to dependence. The computer video remote learning teacher-student interaction time is 2:1. When multimodal learning, the teacher-student interaction time ratio is 1:1. The student will actively ask questions and find solutions to solve problems, so that the content of self-harvesting and understanding will be more. According to the questionnaire, students also have a higher understanding of learning when using multiple screens. From the perspective of emotion, face-to-face teachers observed students' learning problems on average 4 times and found that they did not understand the teaching knowledge. Computer video teaching, it is easy to ignore the changes in students' emotions. In multimodal teaching, since students wear E4 wristbands, we will give tips to teachers whenever students have emotional changes (up to 6 times), and teachers will take the initiative to care about students' problems. Students are more likely to have doubts during distance learning, and their tension can also be seen from the skin electricity data. Because remote learning is prone to problems that are difficult to express, it will increase the vigilance and concentration of students. Therefore, from the analysis of learning time, self-harvesting and learning emotions, multimodal interactive learning is more efficient, and it can actively improve the concentration in a quantitative time, and also help teachers understand the emotional changes of students. The effective task assignment in multimodal interactive learning can further improve the efficiency, fun and interaction of distance learning. Therefore, we further analyse the characteristics of multimodal interaction and learn the dynamics of the three scenes.

4.2 The body characteristics of embodied cognition

Table 2 The experience of multimodal interaction in three scenarios

Learning scenario	Interactive features	Interactive experience
Face-to-face learning	**Speaking:** instruction, command, inquiry **Gestures:** parallel, imitation	Students are more **imitating** the teacher's operation, although the teaching is very clear, but more **dependent on** the teacher.
Computer video remote learning (Dell)	**Speaking:** instruction, command, inquiry, descriptive words (e.g. colour, character, direction) **Gestures:** vertical, autonomous emphatic gestures **Screen:** a display	It is **inconvenient** to explain the operation. Teacher need to hold the object up to the camera. It is also **difficult** for teachers to observe students' emotions
Multimodal remote learning (HP Sprout + Empatica's E4 wristbands)	**Speaking:** instruction, command, inquiry, descriptive words (e.g. colour, character, direction), concern **Gestures:** parallel+ vertical, autonomous emphatic gestures, indicative gesture **Screen:** two display	Students can see objects in more **three-dimensional** way and ask questions more **actively**. In teaching, gestures are more **focused on** the explanation of knowledge.

Body dynamics is an important concept in embodied cognition. Embodied cognition means that the human body plays a key role in cognitive processing. Cognition is mainly formed through the interactive experience of the various senses in the environment and active forms[15]. Embodied cognition points out that cognition, body and environment are nested and inseparable from each other; cognition exists in the brain, and the brain exists in the body[16]. I summarized the physical characteristics of multimodal interaction in three scenarios, as shown in Table 2. Face-to-face learning conveys knowledge to students through the interaction of speech and gestures. As can be seen from the blue block of the teacher-student interaction in Figure 3, face-to-face learning is more inclined to synchronous teaching, while the teacher is teaching and the students are following the imitation. Single-screen remote learning tends to be a step-by-step teaching. The teacher needs to pick up the teaching parts and align them with the camera to explain the situation. A single-screen camera with only one front-view camera often causes the item to be picked up and put down, which is a state of vertical gesture, as shown in Figure 3. The teacher can't pick up a lot of parts to explain in the hand, so the teacher takes a step and the student follows one step, which leads to slower efficiency. The amount of information that a screen needs to carry is large, which results in a small learning window and it is not convenient to use it.

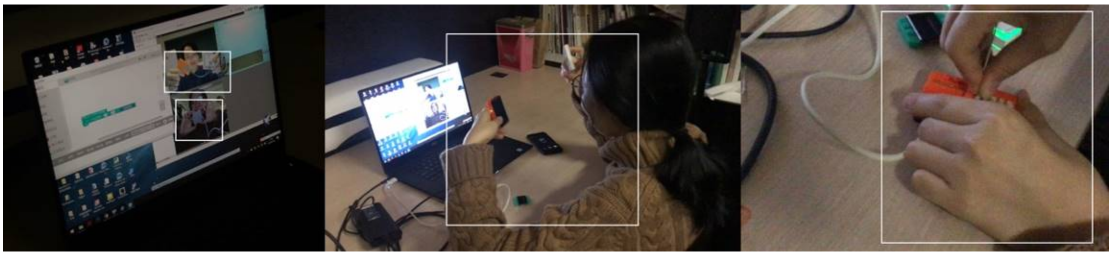


Figure 3. Gesture style when computer video remote learning (when the teacher explains the part, the part should be picked up, and the splicing should be placed on the desktop again, the gesture is a vertical up and down state)

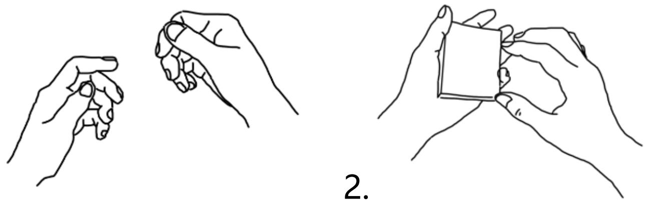
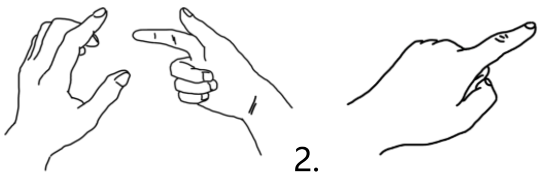
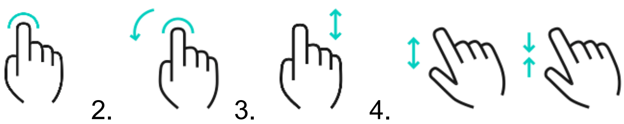
The multimodal learning efficiency can be reached almost in line with face-to-face learning, and the top camera plays a big role. The top camera can capture the hand movements on the desktop, so it is no longer necessary to lift the hand and use the horizontal gesture to guide, as shown in Figure 4 (1). When there is an incomprehensible problem, the teacher will explain through the emphasis gestures and descriptive language, such as lifting a certain part to the camera and saying: "The red block is inserted into the second hole from the right side", then point his finger at that location. There are three components when guiding the physical task: identification of target objects, description of actions to be performed on targets, and confirmation that the targets have been performed successfully. The guiding task includes the elements of pointing object and extracting information from objects (identify objects, location, direction, and orientation). The display can only indicate something by cursor. The touch pad on the desktop is equivalent to the expansion of the host screen. You can drag the software operation into the touch pad, then point your finger to the position of the touch pad. The contents of the desktop are captured by the top camera and can be displayed on each other's screens., as shown in Figure 4 (2). Hand representation is richer than a cursor pointer in terms of degree of freedom. The pointer does not support representational hand gestures which showing orientation and movement[17].

(1) Hands on the table splicing *(2) The teacher points to the touch pad*

Figure 4. Gesture style in multimodal remote learning

Double screens can effectively assign learning tasks to different screens, and double cameras also give teachers and students more perspective. I sorted out the gesture classification under multimodal interaction. As shown in table 3, the splicing gesture, the emphasis gesture and the directional gesture can be used to clearly teach. In the process, we will remind the teacher of the students' emotional changes, and the teacher can also adjust the teaching schedule and content for the students.

Table 3 Gesture of Multimodal Remote Learning

Teaching gesture 1. Insert a cable 2. Stitching module	 1. 2.
Explanatory gestures: 1. Emphasize (hold up and aim at the camera) 2. Point at a position	 1. 2.
Touch screen gestures: 1. Click,2. Drag,3. Slide,4. Zoom in and zoom out	 1. 2. 3. 4.

5 Discussions

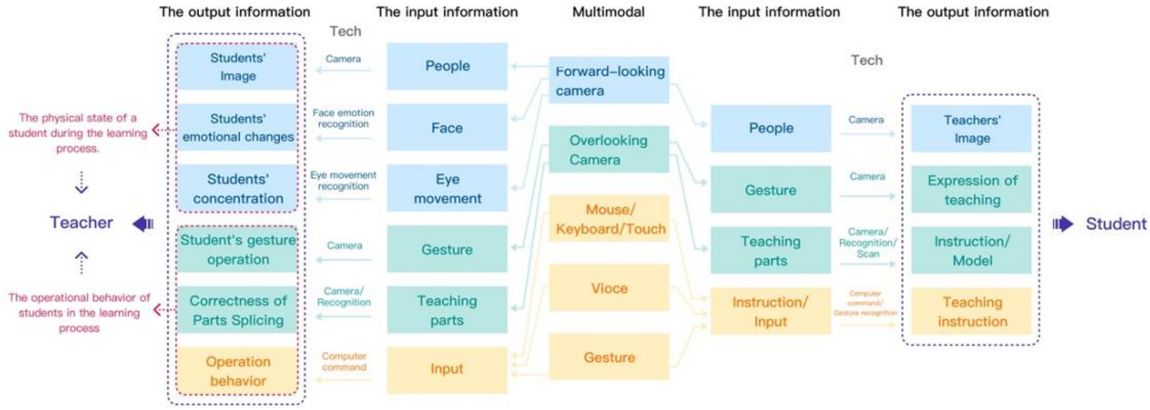


Figure5. Model of Multimodal Interactive based on Remote Learning（MIRL model）

Based on the above analysis, we have established a multimodal interaction model for remote learning between teachers and students, referred to as the MIRL model (Figure 5). In the remote state, the teachers and students interact with each other and then establish a connection between them. After relying on the camera to establish the image of both sides, the ordinary talking and chatting is very smooth, and there will be many communication obstacles when the teaching of the physical object is added. However, the development of multi-screen, AI recognition and data analysis has brought great learning advantages to both teachers and students. Multimodal interaction is to make teaching and learning clearer, and the interaction rate between teachers and students is higher, which enhances students' initiative and learning. However, too many channels may increase the burden of learning, and effective allocation can optimize learning efficiency. How to allocate needs to consider where the individual's concerns are. Teachers focus on the one hand is to express clearly, on the other hand is to observe students, so multi-screen can help teachers to have a clear direction of teaching, emotional recognition and eye movement recognition can convey students' learning status to teachers. Students only pay attention to learning. Remote learning students need to receive a large amount of learning information. The information carried on a single screen is very limited, and many windows are easy to overlap. Multi-screen is good for assigning tasks, and the learning ideas are clearer, not easily interfered by other things, and also beneficial for observing teaching gestures. The identification and scanning of teaching parts can promote students to explore the learning content and promote the initiative of learning.

In real life, when people interact with each other, they often use multiple channels to complete a task[18]. For example, a person likes to explain something in a dance, explaining that speaking is the main channel, and dancing is the auxiliary channel. The same strategy can be used in remote learning (Figure 6). The language gesture expression of the students in the learning process is the main channel of the task operation, and the individual emotion or eye movement change is the auxiliary channel, and the picture and data are transmitted to the teacher. When the main task is completed, the channel with high flexibility and high recognition accuracy is selected as the main channel, and the auxiliary channel is also used to perfect the user experience. This process is parallel. Then the teacher can judge the right or wrong of the student's task according to the main channel, adjust the teaching task through the auxiliary channel, and continuously update in the process of teaching and learning.

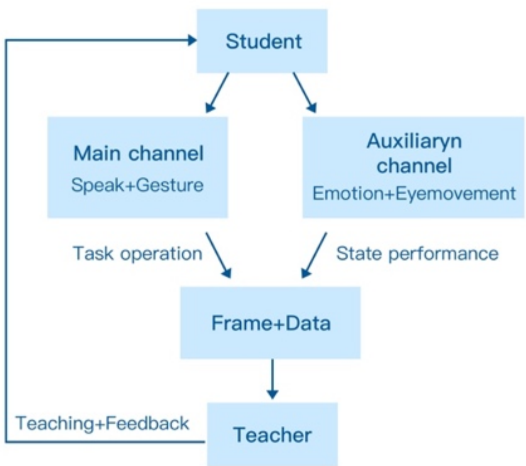


Figure6. Main and auxiliary channel for students

We also summarize several inspirations for the product design of remote learning:

1. It is necessary to present students with a three-dimensional teaching perspective and an immersive teaching atmosphere, which is conducive to students' understanding of physical teaching.
2. In the future, we should consider effectively combining more channels to improve the natural efficiency of human-computer interaction and make human-computer interaction more and more close to human-to-human interaction. Paying attention to the interaction mode of auxiliary channels will be beneficial to observe the details of students and understand students more comprehensively. For example, data analysis of students' emotions, eye movements and hand operations.
3. And further consider how to enhance the user role and personalization in the teaching process. In the future, the teacher's teaching responsibilities should be weakened. Teachers are no longer the masters, but the facilitators and helpers of student learning. They provide guidance and feedback according to the needs of students when necessary.
4. Although face-to-face learning is the current common teaching method, there is a great prospect for remote learning in the future. Remote learning brings a lot of space and time, suitable for synchronous teaching between teachers and students, and also suitable for fragmented interactions. It is worth studying how to use multimodal interaction to help students conduct personalized self-learning and let teachers provide effective guidance in the process. After that, we will also design an interactive kit to help students with remote collaborative learning according to the multimodal interaction model, providing low-cost, immersive, interesting, clear and anytime and anywhere learning.

6 Conclusion

This paper studies the impact of multimodal mode on remote learning quality and explores the effectiveness of body characteristics for knowledge transfer and learning. According to this goal, the research has proved that the multimodal interaction is conducive to improving the efficiency of remote learning, and further explores the reasons from the physical interaction between teachers and students, and studies the multimodal interaction characteristics of multi-screen, multi-view, language gestures and emotions. Thus, we propose a multimodal interaction model of remote learning and a parallel and complementary cooperation mode of main and auxiliary channels. We hope that our research content will provide a theoretical basis for the remote interactive learning. In the future, we will further explore multimodal personalized learning in the distance, meet the learner's demand for learning efficiency, and open the active learning of the whole people.

7 References

New Media Consortium, EDUCAUSE Learning Initiative.(2017). Horizon Report Basic Education Edition

Interaction (Design) is a complex phenomenon. http://fredvanamstel.com/blog/interaction-design-is-a-complex-phenomena

Caschera M. C., Ferri F., Grifoni P. (2007). "Multimodal interaction systems: information and time features". *International Journal of Web and Grid Services (IJWGS),* Vol. 3 - Issue 1, pp 82-99.

Aleksandar Karadimce .(2013).Model for interactive, collaborative and multimedia mobile learning environment. *International Conference on Advances in Mobile,* pp 585-588.

Su li, Saiqi Pi, Lingfang Tian.(2018). Research on Adult Mobile Learning Design Based on Activity Theory. *Adult Education*,8,1-4.

Xiuqi Feng, Ying Liu.(2003).Study interactive system in distance education. *China Educational Technology*, 3,69-71.

Fumihide Tanaka, Toshimitsu Takahashi, Shizuko Matsuzoe, Nao Tazawa, Masahiko Morita.(2014).Telepresence Robot Helps Children in Communicating with Teachers who Speak a Different Language. *HRI '14 Proceedings of the 2014 ACM/IEEE international conference*, pp 399-406.

Kyoung Wan Cathy Shin, Jeonghye Han.(2016).Children's Perceptions of and Interactions with a Telepresence Robot. *HRI '16 The Eleventh ACM/IEEE International Conference on Human Robot Interaction*, pp 521-522.

Kostia Robert,Dingyun Zhu,Weidong Huang,Leila Alem,Tom Gedeon.(2013).MobileHelper: Remote Guiding Using Smart Mobile Devices, Hand Gestures and Augmented Reality. *SA '13 SIGGRAPH Asia 2013 Symposium on Mobile Graphics and Interactive Applications*,NO.39.

Sarah D'Angelo.(2017).Contextually Relevant Gaze Representations for Remote Learning. *CHI EA '17 Proceedings of the 2017 CHI Conference*, pp 268-273.

Nancy Yao, Jeff Brewer,Sarah D'Angelo, Mike Horn, Darren Gergle.(2018).Visualizing Gaze Information from Multiple Students to Support Remote Instruction. *CHI EA '18 Extended Abstracts of the 2018 CHI Conference on Human Factors in Computing Systems*, No. LBW051.

Wearable devices enter the field of education. http://www.jingmeiti.com/archives/8996

David S. Kirk, Danaë Stanton Fraser.(2005).The Effects of Remote Gesturing on Distance Instruction. CSCL '05 Proceedings of th 2005 conference on Computer support for collaborative learning, pp 301-310.

LI Bao-lin, ZHAO Jian-chuan, LIN Wen-bin. (2013)Application of Wavelet Analysis in Signal Denoising. Electronic Design Engineering, 9,: 39-42.

Wei Chen,Benyu Guo.(2014).Embodied cognitive science. Psychological Exploration, 2,111-116.

IONESCU T，VASC D. (2014).Embodied cognition：challenges for psychology and education.Procedia-social and behavioral sciences,128:275-280.

Jane Li, Anja Wessels, Leila Alem, Cara Stitzlein.(2007).Exploring Interface with Representation of Gesture for Remote Collaboration. *OZCHI '07 Proceedings of the 19th Australasian conference on Computer-Human Interaction*, pp 179-182.

Tian Qi.(2018). Human-computer interaction intelligent interface technology based on multimodal. Nanjing University.

About the Authors:

Zhiyong Fu: Zhiyong Fu is doctoral advisor, associate Professor of Information Art and Design Department at Tsinghua University. His areas of expertise are information/interaction design, service design. He is committed to promote art & technology integration and interdisciplinary innovation education.

Yuyao Zhou: Yuyao Zhou is a master of Art and Design Department at Tsinghua University. Her major is information/interaction design. She have published two international conference papers. The main research interests are design thinking and multimodal interaction.

Acknowledgement: This research is a phased achievement of "Smart R&D Design System for Professional Technology" project and supported by the Special Project of National Key R&D Program ——"Research and Application Demonstration of Full Chain Collaborative Innovation Incubation Service Platform Based on Internet+" (Question ID: 2017YFB1402000), "Study on the Construction of Incubation Service Platforms for Professional Technology Fields" sub-project (Subject No. 2017YFB1402004).

Responsible Innovation: A Model for Holistic Design Pedagogy

Salamanca, Juan; Mercer, Lisa; Briggs, Molly

University of Illinois, Urbana-Champaign, United States
jsal@illinois.edu; lemercer@illinois.edu; mbriggs@illinois.edu

Current discourse around innovation has aroused global interest on the part of corporations, governments, and non-profit organizations in applying human-centered design methods to renovate or expand their offerings. While enriched product and service portfolios benefit those who partake in the marketplace, innovations undertaken for innovation's sake have been seen to undermine some social and environmental conditions for the general public. In this paper we argue for a holistic view of responsible innovation that deals with the design, reification, and maintenance of positive, equitable, and meaningful futures desired by sustainable networks of human and non-human actors. We have organized a conceptual model of responsible innovation around clusters of topics, theories, methodologies, and modes of design action. This model offers designers a systemic perspective on the often-overlooked implications of innovative offerings. We explain how the responsible innovation model informs a new graduate design curriculum at the University of Illinois at Urbana-Champaign that offers four tracks of study. The model acts as a scaffold for students to construct research paths across topics and methods, thereby empowering them to outline their learning experiences and develop sustainable solutions. The holistic model also serves as a pedagogical tool to help faculty engage the opportunities and challenges of responsible innovation.

Keywords: social responsibility; innovation; design futures; graduate design education

1 Introduction

In order to actualize ethical research currently being conducted in the realm of innovation, design researchers at the University of Illinois at Urbana-Champaign recently organized a master's program around the concept of responsible innovation. Whereas innovation for innovation's sake has arguably become a cultural obsession, we asked, what would it mean to engage innovation with intentionality and purpose (Sax, 2018), and what might a program guided by a principle of responsibility look like? While we recognize the great value of the human-centered design approach, we propose that its methods and principles should be reevaluated and recalibrated to express and deliver solutions that produce responsible outcomes.

The issue of responsibility is an underdeveloped thread of prevailing discourses about innovation. For much of the 20th century, the definition of well-being was grounded in the availability of products and services that support human activities (Marcus, 2002). This implies a problematic democracy of consumption insomuch as the resources needed to bring those products and services to life are finite and unevenly distributed (Manzini, 2015). For example, while a majority of individuals may benefit from democratically-derived decisions, it is nevertheless the case that a large minority may still experience access barriers that prevent them from benefiting from products and services intended to support and constitute well-being.

In a domain of responsible innovation, the methods and processes that designers use should not only be innovative, interdisciplinary, and team-oriented, but also ethical and sustainable. The ability to deploy critical thinking throughout the design process enables researchers to identify gaps in knowledge on complex social issues. Design researchers can fill these gaps by analyzing primary and secondary research. Factors gathered through the process of analysis can guide researchers to make informed decisions that result in design solutions that are both innovative and ethical. In this manner, creative practices can yield responsible outcomes.

In this paper, we reflect on how designers can contribute to a domain of responsible innovation, by defining the topic and framing its relevance for a new graduate design program at the University of Illinois at Urbana-Champaign. Then we present a theoretical-conceptual model for developing and defining methodologies, followed by a discussion of pedagogical structure and conclusions.

2 Why responsible innovation?

Whereas 'innovation' is typically expressed as a universal value, its impact is often measured in terms of social, economic, and/or political gains that actually serve to reinforce the status quo (Dourish, 2018; Irani, 2018; Jacobs, 2019; Wagner, Taylor, Zablit, and Foo, 2014; Zehtabchi, 2018). As practitioners and researchers in non-design domains embrace processes, methods, and 'designerly' ways of doing that flow from design practice, design researchers in turn gain additional perspective on the scope and range of what design can accomplish. Responsible innovation requires a granular emphasis on the details of a design research process that seeks scalable design solutions for local, state, national, or global application. Ideally, such a process will yield designs that are not only effective but also flexible and enduring. Design researchers often ask what design can do (What Design Can Do, 2019). Defining a framework of responsible innovation offers new insights and tools for addressing complex social, cultural, and environmental challenges that play out in persistently problematic ways.

Our research in major and non-major design pedagogy shows that students from diverse disciplines are both eager and well-prepared to engage design theories and methods in the service of innovations that address the grand challenges of our time, including (but not limited to) climate change, systemic racism, polarized politics, and mental and emotional health and wellbeing. Students in many disciplines are hungry for an approach to innovation that prioritizes meaningful positive impact. Weekly studio logs kept by over 100 students in diverse majors enrolled in online and in-person general-education design courses at the University of Illinois, Urbana-Champaign (courses taught in the academic year 2018-2019 in the School of Art and Design and the College of Fine and Applied Arts, "Design Thinking" and "Design Beyond Boundaries") reflect a consistent, self-motivated interest in these issues, yet little confidence that their major-area coursework is preparing them to enact meaningful change on these fronts. Conversely, when presented with design challenges that ask them to address such issues, the same students tend to make general, predictable, and impractical gestures. But when guided in a design process that builds from their own concerns toward specific, actionable, human-centered design solutions, they gain enthusiasm and confidence in their capacity to collaborate to bring about meaningful positive social, cultural, and environmental outcomes. That this appetite for growth is evident in interdisciplinary, non-major courses as well as undergraduate courses for design majors indicates the opportunities for greater focus and impact that are possible in graduate study.

3 A definition of responsible innovation

Innovation, by definition, is “the introduction of something new; a new idea, method, or device; novelty” (Webster, 2019). For example, the invention of the television was an innovation that moved the consumption of mass entertainment into the home; later, Netflix innovated on the manner in which people consume mass entertainment in their homes. Peter Murphy (2015) defines innovation as the social application of the power of creation and reflects on the necessary conditions in which innovation can emerge. It is not enough to have innovative ideas; these need to be supported by “creative time and creative spaces” (Murphy, 2015, p. 64). Richard Buchanan outlines four orders of design to describe the cultural, temporal, and disciplinary conditions that support creativity on university campuses. These include: 1) the graphic order, i.e. symbols of print; 2) the industrial order, i.e. products; 3) the interaction order, i.e. services, experiences, interfaces, and information; and 4) the systems order, which comprises business, organizations, education and government (Buchanan, 1992). These orders sketch a space for social, technological, and political innovation.

Responsible innovation is an umbrella term that encompasses concerns about social, technological, and political factors in innovation. We define responsible innovation as a domain of intentional action that deals with the design, reification, and maintenance of positive, equitable, and meaningful futures desired by sustainable networks of human and non-human actors. The boundaries of this domain are determined by topics of contemporary debate, such as sustainability, conservation, ethics, justice, equity, culture, and identity. This definition introduces a new dimension to a prevailing definition of innovation that emphasizes value generation. For example, Vijay Kumar defines innovation as “a viable offering that is new to a specific context and time, creating user and provider value” (Kumar, 2012, p.1). In this paradigm users find value in offerings that sustain their fundamental human needs, support the dynamics of their social groups, and maintain or improve their living conditions, while providers find value in user returns on their offerings.

In a market scenario, user and provider logics appear to be concurrent and mutually beneficial. However, a systemic consideration of how and why providers develop their offerings reveals some concerning ethical questions about innovation. In general terms, for-profit providers assess their innovation and product development success by measuring customer satisfaction, margins, revenue growth, return on investment (ROI), sales of new products, and number of patents (Wagner, Taylor, Zablit, and Foo, 2014). These metrics are focused on the fiduciary duty corporations have to their shareholders, who in turn are interested in short-term profits. Such corporations often justify their social duty by arguing that governments use their tax contributions for the general good, or by implementing social responsibility programs that are not necessarily related to the social and environmental impact of their market offerings.

Innovation also occurs on the part of governments and civil and non-profit organizations, as for example when they enact new laws, activate development and inclusion programs, or articulate initiatives that are achievable by the power of collectives that favor underrepresented groups. In these cases, the public good prevails over private interests, and the wider the innovation impact, the better. But the socially-conscious intentions of such innovations do not exclude them from moral scrutiny. Decisions on taxation, public infrastructure, access to justice, or acknowledgement of identity might ameliorate the living conditions of some sectors of the general public at the cost of others. For instance, civil sectors of the city of New York contested the use of public subsidies to entice Amazon's headquarters expansion because the new facilities would raise the cost of living in already gentrifying neighbourhoods. As U.S. congressional representative Alexandria Ocasio-Cortez, (D-NY) explained, "Today was the day a group of dedicated, everyday New Yorkers and their neighbors defeated Amazon's corporate greed, its worker exploitation, and the power of the richest man in the world" (Soper, 2019). In contrast, others embraced the initiative because it would bring tech jobs for highly trained individuals (Goodman, 2019).

In both for-profit and non-profit cases, the user-provider dyad falls short at describing just who is envisioning, designing, servicing and ultimately benefiting from innovative offerings. The binary model obfuscates the roles of stakeholders and shareholders and neglects the possibility that individual actors may be both the recipient and benefactor of a social cause. Therefore, when it comes to analyzing and implementing responsible innovation, *networks of participants* are a more appropriate unit of analysis than the user-provider dyad. In networks, people and organizations constitute nodes, whereas transactions of social, cultural and economic value constitute their interactions.

4 A pedagogical approach to responsible innovation

We believe it is essential to address ethical responsibility within spaces of innovation. While designers have greater and greater capacities to prototype solutions, they also have an increasing ethical responsibility to consider the impact of their activities, including the unintended consequences that can result from their design solutions. The model we introduce herein prompts students to ask, what is responsible design, and what constitutes a responsible designer? Horst Rittel and Melvin Webber argued for the designer's responsibility when they defined the notion of wicked problems in 1973. They articulated ten properties to describe "the social reality of designing" (Buchanan, 1992). The tenth property states, "the wicked problem solver has no right to be wrong—they are fully responsible for their actions" (Buchanan, 1992 citing Rittel and Webber, 1973). This is a clear argument for the designer's responsibility to think through a host of unintended consequences, from early prototypes through the final deliverable.

Graduate faculty noticed that applications to Illinois' graduate program in graphic design reflected increasing research interest in designing for meaningful change. Our new mission statement, which emerges from the research concerns of our faculty, supports students' growing interest and creates a space for collaborative research with faculty:

> The University of Illinois at Urbana-Champaign offers an MFA in Graphic Design that focuses on interdisciplinary making, research, and practice in responsible innovation. This program prepares students to contribute to the field of design by entering into practice, academia, or both. Students can explore responsible futures through research

in traditional print media and emergent technologies including, but not limited to: data visualization, digital interaction, information design, systems thinking, and visual narrative. The degree offers four specialized tracks of study:

1. Sustainable & regenerative design
2. Urban sociology & critical race design
3. Visual and cultural studies
4. Applied research in responsible innovation and social impact (Student Proposed)

To assist students in using these tracks, we offer them our conceptual model for connecting topic, theory, and method within an overarching framework of responsible innovation. The model acts as a scaffold for students to learn to conduct and apply primary and secondary research in interdisciplinary collaborations, thereby empowering them to develop sustainable social and/or environmental solutions.

4.1 Structural model of design for responsible innovation

In order to visualize a process in which design can operate in a domain of responsible innovation, we have organized our conceptual/theoretical model around networked clusters of topics, theories, methods, and modes of design action. We developed the variables that appear in each cluster by aggregating the critical design frameworks that inform our research and that of our colleagues at the University of Illinois, Urbana-Champaign. In addition to our own respective research programs, we have drawn upon readings, conversations, and debate with a network design scholars and practitioners who are informed by a global and critical perspective on design and research practices, many of whom have participated in our visiting scholars program.

Because responsible innovation is a multidimensional subject that cannot be unpacked as a single linear narrative, the model consists of three bipartite networks of interconnected concepts arranged in four clusters (Figure 1). Each cluster describes a broad conceptual domain that contains several categories. Within clusters, the categories are disconnected, because they describe discrete and comprehensive subjects. Between clusters, however, the categories are tightly connected. In other words, categories in one cluster are associated with (or contribute to) the categories in other clusters, yet are discrete from the other categories in the same cluster.

The clusters are named *categories of awareness, topics of concern, modes of inquiry, and methods of design action.* The first and second clusters address issues and topics that can be used to distill spaces of inquiry for responsible innovation, while the third and fourth offer design methodologies that help to actualize critical thinking and making. It is important to note the variables presented in each cluster are non-exhaustive; users of this model may extend or replace them with variables from their own domain knowledges. In the remainder of this section we define each cluster and show the reader how to use the model.

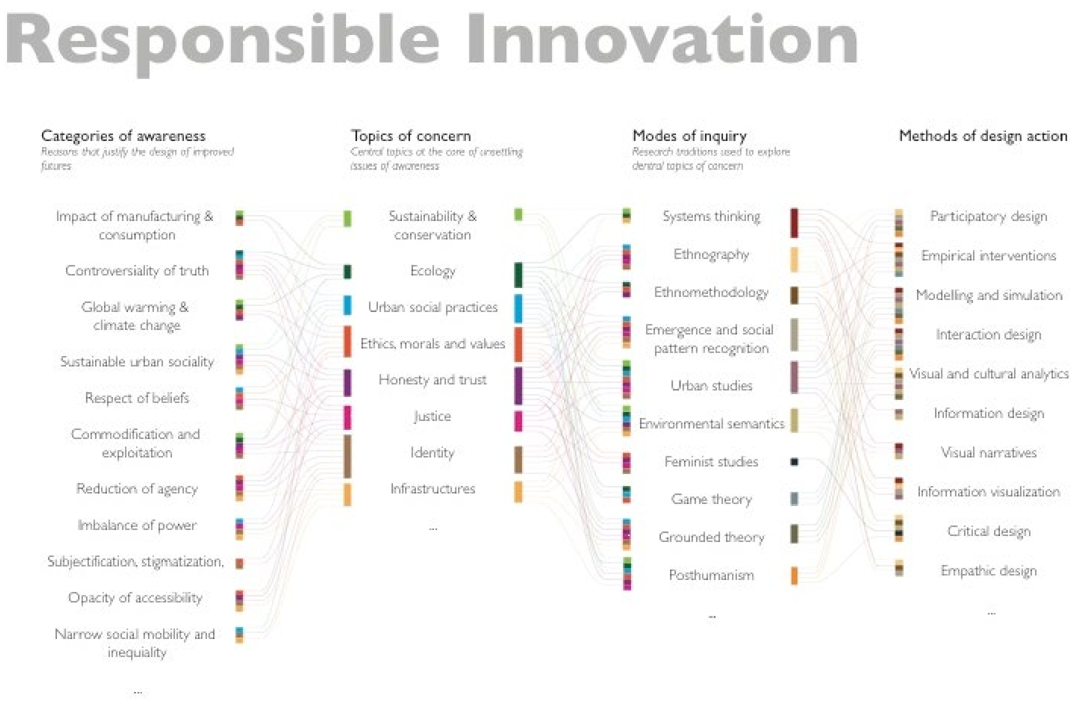


Figure 1. Networked structure of design for responsible innovation.

The *categories of awareness* cluster describes thematic classes of socio-environmental issues constituted by wicked problems. They motivate optimistic visions of futures characterized by fairness, equity, and sustainability. In order to understand these categories, it is necessary to problematize them with the help of methodological tools derived from the bodies of knowledge listed in the second cluster, *topics of concern*. These foundational aspects of the humanities, social sciences, and environmental sciences enable researchers and designers to formulate arguments about values, trust, justice, or identity.

There are no silver bullets to “solve” the wicked problems that arise within the *categories of awareness.* Rather, they can be tackled by devising systemic innovations. That is, a wicked problem can be disentangled by understanding its disposition within the web that emerges at the interface of *categories of awareness* with *topics of concern*. The relationships linking the *topics of concern* with the *categories of awareness* are usually one-to-many. Visualizing these relationships as a web reveals the networked condition in which wicked problems develop.

The *topics of concern* constantly call for the adoption of a responsible position in the innovation process. They bridge the *categories of awareness* with theories and methodologies pertaining to the variety of academic disciplines offered in the third cluster, *modes of inquiry*. Scholars, researchers and practitioners use these modes of inquiry to engage with cultural and social issues and build bodies of knowledge around topics of concern. The relationships between the second and third clusters are also one-to-many, for more than one mode of inquiry is applicable to any one topic of concern. These theories and methodologies can serve to frame the wicked problems nested inside *categories of awareness*. Again, it should be noted that this list is by no means exhaustive; expert researchers and practitioners can incorporate entries from their own domain knowledges as they apply the model.

Finally, the *methods of design action* cluster offers design disciplines and methods that are informed by the *modes of inquiry*. The relationship between these two clusters is, once again, one-to-many. Thus, problematizing *categories of awareness* by using *modes of inquiry* can motivate design action and innovation. Practitioners following this model will find a solid theoretical framework for grounding their work in the domain of responsible innovation. While our objective is to deploy this model from a design standpoint, this cluster could certainly be replaced with methods from other disciplines. Furthermore, we do not claim that solutions from single disciplines solve complex social problems; on the contrary, it takes systemic and multidisciplinary solutions to instantiate responsible visions of the future.

The model is not a design method. Rather, it is a conceptual tool for devising courses of design research for responsible innovation. It could be read according to the syntax illustrated in Figure 2, which begins at the third cluster, modes of inquiry, and proceeds both to the left and to the right. One form that this reading could take: *modes of inquiry* serve to theorize *topics of concern*, which are in turn used to problematize *categories of awareness*. The same *modes of inquiry* inform the *methods of design action* that practitioners and researchers use to develop design solutions for responsible innovation.

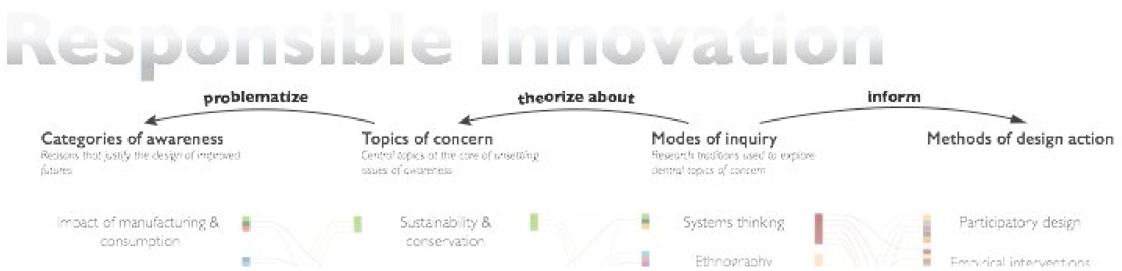


Figure 2. Syntax of the model of design for responsible innovation.

5 Structure/Pedagogical Framework

The four tracks of study, 1) sustainable & regenerative design, 2) urban sociology & critical race design, 3) visual & cultural studies, and 4) applied research in responsible innovation and social impact, emerged directly from faculty research interests. The fourth track is intended for students who are interested in working on individually-proposed topics that emerge from intellectual discovery. All of these tracks of study, and many more, can be accommodated by the *topics of concern*.

In order to demonstrate the efficacy of our model, we apply it to an existing research study led by Illinois M.F.A. candidate Eunmi Moon (Figure 3.) This study is an instance of the fourth track. In her project, *GuidingMe*, Moon developed long-term collaborations with individuals who have a visual disability and together they ran empathic experiences. From the analysis of such experiences Moon developed the Role-playing Living Lab (RpLL) method where users created experiences for makers in order to concentrate on the maker's experience of a real user's experience. The maker and the user work as a team, not only by role-playing but also by taking it a step further: the real user is empowered to develop and facilitate an experiential activity for the maker. Moon's mapping of the development of RpLL into our model reveals how she framed her modes of inquiry using ethnographic methods, pattern recognition from observations, and grounded theory. These modes of inquiry served Moon by helping her to theorize about her *topics of concern* (urban social practices; ethics, morals, and values; honesty and trust). Moon studied users' trust in offerings designed by able bodied designers and the ethics of empathy in the context of fair urban practices. More specifically, the categories of awareness related to her research problem were the stigmatization of people with disabilities, the opacity of infrastructure accessibility, and the issues of social mobility in unequal societies. The modes of inquiry also served Moon to inform design specific methods for the collection of data, structure studies and conduct workshops using participatory design, empirical interventions, simulations and empathic design. Below, we offer further discussion of opportunities afforded by the four tracks of study.

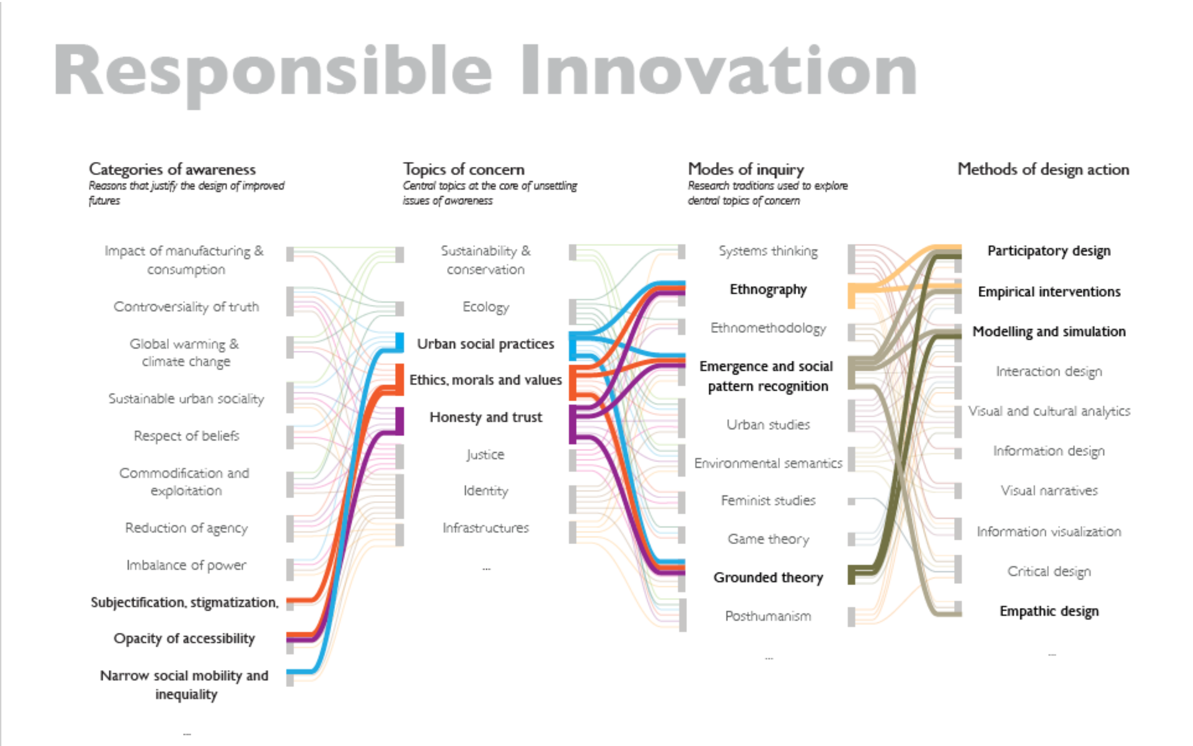


Figure 3. Illinois M.F.A. Candidate Eunmi Moon's methodology can be traced from her methods of design action *to the* categories of awareness *that define her thesis project,* GuidingMe*.*

5.1 Sustainable and regenerative design

Sustainable and regenerative design is focused on the production and consumption of material (Benson and Fine, 2010). Professor Eric Benson of the University of Illinois at Urbana-Champaign collaborated with Professor Peter Fine to define imperative components for sustainable and regenerative design. "A more holistic and deeply collaborative pedagogy that emphasizes creativity and innovation [is] the basis for inspired solutions that are centered within commerce, and a [redefined] craft that explores new materials and processes to confront issues of sustainability" (Benson and Fine, 2010). Benson collaborated with Yvette Perullo to co-found *Re-Nourish,* a non-profit organization, that provides design tools to minimize waste, advocate for awareness & action in environmental impact, and develop sustainable systems thinking in the communication design community (Benson and Perullo, 2017).

5.2 Urban sociology and critical race design

Urban Sociology and critical race design both speak to the constructed nature of gender, race, sexuality, and class (Forlano, 2017). Both frameworks help describe, explain, and address the effect of oppressive procedures, plans, and processes upon the communities that emerge from socially constructed identities (Murphy, 2015). By using these frameworks in an evidence-based design process, researchers are able to analyze the complex cultural issues surrounding these topics. One example of such research currently being conducted on our campus is *Racism Untaught*, a study that examines racialized designed artefacts, systems, and experiences through design research (Mercer and Moses, 2019). This project provides a creative space that supports learning environments in which students and educators can explore issues of race and racism, from the most obvious to the least visible. The visual rhetoric an individual encounters on a daily basis requires designers to be overtly aware of the dominant cultural constructed ideas and systems that influence design (Hum, 2015). It is imperative students engage in an interactive experience that provides context around community issues.

5.3 Visual and cultural studies

Design is a visual medium whose agency depends on the cultures of perception in which it is deployed. While visuality is the dominant perceptual paradigm for graphic design, studies in visual culture need not restrict inquiry to issues of opticality. For example, the emergence of critical visual studies in the 1980s and early '90s showed that visuality offers a basis for problematizing perception across all the senses (Bal, 1993; Bryson, 1983; Jay, 1988; Silverman, 1996). Visual and cultural studies can trace the consequences of design interventions over time in order to reveal not only the intentional processes by which material cultures emerge but also the unintentional intersections that shape the social and economic structures we inhabit. Haptic and aural sensations contribute to this process. For example, the built environment reflects the purposeful efforts of architects, landscape architects, and policymakers as well as the vernacular manner in which popular multi-sensory media have shaped perception, expectation, and desire in urban and rural spaces (Briggs, 2018; Briggs, 2019). Designers organize social and economic structures in smart cities, as in the case of smart bicycles that are synced to traffic infrastructure. The interconnected bicycles convey signals through optic, aural, and haptic interfaces in order to organize schools of cyclists in a flocking pattern (Cespedes and Salamanca, 2018).

5.4 Applied research in responsible innovation and social impact

The final track we recommend for potential study is a general category for exploring the space of responsible innovation. Topics of concern could arise from any of the previously mentioned tracks or from the researcher's particular concerns. Modes of inquiry could allow the researcher to develop a granular focus for design research that is also flexible, enduring, and scalable. Focus points in this track would be student-led and accommodate diverse interests.

6 Discussion/Conclusion

Our framework affords a number of pedagogical and methodological benefits. In its holistic exposition of topical, theoretical, methodological, and modal clusters, it highlights design's capacity to function as a critical lens for interpretation and action. That is, whereas affirmative design perpetuates normative design practices, critical design questions the status quo and opens up new avenues of possibility (Dunne and Raby, n.d.). The structures we have outlined enable the exchange of knowledge and afford students a creative space for discovery in which they can develop an epistemological understanding of design and ethics (Murphy, 2015). The framework encourages students to examine the implications of a variety of methodological choices early in the process, rather than allow premature choices of topic, method, or rationale to diminish their design opportunities. Embracing ethics within a framework of responsible innovation not only permeates the decisions designers make on behalf of users but also illuminates the scale, significance, and consequences of their solutions.

This work urges the need for holistic views and a spirit of inquiry from designers, where action is supported by systemic thinking, designers guide their design process with ethics, and are transformative with their ethical actions. Design can be both practical and critical. Practical actions and critical analysis can help designers understand and navigate complexities that lead to discovery of new knowledge (Murphy, 2015). Designers collaborate with key stakeholders developing design solutions for both human and non-human actors with meaningful positive, social, cultural, and environmental outcomes. A responsible process for innovation must be inclusive and diversify collaborators, providing a space to both analyze and act upon implicit knowledge, provide transparency in our understandings, and support the ability to be flexible within a system (Smallman, 2018).

The model is modular and therefore is adaptable and extends to many domains. Socially responsible innovations may require systemic actions from domains not covered in the model. A revised version of the model from an ecological perspective would add concepts and methods about the natural environment. The fourth cluster (*methods of design action*) is specific to the design domain but it could be replaced by methods and strategies for action from fields such as economics, social work, psychology, information science or education.

We have begun to use the model to advise students as they develop systemic solutions to complex social issues. Students have found it useful for reflecting on the social and environmental impact of the methods and processes they use in the design research process. In this manner, the development of responsible designs should be guided by ethics and result in systemic design solutions for both human and non-human actors.

7 References

Bal, M. (1993). His Master's Eye. *Modernity and the Hegemony of Vision*. D. M. Levin, ed. Berkeley: University of California Press, 379-412.

Benson, E. and Perullo, Y. (2017). *Design to Renourish: Sustainable Graphic Design in Practice*. Boca Raton: CRC Press, Taylor and Francis Group. doi: 10.1201/9781315689517

Benson, E. and Fine, P. (2017). Sustainable Design Education Rethought: The Case for Eco-modernism. *Design Principles and Practices in International Journal*. ISSN: 1833-1874.

Bryson, N. (1983). *Vision and Painting: The Logic of the Gaze*. New Haven: Yale University Press.

Buchanan, R. (1992). Wicked Problems in Design Thinking. *Design Issues*. 8(2), 5-21.

Cespedes, S., Salamanca, J., Yañes, A., Vinasco, D. (2018). Group Cycling Meets Technology: A Cooperative Cycling Cyber-Physical System. *IEEE Transactions on Intelligent Transportation Systems*. Early access. doi: 10.1109/TITS.2018.2874394

Briggs, M. (2018). *The Panoramic Mode: Immersive Media and the Large Parks Movement*. Unpublished doctoral dissertation. University of Illinois at Urbana-Champaign.

Briggs, M. (2019). "Immersion, Chromatics, and Atmoshpheric Effects: Recalling Period Perception in Turrell's Celestial Vault and Mesdag's Panorama." *International Panorama Council Journal* 2, 60-68. ISSN: 2571-7863.

Dourish, P. (2018). The Allure and the Paucity of Design: Cultures of Design and Design in Culture. *Human–Computer Interaction*, 1-21. DOI: 10.1080/07370024.2018.1469410

Dunne, A., Raby. F. (n.d.). *Critical Design FAQ*. http://www.dunneandraby.co.uk/content/bydandr/13/0 (Accessed on 4 April 2019).

Forlano, L. (2017). Posthumanism and Design. *She Ji: The Journal of Design, Economics, and Innovation* (Tongji University and Tongji University Press) 3(1), 16-29. doi: 10/1016/j.sheji.2017.08.001

Goodman, D. (2019). Amazon Pulls Out of Planned New York City Headquarters. *The New York Times*. February 14. Retrieved from https://nyti.ms/2UYaeSh on March 10, 2019.
Hum, S. (2015). “Between the Eyes”: The Racialized Gaze as Design. *College English*, 77(3).
Innovation. (n.d.). In *Merriam-Webster online dictionary.* Retrieved July 4, 2019, from https://www.merriam-webster.com/dictionary/innovation.
Irani, L. (2018). “Design Thinking”: Defending Silicon Valley at the Apex of Global Labor Hierarchies. *Catalyst: Feminism, Theory, Technoscience*, 4 (1), 1-10. Retrieved from https://catalystjournal.org/index.php/catalyst/article/view/29638. doi: 10.28968/cftt.v4i1.29638.
Jacobs, J. (2019). Doctor on Video Screen Told a Man He Was Near Death, Leaving Relatives Aghast. *New York Times*, Science, March 9, 2019. https://www.nytimes.com/2019/03/09/science/telemedicine-ethical-issues.html
Jay, M.(1988). Scopic Regimes of Modernity. *Vision and Visuality*. H. Foster, ed. Seattle: Bay Press, 3-23.
Kumar, V. (2012). *101 Design Methods. A Structured Approach for Driving Innovation in Your Organization*. New Jersey: Wiley.
Malsch, I. (2013). Responsible Innovation in Practice: Concepts and Tools. *Philosophia Reformata*, 78(1), 47-63.
Manzini, E. (2015). *Design, When Everybody Designs: An Introduction to Design for Social Innovation*. London: MIT Press.
Marcus, G. (2002). *What is Design Today*? New York: Abrams.
Margolin, V., and Margolin, S. (2002). A "Social Model" of Design: Issues of Practice and Research. *Design Issues*, 18(4), 24-30.
Mercer, L. and Moses, T. (2019) Identifying Racialized Design to Cultivate a Culture of Awareness in Design, The Design Journal, 22:sup1, 1399-1407, DOI: 10.1080/14606925.2019.1594965
Morelli, N. (2007). Social Innovation and New Industrial Contexts: Can Designers "Industrialize" Socially Responsible Solutions? *Design Issues*, 23(4), 3-21.
Murphy, P. (2015). *Universities and Innovation Economies: The Creative Wasteland of Post-Industrial Society.* London: Routledge.
Nieusma, D. (2004). Alternative Design Scholarship: Working toward Appropriate Design. *Design Issues*, 20(3), 13-24.
Rawhouser, H., Cummings, M., and Crane, A. (2015). Benefit Corporation Legislation and the Emergence of a Social Hybrid Category. *California Management Review, 57*(3), 13-35. Retrieved from https://journals.sagepub.com/doi/abs/10.1525/cmr.2015.57.3.13. doi:10.1525/cmr.2015.57.3.13
Rittel, H.W. & Webber, W.M. (1973). *Policy Sciences,* 4, 155-169.
Sax, D. (2018). End the Innovation Obsession: Some of Our Best Ideas Are in the Rearview Mirror. *The New York Times*. December 7, 2018.
Silverman, K. (1996). *The Threshold of the Visible World*. New York: Routledge.
Smallman, M. (2018). Citizen Science and Responsible Research and Innovation. In Hecker S., Haklay M., Bowser A., Makuch Z., Vogel J., and Bonn A. (eds.). *Citizen Science: Innovation in Open Science, Society and Policy*. London: UCL Press, 241-253.
Soper, S. (2019). Amazon Scraps Plan to Build a Headquarters in New York City. *Bloomberg, Technology*. February 14, 2019.
Tatum, J. (2004). The Challenge of Responsible Design. *Design Issues*, 20(3), 66-80.
Tharp, B., Tharp, S. (2013). Discursive Design Basics: Mode and Audience. In *Proceedings of Nordic Design Research Conference*. Copenhagen-Malmö, 406-409.
Wagner, K., Taylor, A., Zablit, H., and Foo, E. (2014). *The Most Innovative Companies 2014: Breaking Through is Hard to do*. Retrieved from Boston, MA: http://image-src.bcg.com/Images/Most_Innovative_Companies_2014_Oct_2014_tcm9-59902.pdf
What Design Can Do (2019). Retrieved from https://www.whatdesigncando.com/.
Zehtabchi, R. (director and producer), Berton, M., Schiff, G., Tabak, L. (producers). (2018). *Period. End of Sentence* [documentary film]. United States: Netflix.

About the Authors:

Juan Salamanca’s current research inquiries for methods to design and validate the impact of visual and embodied artefacts that support the achievement of unplanned collective goals. He holds a Ph.D. from the IIT

Institute of Design, Chicago, USA, and an M.A. from Domus Academy in Milan, Italy. More info at www.smartartifact.com.

Lisa Elzey Mercer's research interests are in developing, executing, and analyzing co-design frameworks that responsibly fuel and sustain social innovations. The developed frameworks create a space for conversation and knowledge exchange where participants actively collaborate in the creation of new ideas and solutions.

Molly Catherine Briggs's research examines the role of popular immersive media in perceiving and constructing the built environment. She holds a Ph.D. in Landscape Architecture from the University of Illinois, USA, and an M.F.A. in Printmaking from Northwestern University, USA.

Acknowledgement: We would like to thank our colleagues Eric Benson, Wonsil Jang, Linda Kwon, Stacey Robinson, Stan Ruecker, and Nekita Thomas, for their feedback in the construction of the model presented herein.

SBAC: A Community-Based Distributed Education Model Research

Chen, Fan

College of Design and Innovation, Tongji University, Shanghai, China
chenfantj@foxmail.com

Is there any change on contemporary educational paradigm after Frederick Emmons Terman? How will growing grass-root strength affect it? Based on classical University-Business Partnership and modern community micro-generation achievements, this paper attempts to establish a community-based distributed education platform model to promote collaboration among business, schools and academia in a resilient and bottom-up way. By case and literature studying, a conceptual SBAC education model is featured, which suggests to engage resources of business, schools and academia in communities, especially residential areas, and make transformations of professional expertises to enlarge the influence of education and activate communities. What's more, five types of quality are enabled in SBAC, which includes art, enterprise, maker, research and vocation, participants will enjoy related services. Essentially, SBAC is a distributed incubator system, by educational operation, resources are transformed and delivered more efficiently, which may start another educational renovation.

Keywords: University-Business Partnership; community micro-generation; distributed educational system; education paradigm

1 Introduction

Contemporary urban development has witnessed micro-generation in communities occupies a large proportion, and distributed system thinking has directed a large number of urban micro-generation events. In China, residential communities act as power station for social running, though it has not been paid sufficient attention until 2012. QIU Bao-Xing claimed theory of reconstructing microcirculation on International Conference on Urban Development and Innovation, which suggested developing sustainably instead of obsessing with mega-city. In 2016, Shanghai reflects on this call with 22 micro-generation projects within "Walking Shanghai" plan in a bottom-up way and which leads a micro-generation trend ever since. In addition, institutions also respond to this tide in a more academic attitude. For example, College of Design and Innovation of Tongji University started Open Your Space program in Siping community from 2015, which can be seen as a platform lead by faculties, managed by students and social innovators, and residents are engaged in series of projects. Based on former practical and academic research findings, this paper attempts to explore the feasibility of educational micro-generation in communities on an academic conceptual level.

2 Literature Review

From 1862 Morrill Land Grant Act to 1904 Wisconsin Idea to 1951 establishment of the Stanford Industrial Park, the primary classical University-Business Partnership has been formed. Then, Freeman proposed National System of Innovation to supplement University-Business Partnership, in which business, universities and institutions constitute a network system under the leadership of governments and intermediary agencies. Next, this paradigm was introduced into China in 1992, and Joint Development Project of Industry, University and Research was launched and implemented by a top-down approach. Finally, LIU Li summarized characteristics of University-Business Partnership and defined that it is a collaboration between academia and industry in order to realize the target of innovation. However, with emerging social power, such as NGO, bottom-up paradigm begins to contributes on social transformation. This new trend obliges us to reflect how we can promote the collaboration among business, schools and academia (universities and institutes) by a more penetrative and resilient way. Given this, a community-based educational experiment may provide a perspective. For instance, conventional intermediary agencies among business, schools and academia are directly assigned by governments, what if intermediaries changed to social self-governance side?

3 Methodology

Main methods used in this paper are literature study, field study, case study, qualification research and expert interview. This paper has collected research materials from Siping Community by an ethnographic method, including participate community micro-generation projects, interview with local residents and photography. On the other hand, online case study helps to realize other practical programs all of the world. Then, combined with literature study and qualification research, rough materials on hand are classified by characteristics and common operation logics are found, which lays foundation for emerging SBAC education model. Finally, experts interview helps to criticize and iterate the conceptual model.

In general, this paper is based on descriptive study. Cases are selected from worldwide social innovation programs, which can present a certain or a synthetic category of innovative type. In terms of classification of these programs, researcher apply qualification research method to classify them according to their main quality. For instance, children's design thinking cultivation by hand madding is classified into 'maker education'.

4 Discussion

4.1 Case Study

Fifteen international representative educational social innovation cases have been studied and they are classified into five types of educational model by qualification analysis, which will be discussed according to classification below.

Table 1 Worldwide selected educational social innovation programs and classification.

Classification / Program	Art education	Enterprise education	Maker education	research-oriented education	Vocational education
Agency by Design			●		
Artists for Humanity	●				

Boston Design Museum				●	
Cambridge Community Art Center	●				
Cambridge Educator Design Lab				●	
EurekaLab			●		
Lifelong Kindergarten			●		
MIT D-Lab				●	
MIT Media Lab			●		
Startup Institute					●
Shorelight					●
The Possible Project		●			
Urbano	●				
Youth Cities		●			
Zumix	●				

There are two approaches derived from *Artists for Humanity*, *Cambridge Community Art Center*, *Urbano* and *Zumix*, all of them are implemented in art education model. On one hand, when learners had grasped related artistic skills after several week's cultivation, they can participate commercial projects in the lead of supervisors. On the other, works of learner will be invited to exhibit at local galleries, visitors have chance to purchase or rent these works.

Figure 1. photographed by Artists for Humanity group

Figure 2. photographed by Cambridge Community Art Center group

Figure 3. photographed by Urbano group

Figure 4. photographed by Zumix group

In terms of enterprise education, programmers of *The Possible Project* and *Youth Cities* hold regular thematic salons once a week toward community members, they can be undergraduates, educators, lawyers, entrepreneurs or civil servants. Each topic focus on a concrete issue and will be given limited time to generate solutions. In addition, there are also customized projects for school students and make them experience entrepreneurial process under safe circumstance. For example, participates are asked to find out problems toward low income families and middle school students in Boston, then incubate primary business ideas and test prototypes. Then make out practical products and operate projects in order to accumulate practical business experience. Finally, supervisors leave and make participates operate by themselves.

Figure 5. photographed by The Possible Project group

Figure 6. photographed by Youth Cities group

Agency by Design, *EurekaLab*, *Lifelong Kindergarten* and *MIT Media Lab* are engaged in maker education, they implemented four renovations, self-education, didactical subject, didactical object and didactical model. Firstly, self-education indicates to develop 1) ability to observe, which asks students to slow down, consciously watch the things or systems, to understand what systems are made of, what are the intentions of these components in design, to find the nuances between things, to understand one simple things/system complexity; 2) ability to explore complexity, which asks them to think what they can't see? What is the relationship between the part and the whole? How was this item/system made, and how was it used? 3) ability to find design opportunities, which is to find the possibility of invading, building, refining, or redesigning things or systems based on careful observation and exploration complexity. Secondly, didactical subject renovation means decentralization of teaching, in details, 1) let students teach to improve the efficiency, release teachers and help build their confidence; 2) members of communities stand for the resources in maker centres to provide professional guidance, invite creators from communities to share and communicate, set up workshops to teach crafts, participate in student projects and maker educators create more opportunities for students; 3) finding resources on the Internet and deciding how to use them requires students to develop very strong self-driven learning; 4) let students use diverse tools and materials, not only to master a specific skill, but to extend the imagination. Thirdly, didactical object renovation implies to encourage self-directed, interest-driven, peer-to-peer learning, in particular, 1) help students to group, ensure that students have enough time to study with team members, provide goals and principles of action for group tasks; 2) encourage mutual inspiration and evaluation among students; 3) encourage knowledge sharing, change the stereotype of the teacher's mind as the authority to disseminate knowledge, and let students proactively acquire knowledge through peer learning and other resources. Lastly, renovation of didactical model asks to replace traditional one-to-many pedagogy with project-based learning, 1) maker spaces are closely linked to teachers' daily teaching activities, transforming the learning of traditional classroom scenes into a project-based learning, different disciplines such as mathematics, art, language, natural sciences, social sciences can be designed to be project-based learning that requires students to create.

Figure 7. photographed by Agency by Design group

Figure 8. photographed by EurekaLab group

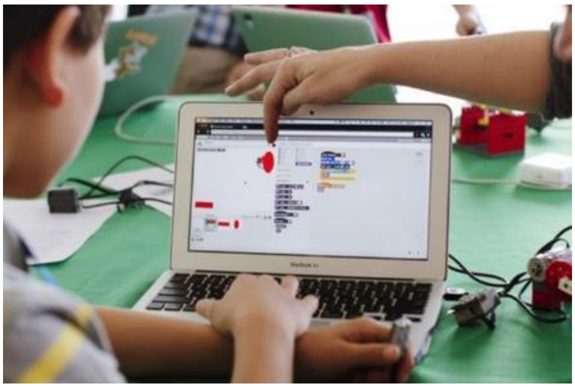


Figure 9. photographed by Lifelong Kindergarten group

Figure 10. photographed by MIT Media Lab group

Research-oriented education model is designed towards teachers and students within *Boston Design Museum*, *Cambridge Educator Design Lab* (in partnership with the *Cambridge Public Schools* and the *Center for Artistry and Scholarship*) and *MIT D-Lab*. On one hand, methods and toolkits of design thinking are expected to introduced to public schools, faculties learn and develop special working systems according to their own characteristics. On the other, for students, 1) organize students to visit companies to increase perceptual knowledge; 2) pay attention to poverty, environmental pollution, garbage disposal, gender equality, education equity, etc., from macro and micro perspectives; 3) global partnerships with local governments/schools/non-profit organizations in a number of poor areas to experience the lives of local people, understand problems, and design solutions; 4) in combination with the demands of local partners, for instance, D-Lab encourages students to solve problems through ‘Design for, Design with, Design by’; 5) raise everyone's awareness of design and bring the transformational power of design to various places to inspire more creative problem solvers in the world.

Figure 11. photographed by Boston Design Museum group

Figure 12. photographed by Cambridge Educator Design Lab group

Figure 13. photographed by MIT D-Lab group

Also, vocational educational model, *Startup Institute* and *Shorelight* involved, is set toward school students and incumbents. Initially, open technical marketing, sales and customer management, and web development courses for students; let employers have different interactions with students in different aspects, let students cooperate with start-up companies during their studies, and recommend them according to the needs of start-ups. What's more, for incumbents, 1) working with foreign universities and develop innovative degree programs based on a two-way understanding of student needs and university needs; 2) working with local schools to reduce infrastructure costs by renting existing spaces; 3) supporting with local language schools so as to reduces students' language and cultural barriers; 4) students enter foreign colleges' alumni systems in order to have opportunities to work on projects, internships, and employment with companies that have been establishing contact with their schools.

Figure 14. photographed by Startup Institute group

Figure 15. photographed by Shorelight group

The five types of educational social innovation model inspire diverse perspectives which should be considered into community-based educational platforms, and they lead to the generation of SBAC.

4.2 Concept of SBAC

As is shown in Figure 1, SBAC consists of four social elements, which are school, business, academia and community. For sharing a similar pronunciation with ‘spark’, SBAC stands that the four elements will invent innovation and wisdom when they get together. Specifically, school mainly stands for preschool education, primary school, junior high school and senior high school; business means all kinds of profit organizations; academia represents universities and institutes; fourthly, community indicates local residential area; Lastly, the directions of arrows indicate the flowing direction of resources. Derived from the collaboration of school, business and academia, education is reorganized. With the help of community platform and external operation, the gap among school, business and academia is closed, which directly cuts the cost of scientific investigation, information transmission, and commercialization. In addition, business, school and academia call on events regularly, which regards communities as consumer end and effectively promote the community-based regeneration.

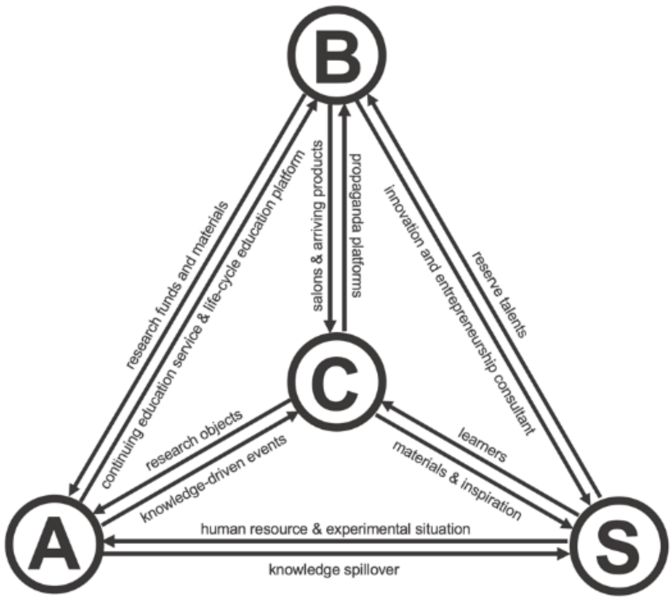


Figure 16. SBAC educational model diagram.

Four loops are raising among school, business, academia and community. People, substance and capital are involved and keep moving in each loop, which provides power and resource with iteration of SBAC. Firstly, schools offer learners to communities, which are main bodies of SBAC; communities provide propaganda platforms to business side; then business rewards schools with resource of innovation and entrepreneurship consultant. Secondly, academia supplies knowledge and intelligence to business, including continuing education service and life-cycle education platform; business calls on innovation and entrepreneurship salons in communities, and also introduces arriving products to residents; communities offer research objects to academia. Thirdly, academia calls on knowledge-driven events in order to enrich spiritual life; communities act as social innovation materials and inspiration toward schools, and make space for learners and educators to carry out social practices; schools can provide potential human resource and experimental situation to academia. Lastly, business supports academia with research funds and materials; there will be knowledge spill over from academia to schools and make updated findings spread to next generation directly; schools also can be a reserve talents pool for business society. For now, a community-based education eco-system has been established.

4.3 Quality of SBAC

As mentioned above, five kinds of educational qualities are expected to nurture SBAC, which are art education, maker education, enterprise education, research-oriented education and vocational education.

Art education within SBAC offers artistic and innovative capacities and job opportunities, which help participants to practice in diverse projects and get paid. On the other hand, artists will be engaged in community micro-generation projects and to be artivists.

Enterprise education is not only an approach of knowing the world, but also inner cognition. Equipped with entrepreneurial thinking qualifies learners with more freedom and flexibility in their occupation, and which will also aware learners to pay more attention to the collaboration with systems.

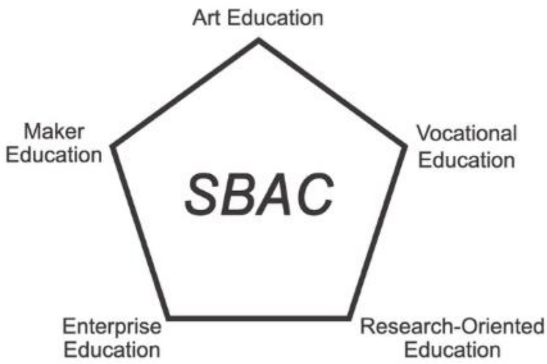


Figure 17. Five qualities of SBAC.

The most significant impact of maker education is not discipline-related curriculum and concrete knowledges, but driving force of learning and inventing. First of all, SBAC colleagues should visit existing maker spaces and maker education bases, interview makers with experience of making and teaching. Then, collaborating with makers and inviting them to build maker bases in communities in order to observe their procedures deeply and in long term. Finally, developing maker enablement, which indicates qualifying learners with sensitive awareness of treating objective things and complex social systems, looking the world as a reformable object and equipping with passion and ability of changing the world by invading, building, repairing and redesigning. There are no absolute-authority teachers in maker education, they come from students, residents, online materials and even tools. Regular activities of maker education include integrating cooperation among learners, encouraging them criticize and evaluate each other and sharing knowledges. In terms of maker space, teaching-based conventional classrooms are expected to be transformed to project-based space, flat structure is encouraged.

There are two educational objectives toward faculties and learners in research-oriented education. In one hand, training the creative thinking of teachers, which is essentially cultivate the attitude of Research through Design and it is probably the customized methodology for design area. In the other, learners have a grasp of design thinking will help them to address issues systematically, and have empathy attitude and understand situations based on daily experience.

Two types of audience are settled in vocational education, school students and incumbents. First of all, SBAC will accelerate vocational education by focusing on entrepreneurship, which provide human resource to start-ups continually and also help applicants to obtain vocational abilities. Next, SBAC may help employees to accept international diplomas without studying abroad.

Besides content qualities, there is a spatial feature rooted in SBAC. Public or vacant space, either community centre or spare garage, may hold SBAC activities, of which the time is regular, but locations can be settled by demands. This enabled SBAC with distributed property and enlarge the influence.

5 Conclusion

As a community-based conceptual educational model, SBAC indicates a more integrated type of collaboration besides single project-based community micro-generation, which regards residential communities as platforms and reintegrates existing social resources of business, schools and academia, and make updated achievements flow to practical situation in a more efficient and low-cost access. On the other hand, SBAC makes knowledges spill over from professional areas and ivory towers to social life, which also responds to the contemporary mission of university. Based on existing findings, this study will go further on practical level to make the influence of education more ubiquitous.

6 References

Aladro-Vico, E., Jivkova-Semova, D., & Bailey, O. Artivism: A new educative language for transformative social action. Comunica, 26(57), 9-18.

Author. (2018). *Cumulus Conference Proceedings Wuxi 2018: Diffused Transition & Design Opportunities*.

Chen, C. (2016). Walking in Shanghai 2016——Micro Regeneration Plan of Community of Urban Space. Public Art, 8(4), 5-9.
[in Chinese 陈成. (2016). 行走上海 2016——社区空间微更新计划. 公共艺术, 8(4), 5-9.]

De Miranda, Michael A. (2004). The Grounding of a Discipline: Cognition and Instruction in Technology Education. International Journal of Technology and Design Education, 14(1), 61-77.

Freeman, C. (1987). Technology and Economic Performance: Lessons from Japan[M]. London: Printer Publish.

Liu, L. (2002). Historic Review and Essential Discussion on the University-Business Partnership. Journal of Zhejiang University (Humanities and Social Sciences), 32(3), 109-116.
[in Chinese 刘力. (2002). 产学研合作的历史考察及本质探讨. 浙江大学学报(人文社会科学版), 32(3), 109-116.]

Lou, Y. Q. (2015). Design Activism in an Era of Transformation. Art & Design, 57(7), 17-19.
[in Chinese 娄永琪. (2015). 转型时代的主动设计. 装饰, 57(7), 17-19.]

Lou, Y. Q. (2018). NICE 2035: An Experiment of Design Driven Community-supported Social Innovation. Art & Design, 60(5), 34-39.
[in Chinese 娄永琪. (2018). NICE 2035: 一个设计驱动的社区支持型社会创新实验. 装饰, 60(5), 34-39.]

Manzini, E. (2015). Design, When Everybody Designs. Cambridge: The MIT Press.

Ni, M. Q., & Zhu, M. J. (2017). Open Your Space: Design Intervention for Urban Resilience. Shanghai: Tongji University Press.
[in Chinese 倪旻卿, & 朱明洁. (2017). 开放营造: 为弹性城市而设计. 上海, 同济大学出版社“光明城”.]

Qian, Y. Y., & Xiao, M. (2000). Going out of the Misunderstanding - Economists talk about the Silicon Valley Model. Beijing: China Economic Publishing House.
[in Chinese 钱颖一, & 肖梦. (2000). 走出误区——经济学家论说硅谷模式. 北京: 中国经济出版社.]

Qiu Bao-Xing: Urban construction needs innovation should abandon the fascination with megacities. (2012, February 24). Retrieved from http://finance.ifeng.com/news/special/gjcscxfz/20120224/5654692.shtml
[in Chinese 凤凰网财经. (2012, February 24). 仇保兴：城市建设需要创新 应摒弃迷恋巨型城市做法. Retrieved from http://finance.ifeng.com/news/special/gjcscxfz/20120224/5654692.shtml]

Wu, J. W., & Wang, J. R. (2002). On the Production, Development Process and Trend of the Cooperation of Industry, University and Research Institute in China. Science and Management, 4(4), 6-8.
[in Chinese 吴继文, & 王娟茹. (2002). 中国产学研合作的产生、发展过程和趋势. 科学与管理, 4(4), 6-8.]

Xia, Y. J. (2006). Discussion on the Structure of Undergraduate Courses of Art Design in Colleges and Universities in China. Unpublished doctoral dissertation, Nanjing University of the Arts, Nanjing, China.
[in Chinese 夏燕靖. (2006). 对我国高校艺术设计本科专业课程结构的讨论. 未发表博士学位论文, 南京艺术学院, 南京, 中国.]

Yang, C. J. (1992). The Significance and Implementation of the "Industry, University and Research Joint Development Project". R&D Management, 4(4), 1-4.
[in Chinese 杨昌基. (1992). “产学研联合开发工程”的意义和实施. 研究与发展管理, 4(4), 1-4.]

Zimmerman, J., Stolterman, E. & Forlizzi, J. (2010). An analysis and critique of Research through Design: towards a formalization of a research approach. O. W. Bertelsen, & P. Krogh (Eds.), Proceedings of the 8th ACM Conference on Designing Interactive Systems (pp. 310-319). New York, ACM New York.

About the Authors:

CHEN Fan: First year PhD candidate of Design, who focused on design education, especially pedagogical research of PhD candidates of design discipline under Chinese context. CHEN Fan has published two papers about design research on Cumulus Conference.

Teaching Futures: Trade-offs Between Flipped Classroom and Design Studio Course Pedagogies.

Scupelli, Peter*[a]; Candy, Stuart[a]; Brooks, Judy[b]

[a] School of Design, Carnegie Mellon University, Pittsburgh, PA, USA.
[b] Eberly Center for Teaching Excellence & Educational Innovation, Carnegie Mellon University, Pittsburgh, PA, USA.
* scupelli@cmu.edu

Change is exponential. Products and services are developed faster, hold a shorter shelf-life disrupted by new offerings, and exist in the wider environment with global challenges emerging such as climate change and sustainability. Thus, design for the 21st century requires different skills; design educators are challenged to adapt. In this paper, we compare two versions of a futures studies course developed for design students: one uses a flipped classroom pedagogy (with interactive online pre-work and in-class workshop activities, meeting for two 80-minute sessions per week); and the other uses a hybrid studio approach (making more use of in-class lectures followed by hands on-studio activities, meeting for 170 minutes once per week) focused on experiential futures practices of tangible artifact and immersive scenario creation. We use four measures: learning activity inventory, course quality with faculty course evaluations, student experience with a post-course survey, and time and feedback on final projects. We discuss design trade-offs for learning: format of reflections is linked to transfer activities, time on learning activities shapes perceptions, less (interference) is more, more (scaffolding, feedback, links to practice, active learning) is better, and timing is everything.

Keywords: design thinking; futures thinking; flipped classroom; studio education; learning science.

1 Introduction

Changes to design curriculum and courses are difficult. Adding something new (topics, approaches, methods) calls for discernment on the best use of limited student time and attention. How should the new topic be taught: studio, lecture, seminar? How should classes be structured: size, duration, frequency? How should effort be paced and allocated in class vs outside? Enlightened course design relies on three pillars: applying the research on what works best for learning, data-informed iteration, and engagement with real-world problems (e.g., Ambrose, et al. 2010). Design educators are examining (and changing) their teaching pedagogies to engage with global challenges such as climate change and sustainability (e.g., Scupelli, 2019).

In this paper, we focus on two case studies and their respective pedagogies: *Dexign Futures*, a design studies course taught as a flipped class; and *Futures*, a redesigned version of the course with a hybrid design studio model emphasising co-creation and experiential learning.

1.1 Four pedagogies frequently used in design education

Design education broadly relies on four pedagogies, each with its own strengths and limitations: studio, laboratory, lecture, and seminar (Lyon, 2012; Tovey, 2015; Boling et al. 2015; Farías & Wilkie, 2016; Davis, 2017). Studio and laboratory courses focus on applied making, while core concepts are often taught through lecture and seminars (e.g., Lawson & Dorst, 2015). In this paper, we discuss a flipped class and a hybrid studio.

1.2 Design studies courses at Carnegie Mellon University

Design studies courses at the School of Design at Carnegie Mellon University focus on design research methods, explorations into design culture, and new topics (e.g., Systems; Cultures; Persuasion). Design studies classes are typically lecture-based, with hands-on application activities. Studio courses complement these and focus on three different tracks (Products, Communications, and Environments).

1.3 Futures Studies within the design studies track

A futures studies class was introduced in the design studies spine as part of a new undergraduate curriculum launched in 2014. Futures studies (or simply “futures”) is a transdisciplinary field of inquiry concerned with the investigation of diverse possible, probable and preferred futures (Bell, 2003; Gidley, 2017), and it has been taught in a range of university departments in the United States and around the world since the 1960s (Dator, 2002). This addition to core curriculum here was spurred by a recognition that emerging designers will, in their lifetimes, confront pervasive challenges such as sustainability and climate change, and that they should therefore be capable of contextualizing and embedding practical short-term design action within long-term thinking (Brand, 1999; Mau et al., 2004; Candy, 2010).

The futures class at Carnegie Mellon University, required for all third-year design students, was introduced to help prepare them for these grand challenges. Design educators addressing such larger-scale concerns confront an inherent tension between covering traditional artifact-centered approaches and the systems perspectives addressing societal level concerns (Irwin et al. 2015; Kossoff, 2011; Scupelli, et al. 2016[ab]; Scupelli, et al. 2017; Scupelli, et al. 2018). Case studies describe ways to bridge such tensions (Scupelli, 2019).

In the first three years, futures was taught in two ways: *Dexign Futures* (2016, 2017) as a flipped class meeting twice a week for 80-minute sessions; and *Futures* (2018) as a studio course meeting once a week for a 170-minute session. Three key challenges were faced in both versions are linked to the broader context of a new curriculum rollout.

First, managing student motivation was difficult. For many students, having to shift perspectives and meaningfully embed a “futures” worldview in their third year was different from the pattern established in their previous two years of study: learning to think about and apply design to immediate or near-term problem spaces for four semesters, then suddenly switching in the fifth to address much longer time horizons.

Second, futures thinking requires students to entertain an unfamiliar epistemology of time: there are no future facts, but multiple possibilities, the very consideration of which may affect what unfolds (Gidley, 2017). Radical differences between typical short-run perspectives on design as a technology-driven foray into the adjacent possible, and the embrace of philosophical pluralism, uncertainty and openness consonant with a longer view, appeared to make some students uncomfortable, avoidant, or dismissive.

Third, promotion of learning transfer from design studies courses, including the futures course, to studio projects, was lacking. Although framed and structured as core competencies, the concepts, methods and skills taught in design studies courses were not always explicitly referenced or reinforced in the briefs and instruction for studio courses, leaving students to make the connections. Consequently, some struggled to integrate futures methods into their developing design practice. Next we describe differences in structure, activities, and learning outcomes between the two versions of the futures course.

1.4 Case Study 1: *Dexign Futures*[1]

Sustainability is often framed in terms of long-range challenges unfolding over periods of a generation or more, for example looking to a specified multi-decadal time horizon like the year 2050 (WBCSD, 2009). *Dexign Futures* explicitly focused on aligning near-term design action with sustainable futures. The "X" in Dexign was originated by Wasserman to signify an experimental form of design and design education combining design thinking with futures thinking to align near term design action with long range vision goals – while navigating uncertainty and accelerating innovation toward desired futures (Wasserman, Scupelli, & Brooks 2015[ab]; Scupelli, Wasserman, Brooks, 2016; Scupelli, Brooks,Wasserman, 2016).

In 2016 and 2017, *Dexign Futures* was taught with the flipped classroom pedagogy as an alternative to the traditional lecture approach (Scupelli & Brooks, 2018). "Flipped" courses shift new-content exposure to pre-class work and use class time for hands-on application activities (Bergmann & Sams, 2012). Pre-class work included online readings, videos, and interactive questionnaires providing immediate feedback; as well as a mechanism for students to submit questions to the instructor ahead of each session. Weekly reflections asked students to explain how they might integrate futures methods into design practice.

The online platform, Open Learning Initiative (OLI), included an information dashboard highlighting the top five questions that students had answered incorrectly in the pre-work, so that the instructor could address student misconceptions. Discussion then paved the way to active engagement with hands-on individual and group activities, during which the instructor provided just-in-time guidance.

McCarthy (2016) lists potential six benefits and limitations to the flipped classroom model. Scupelli and Brooks (2018) suggest three further potential benefits and limitations. The *Dexign Futures* course was based on the premise that students need a broad introduction to futures, the goal being to help them bring these methods of longer-term, pluralistic thinking into applied contexts. As noted above, several challenges impeded this knowledge transfer to other courses. In the next section, we describe revisions in its third year, 2018.

1.5 Case Study 2: *Futures*

In fall 2017, the School of Design hired Stuart Candy, an internationally renowned academic and professional futurist, to embed futures studies (also known as "foresight") approaches throughout the curriculum. Taking existing undergraduate courses as a starting point, the integration strategy developed in collaboration with other design faculty was to weave a "Foresight Thread" through existing design studies courses. The "threaded" structure was devised as a way of distributing unfamiliar — and as we have noted, paradigmatically challenging — perspectives over a four-year degree arc. Instead of a single burst, starting and ending in the space of one semester in the third year, the pedagogical architecture now

---

[1] *Dexign Futures* grew out of a course titled *Dexign the Future* originated in 2013 by Arnold Wasserman as Nierenberg Chair Visiting Professor. The course was co-taught by Wasserman via remote telepresence and Prof. Peter Scupelli on-site. https://dexignthefuture.com/

underway embeds multiple exposures to futures methodologies and practices in smaller doses, starting in the first semester, with a view to them being used and reinforced in concurrent design studio courses in the Products, Communications, and Environments tracks of second and third year students, and culminating in an applied futures research component of the fourth-year (senior) studio.

The inception of the Foresight Thread allowed Scupelli and Candy to create a new *Futures* course for fall 2018. In line with the distributed "drip-feed" strategy of multiple exposures over years, one important parameter and goal for this specific run of the course was to reduce the number of topics from those covered in the course's first two iterations, to enable more in-depth practice with certain methods. A second goal was to help students take a deep dive into both futures and design via "experiential futures", a fast-developing genus of practice (Candy, 2010; Candy & Dunagan, 2017; Candy, 2018; Candy & Kornet, 2019), involving the use of design skills and other idioms such as performance, gameplay, and media production to mediate future scenarios as if they were real in the present.

The experiential futures approaches incubated in futures/foresight have been interwoven with, and in some key respects anticipated and preceded, the ascent over the past decade of futures-oriented methods in design education, such as design fiction and speculative and critical design (Durfee & Zeiger, 2017 including Candy, 2017; Dunne & Raby, 2013). The key difference is that when one starts with the aim of increasing the quality and depth of thinking about the future, all manner of media and approaches in support of that are considered fair game; whereas when one starts with a certain medium or practice and uses it to try to think about the future, the usual boundaries of that practice may unintentionally circumscribe the range of possible thought (Candy, 2017; Candy, 2018).

A way of framing the great challenge — and opportunity — of using experiential futures approaches is to bridge the "experiential gulf"; to shift from high-level, abstract ideas about possible futures down to 1:1 scale fragments that help make a hypothetical world feel real (Candy, 2010, p. 61). Based on Candy's research and teaching, and building also on the first two runs of *Dexign Futures*, in the *Futures* course students were scaffolded and supported through designing three experiential scenarios framed by two major projects.

The course was structured as follows. It began with a three-week introduction to key ideas and concepts in the field (for a broad-strokes sense of these foundational elements, see Candy, 2011). Over the following four weeks, students were guided through an investigation based on Ethnographic Experiential Futures (EXF) (Candy & Kornet, 2019), creating two "artifacts from the future"; the first instantiating a preferred personal future for themselves (i.e. a representative object "from" the world and the life that they would hope to find themselves in 20 years from now); and the second responding to and forming a coherent part of the preferred future of a classmate. These were individual projects, but completed in dyads, with the partner being the key interlocutor and "client of one". These activities in the first seven weeks comprised the first half of semester. The latter half revolved around experiential futures projects co-created in small groups, each producing a "Time Machine," an immersive scenario at the scale of a room, whereby a group of visitors is invited to visit a future scenario for fifteen minutes, and spends the period immediately afterward unpacking and exploring that experience (Candy, 2013; Candy, 2014). The three-hour weekly studio format was adopted for the *Futures* incarnation of the course with a view to supporting deeper peer-to-peer and group-based design exploration. In the next section, we describe methods and measures used to examine the three courses.

2 Methods

We evaluated the 2016 and 2017 *Dexign Futures* courses and 2018 *Futures* course using four measures: inventory of learning activities, faculty course evaluations, student experience surveys (Scupelli, Brooks, 2018), and a culminating assignment in experiential futures called "The Time Machine" (Candy, 2013).

2.1 Inventory of learning activities

For each course, we counted the learning activities listed in the course syllabus, course calendar, and class meeting agendas, taking stock of these as well as the graded assignments, and estimating the time dedicated to each activity. The goal of such an inventory is to compare and contrast students' activities in each iteration.

2.2 Online student learning experience survey.

When the course concluded, we asked students to complete a three-question survey online (Table 1). We coded comments with grounded theory methods (Strauss & Corbin, 1994).

Table 1. Student learning experience online questions for Dexign Futures (DF) and Futures (F).

1.	What activities in the [DF, F] course do you feel contributed the most to your learning?
2.	What are some concrete examples of how you applied what you learned in the [DF, F] course to things you worked on outside of class (e.g., studio projects, independent projects, own life)?
3.	What suggestions do you have to improve the [DF, F] course student experience for next year?

2.3 Faculty Course Evaluations

Carnegie Mellon University conducts a Faculty Course Evaluation (FCE) at the end of each course, consisting of ten questions on students' perceptions of their engagement, learning outcomes, instructor behaviors and course activities (Table 2). Questions are rated on a five-point Likert scale (1=Poor, 2=Below Average, 3=Average, 4= Above average, 5=Excellent). We conducted an independent samples ANOVA to compare the ten FCE questions for 2016, 2018, and 2018 courses. In this paper we focus on five of these questions (see Table 2).

Table 2. Faculty Course Evaluation focal questions.

1. On average, how many hours per week have you spent on this class, including attending classes, doing readings, reviewing notes, writing papers and any other course related work?
2. Does the faculty member provide feedback that helped students improve their performance?
3. Does the faculty member demonstrate the importance and significance of the subject matter?
4. Does the faculty member explain the subject matter of the course (e.g. concepts, skills, techniques, etc.)?
5. How would you rate the overall quality of the course?

2.4 Experiential futures project: The Time Machine

Each year student teams were given a (previously published) future scenario to inspire their "Time Machine" assignment. The purpose of the assignment is to create a live, immersive, and interactive experiential scenario of a possible future (see Candy, 2013). Figures 1, 2, and 3 show selected student projects, illustrating some key differences between these assignments from year to year.

Figure 1. Dexign Futures *(2016) Time Machine performances focused on the future of education set in the year 2050. Student performances were on average five minutes long and often had the resolution of a campfire skit.*

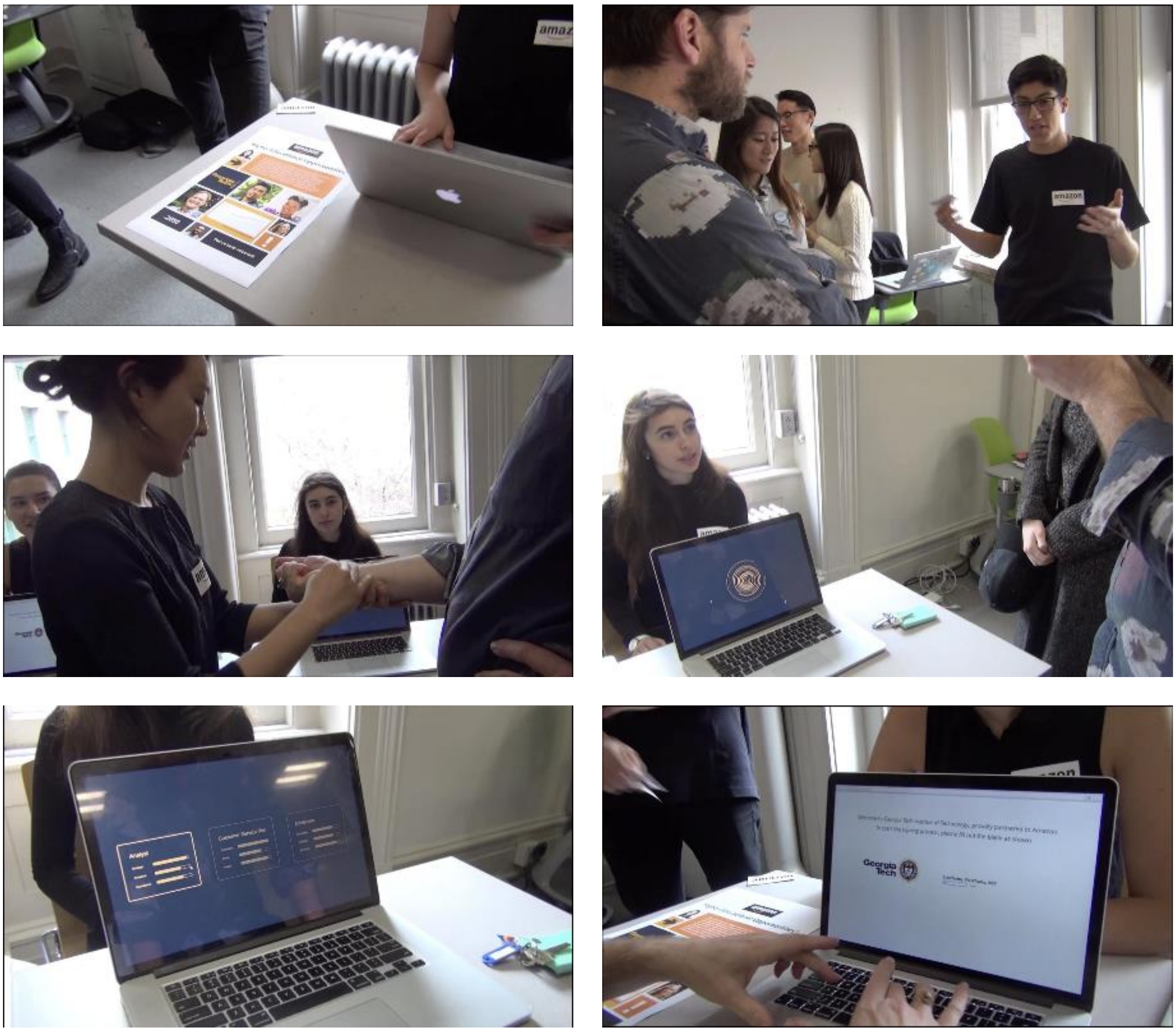


Figure 2. Dexign Futures *(2017) Time Machines again focused on the future of education set in the year 2050. There were two variants: five-minute theatrical performances, and fifteen-minute poster session performances. The project pictured dramatized a scenario where higher education is free because of a university-wide partnership with corporate entities that recruit students to train for specific jobs.*

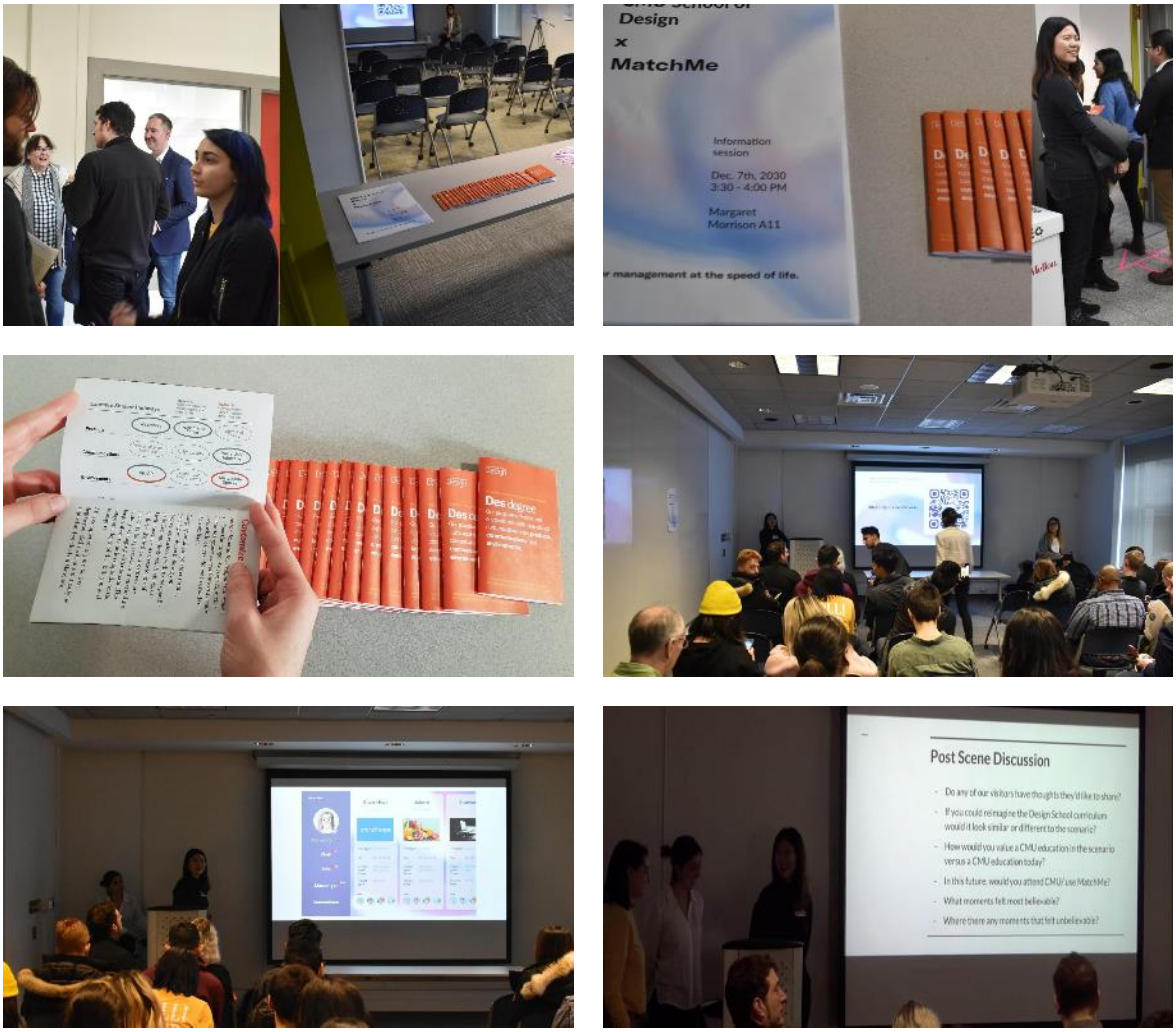


Figure 3. Futures *(2018) Time Machines were immersive scenarios lasting 15 minutes, followed by a 15-minute discussion with participants about the experience and ideas behind it. In a final class debrief , teams presented and reflected both on what worked and on what could have been designed more effectively.*

3 Results

Below we discuss the results in four sections, corresponding to the different measures used: inventory of learning activities, activities perceived by students as contributing to learning, faculty course evaluations, and time machine evaluations.

3.1 Inventory of learning activities

Table 4 lists the learning activities as they appeared in class agendas, and graded homework assignments for each year of the course. The time spent on each activity was estimated by the course instructors for both in-class activity and homework assignments (e.g., OLI pre-work; reading; reflection questions). Figure 4 illustrates an estimate of how much time students spent on graded assignments for the three instances of the course.

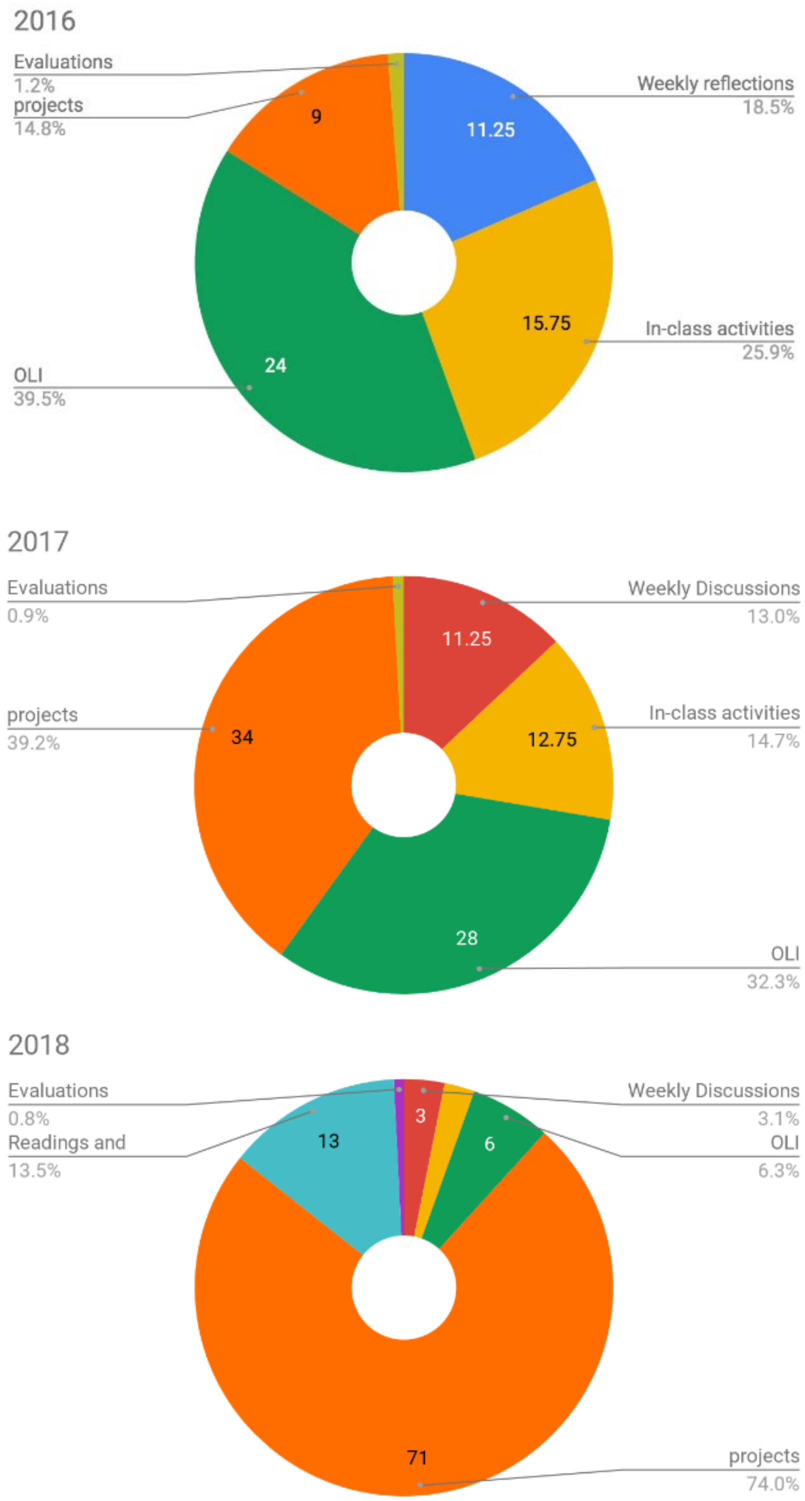


Figure 4. Graded assignments and estimates of in-class and out-of-class time spent expressed in hours spent on each activity. Dexign Futures *2016 (Top);* Dexign Futures *2017 (Middle);* Futures *2018 (Bottom). The circular chart expresses the total percent of hours per graded assignments. Table 4 contains detailed calculations.*

Table 3. Learning activity inventory based on graded work (9 credit course; times are estimates).

	2016	2017	2018
Weekly reflections	15 reflections (45 minutes writing and peer review) 11.25 hours total	15 weekly reflections (30 minutes writing each) (15 minute in-class discussion) 11.25 hours total	6 reflections (30 minutes each) 3 hours total
In-class activities	21 assignments (45 minutes each) 15.75 hours total	17 assignments (45 minutes each) 12.75 hours total	3 assignments (45 minutes each) 2.25 hours total
OLI	12 modules (4 hours each) 48 hours total	14 modules (4 hours each) 56 hours total	3 modules (2 hours each) 6 hours total
projects	1 project (4 hours in class) 9 hours total	1 project (9 hours in class) 34 hours total	3 projects (28 hours in class) 71 hours total
Homework	-	-	12 (15 minutes) 3 hours total
Readings	-	-	10 (1 hour) 10 hours total
Evaluations	3 surveys (15 minutes each) 45 minutes total	3 surveys (15 minutes each) 45 minutes total	3 surveys (15 minutes each) 45 minutes total

3.2 Post-course student survey results

Students answered three open-ended questions at the end of the course (Table 1). Responses were coded iteratively for content using a bottom up approach; identifying themes that could work across all three courses so that comparisons could be made. Below we discuss each question. 3.2.1 Activities perceived by students as contributing to learning The first question was: “What activities in the [*Dexign Futures, Futures*] course do you feel contributed the most to your learning?” in 2016, 44 students responded on average 32 words (SD 24.54). In 2017, 30 students responded on average 28.63 words (SD 29.99). In 2018, 33 students responded on average 34.42 words (SD 27.85). Emergent topics included: Open Learning Initiative materials (OLI), in-class activities, discussion, videos, reflections, experiential futures (i.e., personal artifacts from the future, Time Machines) groups, instructor, lecture, readings, methods, and other (Figure 5).

In total, we coded 110 topics in 2016, 74 topics in 2017, and 45 topics in 2018. In 2016, on average, students listed 2.5 activities contributing most to their learning (SD 1.11); 2017 was similar, with students listing 2.47 activities (SD 2). In 2018, in total, we coded 45 topics students responded on average 1.36 activities (SD 0.55). Table 4 distills students’ evaluation of course activities’ contribution to their learning; Figure 5 shows the same information in a bar graph format.

Table 4. “What activities in the [Dexign Futures, Futures] course do you feel contributed the most to your learning?”

	OLI	Class Activity	Discuss	Videos	Reflect	Time Machine	Artifact	Group	Instructor explains	Read-ings	Method	Other
2016	25%	11%	17%	12%	7%	10%	0%	9%	9%	0%	0%	0%
2017	11%	27%	9%	8%	3%	20%	0%	12%	3%	0%	8%	0%
2018	0%	0%	13%	0%	0%	38%	29%	0%	4%	4%	7%	4%

2016 2017 2018

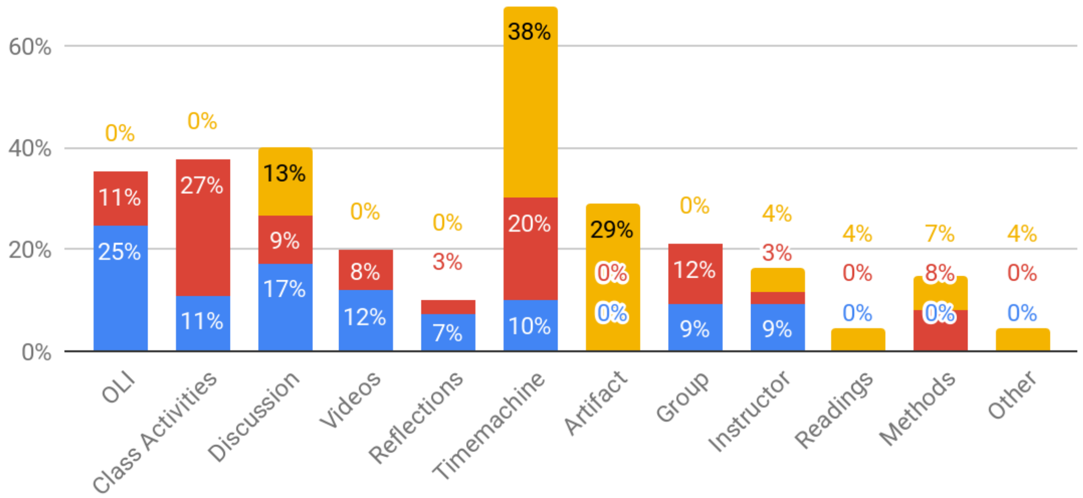


Figure 5. "What activities in the Futures course do you feel contributed the most to your learning?"

3.2.2 Activities perceived to transfer beyond course

The second question was: "What are some concrete examples of how you applied what you learned in the [*Dexign Futures, Futures*] class to things you worked on outside of class (e.g., studio projects, independent projects, own life)?"

In 2016, 44 of 48 students responded on average 74.41 words (SD 71.12). In 2017, 30 of 35 students of responded on average 38.47 words (SD 33.06). In 2018, 30 of 35 students of responded on average 45.70 words (SD 31.50).

We coded in: 2016, 56 topics; in 2017, 34 topics; and in 2018, 34 topics. In 2016, on average, each student listed 1.27 concrete examples (SD 0.54). In 2017, students listed on average 1.13 concrete examples (SD 0.35). In 2018, students listed on average 1.03 concrete examples (SD 0.17). Figure 6 illustrates the key aspects of where students believed they were transferring what they learned in the futures courses to outside activities.

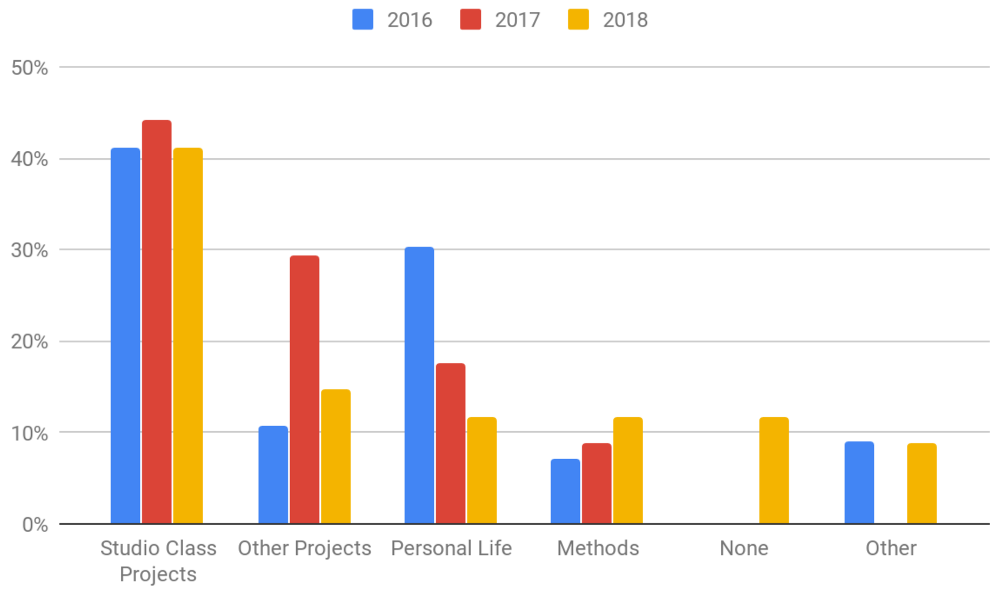


Figure 6. "What are some concrete examples of how you applied what you learned in [Dexign Futures, Futures] *class to things you worked on outside of class (e.g., studio projects, independent projects, own life)?" Student responses as a percent of total comments per year.*

3.2.3 Student suggestions to improve student learning experience
The third question was: "What suggestions do you have to improve the [*Dexign Futures, Futures*] course?" In 2016, 44 of 48 students responded on average 44.5 words (SD 96.01). In 2017, 30 of 35 students responded on average 49.70 words (SD 54.04). In 2018, 30 of 35 students of responded on average 72.09 words (SD 85.99).

We coded: in 2016, 136 topics; in 2017, 76 topics; and in 2018, 79 topics. In 2016, on average, each student listed 3 improvement topics (SD 1.85); in 2017, students listed 2.53 improvement topics (SD 1.41); in 2018, students listed 2.39 improvement topics (SD 1.65). Figure 7 illustrates the percentage of student suggestions for improvement topics by year.

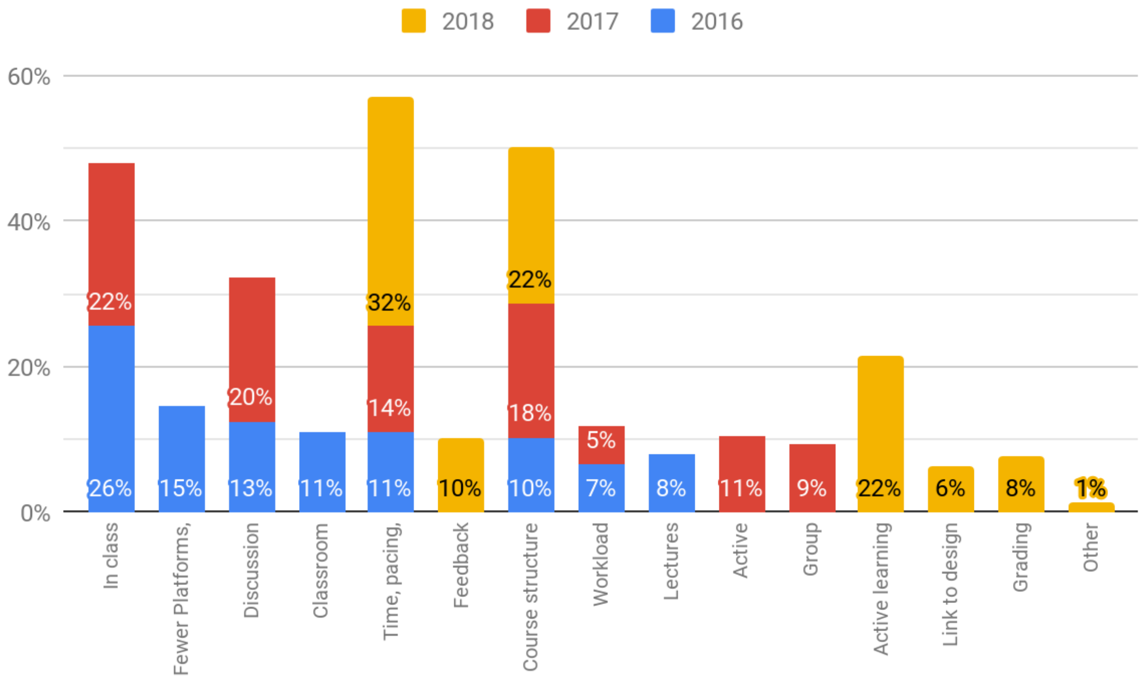


Figure 7. "What suggestions do you have to improve the [Dexign Futures, Futures] *course student experience for next year?" Student responses as a percent of total comments per year.*

3.3 Faculty Course Evaluation (FCE) Results
In 2016, 43 of 48 students (89%) filled out the FCE; in 2017, 31 of 35 students (88%) filled it out; and in 2018, 29 out of 38 students (76%) filled out the FCE. An ANOVA analysis was conducted to compare students' responses to the ten FCE questions in the 2016, 2017, and 2018 courses (Table 5). We report on five questions analyzed below (Figures 8 - 12).

*Table 5. Faculty course evaluation questions for Scupelli, courses taught in 2016, 2017, and 2018. Averages calculated for five point Likert scale values (1=Poor, 2=Below Average, 3=Average, 4= Above average, 5=Excellent). * p < .05; t p < .15. In italics are the questions discussed in this paper.*

	2016	2017	2018
1. Weekly hours spent on class	*6.86^{at} (SD 2.96)*	*5.77^{at} (SD 2.79)*	*6.55 (SD 2.96)*
*2. Feedback to improve performance **	*3.10^{a*} (SD 1.23)*	*3.71^{a*b*} (SD 1.16)*	*2.90^{b*} (SD 1.08)*
*3. Importance of subject **	*3.79^{a*} (SD 1.07)*	*4.23^{a*b*} (SD 0.80)*	*3.2^{b*} (SD 1.10)*
*4. Explains the subject matter **	*3.43^{a*} (SD 1.15)*	*3.94^{a*b*} (SD 1.00)*	*3.03^{b*} (SD 1.09)*
*5. Rate quality of course **	*2.79^{a*} (SD 1.01)*	*3.58^{a*b*} (SD 0.76)*	*2.72^{b*} (SD1.22)*

- There were no significant differences for weekly hours spent on the class (Figure 8).
- There was a significant effect of year for Question 5, ‘instructor provides feedback to improve performance’ at the $p<.05$ level for the three conditions [$F(2, 100) = 4.14$, $p < .02$] (Figure 9). A post hoc Tukey test showed that more feedback was provided in 2017 compared to 2018 ($p < .02$).
- There was a significant effect of year for Question 6, ‘instructor explains importance and significance of subject’ at the $p<.005$ level for the three conditions [$F(2, 100) = 6.57$, $p < .002$] (Figure 10). A post hoc Tukey test indicated significantly more ‘explanation of importance and significance of subject matter’ was provided in 2017 compared to 2018 ($p < .001$).
- There was a significant effect of year for Question 7, ‘instructor explains subject matter’ at the $p<.01$ level for the three conditions [$F(2, 100) = 6.08$, $p < .007$] (Figure 11). A post hoc Tukey test showed that students perceived more ‘explanation of subject matter’ in 2017 compared to 2018 ($p < .005$).
- There was a significant effect of year on Question 10, ‘overall quality of the course’ at the $p<.005$ level for the three conditions [$F(2, 97) = 6.96$, $p < .002$] (Figure 12). A post hoc Tukey test showed that the quality of the 2016 course was rated significantly lower than in the 2017 course ($p < .005$); and the 2017 course was rated significantly higher than the 2018 course ($p < .005$).

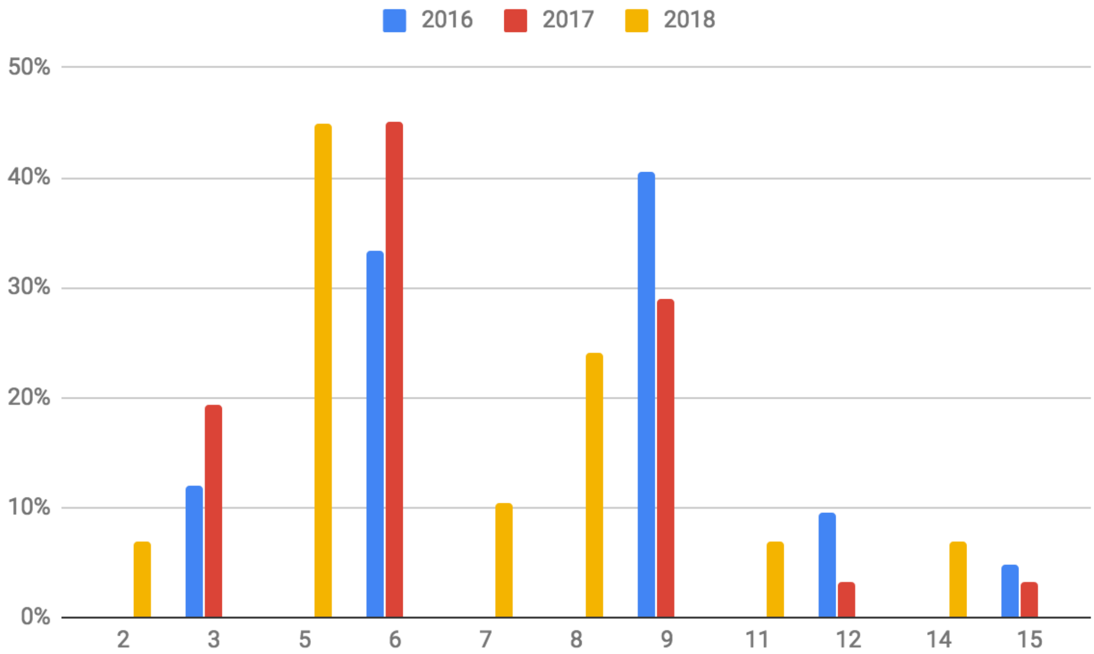


Figure 8. “On average, how many hours per week have you spent on this class, including attending classes, doing readings, reviewing notes, writing papers and any other course-related work?”

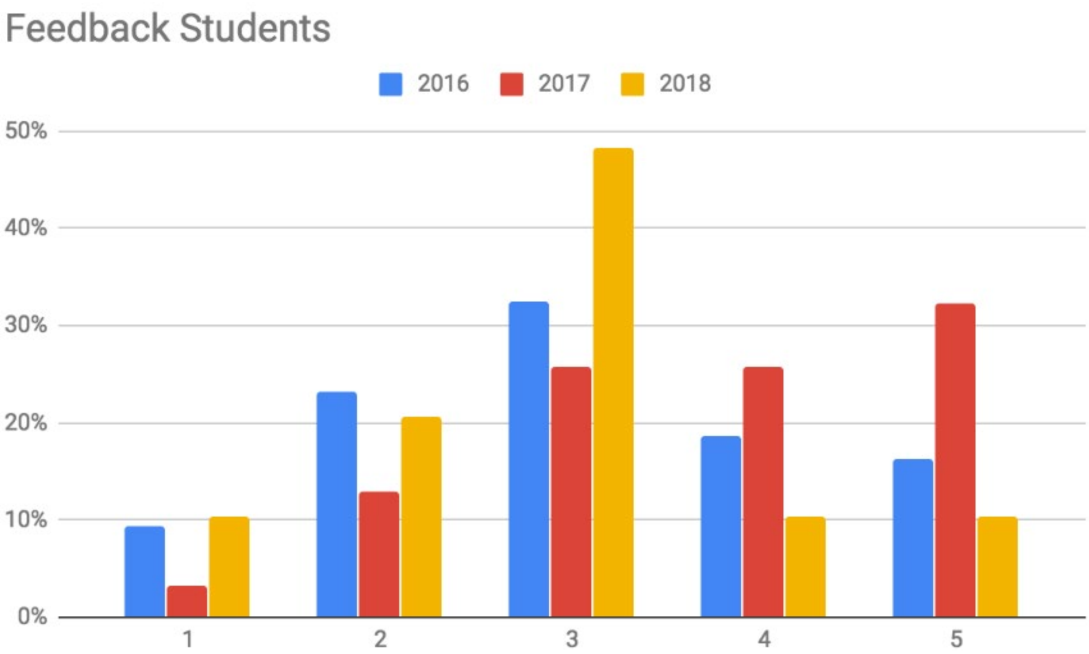


Figure 9. "Does the faculty member provide feedback that helped students improve their performance?" (1=Poor, 2=Below Average, 3=Average, 4= Above average, 5=Excellent).

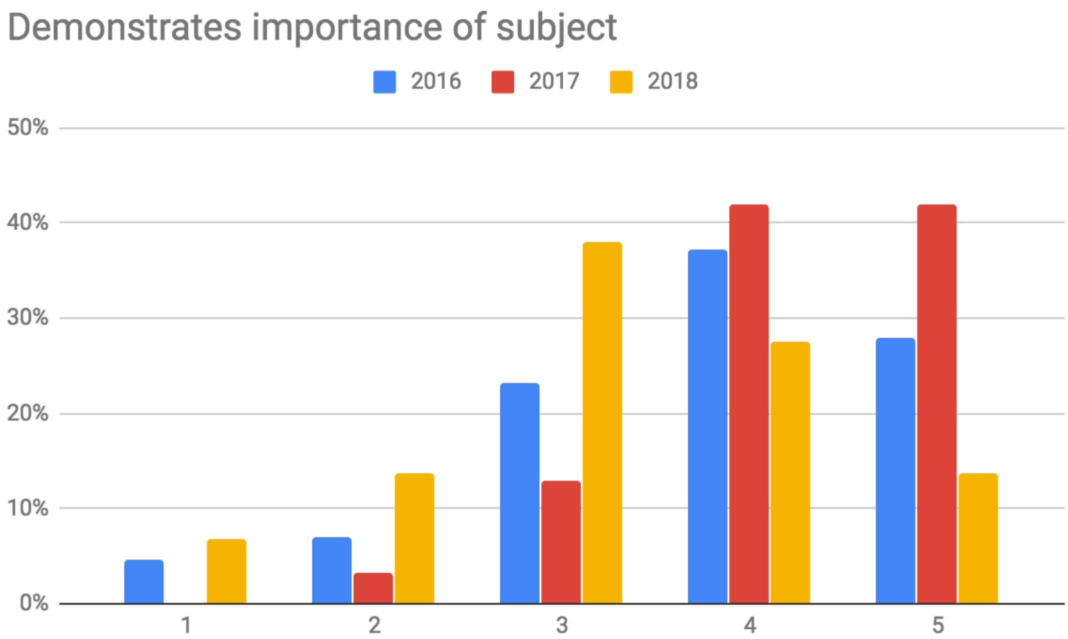


Figure 10. "Does the faculty member demonstrate the importance and significance of the subject matter?" (1=Poor, 2=Below Average, 3=Average, 4= Above average, 5=Excellent).

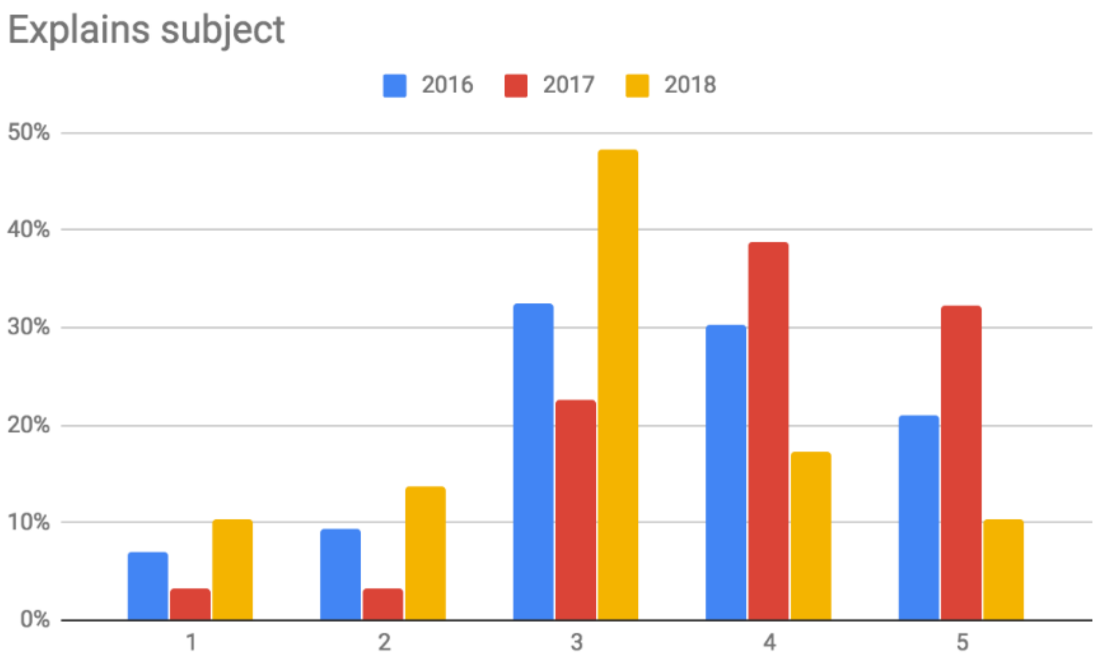


Figure 11. "Does the faculty member explain the subject matter of the course (e.g. concepts, skills, techniques, etc.)?" (1=Poor, 2=Below Average, 3=Average, 4= Above average, 5=Excellent).

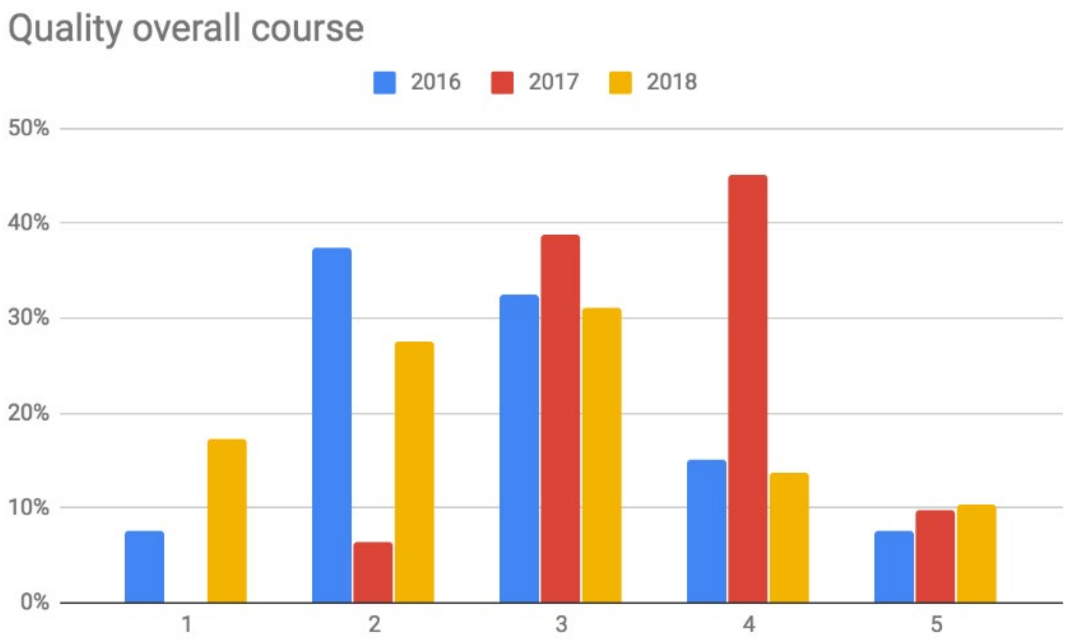


Figure 12. "How would you rate the overall quality of the course?" (1=Poor, 2=Below Average, 3=Average, 4= Above average, 5=Excellent).

3.4 Time Machine results

Time spent on the experiential scenarios assignments, and instances of feedback provided along the way, were calculated for each year (Table 6).

Table 6. Time spent on the experiential futures assignments, and instances of feedback

	Time on assignment	Number of classes	Contact time	Expected homework time	Feedback given
2016	1 Week	3 x 80 minutes	4 hours	6 hours	1
2017	4 Weeks	7 x 80 minutes	9 hours	25 hours	3
2018	6 Weeks	6 x 170 minutes	17 hours	37 hours	5

4. Discussion and future work

Next we discuss the findings according to multiple cross-cutting themes for the four data collected (i.e., learning activity inventory, online student learning experience survey, faculty course evaluations, immersive scenarios). Five insights emerge between the 2016-2017 *Dexign Futures* courses[2] in relationship to the 2018 *Futures* course: (a) reflection format shapes knowledge transfer, (b) time on learning tasks shapes perceptions of learning, (c) less is more (for learning), (d) more is better (for learning), and (e) timing is everything (for learning).

4.1 Reflection format associated with knowledge transfer

We interpret Figure 6 to mean that students transferred differently what they learned in each course based on the course's features each year (Figure 4; Table 3). Given the nature of these case studies, we can only speculate about the causation of such associations. We frame our interpretations with a view to enabling future field experiments to empirically test these hypotheses.

Studio course transfer. In all three courses, over 40% of the students claimed that they applied lessons from the futures class to their studio courses.

We notice three interesting spikes in Figure 6 regarding transferring what was learned in the *Dexign Futures* courses for "personal life" in 2016, "other projects" in 2017, and for *Futures* "none" in 2018. What might explain such differences? We suspect two factors in particular: differences in the format of the weekly reflections between 2016-2017, and differences in the total number of reflections assigned (15 in 2016-2017 vs. 6 in 2018).

We interpret with caution here given a single open-ended question, subject to self-presentation bias in student responses; future work should more robustly assess knowledge transfer to studio courses with the use of multiple measures. For example, how effectively do they incorporate futures methodologies in studio projects?

Personal life transfer. In 2016 we see a spike in students reporting learning being applied to their "personal life" (Figure 6). Different reflection prompts were provided in each course. In 2016, they wrote weekly reflections on a personal blog, and were required to review peer contributions. Each time they answered three questions: What did you learn this week? How might you apply what you learned to other projects you are working on (e.g., in studio course, other projects, personal life)? How might your design practice change to accommodate what you learned? Scupelli made this course design choice to promote students' transfer of *Dexign Futures* learning to other contexts/projects/life. In 2016, some

[2] For detailed discussion on the 2016-2017 Dexign Futures courses see Scupelli & Brooks 2018. Five key points were identified: match physical classroom format to in-class hands on activities, streamline online learning environments, reduce online cognitive load, scaffold time-critical activities, and require thinking fast and thinking slow.

students questioned the value of answering the same questions each week and described the peer-review component tedious.

Other projects transfer. In 2017, Scupelli overhauled the weekly reflections by prompting students to reflect on specific topics covered each week. In an online discussion board, students were required to write a reflection and comment on the posts of two other classmates. In class, small groups then discussed comments received and one person reported any patterns noted to the whole cohort. We hypothesize that the spike in "other projects" for 2017 in Figure 6 may be linked to this format, although further empirical work is needed to test what type of reflection questions, format, and timing promote better learning transfer.

No transfer. In 2018, the *Futures* course was designed to operate more like a studio course with an emphasis on learning by making. Three making projects were central (personal future artifact; future artifact for a classmate; Time Machine). Given the increase in making outside of class, we reduced the total number of weekly reflections to six, assigning three in the first three weeks of the course to follow the introduction of key concepts; and the other three to coincide with key readings and stages in the assignments. Unlike in 2017, the online reflections were not reincorporated into the classroom for collective discussion. We speculate that the total number of reflections, and lack of in-class discussion on the student reflections is linked to the 10% of students that professed to find no clear connections between the course and their external activities.

Other data sources confirm the trend; in the 2018 FCE, students rated the 'importance of subject matter' (Figure 10) and 'instructor explains subject' significantly lower than in 2017 (Figure 11). More empirical work is needed to understand how reflections and discussions have worked for learning in the various course contexts. One possible future research direction would be to code the content of reflections across multiple years to look for deeper patterns.

Limitations. The observed differences in student comments on transfer activities could be due to external factors such as current events, or possible differences among the three cohorts (Figure 6). An example of a potentially confounding external event is the 2016 United States presidential election of Donald J. Trump.[3] In particular, foreign students, minorities, women, and GLBTQ students worried about future discrimination. Future work could probe links between political climate and students' views on their personal futures, and further content analysis would be needed to uncover the deeper differences each year.

We found no significant differences among cohorts. Each was mostly composed of third year design students (with 2-3 non-design majors each year). The university admissions process for design students was the same for the three years. Furthermore, we see no significant differences in the distribution of gender, countries of origin, or age. Though theoretically possible, it seems unlikely that cohort differences are driving the results.

4.2 Time on task shapes perceived learning

There are many different ways to teach futures. Figure 4 illustrates the differences of time spent on learning activities by course year. Figure 5 shows the activities that students said contributed most to their learning each year. Previously, Scupelli and Brooks (2018) noted

[3] Donald J. Trump was elected as US president, the Senate, and House of Representatives all had Republican majorities. Some students expressed dismay and strong emotions after the election (e.g., concern about the impact on their lives and career plans; agency/ability to design positive futures). It is plausible that international students on with a student visa, racial minorities, and GLBTQ students may have feared personal impacts on their future plans and thus reflected more about their personal futures.

that the features of the OLI and in-class activities in 2016 and 2017 were salient to students (Figure 5). Looking across all three courses, it appears that students' focus on learning activities correspond to time spent on them (Figure 4; Table 3).

The learning activities are the vehicle to teach futures studies, not the destination. The question: "What activities in the [*Dexign Futures, Futures*] course do you feel contributed the most to your learning?" likely biased students toward describing more superficial aspects of the learning activities, rather than the deeper perspectival shifts that we hope students may cultivate. Future work should ask directly about key ideas learned for each learning activity and the course, and explore the content of reflections to link the articulation of the core ideas to the different learning activity inventories for each year.

4.3 Less is more (for learning)

In 2016 students wanted less: (a) lecture hall and more of a design classroom to match the teaching style of the flipped classroom; (b) fewer online platforms, (i.e., wordpress course, Blackboard™, Peermark™ for reviews, student online journals); (c) shorter assignments that could be finished in class.

In 2017, students wanted fewer fast-paced in-class assignments and more slow-paced homework assignments. Consequently, projects in the 2018 course were designed so that in-class assignments would have homework components. The 2018 course differed with students wanting less time spent on the in-class parts of artifact-based assignments, running past the end of class, and less complex instructions in scaffolded assignments. It is unclear if the student desires is driven by the type of exercise, the class duration (3 hours), or both factors together. These insights are informing the redesign of the 2019 edition.

4.4. More is better (for learning)

Four factors from 2018 could be seen as pointing to the principle that "More is better": scaffolding, feedback, links to professional practice, and active learning.

Scaffolded in-class activities. The learning science literature describes the nuanced yet positive role of scaffolding (e.g., Hogan & Pressley, 1997). In 2016, limited scaffolding of in-class activities created a need for more discussion around them (Figure 13). This reduced time available for hands-on activities, which were therefore often finished as homework.

Figure 13. Dexign Futures *instructor scaffolding student questions on in-class activities in real time during class. This reduced the time available for these activities so that students had to finish them outside class.*

In 2017, more scaffolded activities allowed students to finish assignments during class time. The in-class activities were explicitly mapped to new material learned in OLI beforehand, and through 5-minute mini-lectures in class. Each activity listed learning objectives and provided step-wise instruction (Figure 14). The instructor time-boxed each activity and circulated to answer students' questions, surfacing common questions to the full class. Each class ended with a recap discussion complemented with an online sum up of key take-aways. Students commented that they were able to work quickly through these activities within the 80-minute class time allotted, but lamented that they wanted time outside to work and think more slowly and reflect about the ideas.

In 2017, the in-class activities played a larger role in supporting learning, with the intent to help students to integrate futures methods more deeply (Figure 5). However, the fast pace left some wanting more time to work on assignments outside of class, and more time in class for discussion. In 2018, we developed assignments that mixed fast-paced in-class activities with slower-paced project-based homework, and added in-class discussion of finished assignments.

In 2018, the two "Ethnographic Experiential Futures" (see Candy & Kornet, 2019) artifact-centred projects used detailed stepwise scaffolding in class, combined with homework tasks to accommodate multiple speeds of thinking. With the class meeting once weekly for 170 minutes, some students said the scaffolded in-class activities were tedious and repetitive; others described them as engaging and intense.

The scaffolded activities in 2018 instructed students on what to do, but may have benefited from closer and repeated reference to learning objectives, and explicit theoretical framing linking in-class activities to prior readings.

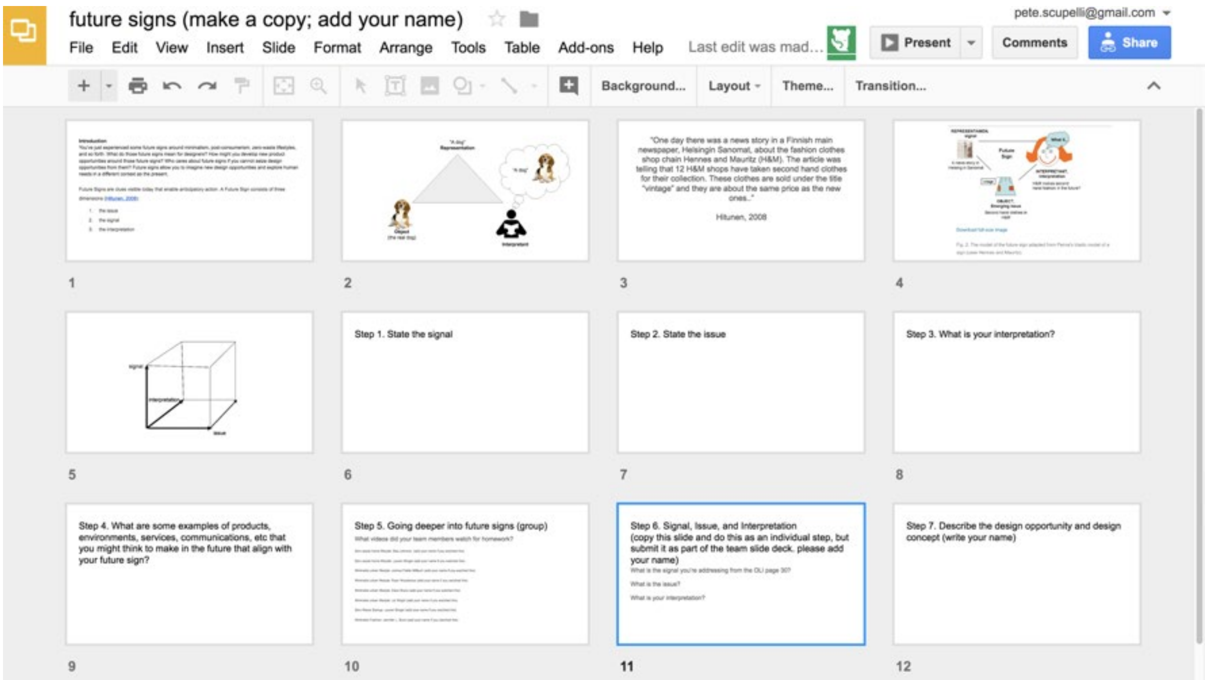


Figure 14. Google slide deck shared with students in 2017 for the same session as Figure 15. The slide deck includes a 5 slide mini-lecture followed by stepwise instruction for students to follow.

Feedback was not mentioned as an issue in the 2016 and 2017 courses (Figure 7) though there was a significant increase in feedback reported in FCEs (Table 6; Figure 9). The OLI homework likely provided immediate correctness and explanatory feedback. And for the interactive in-class activities the design classroom in 2017, compared to the 2016 lecture hall, afforded more interaction and feedback opportunities for peer and instructor feedback. In future work scheduled for Fall 2019, we plan to use a fully instrumented classroom to explore such hypotheses empirically.

In the 2018 course, students expressed lower levels of feedback given (Figure 9). We conjecture that this may be the result of assigning readings combined with a homework comprehension quiz that provided correctness feedback only, as well as an unusual peer-to-peer review process for “future artifact” creation that might be more explicitly highlighted as a form of project feedback and insight. Some students struggled with the first artifact design projects, where peer responses were incorporated as the primary feedback mechanism, and reported a desire for additional in-process feedback from instructors.

The 2018 artifact assignments were scaffolded with explanation and process guidance to the point of being nearly self-explanatory. However, some students still produced concepts that could be critiqued as glib or uninteresting from a critical futures perspective; for instance, in positing an idealized personal future unmoored from larger societal concerns.

The challenging task of creating personal future artifacts was scaffolded with more “how-to” and process-oriented assistance, but less directive with regards to “what to make” in the service of greatest meaning and impact. More personalized process feedback may help newcomers to avoid the trap of superficial personal futures, although individualized in-progress feedback at the scale of ~40 students is a perennial structural challenge.

Noting this difficulty in the first half of the 2018 course, we incorporated five feedback touchpoints for the experiential futures project in the second half of semester, responding to the evolving plans of eight project groups, both in writing and during class sessions.

Next, we interpret the differences in grades of student learning on the Time Machine project for the three years the assignment was given.

First, time on task estimates, measured as number of hours spent on the Time Machine assignments, went from 10 hours in 2016 to 34 hours in 2017 and finally to 54 hours in 2018 (Figure 4, Table 3). The increased time afforded students more opportunities to generate and explore ideas, refine their thinking, and iterate. Dow’s research shows that exploring more design ideas is linked with higher quality design outcomes (e.g., Dow et al., 2011).

Second, instances of feedback on the Time Machine project rose from one, to three, to five. In 2018, feedback was both written and face-to-face in class throughout different stages of the project. Meta-analysis studies on over 800 published studies indicate that feedback is the single most effective intervention for learning (Hattie, 2008).

Third, co-instructors can offer more support to the students than one instructor; furthermore, having two instructors from different backgrounds can provide alternative perspectives and the potential to broaden student thinking.

Link to design. Noticing the linkages between a topic and professional practice is inherently motivating to students (Ambrose et al. 2010), and highlighting multiple connections to professional practice (e.g., methods, content expertise, professional skills) helps students to persist in face of learning challenges.

To our surprise, in 2018, 6% of student responses (N=79) missed how the *Futures* course related to design (Figure 7) and 12% could not connect the course with other projects or their personal life (Figure 6). We speculate that six activities in a multi-tier strategy utilized in the 2016-2017 *Dexign Futures* courses allowed students to make more connections to design practice: (a) mini-lectures in class prior to the in-class activity, (b) applied workshop-like exercises that forced students to apply concepts learned in the online modules to specific design thinking problems, (c) lesson recaps reinforcing the connections (both verbal and written in the class agenda), (d) weekly reflections where students were explicitly prompted to make connections to design, (e) students discussing and presenting back on their online reflections, and (f) the instructor's practice of explicitly describing how such future methods applied to his own professional practice and how such methods could be used in studio projects. Future work will explore if the six-tier strategy is indeed linked to deeper connections between futures studies and design practice.

Active learning. Research indicates active learning is better for learning outcomes; unsurprisingly we also found it to be more effortful for students. The learning science community clearly links active learning to improved learning outcomes. As previously mentioned, limited interaction in class with content and instructor may result in superficial understanding rather than deep learning (e.g. Pellegrino & Hilton, 2012).

In 2016-2017 the class activities were based on extremely active learning modes, and students voiced a desire for more passive sessions (e.g., lectures). In 2017 students commented on how intense the 80-minute class sessions were, due to constant active learning and time pressure to complete tasks due by the end of class. By contrast, in 2018 the requests were for more active modes such as interactive critiques, fishbowl discussions, and participatory discussions (Figure 7); all of which were used in the course in differing proportions. During lectures and class discussions some tendencies towards student disengagement emerged, with the ever-present temptations of laptops and mobile devices; also likely hindered by scheduling (three-hour sessions each Friday afternoon). These two observations point to the challenge of striking a balance between active learning activities and passive learning, especially in relation to class duration.

4.5 Timing is everything (for learning)

Time management, timing, and pacing were mentioned in all three courses (Figure 7). In 2016 and 2017, students commented on lacking time to finish the in-class activities. In 2018, students related three issues with the once-weekly, 170-minute class: (a) a strict absentee policy (because the class met only once a week, missing any class meant missing a lot); (b) the end-of-week timeslot (Fridays 1:30-4:20pm) was unpopular, and classes often ran slightly long; (c) students opined that too much time was spent on the first two artifact-based projects, relative to the Time Machine group project.

There were no significant differences in average number of hours that students reported spending on the courses (Table 6).

In Fall 2019, we plan to split the futures studies requirement into two 7-week mini courses. Scupelli will teach *Futures 1* as two weekly 80-minute classes, with a condensed version of the *Dexign Futures* course described, focused on linking futures methods to design practice and using a flipped design classroom pedagogy (e.g., OLI interactive homework, in-class hands-on activities, weekly reflections). Candy will teach a studio-based format for 170 minutes weekly, called *Futures 2*, focused on experiential futures. New data collected from the *Futures 1&2* mini courses may help clarify the multiple factors at play.

5 Summary

In this paper, we compared two versions of a futures studies course developed as a core class for undergraduate design students: *Dexign Futures* (flipped pedagogy) and *Futures (studio hybrid)*.

We looked at three measures in particular: learning activity inventory, course quality with faculty course evaluations, student experience with a post-course survey.

We found five design trade-offs for teaching and learning: format of reflections is linked to transfer activities, time on learning activities shapes perceptions, less (interference) is more, more (scaffolding, feedback, links to practice, active learning) is better, and timing is everything.

The data presented in this paper also informs our plans for the next iteration of *Futures* courses. We expect to see gains in FCE scores similar in scale to what we observed between the first two runs of *Dexign Futures* courses (Figure 12). Clearly more research is needed to disambiguate the questions raised in this paper.

6 References

Ambrose, S. A., Bridges, M., DiPietro, M., Lovett, M., Norman, M., & Mayer, R. E., (2010). How learning works: Seven research-based principles for smart teaching. San Francisco: Jossey-Bass.

Bell, W. (2003). Foundations of Futures Studies (Vol. 1, rev. ed.). New Brunswick, NJ: Transaction.

Bergmann, J., & Sams, A. (2012). Flip your classroom: Reach every student in every class every day. Eugene: International Society for Technology in Education.

Boling, E., Schwier, R., Campbell, K., Smith, K. M., & Gray, C. M. (2015). Studio teaching in higher education: Selected design cases. London : Routledge

Brand, S. (1999). The Clock of the Long Now. New York: Basic Books.

Candy, S. (2010). The futures of everyday life (Doctoral dissertation, University of Hawaii at Manoa).

Candy, S. (2011). Strategic Foresight. In N. Shedroff (Ed.), Design strategy in action (pp. 91–98). San Francisco: California College of the Arts.

Candy, S. (2013). Time machine / Reverse archaeology. In C. Briggs (Ed.), Seventy-two Assignments: The foundation course in art and design today (pp. 28–30). Paris: PCA Press.

Candy, S. (2014). Experiential futures. The Futurist, 48(5), 34–37.

Candy, S. (2017). Dreaming together. In T. Durfee & M. Zeiger (Eds.). Made up: Design's fictions (pp. 44–48). New York: ArtCenter Graduate Press / Actar.

Candy, S. (2018). Gaming futures literacy: The thing from the future. In R. Miller, Transforming the future: Anticipation in the 21st century (pp. 233–246). New York: Routledge / UNESCO.

Candy, S. & Dunagan, J. (2017) Designing an experiential scenario: The people who vanished, Futures, 86, 136–153. http://dx.doi.org/10.1016/j.futures.2016.05.006

Candy, S. & Kornet, K. (2019). Turning foresight inside out: An introduction to ethnographic experiential futures. Journal of Futures Studies, 23(3): 3–22.

Dator, James A. (2002). Advancing futures: Futures studies in higher education. Westport, CT: Praeger.

Davis, M. (2017). Teaching design: A guide to curriculum and pedagogy for college design faculty and teachers who use design in their classrooms. New York: Allworth Press.

Dow, S., Fortuna, J., Schwartz, D., Altringer, B., Schwartz, D., & Klemmer, S. (2011, May). Prototyping dynamics: sharing multiple designs improves exploration, group rapport, and results. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (pp. 2807-2816). ACM.

Dunagan, Jake, et al. (2019) Strategic foresight studio: A first-hand account of an experiential futures course. Journal of Futures Studies, 23(3): 57–74. doi:10.6531/JFS.201903_23(3).0001

Dunne, A., & Raby, F. (2013). Speculative everything: Design, fiction, and social dreaming. Cambridge, MA: MIT Press.

Durfee, T., & Zeiger, M. (Eds.). (2017). Made up: Design's fictions. New York: ArtCenter Graduate Press / Actar.

Farías, I & Wilkie, A., (2016). Studio studies: Operations, topologies and displacements. London ; New York : Routledge, Taylor & Francis Group

Frascara, J. (2002). Design and the social sciences: Making connections. New York: Taylor & Francis.

George, J. M. (1992). Extrinsic and intrinsic origins of perceived social loafing in organizations. Academy of Management Journal, 35(1), 191-202.
Gidley, Jennifer M. (2017). The Future: A Very Short Introduction. Oxford, UK: Oxford University Press.
Hattie, J. (2008). Visible learning: A synthesis of over 800 meta-analyses relating to achievement. routledge.
Hogan, K., & Pressley, M. (Eds.). (1997). Advances in learning & teaching. Scaffolding student learning: Instructional approaches and issues. Cambridge, MA, US: Brookline Books.
Irwin, T., Kossoff, G., Tonkinwise, C., Scupelli, P. (2015). Transition Design. Pittsburgh, PA: Carnegie Mellon School of Design.
Kossoff, G. (2011). Holism and the reconstitution of everyday life: A framework for transition to a sustainable society (Doctoral dissertation). University of Dundee, Centre for the Study of Natural Design, Dundee, Scotland.
Lawson, B., & Dorst, K. (2015). Design expertise. Abingdon, Oxfordshire ; New York : Architectural Press, an imprint of Routledge.
Lyon, P. (2012). Learning and teaching through design: An anthology of models, approaches and explorations. Burlington: Gower Pub. Co.
McCarthy, J. (2016). Reflections on a flipped classroom in first year higher education. Issues in Educational Research, 26(2), 332-350. http://www.iier.org.au/iier26/mccarthy-j.html
Nathan, M. J., Koedinger, K. R., & Alibali, M. W. (2001, April). Expert blind spot: When content knowledge eclipses pedagogical content knowledge. In Proceedings of the third international conference on cognitive science (pp. 644-648).
Pellegrino, J. W. & Hilton, M. L. (2012). Education for Life and Work: Developing Transferable Knowledge and Skills in the 21st Century. Washington, DC: The National Academies Press.
Schön, D.A. (1990). Educating the reflective practitioner: Toward a new design for teaching and learning in the professions. San Francisco, Cal: Jossey-Bass.
Schwartz, P. (2004). Inevitable surprises: Thinking ahead in a time of turbulence. London: Free.
Scupelli, P. (2019) Teaching to Transition Design: A Case Study on Design Agility, Design Ethos, and Dexign Futures, Cuadernos del Centro de Estudios de Diseño y Comunicación Nº73, pp 111-132.
Scupelli, P. (2016). Designed transitions and what kind of design is transition design? Design Philosophy Papers, 13(1), 75–84.
Scupelli, P., & Brooks, J. (2018) What Features of a Flipped Course Improve Design Student Learning Experiences? 21st DMI: Academic Design Management Conference, Next Wave, London, UK, 1-2 August, 2018.
Scupelli, P., Wasserman, A., Wells-Papanek, D. & Brooks, J. (2018) The Futures of Design Pedagogy, Learning, and Education. 21st DMI: Academic Design Management Conference, Next Wave, London, UK, 1-2 August, 2018.
Scupelli, P., Wells-Papanek, D., Wasserman, A., & Brooks, J. (2017) Opening a Design Education Pipeline from University to K-12 and Back. IASDR 2017 Re: Research. Cincinnati, October 31 - November 3, 2017.
Scupelli, P., Brooks, J. & Wasserman, A. (2016) Making Dexign Futures learning happen: A case study for a flipped, Open-Learning Initiative course. Design Educators IDSA International Conference 2016: Making Things Happen. August 17-20, Detroit, MI, USA.
Scupelli, P., Wasserman, A., Brooks, J. (2016). Dexign Futures: A Pedagogy for Long-Horizon Design Scenarios. Proceedings of DRS 2016, Design Research Society 50th Anniversary Conference. Brighton, UK, 27–30 June 2016.
Steffen, A., & Gore, A. (2008). Worldchanging: A user's guide for the 21st century. New York, NY: Abrams.
Stewart-Wingfield, S., & Black, G. S. (2005). Active versus passive course designs: The impact on student outcomes. Journal of Education for Business, 81(2), 119-123.

Strauss, A., & Corbin, J. (1994). Grounded theory methodology. Handbook of qualitative research, 17, 273-285.
Thorndike, E.L. (1920). A constant error in psychological ratings. Journal of Applied Psychology, 4(1), 25-29. http://dx.doi.org/10.1037/h0071663
Toffler, A. (1990). Future shock. Bantam.
Tovey, M. (ed) Design Pedagogy. (2015). Taylor & Francis Ltd.
Wasserman, A., Scupelli, P., & Brooks, J. (2015) Learning to Dexign the Future. Design Educators Asia Conference 2015. December 1-2, Jockey Club Innovation Tower, Hong Kong, China.
Wasserman, A., Scupelli, P., & Brooks, J. (2015) Learn!2050 and Design Futures: Lessons learned teaching design futures. Design Educators IDSA International Conference 2015: Future of the Future. August 19-22, Seattle, WA.
WBCSD - World Business Council for Sustainable Development. (2009). Retrieved from http://www.wbcsd.org/vision2050.aspx

About the Authors:

Peter Scupelli is the Nierenberg Associate Professor, Chair of the Environments Track, and Director of the Learning Environments Lab in the School of Design at Carnegie Mellon University. He holds a PhD in HCI, MDes. in interaction design, and an architecture degree.

Stuart Candy (BA/LLB, MA, PhD) is Director of Situation Lab and Associate Professor at CMU School of Design, where he leads the initiative to integrate foresight throughout the curriculum. He has developed approaches to design and futures that are used by leaders, researchers and creatives worldwide.

Judy Brooks is Director of EdTech & Design at CMU's Eberly Center for Teaching Excellence & Educational Innovation. Judy consults with faculty on technology-enhanced learning (TEL) projects, course design, and teaching. She directs and implements TEL initiatives and programs.

Acknowledgements: We would like to thank the following: Arnold Wasserman for his ground breaking work in the 2013 Dexign the Future class while the visiting 2013 Nierenberg Chair. The Nierenberg Family for support to Peter Scupelli as the Nierenberg Associate Professor of Design. Second, the Wimmer Family Foundation for the support of Peter Scupelli as a Wimmer Faculty Fellow in 2013-2014. And, third the Eberly Center for Teaching Excellence and Educational Innovation at Carnegie Mellon University for their continued encouragement and support.

The Role of the Brief in Supporting Creative Ideation in the Design Studio: Quantitative Requirements and Visual Props

Casakin, Hernan*[a]; Koronis, Georgios[b]; Silva, Arlindo[b]

[a] Ariel University, Ariel, Israel
[b] SUTD-MIT International Design Centre, Singapore; University of Technology and Design, Singapore
* casakin@ariel.ac.il

This study identifies ways to assess and improve creativity among student designers in the design studio. We examine the influence of different kinds of stimuli and communicated requirements on idea generation in creative design outcomes. The procedure entails a controlled yet analytical approach to measure and determine whether the stimuli of quantitative data, visual and physical stimuli can potentially affect creativity. The first factor controls how much numerical/descriptive information should be provided in brief composition. The second factor controls whether visual props should be attached to the brief. The third factor controls whether physical props should be provided to the teams before the ideation sessions. The statistical analyses, along with the qualitative analysis, suggests that design briefs with quantitative data and visual props produce high scoring ideas for both appropriateness and usability, while inversely affecting novelty measures.

Keywords: design brief; quantitative requirements; visual props; creative ideation; design studio

1 Introduction

Design is an ill-defined, complex, and multifaceted problem-solving activity concerned with cognitive abilities, such as creative thinking. During the process of solving design problems, novice design students face several issues, including underdeveloped knowledge structures, and insufficient communication with their instructors (Yang et al., 2005). Another challenge is that design problems are fuzzy, and students are rarely aware of how their design solutions are evaluated. While some degree of ambiguity is desirable to promote innovation and creativity in the design studio, instructors should take care to provide the necessary conditions for minimal frustration and confusion (Sawyer, 2017). This raises the question about the kind of design brief that should be given to the students.

The design brief is a document available from the beginning of the design process, that is used by an individual or a workgroup to outline the expectations for the commissioned design task. In consultation with the 'client', the design brief articulates in a condensed form the desired results and the businesses', persons' or organizations' needs for the design. It generally conveys what is to be achieved for the client, but by no means the way to do it (Koronis et al., 2019). It is frequent that design instructors are not always conscious of insufficiently tackling this problem, and consequently, they do not facilitate appropriate resources to support students during the design problem-solving activity. Addressing this gap is highly impactful because the way that the design problem is described in the brief, together with the available stimuli supporting the design assignment, has a determinant influence on the creativity of the design outcomes.

Unclear communication of helpful sources for problem resolution can lead to misunderstandings and have a negative influence on the students' motivation to produce innovative outcomes. Therefore, a brief constructed with relevant information, paired with a supportive environment is crucial to understanding the design assignment, and developing the design solution successfully (Chen, 2016).

While considering the above dilemmas, this paper seeks to contribute to the field of creativity research, by investigating the differences between various design brief conditions. Accordingly, this study attempts to analyze how quantitative brief requirements and different types of available stimuli contributes to enhancing the creativity of design outcomes. The main goal is to explore how different conditions, in which the brief and external props such as a video and a physical representation are provided, can affect the creativity of design outcomes. Consequently, the following research questions are addressed:

RQ1: What are the props/information combination that best support creativity of the design outcomes in terms of novelty, appropriateness, and usability?

RQ2: From those conditions which are the ones more likely to show multiple significant differences in terms of each metric creative outcome?

2 Background

2.1 Measures of creativity: Novelty, Appropriateness, and Usability

The study of creativity is broad and interdisciplinary, spanning the social sciences of psychology and sociology, as well as the sciences of architecture, engineering and design. Creativity itself is composed of novel ideas; however, even the most profound ideas do not arise from nowhere. Studies which explore students' creative outcomes observed that the participants appear to be affected by stimuli; thus, suggesting that fixation emerges when participants are exposed to concept ideas (Smith et al.,1993; Howard et al., 2010; Kang et al., 2018;).

There is a consensus in the design creativity literature that creativity can be assessed using metrics of novelty and appropriateness (Amabile, 1982; Kampylis & Valtanen, 2010; Madni, 2012), and usability. The latter is a quality attribute described by Nielsen (1993) as an outcome encompassing effectiveness, efficiency, and user satisfaction in the context of use (ISO, 2013). As such, in the present study, we evaluated the creativity scores of the produced outcomes based on assessments from professionals and academic expert judges on these metrics. Three independent raters evaluated concept drawings produced by the students in line with Amabile's (1996) peer evaluation technique, utilizing a rubric-based system. The total score for each sketch was obtained as an average of the three scores. For complete evaluation rubrics and examples on grading analogous design solutions see Kang et al. (2018) and Koronis et al. (2019).

2.2 The design studio and the development of creative skills

The design studio is commonly referred to as the core of design education, where the largest number of credit hours of one's studies is dedicated (Gajda, 2016). As a teaching environment, the design studio is long viewed as paradigmatic for many other areas of education, including professional education (Waks, 2001). In this setting, students practice with real-life problems to acquire theoretical and professional knowledge, skills and techniques (Crowther 2013) and integrate them with what they have learned in different courses (Dermibas & Demirkan, 2007).

Enhancing design creativity is a central concern in the educational curriculums of design departments. How creativity can be promoted and nurtured, and under what learning conditions, is a constant challenge in a studio-based environment (Budge et al., 2013). An underlying assumption is that interaction among students working in a group enhances the flow and mutual development of ideas (Goldschmidt & Tatsa, 2005). That is why exposure to as many ideas as possible is essential to promoting and encouraging creativity in the studio.

Encouraging students to take risks and giving them the freedom to experiment in the generation of their own concepts and ideas was found to help promote creativity, even at the expense of committing mistakes (Graham & Zwin, 2010). The idea generation process can be strengthened by an educational environment in which the traditional figure of the instructor as an authority is avoided (Goldschmidt et al., 2010), and students are encouraged to work synergistically as a group (Casakin & Badke-Schaub, 2015).

Whereas several studies focus on how creativity in learning environments, such as how the studio can be stimulated, enhanced, and developed (Craaft, 2006), this study focused on how creativity can be supported (e.g., Budge et al., 2013), particularly through the crafting of design briefs to maximize creative idea generation.

2.3 The design studio and the design briefs

One of the recurring difficulties in teaching design is that the process is poorly understood. Gaining insight into the design assignment is critical to deal with a task. It is quite frequent that students experience problems of communication with their instructors or feel that they do not receive the support they require. These lapses have significant consequences on the manner in which design students approach and structure the problem at hand.

According to Brown (1989), designers tend to develop expertise in response to the requirements of the briefs they deal with. Indeed, the way that design briefs are represented and framed plays a crucial role in design problem solving in general (Paton & Dorst, 2011), and particularly in design education (Liu et al., 2018). Framing briefs and supporting them with appropriate information can help students to improve design problem-solving skills and develop creative outcomes from the early stages of the process.

There is an emerging corpus of research dealing with the effects and use of design studio briefs on the designers' outcomes. Among these studies, the need for structuring briefs to assist the learning process in the studio, in contrast to the availability of open-ended assignments to promote creativity has been a matter of debate in the design pedagogy literature (Sawyer, 2017). Whereas design problems are ill-defined, and therefore encompass a vast number of potential solutions, students commonly find difficulties and even get confused with design briefs that are open-ended (Chen, 2016). This phenomenon explains why some students feel secure when more constraints are added to the brief

(James, 1996). Osmond and Tovey (2015) showed that while struggling to be creative, students reported a feeling of 'being stuck' when exposed to unstructured briefs. However, these researchers also found that those students who managed to deal with the challenges of an open-ended assignment were able to increase their creative confidence and defend their ideas. In another study, Oliveira and Marco (2017) showed that the absence of a prescribed brief allowed students to focus on different aspects of the design from a personal and broader perspective. However, framing briefs based on individual ambition led to too many different interpretations of the design problem. This was in detriment of fully engaging and developing the design solution in line with the initial requirements.

Some researchers suggested balancing open-ended with more structured approaches. Lee (2009), for example, proposed to deliver projects differing in their level of freedom, from structured to highly structured. Rutherford and Wilson (2006) suggested that open-ended briefs should be encouraged, but also reviewed to ensure that the design studio aims, and objectives are preserved. On the other hand, there also appears to be some consensus that less prescriptive and more flexible design studio briefs can encourage personal reflection, creative thinking, and may contribute to support more individuality in the projects (Pan et al., 2012; Rutherford & Wilson, 2006).

The manner in which a brief is framed has important consequences on the way in which a task is approached, what aspects of the design are stressed, and what kind of creative outcomes are produced. The factorial studies of Kang et. al (2018) and Koronis et. al (2019) demonstrated that including conditions such as visual and physical props during the presentation of the design brief decreases the novelty of the produced concepts. Therefore, it seems that giving less specific requirements without examples appears to be more effective for the generation of novel ideas (Koronis et al., 2018). On the other hand, it is essential to provide students with good examples of successful products together with detailed specifications to ensure that their concepts will be aligned with the brief guidelines (Kang et al., 2018). In this study, we will explore the extent to which using different brief conditions supports creative ideation in design problem-solving. The design outcomes are measured with Amabile's (1996) Consensual Assessment Technique, measuring novelty, appropriateness and usability.

3 Research Method

3.1 Participants

The sample consisted of 171 student designers between the ages of 18 and 25 (mean age = 20 years old), 65% of which were male and 35% female. Participants were recruited in a first-year undergraduate design class, and students who participated had yet to select their major. All students were randomly assigned to the control and the other 7 conditions. They were informed that their participation would have no impact on their academic grades, as it has been argued that students tend to be less creative in class projects when there is a risk of receiving poor grades (Linnerud & Mocko, 2013). Although this experiment design studios had different instructors, they followed the same curriculum and progressed at the same pace. Therefore, we assume that the combination of students in the design studio groups are reasonably homogeneous, thus allowing for a fair comparison between the different conditions.

3.2 Design Task

All participants were provided with the same design problem, which consisted of designing "A device to extract juice from fresh oranges at home" and were tasked with sketching solution concepts. The same design problem was delivered to subjects in previous work on idea generation sessions carried out by Koronis et al. (2018). As in that study, they were told to avoid using blenders or blender-type machines as a reference for their concept designs. Orange juice extraction devices were chosen for the design problem as they are relatively common and reasonably familiar devices, which most students have used or encountered before.

3.3 Procedure

The experiment was run in a total of 8 design studios consisting of 20-24 students each. Students were grouped in mixed-gender groups of 4-6 participants. Each design studio was given the baseline design brief with different combinations of supplementary information in the form of visual or physical props or quantitative information along.

Based on the design brief given to each design studio, each workgroup completed a combination of Collaborative Sketching (C-Sketch) / 6-3-5 exercises. We consider it a combination as the groups were not consistently composed of 5 students as would be required by the 6-3-5 methodology. Moreover, writing of notes, and minimal talking was allowed among the teams. The design brief was displayed on projectors in the classrooms for around 2 minutes before the commencement of the C-Sketch / 6-3-5 exercise. Thereafter, it was projected again during the design activity as a reference for the students throughout the duration of the exercise (≈1hr). There was no group discussion session after the screening of the design brief and thus students were expected to respond according to their interpretations.

Each team member spent the first 15 minutes sketching three different ideas. Subsequently, at 10-minute intervals, each student passed on the sheet to a group peer, so that he or she could add sketches and annotations to the ideas of previous team members. This rotation process was repeated until each student got his/her original sheet back. Students received no prior training on this set apart from the instructions provided in this experiment. In total, 506 concept sketches were generated in this exercise. After students' drawings were completed, they were submitted back to expert assessors for their assessment.

3.4 Conditions and evaluation of sketches

This study investigates three information types paired with design briefs including: i) quantitative requirements; meaning information on specific costs, maximum number of manufacturing processes, durability cycles and product volumes; ii) a visual example, represented by a video showing a person using a conventional orange squeezer, and iii) a physical example, which consisted of a single-part orange squeezer sample that is handed over to selected design studio groups. Table 1 shows the mean scores and standard deviations (Std) for each response. Under the column titled "Condition," a "+" indicates the presence of that variable, while a "-" indicates its absence. In this arrangement all possible combinations of the three different types of stimuli, yielding 8 different conditions, are analyzed. Mean scores for novelty, appropriateness, and usability, with the standard deviation bars for each brief, are displayed in Figure 1.

This resulted in each sketch having a score for novelty, defined as the extent to which the design is different from the usual way of extracting juice; a score for appropriateness, defined as the extent to which the design is aligned with guidelines of the design brief; and a score for usability, seen as the ability of the design to extract the most amount of juice with minimal effort efficiently. The analytical rubric score ranges can be found in the earlier works of Koronis et al. (2018) and Koronis et al., (2019).

Table 1. Descriptive Statistics for the Three Creativity Metrics, by Brief Setting

Brief	Condition	No. of Student	No. of Sketches	Novelty Mean		Novelty Std	Appropriateness Mean		Appropriateness Std	Usability Mean		Usability Std
A	Q-V-P-	26	76	3.01	±	0.77	2.57	±	0.79	2.61	±	0.52
B	Q-V-P+	24	70	2.71	±	0.65	2.63	±	0.71	2.63	±	0.64
C	Q-V+P+	21	60	2.68	±	0.65	3.08	±	0.54	2.83	±	0.66
D	Q-V+P-	20	63	2.84	±	0.81	2.75	±	0.72	2.89	±	0.58
E	Q+V-P-	23	68	2.99	±	0.86	2.79	±	0.86	2.65	±	0.78
F	Q+V-P+	14	40	2.47	±	0.82	2.58	±	0.71	2.78	±	0.61
G	Q+V+P+	20	60	2.52	±	0.74	2.96	±	0.78	2.69	±	0.51
H	Q+V+P-	23	69	2.49	±	0.75	3.14	±	0.66	3.02	±	0.51
Totals		171	506	2.71		0.76	2.81		0.72	2.76		0.60

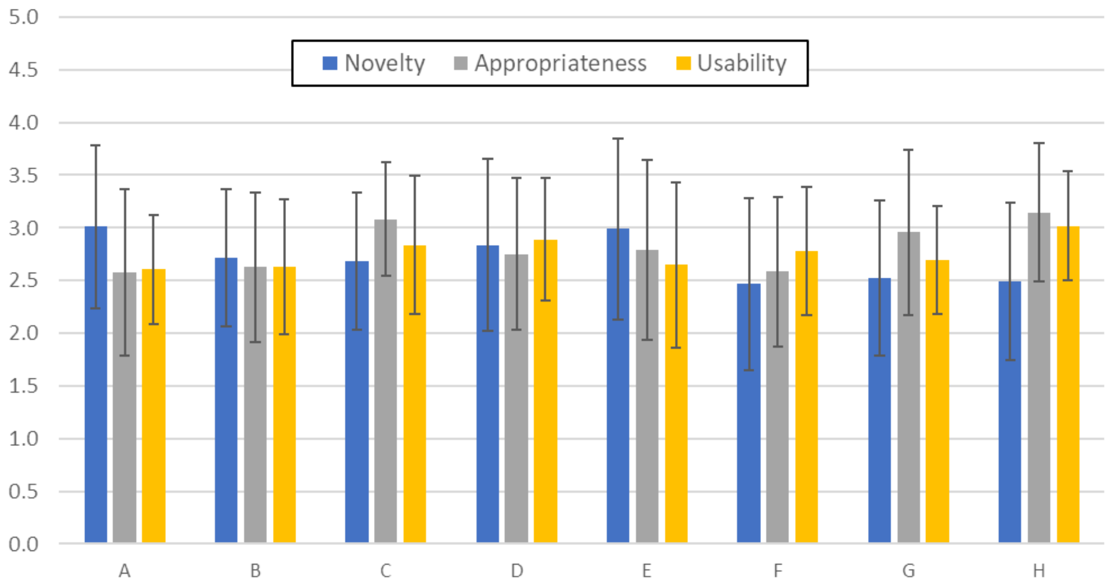


Figure 1. Bar chart of the three responses values per brief

4 Results

In the first part of this section, we carried out a quantitative analysis to explore whether significant differences emerged between the varying conditions, as presented in Table 1. The pairwise comparisons between the different briefs determined whether likely ranges for the differences can be found. In order to gain further insight, in the second part we selected and analyzed conditions with the higher and lower averages for each of the creativity variables assessed by novelty, appropriateness, and usability. We illustrated successful and unsuccessful examples of the solutions produced by the different teams in the Collaborative Sketching (C-Sketch)/6-3-5 exercise.

4.1 Quantitative analysis

A one-way between-groups analysis of variance was conducted to explore the relationship between the varying conditions. Subjects were divided into eight groups according to the different conditions they were exposed to. A Kruskal–Wallis Test revealed a statistically significant difference was found across the eight conditions followed by pairwise comparisons which indeed pointed out in-between difference across briefs. In this work, the statistical analysis was run on sketch-level (N = 506) where each sketch is treated as a unique observation.

4.1.1 ANOVA Testing Assumptions

The Levene's Test for Equality of Variances showed a departure from homogeneity (p>0.05) and the assumption of homoscedasticity was violated for Appropriateness and Usability but was found acceptable for Novelty. The data were non-normally distributed for the dependent variables according to the Shapiro–Wilk's test of normality and Levene's test for equality of variances shows that the assumption of equal variance was not met for all variables. As such, a Kruskal–Wallis, the non-parametric equivalent to the standard ANOVA test was employed. All the above indicating a non-normal distribution and inferring the use of non-parametric measures for analyses such as the Kruskal–Wallis ANOVA.

4.1.2 Inter-Rater Reliability

At the cessation of the creativity evaluation, the interrater reliability was checked for consistency between judges. The degree of agreement between judges is reported under the intra-class correlation coefficient (ICC-1) estimates in Table 2 based on a two-way random effect, average measures model. To check inter-rater reliability, IBM SPSS version 25 was used to calculate the intra-class correlation coefficient (ICC-1) Based on the 95% confidence interval of the ICC estimates, all reliability values were in the good to fair range, for novelty (ICC=.642), appropriateness (ICC=.649) and usability (ICC=.483).

Table 2. Interrater Reliability Results and ANOVA Assumption Testing

Distributional Label	Intraclass Correlation[a]	Normality test, Shapiro-Wilk	Homoscedasticity, Levene's test
Novelty	.642[b]	nonnormal	homogeneous
Appropriateness	*.649*[b]	nonnormal	non-homogeneous
Usability	*.483*[b]	nonnormal	non-homogeneous

a. Type A intraclass correlation coefficients using an absolute agreement definition.
b. This estimate is computed assuming the interaction effect is absent

4.1.3 Novelty statistics

The Kruskal-Wallis Test revealed a strong statistically significant difference (p<0.001) in novelty scores across six different conditions in the mean ranks of at least one pair of groups (χ^2 (7, n=506) = 33.22, p=0.00). There was very strong evidence (p < 0.003, adjusted using the Bonferroni correction) of a difference between the briefs A-G (p=0.012), A-F (p=0.011), A-H(p=0.003), G-E (p=0.019), E-F (p=0.017) and E-H(p=0.005). There was no evidence of a difference between the other brief pairs.

4.1.4 Appropriateness statistics

Further, the Kruskal-Wallis Test reported a statistically significant difference across six different conditions in appropriateness scores (χ^2 (7, n=506) = 37.27, p=0.000). A difference between the briefs was observed in the pairwise comparisons for F-C(p=0.015), F-H(p=0.009), A-C(p=0.003), A-H(p=0.003), B-C(p=0.007) and B-H (p=0.003). There was no evidence of a difference between the other brief pairs.

4.1.5 Usability statistics

A Kruskal-Wallis Test revealed strong evidence of difference across four different conditions in Usability scores (χ^2 (7, n=506) = 29.48, p=0.000). A difference between the briefs was observed in the pairwise comparisons A-H(p=0.001), B-H (p=0.001), E-H(p=0.012) and G-H(p=0.047). There was no evidence of a difference between the other brief pairs.

4.2 Qualitative Analysis

4.2.1 Novelty and the generation of creative design solutions

In the condition where most design solutions rated as highly novel, only the baseline brief was provided to students. Figure 2 illustrates an example of a highly novel solution to the orange squeezer problem by one of the teams that participated in this condition. The solution, which was considered to some extent surprising since it succeeded in modifying existing paradigms, created a sophisticated machine characterized by an isolated electric moving system fed by batteries. The juice is extracted because of the rotation of a mounted disc around the orange. The mechanism is enabled to hold the orange in place within an internal cabin, but at the same time extracts the juice via rotation out through an external pipe. The system is waterproof designed, and sports a screen door fastened by four magnets from which the user can observe the whole juicing process. It is remarkable that although no additional aids or props were provided to the design team, the produced solution scored a 5 for novelty, the highest possible score for the Likert-based metric. A plausible reason for this could be that the basic brief was informative enough to let the students know about the design needs and gave wing to their imagination, without constraining or fixating them to example solutions.

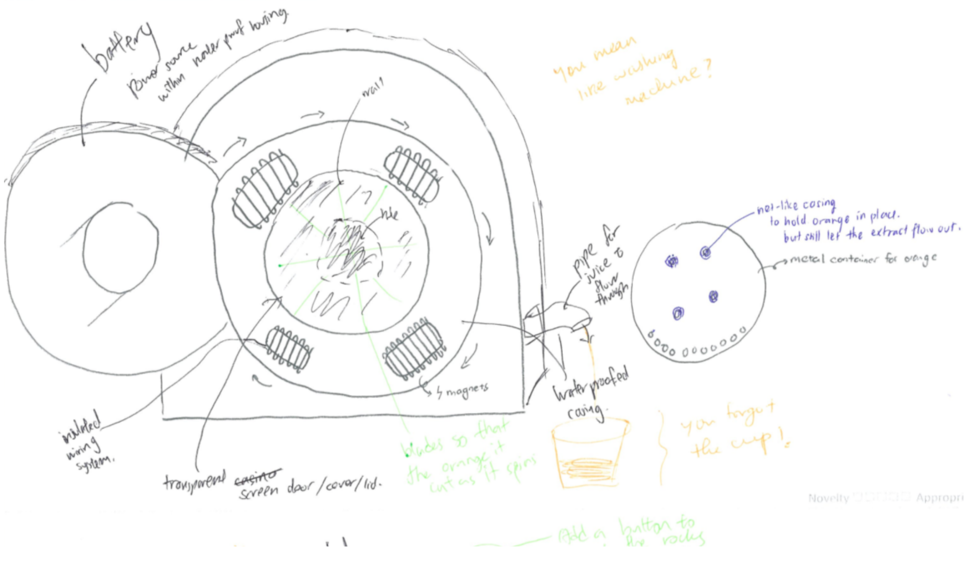


Figure 2. Sketch from Brief A (control) that scored high in novelty

The condition where most solutions scored lowly on novelty was that in which the control brief in addition to quantitative information about the problem and a physical model was provided to the participants, also known as Brief F. In Figure 3 an example of a solution for this condition can be found. Remarkably, the design outcome was almost a copy of the standard prototype for the manual orange squeezer in the market. Probably, the standard prototype is common knowledge to most designers, and combined with the stimuli provided and the quantitative requirements and constraining information may have caused the participants of this group some level of fixation thus affecting the novelty of their design solution. Only slight modifications were observed, such as the addition of a filter added to the base of the squeezer not found in the visual props. As a result, this solution scored only 1.00 point for novelty.

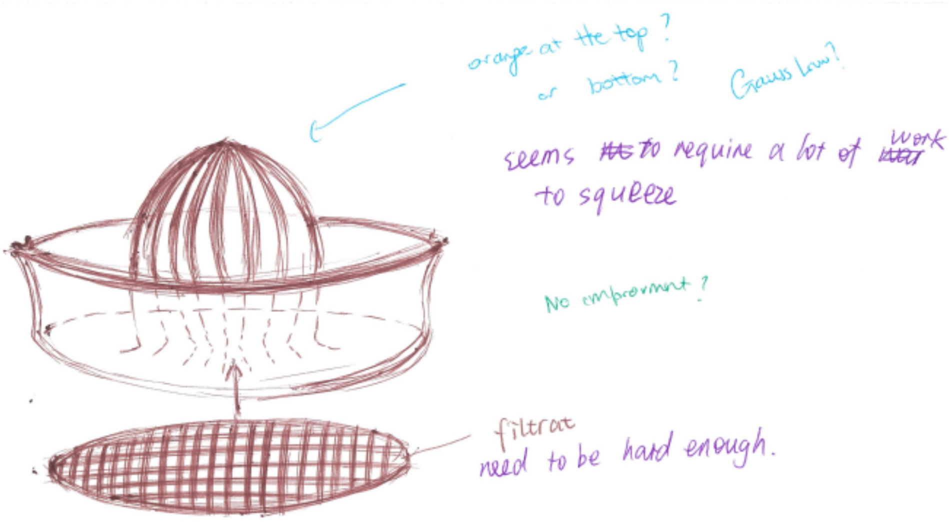


Figure 3. Sketch from Brief F with low novelty score

4.2.2 Appropriateness and the generation of design solutions

The condition where the most solutions scored highly for appropriateness was that of Brief H, where students were exposed to the baseline brief accompanied by quantitative information and a video example. Figure 4 shows an example of a representative solution for this condition, which was considered to respond satisfactorily to all the needs and requests from the brief (e.g., easy to manufacture, washable, low cost, etc.). It is possible that the supplementary quantitative information, which served to gain more insight into the design requirements, helped students pay particular attention to the initial needs of the baseline brief. On the other hand, the video example probably aided to figure out tangibly how such requirements can be materialized in practice. The solution was seen as very appropriate and in line to the brief requests and thus scored 4.67.

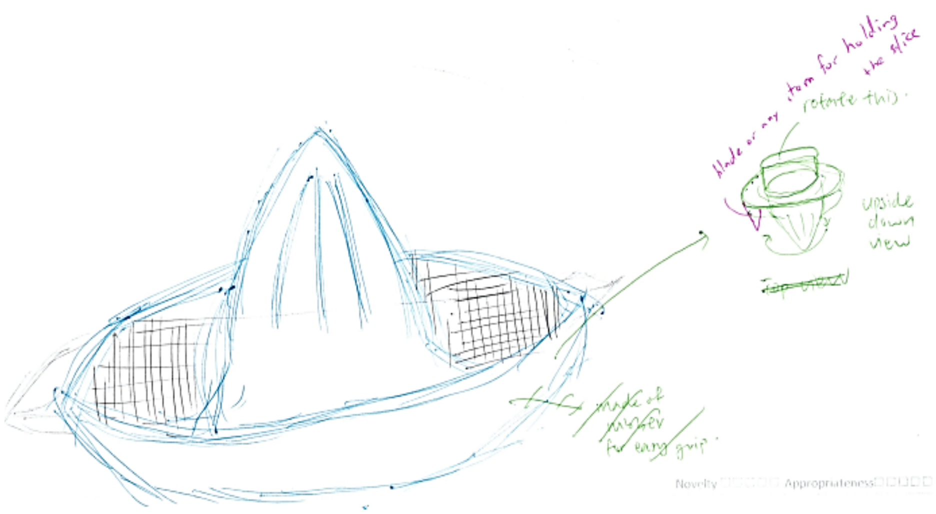


Figure 4. Sketch from Brief A (control) that scored high in appropriateness

In the condition where most solutions scored lowly in appropriateness, the control brief without any example was provided to the students, namely Brief A. Figure 5 illustrates an example of a solution for this condition that did not address the design requests. It can be observed that the device is characterized by a complex mechanism composed of many parts, which makes it difficult to manufacture and clean, and that largely exceeds the target cost. It seems reasonable to consider that the lack of external aids such as quantitative requirements with specific numerical values, or a visual example were the main causes for these low scores observed. It is remarkable that whereas the final solution only scored 2.57 for appropriateness, it was rated highly for novelty. As demonstrated earlier, the lack of external props seemed to contribute to the production of unique solutions.

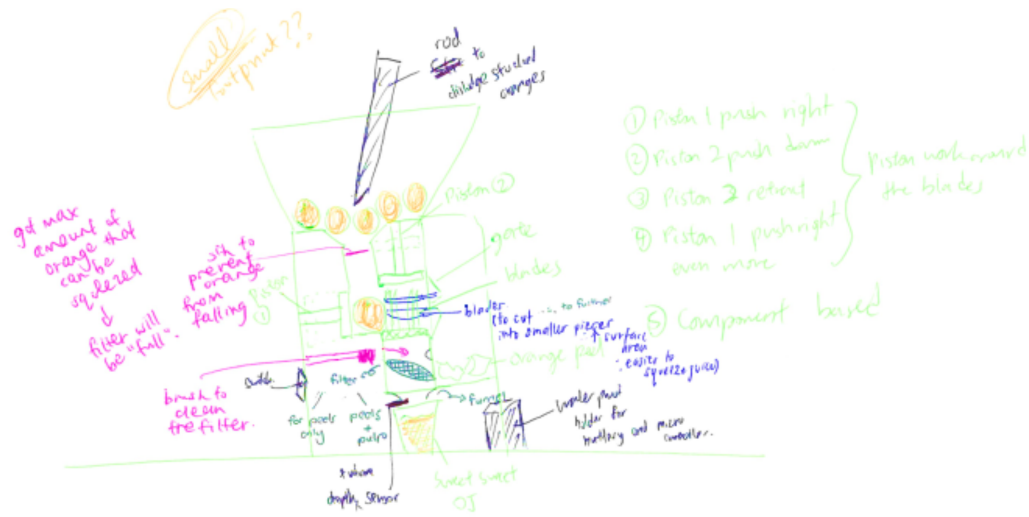


Figure 5. Sketch from Brief A that scored low in appropriateness

4.2.3 Usability and the generation of design solutions

In the condition where most solutions scored highly for usability, participants were provided with the baseline brief accompanied by quantitative information and a video of a typical orange squeezer, namely Brief H. An example of an idea solution produced in this condition can be seen in Figure 6. The solution, consisted of a practical device composed of a handle with an ergonomic grip used to press the fruit, a removable squeezer element, a rotatable plate, and a cup to store the juice fixed to a heavy base, which was intended to increase the stability of the device. It is remarkable that the same condition was beneficial to produce not only the most usable solutions but also the most appropriate ones. It is likely that the available quantitative information helped students to produce a very efficient design outcome that did not violate initial design constraints, which combined with an instructional video prop served to gain a better understanding of the devices' function and how it can be easily implemented and materialized in practice. The solution was regarded as very useful and scored 4.00.

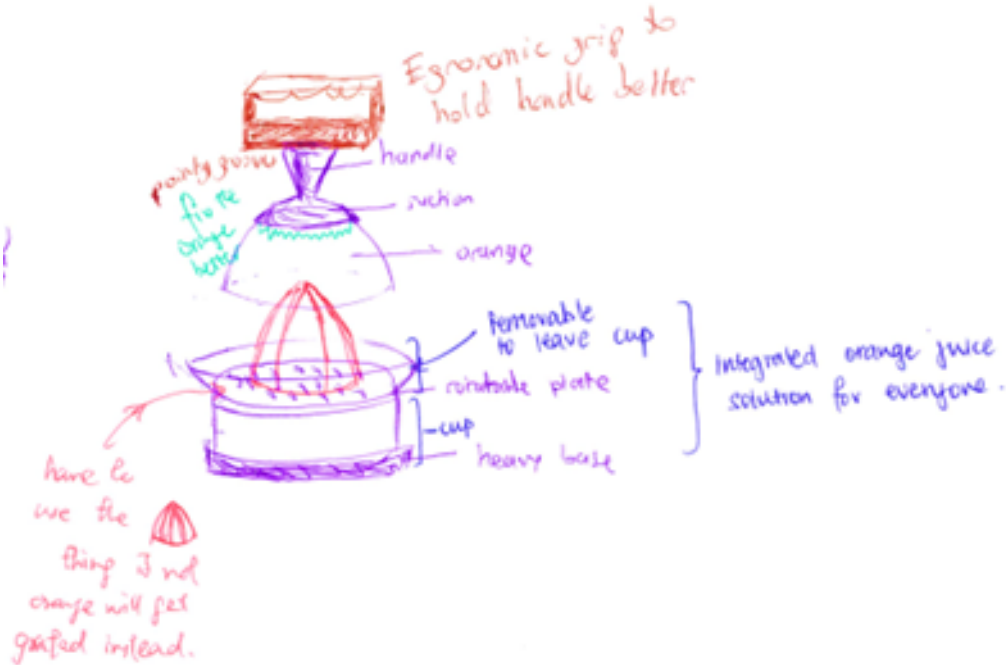


Figure 6. Sketch from Brief H that scored high in Usability

When students were exposed to the baseline brief and a physical model as a possible solution example, namely Brief B, most design outcomes scored lowly for usability. Figure 7 depicts an example of an idea-solution for this condition that did not manage to satisfy functional needs. The solution consisted of a detachable sharpened straw, which could be inserted directly into the fruit. The lower part of the straw has a rough surface that when turned around breaks the skin of the orange. The idea was that the device would allow users to drink juice directly from the orange. However, the idea was considered impractical and scored 1 for usability. With the absence of quantitative information, it seems that the physical model alone was not effective to exemplify how the device could be implemented in real life.

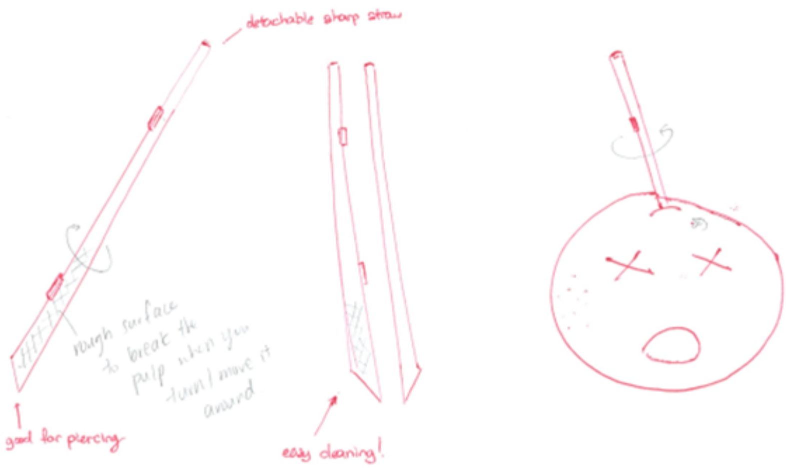


Figure 7.Sketch from Brief B that scored low in Usability

5 Discussion and conclusions

The Kruskal-Wallis ANOVA results showed that there are significant differences in the design outcomes between design studio groups that received briefs with different sets of stimuli. Surprisingly, the simultaneous statistical tests revealed that the inclusion of visual and physical props in the design brief decreased the novelty scores of the ideas developed by the students. Hence, for novelty, the control condition (Brief A) was found to have significant differences with the other conditions. These findings are consistent with prior studies which showed that participants who are exposed to examples of existing products tend to produce fewer novel examples because of the design fixation effects (Jansson & Smith, 1991). An earlier factorial study on the same design problem as this study indicated design fixation as one of the factors for a lack of novelty (Kang et al., 2018).

Regarding the appropriateness and usability creativity metrics, the pairwise comparisons indicated that Brief H, in which a video example was given in addition to the baseline brief, had multiple significant differences compared to the other conditions. If the primary aim is to increase performance and user-friendliness, it can be argued that providing a visual/video example is beneficial for usability. This claim can be supported by Fu et al. (2010), who claimed that good examples can help design teams to generate high-quality ideas that fulfill the brief's requirements. Accordingly, students can build on solutions that are known to be effective.

Implications for design education can be concluded from the present findings. Educational programs aimed at promoting design creativity in engineering and architecture studios may find it useful to consider the way that design briefs are structured, and support from instructors can either encourage or deter different aspects of design creativity. Whether using examples or not as a pedagogical tool to enhance design creativity, and the type of examples used showed to be largely dependent on the aspect of creativity that is intended to be promoted. In this sense, a remarkable finding was that no brief was helpful enough to enhance all creativity metrics simultaneously. On the other hand, briefs that supported design novelty, failed to yield high appropriateness and usability scores, and vice versa.

One limitation of the present study is that it was carried out in a classroom environment that only addressed the ideation phase of the early design process. Therefore, in spite that the present findings provide insights into the advantages and disadvantages of considering the different conditions in the design studio, they should be taken with some caution. It is possible that when considering the overall design process along a whole semester, students would become more familiar with the use of the different briefs. Consequently, the influence of the type of brief on the creativity of the design outcomes might differ to some extent compared to the present findings. Irrespectively of this, it seems that training student designers in using briefs with different types of information can be seen as an important part of the educational scaffold of the studio aimed at enriching the learning experience of the student.

Another limitation of this study is the relatively small sample size and the fact that employing university students as participants may be imperfect if studio managers consider applying the key findings to senior and professional populations. Future research in this area should consider extending this study with professionals from the engineering, design, and architecture domains to validate the findings of this paper.

6 References

Amabile, T. M. (1982). The Social-Psychology of Creativity: A Consensual Assessment Technique. *Journal of Personality and Social Psychology*, 43(5), 997-1013.

Amabile, T. M. (1996). *Creativity in Context* (1st ed.). Boulder, CO: Westview Press.

Brown, S. (1989). Opening up Design Education. *Design Studies*, 10, 4-11.
Budge, K., Beale, C., & Lynas, E. (2013). A Chaotic Intervention: Creativity and Peer Learning in Design Education. *iJADE*, 32, 146-156.
Casakin, H. & Badke-Schaub, P. (2015). Mental Models and Creativity in Engineering and Architectural Design Teams. In J.S. Gero, & S. Hanna (Eds.). *Design Computing and Cognition '14* (pp. 155-171). Cham, Springer International Publishing AG.
Chen, W. (2016). Exploring the Learning Problems and Resource Usage of Undergraduate Industrial Design Students in Design Studio Courses. *International Journal of Technology and Design Education*, 26, 461-87
Craft, A. (2006). Fostering Creativity with Wisdom, *Cambridge Journal of Education*, 36 (3), 351–62.
Crowther, P. (2013). Understanding the Signature Pedagogy of the Design Studio and the Opportunities for its Technological Enhancement. *Journal of Learning Design*, 6(3),18–28.
Demirbas, O. O., & Demirkan, H. (2003). Focus on Architectural Design Process through Learning Styles. *Design Studies*, 24(5), 437–456.
Fu, K., Cagan, J., & Kotovsky, K. (2010). Design Team Convergence: The Influence of Example Solution Quality. *Journal of Mechanical Design*, 132(11), 111005-111005-111011.
Gajda, A. (2016). The Relationship between School Performance and Creativity at Different Educational Stages. *Thinking Skills and Creativity*, 19, 246–259.
Goldschmidt, G., Hochman, H., & Dafni, I. (2010). The Design Studio “Crit”: Teacher-Student Communication. *Artificial Intelligence for Engineering Design*, 24, 285-302.
Goldschmidt, G., and Tatsa, D. (2005). How Good are Good Ideas? Correlates of Design Creativity. *Design Studies*, 26, 593-611.
Graham, M. A., & Zwirn, S. G. (2010). How Being a Teaching Artist can Influence K-12 Art Education. *Studies in Art Education*, 51(3), 219-232.
Howard, T. J., E. A. Dekoninck, & S. J. Culley. (2010). The Use of Creative Stimuli at Early Stages of Industrial Product Innovation. *Research in Engineering Design*,21, 4, 263-274. doi: 10.1007/s00163-010-0091-4.
James, P. (1996). The Construction of Learning and Teaching in a Sculpture Studio Class. *Studies in Art Education*, 37(3), 145-159.
Jansson, D. G., & Smith, S. M. (1991). Design Fixation. *Design Studies*, 12(1), 3-11. doi:https://doi.org/10.1016/0142-694X(91)90003-F
ISO. (2013). Usability of consumer products and products for public use - Part 2: Summative test method ISO/TS 20282-2:2013 (pp. 50).
Kampylis, P. G., & Valtanen, J. (2010). Redefining Creativity — Analyzing Definitions, Collocations, and Consequences. *The Journal of Creative Behavior*, 44(3), 191-214. doi:10.1002/j.2162-6057.2010.tb01333.x
Kang, K. S. J., Chia, P. Z., Koronis, G., & Silva, A. (2018). Exploring the use of a full factorial design of experiment to study design briefs for creative ideation. Paper presented at the ASME-IDETC, Quebec, Canada.
Koronis, G., Chia, P. Z., Kang, K. S. J; Yogiaman, C., Raghunath, N., & Silva, A. (2019). An Empirical Study on the Impact of Design Brief Information on the Creativity of Design Outcomes with consideration of Gender, and Gender Diversity. *Journal of Mechanical Design* (Accepted Manuscript).
Koronis, G., Silva, A., & Kang, J. (2018, 20-24 May). The impact of design briefs on creativity: a study on measuring student designers outcomes. Paper presented at the 15th International Design Conference, Dubrovnik, Croatia.
Lee, N. (2009). Project Methods as the Vehicle for Learning in Undergraduate Design Education: A Typology. *Design Studies*, 30, 541-560.
Linnerud, B., & Mocko, G. (2013). Factors that Effect Motivation and Performance on Innovative Design Projects, ASME Design Engineering Technical Conferences; Portland, OR, USA.
Liu, E., Carta, S., & Sopeoglou, E. (2018). Study trip as means of expanded learning. *Information, Communication, & Society*, 21(9), 1293-1304.
Madni, A. (2012). Elegant systems design: Creative fusion of simplicity and power. Systems Engineering, 15(3), 347-354.
Nielsen, J. (1993). *Usability Engineering*. Cambridge, MA: Academic Press.
Oliveira, S., & Marco, E. (2017). Preventing or Inventing? Understanding the Effects of non-Prescriptive Design Briefs. *International Journal of Technology and Design Education*, 27, 549-561.
Osmond, J., & Tovey, M. (2015). The Threshold of Uncertainty in Teaching Design. *Design and Technology Education: An International Journal*, 20(2), 50-57

Pan, W., Murray, P., Cotton, D., & Garmston, H. (2012). Integrating Research-Informed Teaching into Sustainable Construction Education. *Journal of Education in the Built Environment*, 7(1), 94–117.
Rutherford, P., & Wilson, R. (2006). Educating environmental awareness: Creativity in integrated environmental design teaching. In Architecture (Ed.), Challenges for architectural science in changing climates. ANZAScA: Adelaide.
Sawyer, R. K (2017). Teaching creativity in art and design studio classes: A systematic literature review. *Educational Research Review*, 22, 99-113.
Smith, S. M., Ward, T. B., & Schumacher, J. S. (1993). Constraining effects of examples in a creative generation task. Memory and Cognition, 21(6), 837-845. Waks, L. (2001). Donald Schon's Philosophy of Design and Design Education. *International Journal of Technology and Design Education*, 11, 37–51.
Yang, M. Y., You, M., & Chen, F.C (2005). Competencies and Qualifications for Industrial Design Jobs: Implications for Design Practice, Education, and Student Career Guidance. *Design Studies*, 26, 156-189.

About the Authors:

Hernan Casakin is an Associate Professor in Architecture. His primary research interest is in design thinking, design tools, creativity, and design education. He also has investigated in the areas of environmental psychology and urban design.

Georgios Koronis is a Research Fellow in Engineering Design, and his primary research interests focus on the areas of creative processes in product design and design thinking. Second, he investigates composite materials properties and cause-and-effect relationships via the design of experiments.

Arlindo Silva is an Associate Professor in the Engineering Product Development pillar. His current research interests rest on design methods and techniques, product design and development, engineering education, creativity, materials selection methodologies, renewable composites, cost modeling and management of uncertainty in design.

Acknowledgment: The experiment conducted at Singapore University of Technology and Design (SUTD) and supported by the SUTD-MIT International Design Centre (IDC, idc.sutd.edu.sg), project IDG 11600102. We are grateful to the participating students, faculty and teaching assistants from SUTD. The authors would like to thank Rianne Meurzec who kindly reviewed an earlier version of this manuscript and provided valuable suggestions and comments.

Using a Mobile Phone App as a Teaching Aid for Aesthetics Education: Case Study of a Photography Course at a Taiwanese Junior High School

Wu, Shi-Chi [a]; Li, Elena Carolina *[b]

[a] Department of Information Communication, Yuan Ze University, Taoyuan City, Taiwan
[b] Department of Visual Arts, University of Taipei, Taipei City, Taiwan
* helena1799@gmail.com

Aesthetic literacy is one of living literacies that human live should have. Currently, Taiwanese students usually have their first experiences with photography using smartphones at junior-high-school age, which is an activity directly connected with aesthetics. To determine whether mobile phone apps can assist aesthetic education, this study designed a photography course and developed a specially designed photography app to assist students in learning photography through the course. The participants were 25 junior high school students, who were asked to take photographs before the course began, after they were taught using PowerPoint presentations, and after they were taught using the mobile phone app. Their photography from after the course was evaluated by experts to determine the effect of using the app-taught course on the students' aesthetic literacy. The results of this study revealed significant improvements in students' composition and aesthetic abilities after participating the app-taught course. From the aforementioned research procedures and results, several findings and suggestions were proposed. These suggestions can serve as a reference for future aesthetic education courses that plan to employ mobile phone apps as teaching aids.

Keywords: Aesthetics, photography; composition; mobile application

1 Introduction

The importance of aesthetic education was indicated by the NMC Horizon Report: 2015 K-12 Edition issued by the New Media Consortium in the United States. In this report, Science, Technology, Engineering, Arts, and Math (STEAM) education was listed as a mid-term goal. The purpose of STEAM education is to educate students with interdisciplinary knowledge. Moreover, it described an experiment analyzing the math scores of students who did or did not participate in music, which found that students who did participate obtained higher math scores than those who did not participate by 42 points. Compared with students who only participated in music and art classes for half a year or less, students who had taken four years of music and art classes obtained 98 points more in their math score. Thus, art classes can develop creative thinking, adaptation ability, and other problem-solving techniques (Johnson, Adams Becker, Estrada, & Freeman, 2015). In other words, creativity is a foundation for cultivating students' comprehension and problem-solving abilities.

Chen (2012) indicated that learning photographic techniques enabled students to express their thoughts and share their emotions, value, and ideas with their peers, which was consistent with the objective of the arts and humanities course. In other words, learning photography would help the development of aesthetic literacy. According to a 2014 survey conducted by Foreseeing Innovative New Digiservices of the Institute for Information Industry, 70% of the Taiwanese public aged 12 years and older possessed a smart device. Sun (2016) surveyed 564 junior high school students in Keelung, where is a city in North Taiwan, 48.7% of the students indicated that the camera was their most frequently used smartphone function. Taking photographs or videos with a mobile phone is one of the most common aesthetic activities for junior high school students; it is also the beginning of their photographic experiences.

Since the mid-1980s, the Taiwanese government has promoted the grade 1-9 curriculum, of which reform in the arts field featured appropriate courses with students' life experiences to develop abilities that they could retain (Chao, 2014). Chang (2011) indicated that during learning, whether in creation or discussion, teachers must guide their students to make connections to their daily lives and explore the context of daily culture to integrate learning and living. Contemporary photographic technology allows anyone with an idea to engage in image creation, and appealing images often receive wide recognition. In addition to perfect and professional images, the content and creativity of an image are also substantial learning indicators and are closely associated with personal experiences (Yu, 2008).

Therefore, this study implemented a photography course in a Taiwanese junior high school using mobile phone apps as teaching aids to determine whether the course and app were able to enhance the photographic techniques and aesthetic literacy of junior high school students. The objectives of this study were as follows:

(1) Design mobile phone photography-composition app based on the photography principles.
(2) Compare the photographic outcomes of students instructed by using photography apps and PowerPoint presentations.
(3) Explore the influence of photography-composition teaching on students' aesthetic literacy.

2 Related works

2.1 Aesthetic education

Aesthetic education means integrating the principle and theory of beauty into teaching and employing activities related to beauty to inspire the perception of students, develop their tastes, and increase their aesthetic experiences to cultivate their minds and enlighten creative thinking (Lu, 2012). The Taiwanese Ministry of Education (2013) stated that the meaning of aesthetic education was to offer the learner a method, opportunity, and environment to perceive, explore, experience, recognize, and practice beauty, as well as to sharpen their minds and bodies for diversified perception.

Liu (2012) stated that teaching photography enhanced the ability of aesthetics and appreciation for students in addition to training their ability to discover beauty and motivating them to document beauty and creation. In 2008, the Taiwan Ministry of Education disclosed the Grade 1–9 Curriculum Guidelines for Elementary and Junior High Schools, in which the objectives of arts and humanities courses comprised three principal axes: (1) Exploration and expression; (2) beauty appreciation and comprehension; (3) practice and application. Photography teaching and creation can achieve the abovementioned three objectives.

Specifically, the process of photoshoots enables students to explore the environment–individual relationship while simultaneously achieving creative expression through photography. Photographic work also enables students to conduct aesthetic discussions and appreciation, and the theme and preservation of photographic work enable students to understand the connection between the work and life of an individual. Finally, acquired photography techniques enable students to constantly connect their creations to their lives. Therefore, the present study incorporated photography teaching and outdoor photoshoots to implement aesthetic education. The influence of this course on aesthetic literacy was also explored.

2.2 Photographic composition

Once a person picks up a camera and looks at the world through photographic vision, the relationship of this person and the photographed object becomes one of beauty appreciation (Liu, 2012). The outcome of a photograph is also associated with the principles of beauty; therefore, photography is suitable for learning aesthetics.

Patterson (2011) indicated that photography comprises two types of visual design: the design feature observed from the photographed object and the image design from arranging the photographed objects. Key elements of photography include the subject matter, lines, outline, color, texture, and composition (Hsieh, 2007). Savakis, Etz, and Loui (2000) indicated that composition to be one of the most important attributes when evaluating an image appeal.

The photographer Freeman (2014) proposed that an outstanding photograph must be based on remarkable composition. If the photograph is narrative, a powerful composition is required to present its content. Hoffmann (2008) stated that the composition of a photograph is similar to that of music; that is, the success of a photograph lies in the connection of each of the individual visual elements. Moreover, Zou (2010) considered that the purpose of composition is to effectively enhance all elements in the viewfinder to achieve a sensory impact. Hedgecoe (2006) indicated that the composition of a photograph must connect different elements logically to tell the story behind the image. An outstanding composition could emphasize the subject and content of a work; the combination of a remarkable technique and an excellent composition form an outstanding photographic work (Prakel, 2012). The composition holds a position in photography that is not to be underestimated. Thus, a student must properly learn composition to present the original idea with adequate emphasis.

The travel photographer Huang (2012) deduced several composition principles based on reviewing and analyzing his work over the years. These principles included horizontal, vertical, symmetrical, diagonal, crooked, golden ratio, L-shaped, T-shaped, cross, V-shaped, crevice, and centered compositions. The author of the present study compiled and organized nine composition principles fit for beginners, which were parallel, diagonal, curve, triangle, rule of thirds, subject-centered, symmetrical, contrast, and framed compositions. These nine types of composition formed the basis of the course and experimental design of the study.

2.3 Photographic evaluation criteria

For the sake of objectivity in photographic evaluation, specific criteria must be established. Wu, Su, and Ouyang (2009) developed the Assessment Regulations for Photography Courses in which the assessment criteria for photographs were categorized into five aspects, namely the composition, exposure, shutter opportunity, depth control, and color. The evaluation criteria for the 2017 National Geographic Photo Contest: Travel Photographer of The Year Contest of the United States included the following three items: creativity (35%), photographic quality (35%), and composition (30%). The evaluation criteria for the 100th Anniversary Nikon Photo Contest (2017) included creativity (30%), photographic quality (30%), techniques (including composition) (30%), and votes (10%).

In the Assessment Regulations for Photography Courses proposed by Wu et al. (2009), composition was listed as an individual evaluation criterion. The 2017 Travel Photographer of The Year Contest also listed composition as an individual item in the evaluation criteria. These two examples revealed the importance of composition. In the evaluation criteria of the 100th Anniversary Nikon Photo Contest, composition was particularly listed as one of the photographic techniques. Overall, most photography evaluations have employed the concepts of creativity, quality, and composition.

The objective of this study was to improve the aesthetic ability of students through a photography app for mobile phones to determine whether the app design could teach students about photographic composition. Therefore, composition was singled out as an individual item in the evaluation criteria. The creativity and other presentation methods with particular inspiration or significance were categorized as work aesthetics. These two items served as evaluation criteria in this study.

2.4 Mobile application of photographic composition

Mobile learning (m-learning) refers to establishing a new learning environment wherein students use mobile devices as aids to teaching materials. In m-learning, teachers and students can learn anytime and anywhere. The learning content is related to the environment and varies with changes in it; moreover, the learning progress can be recorded (Mikic, Anido, Valero, & Picos, 2007). M-learning tools can be a tablet personal computer (PC), a smartphone, a pocket PC, a personal digital assistant, a notebook, or any aids or devices that can load digital information content (Quinn, 2000). Kukulska-Hulme (2005) revealed seven desirable attributes of m-learning, which were spontaneous, personal, informal, contextual, portable, ubiquitous, and pervasive. With the development of digitalization, conventional cameras using photographic film have been replaced by digital cameras; moreover, mobile phones, which almost everyone possesses currently, can take pictures. However, the advancement in tools does not mean the art or techniques of photography can be simplified. Learners must learn conventional photography as well as understand digital image processing techniques.

Most commercially available photography smartphone apps are designed to assist photographers in taking photographs that fit their demands or aesthetic requirements. Such apps play an assistive role that could be applied to m-learning. This study selected three apps related to photographic composition that had higher feedback scores in both Google Play (2017) and Apple Store (2017): Hypocoam, cam0.618, and Insight. Hypocoam had two kind compositions for users; cam0.618 provided six compositions for users, but the direction of composition outlines cannot be flipped based on the smart phone screen; Insight app had easy-use interfaces and 24 types of composition. Either the operation is too complicated for a beginner or too simple to offer much operational freedom. Therefore, this study designed a composition-assistive app integrating the aforementioned advantages for photography beginners.

3 Experiment

This study employed an experimental research design and recruited junior-high eighth-graders through purposive sampling. This study designed a photography course for a student club and focused on teaching photographic composition using the photographic composition app as a learning aid. The aim was to determine the effect of the classes and photography app on learners' photography techniques and aesthetic literacy.

3.1 Experiment flow

The experimental flow was as follows: (1) designing the course and photography teaching app: Photo Time; (2) inviting two experts to verify the content, learn about the course design, and comment on possible improvements to the app; (3) conducting actual course teaching and student practice; (4) inviting three experts to evaluate three photographic works of the students; (5) conducting statistical analysis on the three actual photographic outcomes; and (6) interviewing three students to know their learning experience.

To explore whether the use of the photographic composition app to assist teaching could effectively improve the learning outcomes of learners, three actual photoshoots were conducted. The first was conducted before the students learned any photography techniques and the second was conducted after they were taught using PowerPoint presentations, covering the principles of form and photographic composition. The third photoshoot was conducted after students were taught using the photographic composition app developed by the authors. This app was used to explain composition theories as well as employed in the actual photoshoot. For all three photoshoots, students were requested to use their devices as photography tools to mitigate the effects of various photography tools or operation styles on the objectivity of the experiment.

Finally, these photographs were given to experts for evaluation focusing on their composition and aesthetics. The composition included all nine composition principles, and the aesthetics involved the subject, creativity, lighting, focus, and colors. This evaluation was used to determine the photographic composition and aesthetic ability of students before and after they participated in the class.

The participants were recruited from the eighth grade of a junior high school in Taoyuan City, Taiwan. The entire course was conducted using student club activity time. Each class lasted 90 minutes and was conducted once every two weeks for a total of four times within eight weeks. For each photoshoot, students were requested to take at least three pictures for a total of at least nine by each student after the three photoshoots. All the photoshoots took place on the school campus.

3.2 Mobile application design

The photographic composition app was designed to simulate actual usage conditions, which enabled students to choose different compositional frames when taking pictures. The software used to write this app was Unity 3D. The app operates on Android version 4.1 or higher and can be found and downloaded in Google Play by searching for "Photo Time." The interface introduction was divided into two parts: the first focused on the main operational interface of the app (Table 1) and the second focused on the part of composition layout of the application (Table 2).

Table 1 Interface design of Photo Time

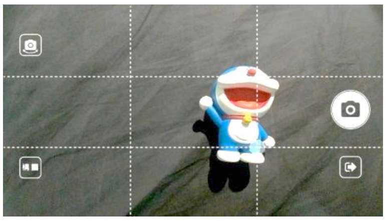
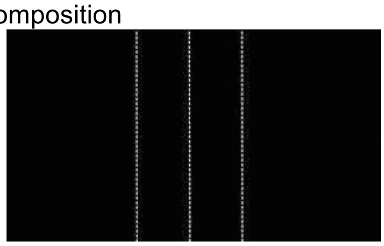
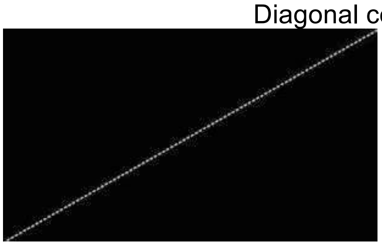
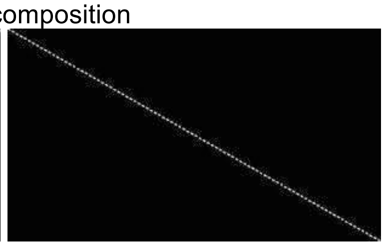
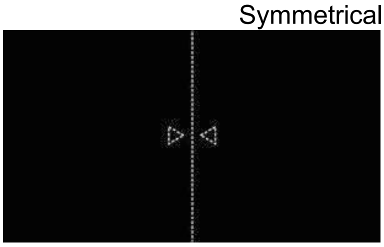
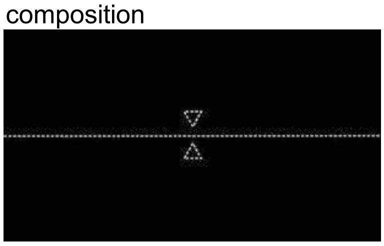
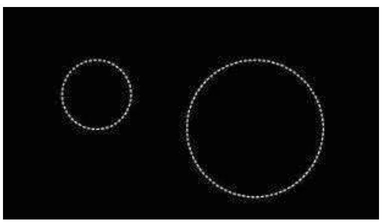
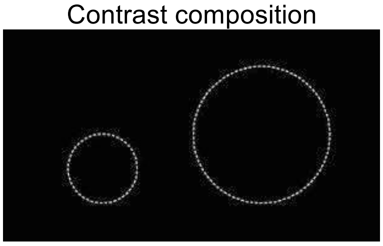
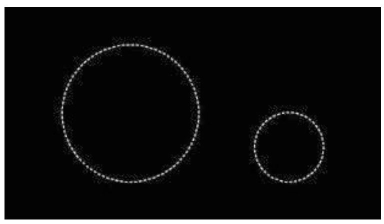
Name and LOGO	Menu
	
Samples of actually interface	
	

Table 2 Part of the composition layout for the Photo Time app.

Parallel composition		
		
Diagonal composition		
		
Symmetrical composition		
		
Contrast composition		
		

3.3 Photographic topics

In the photoshoot area (i.e., the school campus), no fitting location to practice curve composition was found, and furthermore, the experts indicated that curve composition is more difficult for a beginner than other composition types. Therefore, the curve composition was eliminated from the present study, leaving parallel, diagonal, triangle, rule of thirds, subject-centered, symmetrical, contrast, and framed compositions to be practiced.

As previously described, the experiment comprised three photoshoot stages. For each photoshoot, students were required to submit at least three pictures for each of the three composition types assigned to them by a draw. Moreover, the topic for the first photoshoot was decided by a draw. The topics were as follows: (1) contrast, frame, and triangle composition; (2) rule of thirds, symmetry, and frame composition; (3) subject-centered, parallel, and diagonal composition. The topic for the second photoshoot was a topic that differed from the first photoshoot (for example, if topic 2 was drawn for the first photoshoot, then topic 1 or 3 would be selected for the second photoshoot). Similarly, the topic for the third photoshoot was one that was not applied in the first or second photoshoot. This measure prevented participants from taking the same photograph with the same topics. The experts evaluated and determined that the three topics were similar regarding difficulty.

3.4 Expert content verification and photoshoot works evaluation

All students were asked to download the app from Google Play without being told the identity of the developer. Two experts were invited to comment and provide opinions on the experimental procedure, course content, mobile phone app, and photography topics after the completion of experiment, course, and app designs; relevant modifications and corrections were made according to these opinions. The professional background of the two experts; both had been photography teachers over 5 years and were keen to determine whether these nine composition designs were fit for regular photography demands, in addition to wishing to provide suggestions about the course design. After the three actual photoshoots in the classes, three experts were invited to evaluate all the photographic works of the students. All three experts had at least 15 years of experiences in aesthetic professions, such as photography, artistic creation, and communication design.

Items evaluated for each photograph were divided into the following two categories: composition and aesthetics were evaluated. For each category, a score was assigned from 1 to 5; the higher the score was, the favorable the performance was. Students were numbered according to the number of strokes in their last name in an order. Additionally, to prevent students' images being in the same order influencing the evaluation results, students were divided into an odd-number group and an even-number group; images of students in the odd-number group were presented in the order of photoshoots (1), (2), and (3), whereas those of the students in the even-number group were presented in the order of photoshoots (3), (2), (1).

After all evaluation results had been collected, statistical analysis was conducted in Statistical Product and Service Solutions (SPSS). First, the reliability of the three experts' evaluations was analyzed, and the reliability of internal consistency (Cronbach's α) was tested; the present study employed 0.7 as the standard, which meant that the questionnaires with test results higher than 0.7 were highly reliable (Chiou, 2006). Subsequently, analysis of variance (ANOVA) with dependent samples was conducted to analyze the differences in evaluation scores provided by the three experts for the composition and aesthetics items. The ANOVA significance standard was set as $\alpha = 0.05$; that is, if the p value of the ANOVA result was lower than 0.05, this result was significant and had explanatory significance. Finally, the least significant difference (LSD) test was used as the post-hoc method.

3.5 Participants interview

A semi-structured interview was conducted after the entire course had been completed to determine what the participants had learned and thought. The interviewees were three students selected through purposive sampling. The interviews were conducted with the consent of the students and conducted individually. The interviews comprised two sections: (1) App usage: Do you think learning with an app improved your photography techniques and aesthetic literacy? Can you provide a few examples? (2) Suggestions for classes: Did you prefer learning with the app or the PowerPoint presentation? Why?

4 Results and discussion

The original number of participants in this study was 28. However, due to sick leave, official business leave, and other reasons, the final number of the actual research sample in each stage was 25. In this section, the reliability analysis of the questionnaire was conducted first, and the results were as follows: the internal consistency value (Cronbach's α) of the three evaluations by expert 1 was .855; that by expert 2 was .863; and that by expert 3 was .750.

4.1 Results of experts' evaluation

To investigate whether the photographic composition and aesthetic ability of students improved after three classes, the three experts were requested to evaluate the students' images taken during the three photoshoots. The experts evaluated individual work based on composition and aesthetics. Finally, the ANOVA with dependent samples was conducted by the author on the scores of these works.

Regarding the evaluation results of expert 1, according to Table 3, the mean of the three groups was significantly different ($F = 6.740$; $p = .003 < .05$). The post-hoc results indicated a significant difference between the first and third photoshoots ($p = .004 < .05$) as well as between the second and third photoshoots ($p = .043 < .05$). According to Table 4, the mean of the three groups was significantly different ($F = 9.129$; $p = .000 < .05$). The post-hoc results indicated significant differences between the first and third photoshoots ($p = .000 < .05$) as well as between the second and third photoshoots ($p = .005 < .05$).

Table 3 Summary table of within-subject ANOVA analysis: composition (expert 1)

Sources	SS	df	MS	F	Post Hoc: LSD
Between groups (A)	3.947	2	1.973	6.740**	Third photoshoots (M = 2.68, Sd = 0.63) > Second photoshoots (M = 2.36, Sd = 0.57), First photoshoots (M = 2.12, Sd = 0.53)
Within groups					
Between-subjects (S)	9.787	24	.408		
Error (A*S)	14.053	48	.293		
Total	27.787	74			

Note: **$p < .01$.

Table 4 Summary table of within-subject ANOVA analysis: aesthetics (expert 1)

Sources	SS	df	MS	F	Post Hoc: LSD
Between groups (A)	3.307	2	1.653	9.129***	Third photoshoots (M = 2.20, Sd = 0.76) > Second photoshoots (M = 1.80, Sd = 0.65), First photoshoots (M = 1.72, Sd = 0.54)
Within groups					
Between-subjects (S)	22.347	24	.931		
Error (A*S)	8.693	48	.181		
Total	34.347	74			

Note: ***$p < .001$.

Regarding the evaluation results of expert 2, according to Table 5, the mean of the three groups was significantly different (F = 5.401; *p* = .008 < .05). The post-hoc LSD results indicated a significant difference between the first and third photoshoots (*p* = .004 < .05) as well as between the second and third photoshoots (*p* = .022 < .05). According to Table 6, the mean of the three groups was significantly different (F = 6.573; *p* = .003 < .05). The post-hoc results indicated significant differences between the first and third photoshoots (*p* = .001 < .05) as well as between the second and third photoshoots (*p* = .043 < .05).

Table 5 Summary table of within-subject ANOVA analysis: composition (expert 2)

Sources	SS	df	MS	F	Post Hoc: LSD
Between groups (A)	3.307	2	1.653	5.401**	Third photoshoots (M = 3.84, Sd = 0.62) > Second photoshoots (M = 3.44, Sd = 0.65), First photoshoots (M = 3.36, Sd = 0.64)
Within groups					
Between-subjects (S)	14.587	24	.608		
Error (A*S)	14.693	48	.306		
Total	32.587	74			

Note: ***p* < .01.

Table 6 Summary table of within-subject ANOVA analysis: aesthetics (expert 2)

Sources	SS	df	MS	F	Post Hoc: LSD
Between groups (A)	3.440	2	1.720	6.573**	Third photoshoots (M = 3.56, Sd = 0.65) > Second photoshoots (M = 3.24, Sd = 0.60), First photoshoots (M = 3.04, Sd = 0.61)
Within groups					
Between-subjects (S)	15.120	24	.630		
Error (A*S)	12.560	48	.262		
Total	31.120	74			

Note: ***p* < .01.

Regarding the evaluation results of expert 3, according to Table 7, the mean of the three groups was significantly different (F = 8.377; *p* = .001 < .05). The post-hoc results indicated a significant difference between the first and third photoshoots (*p* = .001 < .05) as well as between the second and third photoshoots (*p* = .031 < .05). Moreover, regarding the aesthetics item for expert 3, the mean of the three groups was not significantly different (F = 2.471; *p* = .095 > .05).

Table 7 Summary table of within-subject ANOVA analysis: composition (expert 3)

Sources	SS	df	MS	F	Post Hoc: LSD
Between groups (A)	8.107	2	4.053	8.377**	Third photoshoots (M = 3.16, Sd = 0.75) > Second photoshoots (M = 2.68, Sd = 0.80), First photoshoots (M = 2.36, Sd = 0.57)
Within groups					
Between-subjects (S)	13.333	24	.556		
Error (A*S)	23.227	48	.484		
Total	44.667	74			

Note: ***p* < .01.

4.2 Results of interview

This section presents the semi-structured interviews with the three students to understand the influence of the course on its participants. The results of these interviews are described as follows.

4.2.1 Interviewee 1

The expert evaluation results for the photographs from the first photoshoot by interviewee 1 were 3, 2.5, and 2 points (means of composition and aesthetics), whereas the evaluation results the third photoshoot were 4, 3, and 4 points. The results indicated that the photography techniques of the interviewee were notably improved.

The author asked whether the app-taught course helped improve photography techniques and aesthetics, interviewee 1 answered, “I think so! Because the composition lines were very clear when taking pictures with the app.” In other words, interviewee 1 was confident about the effect of the app on improving composition techniques.

In response to the question, “Did you prefer the app-taught or PowerPoint-taught course?” the interviewee 1 answered, “I prefer the app because using the app I could take pictures myself. Taking pictures by myself was more interesting.” This response indicated that interviewee 1 was interested in actual hands-on operation, satisfied with the photoshoots. Relevant responses from interviewee 1 included: “I felt a sense of accomplishment about taking pictures.”

4.2.2 Interviewee 2

The expert evaluation results for the photographs from the first photoshoot by interviewee 2 were 4, 2, and 3 points, whereas those of the final photo were 5, 3, and 4.5 points. The results revealed an improvement in both the composition ability and aesthetics.

The author asked, “Did the app help improve your photography techniques and aesthetics?” The interviewee answered, “Yes. I think I can take better pictures now than I could before.” The result indicated that interviewee 2 was confident about the effect of the app-taught course in photography.

Regarding the class contents, the author asked, “Did you prefer the app-taught or PowerPoint-taught course?” Interviewee 2 answered, “I preferred the PowerPoint-taught course. I am not sure why, but the presentation seemed clearer.” This response indicated that interviewee 2 determined the app to be a teaching aid and preferred the information to be listed in a presentation.

4.2.3 Interviewee 3

The evaluation results for the photographs from the first photoshoot by interviewee 3 were 5, 1, and 3 points, whereas the results for the final photographs were 4, 2, and 3 points. Interviewee 3’s photography techniques did not demonstrate remarkable improvement.

The author asked, “Did the app help improve your photography techniques and aesthetics?” The interviewee answered, “I think so, compared with the pictures I took before.” Therefore, interviewee 3 had noticed an improvement compared with before the course.

Regarding the class content, the author asked, “Did you prefer the app-taught or PowerPoint-taught course?” Interviewee 3 answered: “The app was better because it felt more convenient, particularly because I could take pictures by myself. I prefer taking pictures by myself.” This indicated that interviewee 3 was interested in actual hands-on operation.

4.3 Discussion

Analysis results of revealed that scores for the students’ photographs from the third photoshoot were significantly higher than those of the first and second photoshoots.
The results indicated that the students’ composition ability may be improved after classes. Interviewee 1 indicated that the clear markings for composition on the app facilitated photo taking. Lin (2014) indicated that employing tablet PCs with an app for information courses resulted in exceptional learning outcomes. This outcome was similar to the results obtained in this study, which indicated that using an app as a teaching aid was beneficial.
Interviewees 1 and 3 preferred using the app in classes because the hands-on operation

was interesting, whereas interviewee 2 preferred the presentation in class because it was clear. In summary, both teaching methods had their advantages.

Several inevitable problems were encountered during the study that might affect its research results: (1) A few students were not able to participate in the complete course because of sick leave or personal leave; therefore, a complete collection of student images was not possible. Moreover, because the number of students who signed up for this course was fixed, adding additional participants was not an option. (2) Changes in the seasons and weather were impossible to control; for example, the day of the first photoshoot was sunny and those for the second and third photoshoots were cloudy with slight rain. This caused a change in lighting, which rendered quality control of photographs difficult. (3) The app designed for this study was uploaded for Android by the author. However, certain brands of mobile phone were unable to install the app that the students had to take turns using another mobile phone to practice. The unfamiliarity of students with the mobile phone's operation could have influenced the photographic outcomes. (4) The length of time of using the App was no longer than 60 minutes for each participant; therefore, it is hard to evaluate the long-term effect of the aesthetic ability through using the App.

5 Conclusion

According to the experiment results of the present study, the composition and aesthetic abilities of the students were improved after the course on photographic composition. These results proved that teaching could indeed shape and nurture aesthetic literacy. In addition, the app served as a teaching aid to improve the students' photographic techniques and aesthetic literacy. The variable in this study was the use of a mobile phone app in teaching photographic composition, and the influence of the variable on aesthetic education was determined. The results indicated that both the use of an app and a PowerPoint presentation were liked by students. The author suggests starting the course with an app to attract students' attention before continuing with further teaching of knowledge to achieve the optimal advantages of each teaching method.

Concerning the research participants, the participants of the present study were selected through purposive sampling; thus, some students volunteered and some were assigned. This situation resulted in different students' active participation levels. Future studies are suggested to employ random sampling and conduct their research in art classes instead of student clubs to prevent excessive similarity in participants' features.

Regarding the research time, because this study was limited to teaching during the time allotted for student club activities, the research schedule could not be postponed even when the weather conditions were not ideal for the activities. Future studies are suggested to set the photoshoots indoors to mitigate the influence of weather conditions. In addition, the long-term effect of photography skill through the App should be further studied in the future. For instance, whether the users can really has a good skill of photography composition without using the App when they have learned the photography with the App after a period time.

Finally, the paper presented that the mobile applications can be a teaching aid for design or art education. However, when the courses overuse the Apps as the teaching aids, does it possible make students over focus on the training of technical ability, which in turn of the affects the development of creativity or imagination. The balance of knowledge teaching and skill training when using Apps as the teaching aids, which is worth to be studied in the future.

6 Acknowledgement

This study was partially supported by the Ministry of Science and Technology, Taiwan, MOST 106-2813-C-155-019-H. The authors are grateful for this support.

7 References

100th Anniversary Nikon Photo Contest. (2017). Evaluation criteria for 100th Anniversary Nikon Photo Contest. Retrieved 15th February, 2019 from https://100th.coolpix.com.tw/rules.php.

2017 National Geographic Travel Photographer of the Year. (2017). Travel Photographer of The Year Contest 2017. Retrieved 10th February, 2017 from http://travel.nationalgeographic.com

APP Store. (2017). APP Store. Retrieved 10th February, 2017 from https://itunes.APPle.com.

Chang, C. –T. (2011). 'Photography Is Not Only Taking Pictures:' AN Action Research of Integrating Visual Culture Concepts into Photograhy Teaching in a Junior High School (Unpublished master thesis). National Changhua University of Education, Changhua County, Taiwan.

Chao, H. –L. (2014). Curriculum Policy and Teachers' Awareness of Curriculum: Example from Art and Humanities Disciplines. *Secondary Education*, *65*(1), 6-18. doi:10.6249/SE.2014.65.1.01.

Chen, Y. (2012). An application of instructional design and motivation principles: sixth grade photographic teaching in the field of arts and humanities (Unpublished master thesis). National Taipei University of Education, Taipei City, Taiwan.

Chiou, H. (2006). *Quantitative research and statistical analysis in social & behavioral sciences*. Wunan Publishing, Taipei, Taiwan.

Foreseeing Innovative New Digiservices of Institute for Information Industry. (2014). Consumer behavior survey for the first half year of 2014. Retrieved 5th February, 2017 from http://www.iii.org.tw/

Freeman, M. (2014). *Michael Freeman's photo school: Composition*. Flag Publishing. Taipei City, Taiwan.

Google Play. (2017). Google Play Android APPs. Retrieved 10th February, 2017 from https://play.google.com/store/APPs

Hedgecoe, J. (2006). *The art of digital photography.* London: Dorling Kindersley.

Hoffmann, T. A. (2008). *The art of black and white photography, 1st Edition*. Published by Rockynook Inc.

Hsieh, C. –F. (2007). "Construction" and "Representation" in 2007 Camellia Photography. *Art Appreciation, 3*(6), 102-106。

Huang, D. –S. (2012). *Great composition of attractive photos*. Sharp Point Publishing Group: Taipei, Taiwan.

Johnson, L., Adams Becker, S., Estrada, V., & Freeman, A. (2015). NMC Horizon Report: 2015 K-12 Edition. Austin, Texas: The New Media Consortium.

Kukulska-Hulme, A. (2005). Mobile Usability and User Experience. In A. Kukulska-Hulme & J. Traxler, J. (Eds.) *Mobile Learning: A handbook for educators and trainers* (pp. 45-56). London: Routledge.

Lin, S. –T. (2014). An Action Research of Applying App and Tablet Computer in Information Education for the Six Graders in Elementary School (Unpublished master thesis). National Chung Cheng University, Chiayi, Taiwan.

Liu, B. –H. (2012). The aesthetic function of college photography courses. *Theory and Practice of Contemporary Education, 10*, 45-47.

Lu, M. –H. (2012). *Encyclopedic dictionary of education*. Winjoin Book. Taipei City, Taiwan.

Mikic, F., Adino, L., Valero, E., & Picos, J. (2007). Accessibility and Mobile Learning Standardization. *Paper presented in Second International Conference on Systems (ICONS'07) (ICONS)*, Sainte-Luce, Martinique, France, pp. 32. doi:10.1109/ICONS.2007.8.

Patterson, F. (2011). *Photography and the art of seeing: A visual perception workshop for film and digital photography*. Firefly Books: Fourth edition.

Prakel, D. (2012). *Basic photography 01: Composition*. AVA Publishing: Second edition.

Quinn, C. (2000). mLearning: Mobile, wireless, in-your-pocket learning. *Line Zine.* Retrieved December 21, 2018 from https://www.linezine.com/2.1/features/cqmmwiyp.htm.

Savakis, A. E., Etz, S. P., & Loui, A. C. (2000). Evaluation of image appeal in consumer photography. Proceedings of SPIE 3959, Human Vision and Electronic Imaging V; doi: 10.1117/12.387147; https://doi.org/10.1117/12.387147.

Sun, C. –S. (2016). A Study on Junior High School Students' Addiction to Smartphone in Keelung City (Unpublished master thesis). National Taiwan of Ocean University, Keelung City, Taiwan.

Taiwan Ministry of Education. (2008). Grade 1-9 curriculum for art and humanities field in primary and secondary schools. Retrieved 15th December, 2018 from https://www.k12ea.gov.tw/97_sid17/藝術與人文學習領域課程綱要修訂(分冊).pdf

Taiwan Ministry of Education. (2013). Long-term plan for the aesthetic education of the Ministry of Education: the first five-year plan (2014 to 2018). Retrieved 15th December, 2018 https://ws.moe.edu.tw/001/Upload/8/relfile/0/2073/e221c236-b969-470f-9cc2-ecb30bc9fb47.pdf

Wu, J. –H., Su, Y. –N., & Ouyang, Y. (2009). Preliminary study on the construction of the evaluation standards of photography courses. *Proceedings of 2009 Taiwan Academic Network Conference (TANET 2009),* I1-I6. National Changhua University of Education, Changhua County, Taiwan.

Yu, B. (2008). Learn Taking a Picture or Photography? *Journal of Arts Education, 162*, 74-79.

Zou, C. –H. (2010). *Photography*. Chuan Hwa Publishing. New Taipei City, Taiwan.

About the Authors:

Wu, Shi-Chi: The college student who majored in communication design and multi-media design in Yuan Ze University since 2014 to 2018. Now, she is a postgraduate student in the National Taipei University of Education.

Li, Elena Carolina: The assistant professor in the University of Taipei since 2019. The author's experts include user interface design, product design and graphic design. The author's research interests include user experience and human-computer interaction.

Working Where We Live: Designing Future Employment for Young People

Wareing, Laura*; Rodgers, Paul. A.; Dunn, Nick

Lancaster University, Lancaster, United Kingdom
* l.e.wareing@lancaster.ac.uk

This paper describes ongoing research exploring how a place-based collaborative approach to design has the potential to enhance learning experiences for young people and businesses, as well as raise awareness of future employment opportunities in the local area. It highlights current challenges in skills and education, focusing on how a new approach to tackling these issues could be nurtured through design. The paper explores two projects in towns in the North West of England that have barriers to future work opportunities, in which collaborative design processes are having a positive influence on young people, businesses and the wider community. In the first project, a design company, youth workers and design researchers are designing a digital intervention for young people and businesses to connect through learning and work experiences. In the second project, a creative practice, secondary school pupils and design researchers are co-designing a place-appropriate programme of activities to be included in a major festival in the North West. This paper concludes with findings on how a co-design approach can engage and inspire local young people and businesses around future work opportunities, shape learning experiences, as well as foster resilient, sustainable communities, an area to be explored further in design research.

Keywords: Young people, future employment, co-design, place-based, inequality

1 Introduction

This paper focuses on ongoing research that examines how the application of a place-based collaborative approach to design in overlooked areas of the United Kingdom can engage and inspire local young people and businesses around future employment opportunities. It highlights how design might respond to current challenges in education and regional disparities in the UK, contribute to communities' resilience, as well as enhance learning for young people. The paper describes two projects 'Yplinkedin' and 'Redesign by the Sea' where a co-design process is being applied to engage young people around their views on future work prospects in their hometowns and create meaningful engagements with local businesses. Within both of the examples, various actors including design researchers, creative businesses, school pupils and other organisations have connected at various stages of the co-design process. In doing so, the collaborations help to produce a variety of design interventions including experiences, strategies, visualisations and service concepts. There are also opportunities for the voices of young peoples from a variety of backgrounds to be heard and for mutual learning to take place.

Section three of the paper discusses the approaches taken and the outcomes of the projects. Section four presents findings from the two projects that link to four key themes; employment and learning opportunities, learning through a collaborative design process, learning about and shaping places and design for inclusive growth. It concludes with a reflection of how design practice and research can help to bring about creative and meaningful place-based engagements between communities and businesses.

2 Background

The research in this paper is being conducted as part of doctoral research on a programme called Transformation North West (TNW), which is part of the North West Consortium Doctoral Training Programme (NWCDTP), funded by the Arts and Humanities Research Council (AHRC). Through TNW, a cohort of twelve PhD researchers from different creative backgrounds, supported by five universities (figure 1) are co-creating projects with businesses and organisations, exploring how design and creative techniques can foster growth and prosperity throughout the North West of England.

Figure 1: A map of the North West including the locations of the TNW universities and the two projects. Source: Transformation North West

The research presented in this paper is being conducted in support of the UK Government's Industrial Strategy, published in December 2017, which provides a plan for how to transform the country's economy and productivity. The strategy highlights how the UK has greater regional inequalities in productivity than any other countries in Europe and has regional differences in education and skills, including major disparities in educational attainment for young people. One of the biggest challenges is to make improvements across the entire country ‘with opportunities available for everyone wherever they live’ (HM Government 2017, 229). It suggests that this can be reached by making better use of local assets, working to address regional differences in educational attainment, providing clear careers information and opportunities for lifelong learning, not just learning in formal educational settings.

The TNW cohort have collectively highlighted how the UK’s creative industries, in which design is the fastest growing sub-sector (DCMS 2016) can play a key role in driving growth across the country. TNW believes that design research and practice has the potential to influence future policymaking, support work readiness in young people, as well as tackle the place-based divide in the country, bringing together local communities and businesses to shape where they live (TNW 2017 Cohort 2018).

2.1 Challenges for Young People and Skills Development

Young people, aged between 15 and 24, need to be provided with better opportunities to develop new skills and confidence required for the future employment markets, which will in turn have a positive influence on the UK’s workforce and productivity. Schools, colleges and businesses need to work together more creatively to provide pupils with rich and meaningful employer encounters that help build a clearer picture of what is required to be successful in the workplace (CDI and The Careers & Enterprise Company 2018; Children’s Commissioner for England 2018; Collins and Barnes 2017). Meaningful employer encounters occur when young people are active participants, experience detailed, hands-on learning and are able to choose and shape the engagement and experience that takes place and reflect on their learning (Children’s Commissioner for England 2018; Collins and Barnes 2017; Mann and Dawkins 2014). Creative roles are three times less likely to be replaced by automated processes than other workplace roles in the future (Mateos-Garcia and Bakhshi 2016). As a result, there is growing demand for a workforce equipped with these skills, sometimes referred to a ‘soft skills’ or ‘twenty-first century skills’ including creativity, communication and teamwork, which are typical of creative and design practitioners (Bakhshi et al. 2017; Design Council 2018; Wright et al. 2018). Young people, teachers and businesses value these skills as highly as good grades, yet not enough is being done to help young people achieve these skills (The Princes Trust 2017; Wybron, Vibert, and Smith 2017). Barriers include educator’s lack of experience, training and resources, as well as barriers in the educational system such as assessments and curriculum priorities (Luckin et al. 2017).

Design approaches can be drawn upon to connect young people with businesses and future opportunities, enhancing learning experiences, generating meaningful encounters that contribute to growth and prosperity in communities across the UK. In a co-design process, which builds on participatory design, participants with different backgrounds and experience actively participate in ‘collective creativity’, which is applied across an entire design process (Sanders and Stappers 2008). In this process, participants share knowledge from their own backgrounds and develop a shared understanding in order to develop a design intervention, such as a product, service or process (Kleinsmann and Valkenberg 2008). Joint inquiry throughout the design process results in mutual learning, where all participants learn together through participating in the design process (Merkel et al. 2005; Sejer Iversen and Dindler 2014; Steen 2013). Co-design has similarities to learning through collaborative problem solving in which a number of people work together as equals to apply knowledge and solve a problem, which are key skills for improving attainment and preparing young people for future work (Luckin et al. 2017).

Carvalho and Goodyear (2018) and Bang and Vossoughi (2016) link participatory design to innovative learning. Carvalho and Goodyear state that although learning outcomes are emergent and cannot be designed, it is possible to design the components of a network of learning, a complex configuration of various tasks, activities, roles, relationships and artefacts that generate learning. They explore this through their Activity Centred Analysis and Design (ACAD) framework, which they use for service design in educational contexts, highlighting components that could be improved in further design iterations. The tasks and artefacts are comparable to the structure and tools used within a co-design process, which help draw out dialogues between participants and 'identify, frame and solve design problems' during a design process (Vaajakallio and Mattelmäki 2014, 68). The designed components of a network of learning can support designing as well as the learning, which could be the 'hands-on learning' of the participants involved in the co-design process, potentially contributing to the high-quality employer encounter.

2.2 Inequalities in the UK

The UK has significant regional inequalities (Children's Commissioner for England 2018; Cox 2018; Cox and Longlands 2016; HM Government 2017; Pike et al. 2016) and within those regions, there are inequalities that vary from place to place. This paper focuses on the North West region of England where, like other regions in the country, there are prosperous areas but there are also more deprived communities than many other regions in the country (Children's Commissioner for England 2018; New Economy 2015; ONS 2016), badly affected by public funding cuts (CentreforCities 2019; Raikes and Johns 2019). The Northern Powerhouse is a government strategy for rebalancing the country's economy and strengthening the North, which has been criticised for being vague and not giving enough attention to people's needs (Lee, 2017; The People's Powerhouse, 2017). Many young people in the North are not confident that they will benefit from regeneration through initiatives, such as the Northern Powerhouse, believing the effect is only skin deep (Children's Commissioner for England 2018).

People who grow up in remote rural, coastal or former industrial areas face more barriers to improving their future life prospects than those who grow up in cities and the surrounding areas (Social Mobility Commission 2017; The Select Committee on Regenerating Seaside Towns and Communities 2019). People in these areas may face lower levels of educational attainment, weak employment markets, more low skilled, low paid employment, poor physical and mental wellbeing and poor transport links (Balata 2015; Goodwin and Heath 2016; Rodríguez-Pose 2018; Social Mobility Commission 2017). The Inclusive Growth Commission's strategy tackles an economy 'leaving too many people behind' (p.5), which benefits a wide range of people facing barriers to high quality employment (RSA 2017). Inclusive growth is place-based, therefore utilising local assets, connects different groups including businesses and schools, delivers opportunities to learn skills needed in the future, find quality jobs and attracts people to 'live, work and stay in the place' (RSA 2017, 44).

The potential of design and creativity to contribute to growth and prosperity in disadvantaged communities, including rural, coastal or former industrial towns is underexplored. Yet a need has been identified, for example, The European Design Leadership Board believes that design can contribute to 'inclusive growth' and help improve the lives of 'all the citizens of Europe'(European Design Leadership Board 2012, 3). The Design Council has highlighted the challenge alongside a need for the benefits of the design economy to be better distributed, bridging an increasing gap between regions, companies and people that use design and those who do not (Design Council 2018). Both emphasise developing design skills specifically as means to drive growth throughout the country, rather than how design interventions could contribute to social change, linking local assets as well as focusing on positive impacts in learning and employment. An example of design research in rural areas by Wright and colleagues (2018), found that running a place-based learning programme for design skills in rural areas had the outcome of providing 'tools for active citizenship and resilience' (p. 17) and awareness of the local community and industry beyond the classroom. Their approach was influenced by place-based learning, which enables people to actively engage with their community through 'hands-on experiences', which is believed to improve academic achievement, active citizenship and building twenty-first century skills (Sobel 2004; Wright et al. 2018)

2.3 Methodology

The two projects described in this paper form case studies for the larger TNW doctoral training programme described in section 2.1. The methodological approach to these two projects is influenced by the nature of the TNW programme where PhD researchers co-create short projects with businesses, which may produce new products or services and also develop an understanding of how design techniques can drive growth and prosperity in the North West.

Broadly, the approach to research on the TNW programme is, as Christopher Frayling (1993) describes it, 'Research through Design' wherein research takes place throughout the design process, gaining an understanding of *how* the design takes shape, not simply shaping the final outcome. An action research approach is suitable for these projects, building upon the learning in each one and applying to the next. The aim is for the researchers, businesses and organisations to collaborate equally and for the projects to include cycles of planning, acting, observing and reflecting, which is similar to a design process (Swann 2002). The aim is to gather information for the researcher, as well as produce a beneficial outcome for other participants, which may be business partners or groups of people taking part in the design process. Swann stresses that action research in design is more than 'just a multidisciplinary design team approach', that the beneficiaries of the work should be 'genuine collaborators', not merely involved for tokenistic feedback (2002; p.57), which fits well with the aims of a co-design approach, where participants work together as equals.

Design work for education can be categorised as a sub-category of socially responsible design (Carvalho and Goodyear 2018). The social design presented in this paper is in line with one of Tromp and Hekkert's (2019) three definitions of social design, which 'builds social capital', a network of values and understandings that facilitates co-operation in communities (OECD 2007). Design is used with the community rather than for the community and there is a focus on the well-being and resilience of a community, using a participatory design process that 'empowers people to redesign better alternatives' to current solutions (2019, 19). A co-design approach complements research in this area, combining a range of different experience and learning through a process of mutual inquiry, aiming to support the sustainability of designed interventions. TNW is focused on the North West of England and both of these projects focus on drawing on the strengths and ideas of businesses, organisations and groups of people who work or live in specific locations. Therefore, a place-based approach, as described in section 2.2 is combined with a co-design approach in these projects in order to use design as means to engage, draw out local knowledge and connect a variety of people with the assets where they live.

2.4 Transformation North West Projects

This section includes a description of project one; Yplinkedin and a brief description of project two, Redesign by the Sea, which is still in progress. The Yplinkedin project outlines how a place-based collaborative design approach engaged young people and businesses around learning and future employment opportunities, as well as adapting Carvalho and Goodyear's 'Activity Centred Analysis and Design' (ACAD) framework (2018) to visualise and analyse the components of the engagements contributing to emergent learning and for this research, includes an adaptation on the original framework, the outcomes of the co-design.

2.5 Project One: Yplinkedin, Burnley

TNW researchers co-designed with digital design practitioners from a company called Blackbeard and youth workers from Participation Works, a not-for-profit company in Burnley, Lancashire on a six-month Big Lottery funded project called Yplinkedin, which aimed to connect local young people to learning and work opportunities. Figure 2 shows the many different actors involved in the project. The project aimed to tackle challenges facing school pupils across the town, such as limited knowledge of work and low confidence, as well as factors contributing to economic decline including low educational attainment and a declining population (Burnley Council 2017; Lancashire County Council 2018).

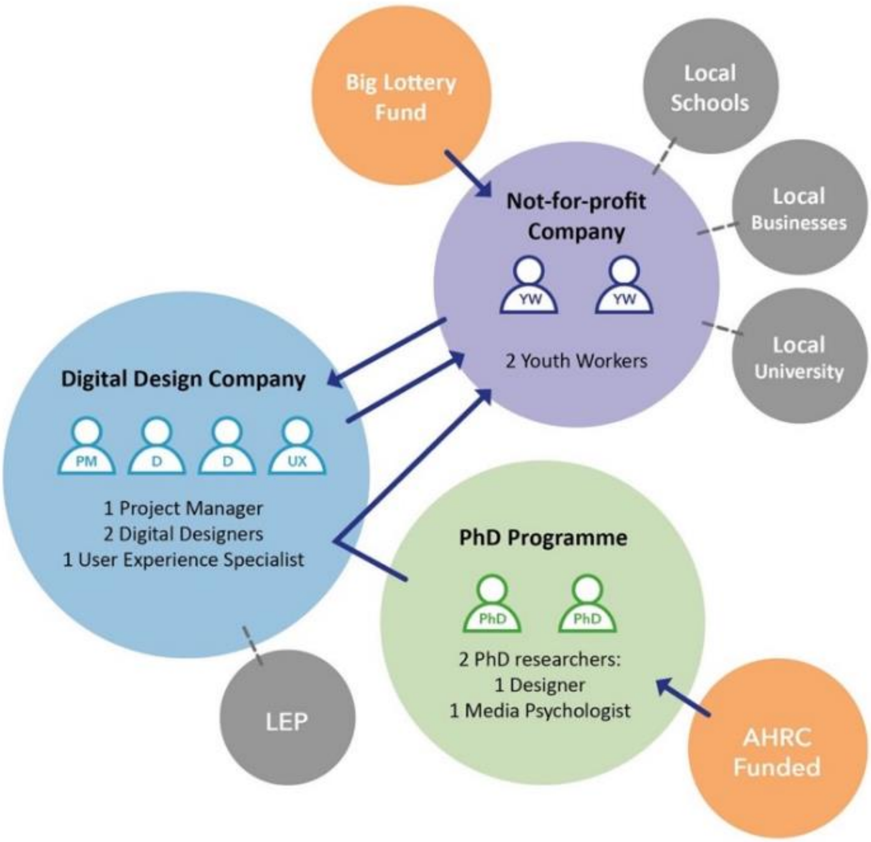


Figure 2: The range of actors involved in the Yplinkedin project in Burnley. Source: Author's own

The design practitioners structured the phases of their design process based on the Design Thinking Model created by the Hasso Plattner Institute (Plattner, Meinel, and Leifer 2011), moving through phases of planning, discover, define, ideate, pausing the project at the deliver stage whilst seeking additional funding to deliver the design intervention (Figure 3).

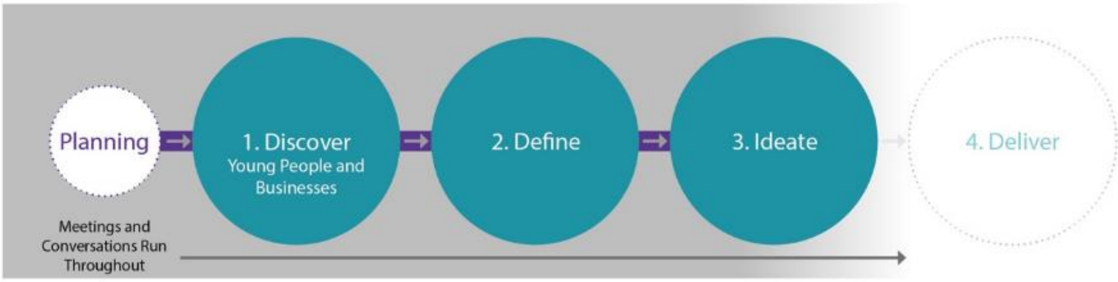


Figure 3: The design process used to structure the project. Source: Author's own

The youth workers used existing local networks of schools and businesses to set up and deliver engagement sessions for both groups, seeking views on skills, work experience and living in Burnley from the two different groups. These sessions were structured with a range of tasks, supported by various tools and the facilitation skills of the youth workers and design practitioners. Figure 4 adapts the Activity Centred Analysis and Design framework to visualise the configuration of designed components that contributed to the emergent learning and design activity and outcomes on the project. The team co-designed a number of tasks for the project, which were organised according to the Design Thinking Model, which were supported by a number of different tools for capturing information, analysing and designing, as well roles and division of labour depending on background and expertise (Figure 5 and 6). This combination resulted in emergent activity, such as capturing the views of young people and businesses, the input of larger organisations, such as the Local Enterprise Partnership (LEP) and the decisions made on the direction of the design, which produced the outcomes of learning for the various actors involved, design prototypes for a website and new youth service outcomes.

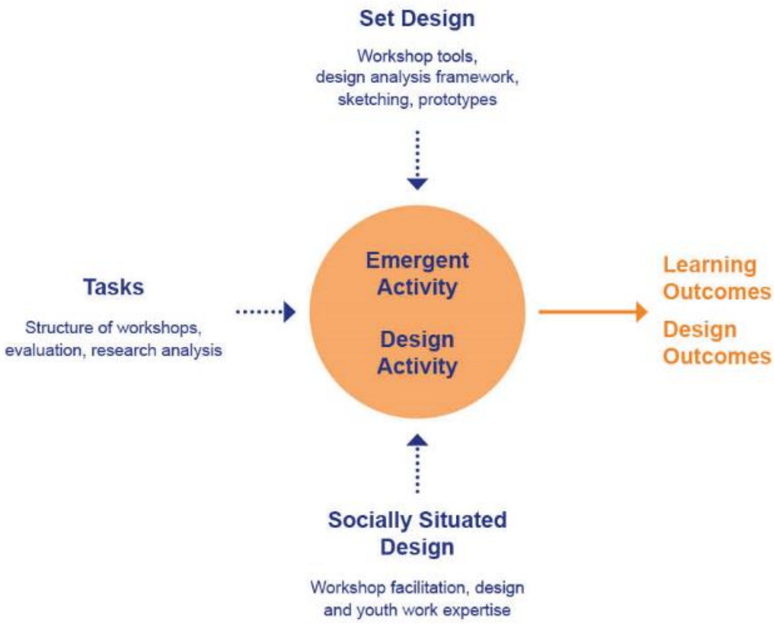


Figure 4: Activity Centred Analysis and Design (ACAD) for the Yplinkedin project. Source: Author's own, based on Carvalho and Goodyear's framework

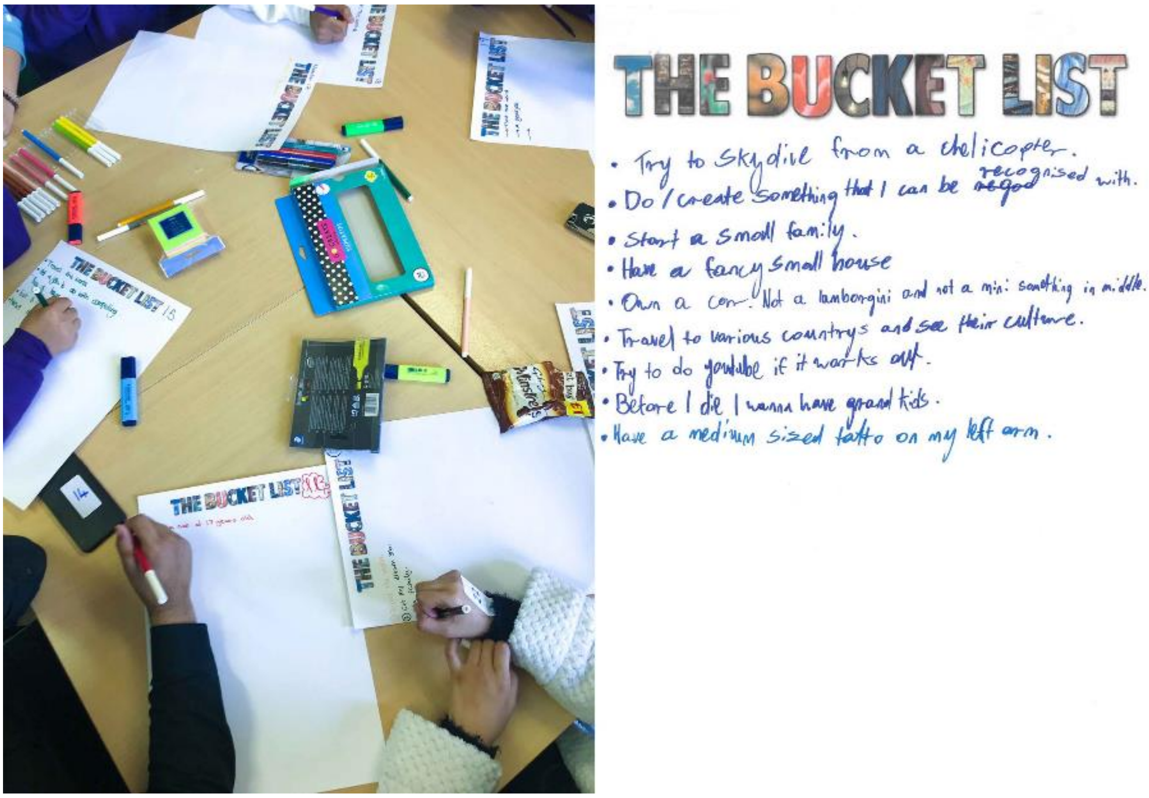


Figure 5: An example of one of the tools used in the discover phase of the project, asking young people to list what they wanted to do in the future as a 'Bucket List'. Source: Yplinkedin project

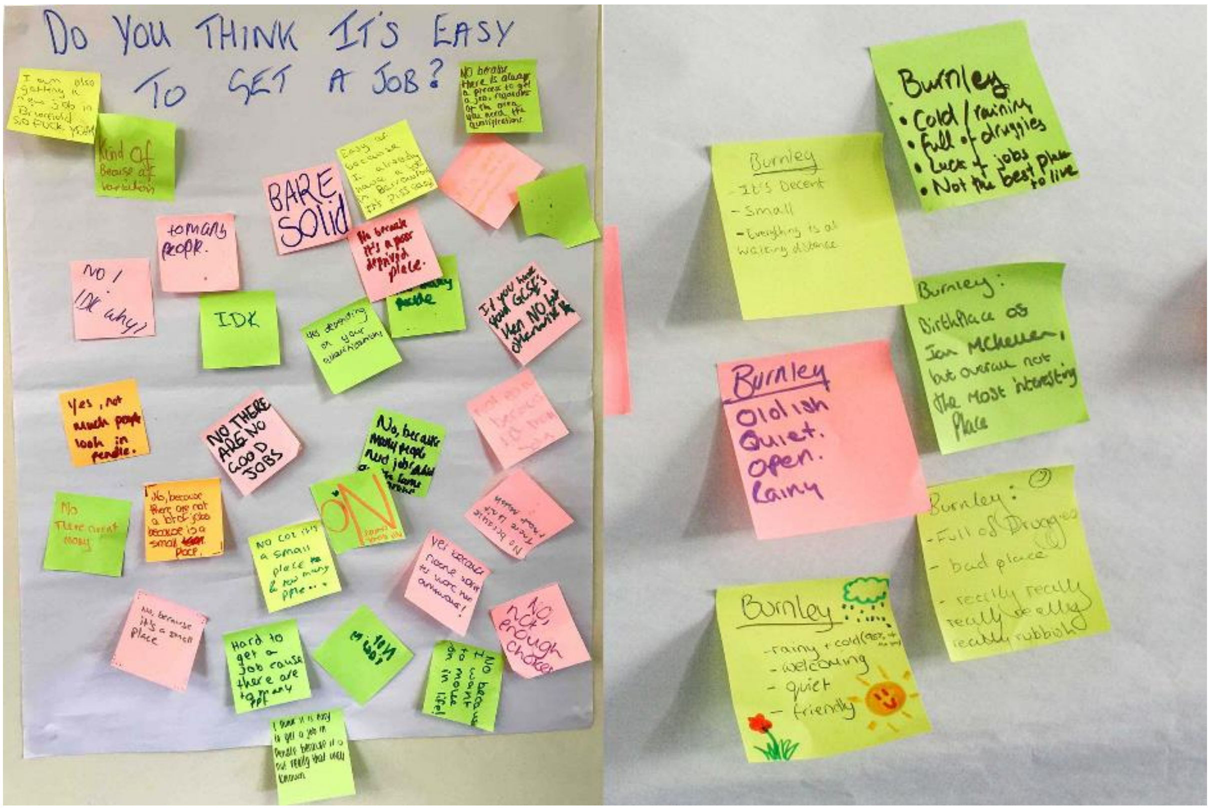


Figure 6: Young people responded to questions about their opinions of Burnley and finding a job there. Source: Yplinkedin project

Co-design on the project took place between the team of design practitioners, youth workers and researchers (Figure 7). The co-design team worked together throughout the entire design process, ensuring that the youth workers had ownership of the final design intervention as they would be responsible for driving and sustaining it. In interviews throughout the process, the team reflected on a range of learning outcomes the co-design process had delivered, from knowledge of the challenges facing Burnley, new methods, skills and increased confidence in their own abilities, as well as its effect on strengthening their social capital. Restraints on time and funding prevented the team from engaging the school pupils and businesses in actively designing the intervention and no evaluation of emergent learning for the school pupils was undertaken. However, we can assume that the young people developed awareness of their skills and views of Burnley from informal feedback collected during the workshops. It was generally felt that the co-design experiences had a positive effect on the careers support service provided by the youth workers as a result of the project.

Figure 7: The co-design team analysing the information collected in the workshops. Source: Yplinkedin project

The designed outcome is a prototype website aimed at young people, businesses and education providers in Burnley, which enables connections with each other for mutual benefit (Figure 8). Businesses can advertise opportunities and seek young people who fit their criteria, young people can access support, opportunities and build and seek mentorship from role models, and educators can help to mediate the connections. Focus groups were held with school pupils and businesses to gain feedback to shape the prototype and the team are now seeking funding for further development of the prototype website. More detail on this project is included in the author's previous paper (2019).

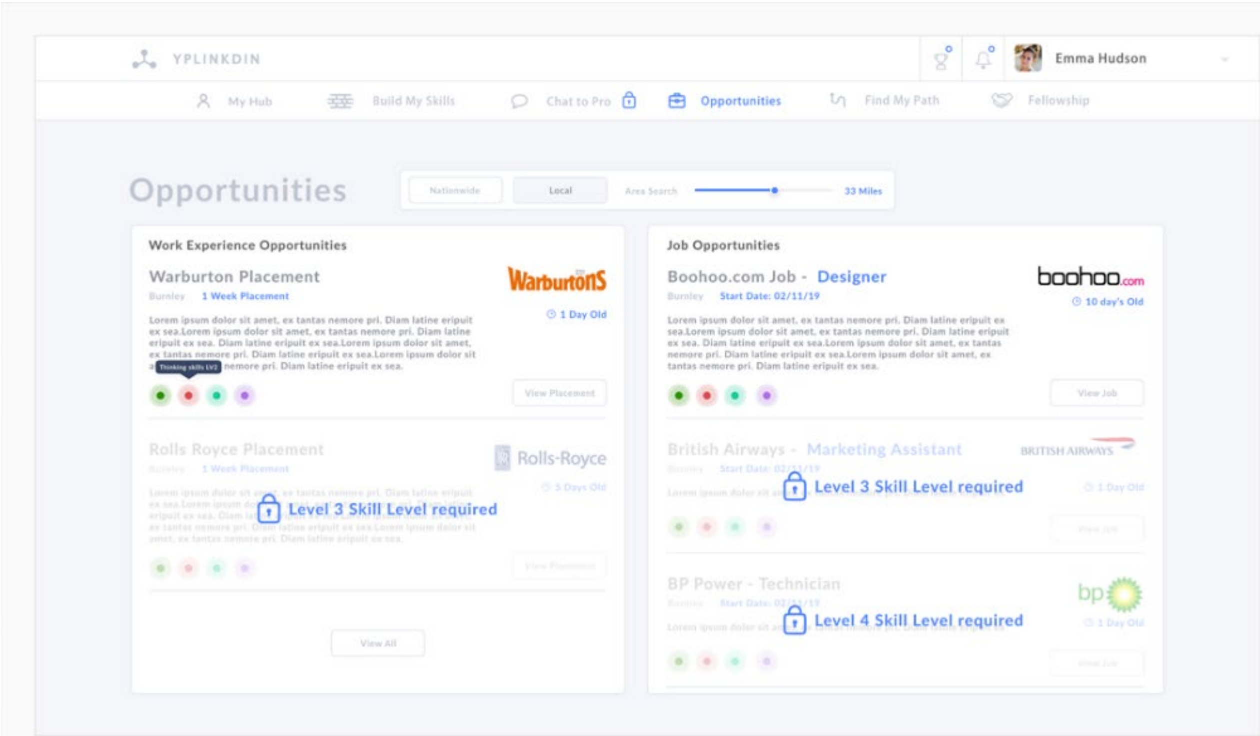


Figure 8: A screenshot of the prototype Yplinkedin website. Source: Yplinkedin project

2.6 Project 2: Redesign by the Sea, Morecambe

This project, in progress at the time of writing, is a collaboration with a creative practice called Deco Publique who co-curate major public art and cultural festivals throughout the North West of England with a focus on placemaking and regeneration. The aim is to foster new sustainable links between the creative practice and the community and co-design a place appropriate programme of activities with and for young people at the annual Morecambe Vintage Festival. Although Morecambe is challenged by significant economic decline and areas of deprivation, the Festival is a major asset, celebrating arts and culture from the past and present as well as reflecting the character of the town. Each year the festival generates over £1 million a year to the area providing a much needed economic boost (Lancaster City Council 2016). The project comes at a turning point for Morecambe, as it plans to be the new home to Eden Project North (Eden Project 2018).

Co-design sessions have been co-developed with Deco Publique, the first author, TNW PhD researcher colleagues, and teachers at a local secondary school in the centre of Morecambe. The lead researcher (first author) conducted conversations between the different actors to deliver co-design activities that will produce benefits for all involved, which will be reflected on through the cycles of the action research process. Figure 9 shows the different needs of everyone involved in the co-design sessions, which feed into the festival programme.

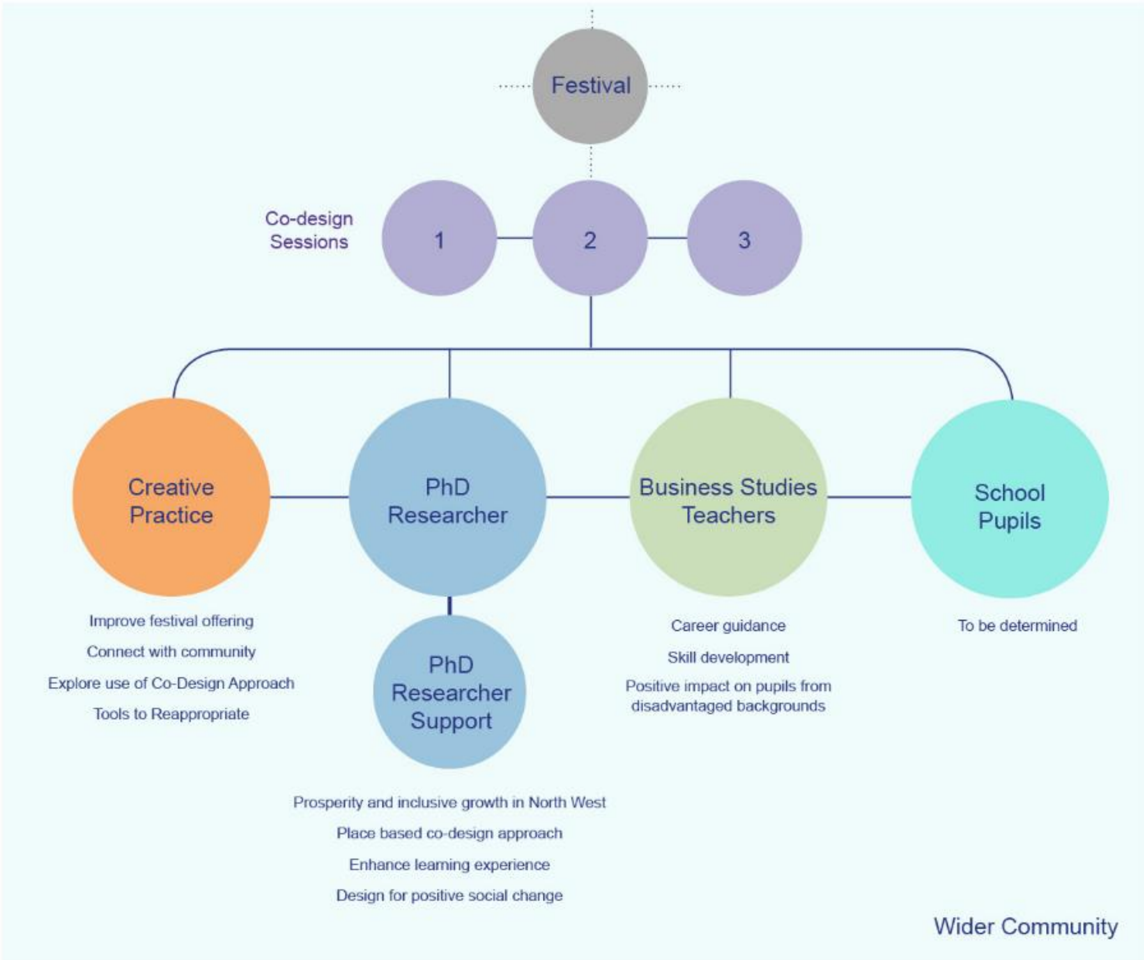


Figure 9: The different actors and their needs for the co-design engagement. Source: Author's own

The plan is to run three 2-hour workshop sessions for the school pupils. The first workshop will gain an overview of the views of the group and the second will aim to redesign the programme for the Vintage Festival. In the third workshop, the ideas will be refined further with expert input from Deco Publique. The ACAD framework for the project will have a similar form to the one from the Yplinkedin project (Figure 4). However, the teachers will be present to encourage the young people and the project will aim to provide a meaningful employer encounter through an exploration of Deco Publique's work, skills, roles and its relevance to Morecambe. This will be followed by a hands-on co-design experience, supported by a range of tools and resources to learn what it is like to be an events programmer and develop creative and collaboration skills. The outcome will be learning for all actors involved in the process and festival programme concepts that will be used to shape the Festival in the future.

Like the Yplinkedin project, the young people will provide their views on living in and their future in Morecambe but the discussion they generate will not just benefit Deco Publique, it will help the whole group co-design a programme of Festival activities for young people. In the Yplinkedin project, the information collected on perceptions of current and future life in Burnley were underused in the design development and focus was placed on the specific needs of the young people. This will not be the case in project two, where the views on Morecambe will be key to place-based learning and place-based co-design of festival activities. For example, in the Yplinkedin project the young people were asked for a rating of Burnley based on the website ‘Trip Advisor’, in the second project, we will build on this method in more detail through reviews, ratings and information on what is missing using a specifically developed tool (Figure 10). Observations on how the young people respond to the co-design sessions will be recorded throughout, coupled with an evaluation of the learning and any other outcomes the different actors gain from each workshop, focused particularly on the young people and Deco Publique.

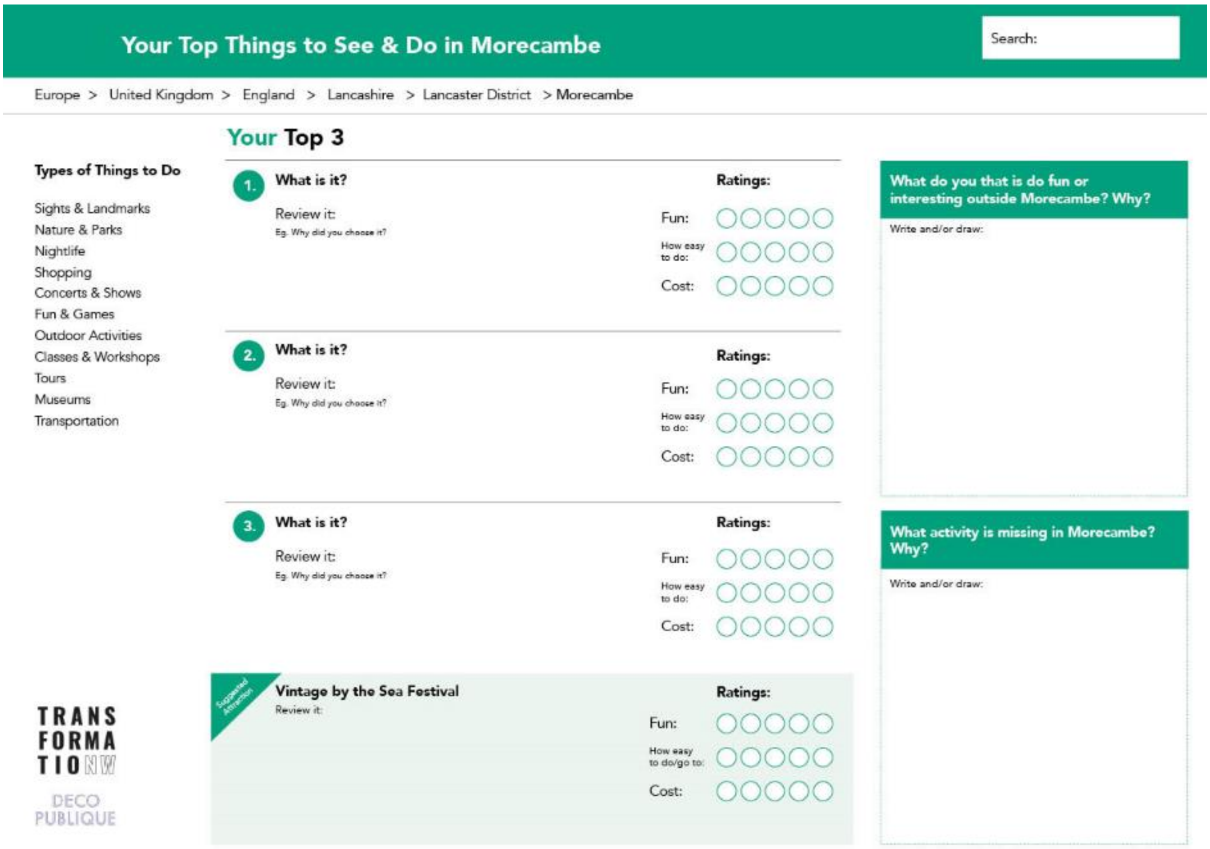


Figure 10: An example of one of the tools used in the first session. Source: Author’s own

Despite the project only being in the planning phase, the collaboration is already having a positive impact on the sustainability of the festival and the local community. Deco Publique has included details of the project in a bid to Arts Council England, stating that the collaboration expands their ‘knowledge in meaningful and impactful cultural intervention and localised change’ (Deco Publique, 2019).

3 Findings

3.1 Employment and Learning Opportunities

A collaborative design approach can structure meaningful and sustainable engagements between young people and businesses, which many careers and education focused organisations are calling for but providing little information on how to implement. These interactions can offer young people a unique and engaging opportunity to learn through designing something beneficial in partnership with professionals working in the field.

The process outlined in the first project demonstrates how a co-design team can gather, analyse and take action through design using the information on aspirations and barriers to work experience and skills development with young people across schools in a town. Specifically, they found that pupils across Burnley had little awareness of the job opportunities in the local area or how to take steps to finding and applying for them. The team transformed these insights into a prototype for a website to connect young people, educators and businesses, which would provide routes to learning opportunities and employment opportunities for a wider community of young people and businesses in the district.

Despite research that shows that schools are inflexible and often difficult to engage with, the youth workers had strong ties to local schools, which made the engagements easy to facilitate. However, engagement between the youth workers, design practitioners and schools could have been reinforced for increased direct benefit to the young people by enabling them to understand more about design, through co-designing ideas for the platform. In the second project, mutual benefits to Deco Publique and the pupils will be delivered by gathering information and opinions on the Festival and pupils will be given the opportunity of a high-quality employer encounter through co-design.

3.2 Learning through a Collaborative Design Process

Working as genuine collaborators in the co-design process facilitates a number of different learning outcomes. In the Yplinkedin project, the designers and youth workers worked together as equals, which helped develop skills and influence future practices for both companies. In the situation where there was limited funding, they were able to learn from each other through practice rather than undergoing any formal training. The youth workers reported during the process that they had new ideas for how to improve their service offering for young people. Five months after the end of the project, they report that they are now running new careers support services and have implemented changes to the way they work as a direct result of the project.

Knowledge of the skills, confidence and aspirations of young people in Burnley were collected as a result of the process, which has fed into both the prototype design and youth workers services. The young people were not directly involved in the co-design of the platform and no formal evaluation of the learning of the young people and businesses involved in the project was carried out due to time and resource. The second project will build co-design into the engagement from the beginning and will evaluate the emergent learning with the actors involved throughout the project to build insight in this area.

This paper has adapted the ACAD framework to reflect the emergent learning activity, with the additional outcome of design produced by the project. The framework includes the design of components, both physical and social, for co-design activity. The tools and tasks utilised are dependent on the skills of the people involved in the facilitation of the project. In the Yplinkedin project, the team reflected that the tools used in the workshops with young people and businesses required the facilitation skills of the team to help identify and frame views. The design practitioners' frameworks applied during the 'define' and 'ideate' stage of the process also needed additional knowledge and facilitation skills to use, as the youth workers found them difficult to grasp corresponding with research by Donetto, Pierri, Tsianakas, & Robert (2015) and Vaajakallio & Mattelmäki (2014). As a result of the Yplinkedin project, the team of facilitators of the second project will be involved in the co-design of the tasks and activities for the engagement so that they are comfortable using them to help prompt ideas from the young people.

3.3 Learning About and Shaping Places

Specific tasks and tools in design projects that prompt a reflection on place help young participants to think about where they live and what learning development and employment opportunities are on offer there. The Yplinkedin project gathered views on the prospects available in Burnley but the ideas were not fully utilised in the design of the platform. The second project will also seek to enable young people to reflect on their hometown, however tools and facilitation will also seek to help the participants think creatively about what they would like in their hometown in the future. The participants will reflect on how arts and cultural events provide benefits to their hometown and come up with new ideas to improve where they live through conversations and interactive activities with creative practitioners who are experts in this field.

These projects have the potential to contribute to discussions and decisions that influence the wider community. Businesses and organisations engaging with and developing ideas with their local communities also have the potential to influence local authorities and organisations with the decisions that affect the communities. For example, youth workers from the Yplinkedin project are approaching Burnley Council and University of Central Lancashire to discuss the outcomes of the project. Deco Publique intend to present information from the project to the local board of councillors, who make funding decisions, demonstrating connections with the local community that contributes to the sustainability of their practice.

3.4 Design for Inclusive Growth

Place-based design has a role to play in delivering inclusive growth. This paper presents examples that demonstrate how a co-design approach and methods have been used to contribute to positive futures in coastal and post-industrial towns in the North of England that face economic and social decline. Both examples utilise and connect local assets, such as businesses varying in size and sector, and youth organisations. Through design processes, they draw out and include the voices of young members of the local community, that may not otherwise be heard. The projects aim to design services and products that break down barriers for community members to find quality work experience or mentorship in the local area. They also bring together young people, educators and businesses to work together creatively, delivering high quality employer encounters through participation in a co-design process. In addition, these encounters can incorporate place-based education, learning and developing through reflecting on the community beyond the classroom walls. All of these approaches have the potential to tackle negative perceptions of the local community and future employment prospects in the local area and throughout the North.

4 Key Contribution to the Field

This paper has highlighted new ways in which design practice and research can structure and strengthen creative and meaningful place-based engagements between communities and businesses, which is underexplored in current research. The paper demonstrates how it is possible to shape co-design projects that draw on and connect local assets, as well as help equip people with the knowledge about high quality work where they live. This paper has stressed how important it is that these meaningful engagements are distributed across the whole country, to places that are often overlooked, which can help with one of the UK's biggest challenges of providing opportunities for everyone everywhere, tackling regional disparities. This is believed to have the potential to influence the future workforce and national prosperity. This paper calls for more design research into both meaningful learning experiences and place-based inequalities, which are interlinked.

The research on the Redesign by the Sea Project is still in progress and therefore insights could only be drawn from the limited work to date. Insights on the impact of the Yplinkedin project are still emerging as the team continue to seek further funding and develop a network of potential users and contributors. However, changes to the services delivered by the youth workers to both young people and businesses as well as ongoing meetings with local institutions should produce new insights.

This paper brings together findings from the first two projects from a series of projects shaping future patterns of work, employment, training and skills for young people. These insights will be strengthened by forthcoming projects, which will contribute further to research in the area of inclusive and sustainable growth and prosperity across the UK.

5 References

Bakhshi, Hasan, Jonathan M Downing, Michael A Osborne, and Philippe Schneider. (2017). The Future of Skills. Employment in 2030. London. www.nesta.org.uk.

Balata, Fernanda. (2015). Blue New Deal. https://neweconomics.org/uploads/files/2ec4a9d52360c8dd5a_a7m6yt6ik.pdf.

Bang, Megan, and Shirin Vossoughi. (2016). “Participatory Design Research and Educational Justice: Studying Learning and Relations Within Social Change Making.” Cognition and Instruction 34(3): 173–93. http://www.tandfonline.com/action/journalInformation?journalCode=hcgi20

Burnley Council. (2017). Making It in Burnley: Burnley Council’s Strategy for Raising Aspiration 2017-2020. Burnley. https://burnley.moderngov.co.uk/documents/s5767/Aspiration Strategy 2017.pdf

Carvalho, Lucila, and Peter Goodyear. (2018). “Design, Learning Networks and Service Innovation.” Design Studies 55: 27–53.

CDI, and The Careers & Enterprise Company. (2018). The Gatsby Benchmark Toolkit Practical Signposting Tools for Schools The Gatsby Benchmark Toolkit. London. https://www.careersandenterprise.co.uk/sites/default/files/uploaded/gatsby_benchmark_toolkit.pdf

CentreforCities. (2019). “Austerity Hit Cities Twice as Hard as the Rest of Britain: Northern Cities Budgets Have Faced the Biggest Cuts.” CentreforCities. https://www.centreforcities.org/press/austerity-hit-cities-twice-as-hard-as-the-rest-of-britain/

Children’s Commissioner for England. (2018). Growing Up North. London. https://www.childrenscommissioner.gov.uk/wp-content/uploads/2018/03/Growing-Up-North-March-2018-1.pdf

Collins, Jill, and Anthony Barnes. (2017). Careers in the Curriculum. What Works? London. www.careersandenterprise.co.uk

Cox, Ed. (2018). “Britain’s New Giants.” RSA. https://www.thersa.org/discover/britains-new-giants

Cox, Ed, and Sarah Longlands. (2016). The Role of Small and Medium-Sized Cities in Growing the Northern Powerhouse. Manchester. www.ippr.org/north

DCMS. (2016). “Creative Industries Economic Estimates - January 2016 - GOV.UK.” gov.uk. https://www.gov.uk/government/statistics/creative-industries-economic-estimates-january-2016

Design Council. (2018). “Designing a Future Economy.” https://www.designcouncil.org.uk/sites/default/files/asset/document/Designing_a_future_economy18.pdf

Donetto, Sara, Paola Pierri, Vicki Tsianakas, and Glenn Robert. (2015). “Experience-Based Co-Design and Healthcare Improvement: Realizing Participatory Design in the Public Sector.” The Design Journal 18(2): 227–48. http://www.tandfonline.com/action/journalInformation?journalCode=rfdj20

Eden Project. (2018). “New Vision for Morecambe’s Eden Project Revealed.” Eden Project. https://www.edenproject.com/media/2018/11/new-vision-morecambes-eden-project-revealed

European Design Leadership Board. (2012). Design for Growth and Prosperity. Helsinki. http://europeandesigninnovation.eu/wp-content/uploads/2012/09/Design_for_Growth_and_Prosperity_.pdf
Frayling, Christopher. (1993). “Research in Art and Design.” Royal College of Art Research Papers 1(1): 9. http://researchonline.rca.ac.uk/384/3/frayling_research_in_art_and_design_1993.pdf
Goodwin, Matthew, and Oliver Heath. (2016). Brexit Vote Explained: Poverty, Low Skills and Lack of Opportunities | JRF. https://www.jrf.org.uk/report/brexit-vote-explained-poverty-low-skills-and-lack-opportunities
HM Government. (2017). Industrial Strategy: Building a Britain Fit for the Future. London. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/664563/industrial-strategy-white-paper-web-ready-version.pdf
Kleinsmann, Maaike, and Rianne Valkenberg. (2008). “Barriers and Enablers for Creating Shared Understanding in Co-Design Projects.” Design Studies 29(4): 369–86. www.elsevier.com/locate/destud
Lancashire County Council. (2018). “Burnley District.” Lancashire County Council. https://www.lancashire.gov.uk/lancashire-insight/area-profiles/local-authority-profiles/burnley-district/
Lancaster City Council. (2016). “Vintage by the Sea Returns!” https://www.lancaster.gov.uk/news/2016/aug/vintage-by-the-sea-returns/
Lee, Neil. (2017). “Powerhouse of Cards? Understanding the ‘Northern Powerhouse.’” Regional Studies 51(3): 478–89. https://www.tandfonline.com/doi/full/10.1080/00343404.2016.1196289
Luckin, Rose et al. (2017). Solved! Making the Case for Collaborative Problem-Solving. London. https://media.nesta.org.uk/documents/solved-making-case-collaborative-problem-solving.pdf
Mann, Anthony, and James Dawkins. (2014). Employer Engagement in Education. Reading. www.inspiringthefuture.org.
Mateos-Garcia, Juan, and Hasan Bakhshi. (2016). The Geography of Creativity in the UK Creative Clusters, Creative People and Creative Networks The Geography of Creativity in the UK. London. www.nesta.org.uk
Merkel, Cecelia Bridget et al. (2005). “Sustaining Computer Use and Learning in Community Computing Contexts: Making Technology Part of ‘Who They Are and What They Do.’” The Journal of Community Informatics 1(2): 158–74. http://ci-journal.net/index.php/ciej/article/view/215/174
New Economy. (2015). The English Indices of Deprivation 2015 - Results for the North West. Manchester. http://www.neweconomymanchester.com/media/1570/the-english-indices-of-deprivation-2015-results-for-the-north-west.pdf
OECD. (2007). Human Capital : How What You Know Shapes Your Life. OECD.
ONS. (2016). Towns and Cities Analysis, England and Wales, March 2016 - Office for National Statistics. London. https://www.ons.gov.uk/peoplepopulationandcommunity/housing/articles/townsandcitiesanalysisenglandandwalesmarch2016/2016-03-18
Pike, Andy et al. (2016). Uneven Growth: Tackling City Decline. York. https://www.jrf.org.uk/report/uneven-growth-tackling-city-decline
Plattner, Hasso, Christoph Meinel, and Larry Leifer. (2011). Design Thinking: Understand - Improve - Apply. Potsdam. http://www.springer.com/series/8802
Raikes, Luke, and Marcus Johns. (2019). “The Northern Powerhouse: 5 Years In.” IPPR. https://www.ippr.org/blog/the-northern-powerhouse-5-years-in
Rodríguez-Pose, Andrés. (2018). “The Revenge of the Places That Don’t Matter (and What to Do about It).” Cambridge Journal of Regions, Economy and Society 11: 189–209. https://academic.oup.com/cjres/article-abstract/11/1/189/4821289
RSA. (2017). Inclusive Growth Commission: Making Our Economy Work for Everyone - RSA. London. https://www.thersa.org/discover/publications-and-articles/reports/final-report-of-the-inclusive-growth-commission
Sanders, Elizabeth B. N., and Pieter J. Stappers. (2008). “Co-Creation and the New Landscapes of Design.” CoDesign 4(1): 5–18. http://www.tandfonline.com/doi/abs/10.1080/15710880701875068
Sejer Iversen, Ole, and Christian Dindler. (2014). “Sustaining Participatory Design Initiatives.” CoDesign 10(2–4): 153–70. http://www.tandfonline.com/action/journalInformation?journalCode=ncdn20
Sobel, David. (2004). “Place-Based Education: Connecting Classroom and Community.” Nature and Listening 4: 1–7. http://www.kohalacenter.org/teachertraining/pdf/pbexcerpt.pdf

Social Mobility Commission. (2017). State of the Nation 2017: Social Mobility in Great Britain. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/662744/State_of_the_Nation_2017_-_Social_Mobility_in_Great_Britain.pdf
Steen, Marc. (2013). “Co-Design as a Process of Joint Inquiry and Imagination.” Design Issues 29(2): 16–28. http://www.mitpressjournals.org/doi/10.1162/DESI_a_00207
Swann, Cal. (2002). “Action Research and the Practice of Design.” Design Issues 18(1): 49–61. http://www.mitpressjournals.org/doi/10.1162/07479360252756287
The People’s Powerhouse. (2017). “The People’s Powerhouse Charter.” https://peoplespowerhouse.org.uk/charter
The Princes Trust. (2017). The Prince’s Trust Report Results for Life. London. https://www.princes-trust.org.uk/about-the-trust/research-policies-reports/research.
The Select Committee on Regenerating Seaside Towns and Communities. (2019). House of Lords Select Committee on Regenerating Seaside Towns and Communities - The Future of Seaside Towns. London. http://www.parliament.uk/mps-lords-and-offices/standards-and-interests/register-of-lords-
TNW 2017 Cohort. (2018). Driving the Industrial Strategy for North West Growth - The Role of the Creative Industries. Lancaster. https://transformationnorthwest.org/wp-content/uploads/2018/06/2018_TNW_Driving_Industrial_Strategy_for_North_West_Growth.pdf
Tromp, Nynke, and Paul Hekkert. (2019). Designing for Society : Products and Services for a Better World.
Vaajakallio, Kirsikka, and Tuuli Mattelmäki. (2014). “Design Games in Codesign: As a Tool, a Mindset and a Structure.” CoDesign 10(1): 63–77. http://www.tandfonline.com/doi/abs/10.1080/15710882.2014.881886
Wareing, Laura, Paul A. Rodgers, and Nick Dunn. (2019). “Co-Designing Pathways to Opportunities for Young People in the North West of England.” The Design Journal 22(sup1): 863–83. https://www.tandfonline.com/doi/full/10.1080/14606925.2019.1595405
Wright, Natalie, Evonne Miller, Les Dawes, and Cara Wrigley. (2018). “Beyond ‘Chalk and Talk’: Educator Perspectives on Design Immersion Programs for Rural and Regional Schools.” International Journal of Technology and Design Education: 1–31. http://link.springer.com/10.1007/s10798-018-9487-7.
Wybron, Ian, Simone Vibert, and Josh Smith. (2017). Next Generation UK. London. https://www.britishcouncil.org/sites/default/files/h030_next_generation_uk_report_final_web.pdf

About the Authors:

Laura Wareing: Design PhD researcher on Transformation North West at Lancaster University. Her research uses a co-design approach with young people in overlooked places in the North. She was a previously designer and researcher at ImaginationLancaster and is a Fellow of the RSA.

Paul A. Rodgers: Professor of Design at Imagination, Lancaster University. He is also the Arts and Humanities Research Council (AHRC) Design Leadership Fellow in the UK. He is a co-founder of the Design Disruption Group who focus their research on making positive change in health and social care and elsewhere.

Nick Dunn: Executive Director and Chair of Urban Design at Imagination the design research lab at Lancaster University. He is Senior Fellow of the Institute for Social Futures, leading research on the future of cities.

Acknowledgement: The authors would like to thank all those who contributed to both projects, including Blackbeard Design, Participation Works North West, Deco Publique, school pupils and staff and those who supported through TNW. We would also like to acknowledge the NWCDTP, funded through the AHRC for their support.

FROM DIGITAL AUTOMATION TO MACHINE LEARNING AND ARTIFICIAL INTELLIGENCE TO THE INTERNET OF THINGS, THE TECHNOLOGY LANDSCAPE THAT DESIGN NEEDS TO ENGAGE WITH IS BECOME INCREASINGLY COMPLEX. LONG GONE ARE THE DAYS WHEN DESIGN WAS ABLE TO HUMANISING TECHNOLOGY WITHOUT ENGAGING WITH OTHER DISCIPLINES. HOW CAN DESIGN SUPPORT THE 4TH INDUSTRIAL REVOLUTION? WHAT IS THE ROLE OF DESIGN IN DISCOVERING NEW TECHNOLOGY? HOW SHOULD DESIGN CONNECT TECHNOLOGY AND HUMANS? HOW CAN DESIGN AND CREATIVITY UNLOCK THE POTENTIAL OF DIGITAL TECHNOLOGIES?

TECHNOLOGY

Building City Mirrors: structuring design-driven explorations of future web-based technologies for local development

Lucia, Lupi

DIST - Interuniversity Department of Urban and Regional Studies and Planning, Polytechnic and University of Turin, Turin, Italy

STEM - Faculty of Science, Technology, Engineering & Mathematics, KMi - Knowledge Media Institute, The Open University, Milton Keynes, United Kingdom
lucia.lupi@polito.it

This paper presents the design-driven approach applied to investigate how web-based technologies can support local development actions in urban contexts. The key elements of this approach are a design proposal, a conceptual framework working as knowledge infrastructure for the design and research explorations, and a research strategy for systematically investigating the variations of the design proposals and the different aspects of the conceptual framework. The design proposal of the City Mirrors envisions a multi-actor, multi-purpose, and multi-scale digital environment reflecting the key aspects of city development processes. The conceptual framework associated with the proposal is based on the three axes of Users' representation, City Ecosystem and forms of technological support. The research strategy is developed across multiple case studies to analyse the practical implications of proposing alternatives to current technologies in various settings and intervening in the city context through different types of web-based technologies. Relying on these three components, the presented approach addresses the design problem of web-based technologies supporting competing goals and a wide range of applicative scenarios in its explanatory and prescriptive aspects.

Keywords: Smart City; Web-based technologies; Conceptual Framework; Research Strategy

1 Introduction

Digital technologies are nowadays loaded by the highest expectations concerning the growth of cities, their future sustainability and the improvement of their resilience. Indeed, digital technologies are seen in urban contexts as the potential solution to address the social challenges associated with the on-going demographic and socio-cultural transformations, the environmental challenges due to climate change, and the economic challenges determined by the tied interdependence between local and global phenomena. Nevertheless, digital technologies are not yet driving radical changes in the way city activities are planned, managed and governed, and even less in the way people interact in cities to collectively address shared challenges. In other words, digital technologies intended to support city activities are still marginal in running public and private services, implementing projects and initiatives, transforming the built environment, making policies and plans for the future, orienting the economic investments on local businesses, working on community development and producing an actionable knowledge to trigger structural social and economic innovations at local level.

When we refer to digital technologies for cities, it is essential to clarify the distinction between smart city technologies and web-based technologies for better understanding the different reasons of their marginality.

Smart city technologies include applications based on Internet of Things (IoT) devices, sensors, big data analytics, geographic information systems, virtual reality [Lim & Maglio 2018a] and recently also artificial intelligence solutions. All these technologies are primarily oriented to *"connect things to people"* [Lim & Maglio 2018b] and remain primarily aimed to monitor the physical environment of the city, in particular in "hard domains" such as resource management, mobility, energy, building, instead than "soft domains" such as living, government, educations, economy and culture [Neirotti et al. 2014]. This characterisation of smart city technologies does not provide support to a significant part of the dimensions of people and communities, local governance, well-being and economic development that constitute fundamental axes of all recent smart city frameworks [Nam & Pardo 2011, Lee et al. 2014, Joshi et. Al 2016, Fernandez-Anez et al. 2018, Yigitcanlar et al. 2018], and more in general to new people-centred paradigms for smart cities [Concilio & Rizzo 2016, Lara et al.2016, Schaffers et al. 2011].

Differently from smart city technologies, web-based technologies already had a profound impact on the way people live in the city, organise their own activities and made decisions at the individual level [Aurigi 2016, Finck & Ranchordas 2016]. Web-based technologies include a wide range of systems such as sharing platforms (e.g. AirB&B, Uber), social networking sites (e.g. Facebook, Twitter), location-based services (e.g. Google Maps), community forums, but also e-gov services, voting tools, self-organisation applications and so on. The common point of all these web-based technologies is that they are explicitly meant to connect people through information exchange, enable people to learn, activate relationships. However, nowadays the potentialities of web-based technologies (in terms of versatility, flexibility, pervasiveness and accessibility) are deeply underexploited to permanently infrastructure collective actions, support city dynamics and enable distributed social change processes.

Against this background, the role of design is essential to unlock the potential of web-based technologies (besides being accessible and pervasive) as instrument intrinsically oriented to build bridges among people and therefore able to bring to life new human and social oriented smart city visions. Indeed, a new design space to be explored in the current technological landscape is the one of web-based technologies intentionally designed to support local development actions by configuring an environment helping people to collaborate for addressing shared city challenges.

This paper presents the research approach structured for exploring this design space along four years of activities (from 2015 to 2019) by using design-driven methods associated to a conceptual framework developed accordingly the three axes of people, city and role of technology in mediating their interactions. This approach had been applied to:

- studying the implications of potential alternatives to the logics of existing web-based technologies with applications in urban context
- understanding users' needs, applicative scenarios and forms of support expected or required from these alternative web-based technologies in city dynamics
- identifying the key barriers, issues and constraints for their design, development and adoption.

The next sections are going to explain:

- the problem framing, and the definition of a design proposal associated to a conceptual framework for systematically explore the design space of web-based technologies intended to support local development actions (section 2)
- the strategy composed to investigate the different components of the conceptual framework by instantiating the design proposal in three artefacts used as case studies (section 3)
- the implementation of the design and field activities for exploring the design space defined by these artefacts (section 4)
- the analysis of the results and implications of using design-driven methods in the research process aimed to understand how web-based technologies can support local development actions (section 5).

2 Problem Framing, Design Proposal and Conceptual Framework

Local development actions are types of actions relying on groups, organisations, communities, classes of stakeholders operating within and across personal, professional and territorial networks. These actions are always interrelated and interdependent from other actions, and often a plurality of goals drive their implementation, both because of the multiplicity of the involved actors and the multiple dimensions of city activities considered in their social, cultural, economic aspects. Respect to these characteristics of local development actions, the main problems of current web-based technologies can be summarised in:

a) misrepresenting social structures in urban context by focusing on users as individuals instead than as part of multiple fluid social entities

b) misrepresenting the city ecosystem as a composite mosaic of unrelated pieces instead than a complex living organism in which each part is interdependent from others

c) misrepresenting local actions as a multitude of mono-purpose flows instead than actions driven and implemented for several coexisting or even conflicting goals at the same time.

For instance, the multitude of web applications for parking or traffic monitoring or bike sharing is oriented to support individuals, but very little the coordination or cooperation among individuals. In addition, these applications usually do not integrate the wide range of mobility-related services provided by different actors operating at the local level. The narrow focus of this kind applications therefore misses also the chance of enabling the coordination between different services and their users to achieve broader goals such as sustainable mobility in cities.

Overcoming the three forms of misalignments between the logic of local actions and their representation on web-based technologies is a design problem. Indeed, this problem matches all the three conditions defined by Gleasurea [2015] to identify a design problem, because of:

- the lack of effective existing solutions to address these misrepresentations
- the lack of artefacts and theories allowing to explore the practical implications of proposing alternatives to current technologies under their analytical, explanatory, and prescriptive aspects
- the impossibility of studying alternative conditions through observation only, because issues and peculiar phenomena associated with the potential uses of web-based technologies in local actions could become evident only through an attempt to change them by using artefacts to make these issues and phenomena evident.

In addition to these three conditions, designing web-technologies intended to support local development actions is more specifically a "*deep design problem*" that requires a comprehensive understanding of the systems and processes to deal with [Deming 2018], that in this case are city dynamics and local processes. This understanding can be built only by combining *"design practice with robust intellectual inquiry"*, knowledge production and its translation in artefacts and vice-versa, reflection on complex social and political issues with experimental attitude [Manzini 2011]. This condition implies that the study of alternative web-based technologies is carried out by joining design and research, theory development and empirical explorations, with the awareness of dealing with social and political issues more than just technological ones. Indeed, the application of design-driven methods for analysing the problem, collecting the needed information and elaborate them in operation form is a path functional to extend our knowledge of the constraints, issues, needs, challenges posed by city dynamics to the development of future technologies.

The starting point to explore this design space had been the formulation of a *design hypothesis* [Cross 2006] based on the principle that web technologies intended to support local development actions should provide at least a representation of users, city context and urban activities reflecting the logic of local dynamics. This principle is expressed through the design proposal of the City Mirror, intended as a web-platform representing social structures, city systems and local actions as they are configured in an urban context by outlining a digital environment that is multi-stakeholder, multi-scale and multi-purpose.

This design proposal of the City Mirror is the core of the conceptual framework developed along the three dimensions of the user, city and technology to explore and describe a digital environment where:

- The Users' identities are layered accordingly to the plurality of social roles covered by users in groups, organisations, communities, classes of stakeholders, across personal, professional and territorial networks. The coexistence of users seen as agents of the social structures to which they belong create a multi-actor environment [Fig.1].

- The City ecosystem is considered as composed by three intertwined physical, functional and social systems and "in-between spaces" corresponding to values and identities, resources and needs, relationships and practices. Each system and intermediate zone can be analysed at different scales, that in urban context range from the building scale to the neighbourhood up to the metropolitan scale [Fig.2].

- The forms of support provided by technology to local actions are classified in support to coordination, cooperation and collaboration practices, within the specific processes structuring each specific action in a short, medium, long term perspective. Each form of support reflects the plurality of purposes of the actors involved in local actions, as well as the level of potential convergence [Fig.3]

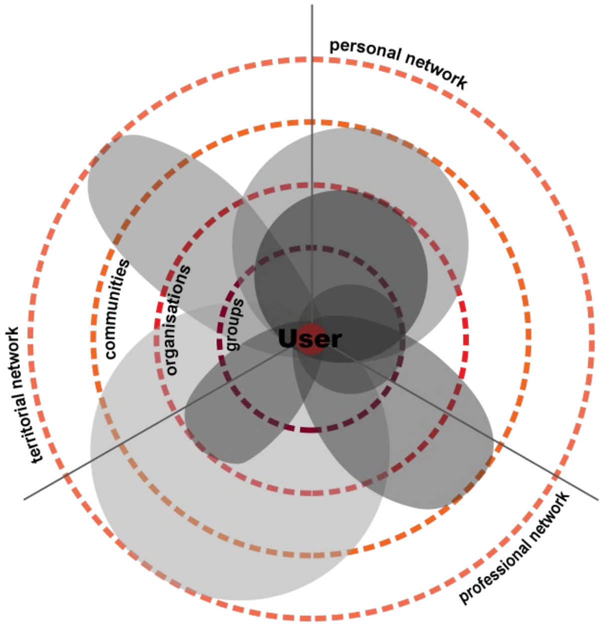


Figure 1: Layers of the users' identities in the conceptual framework of the City Mirror

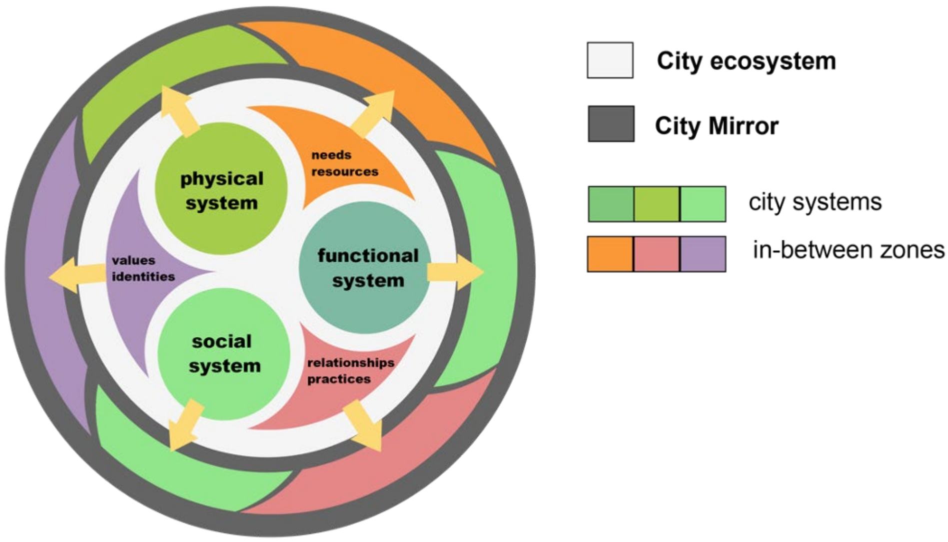


Figure 2: Components of the City ecosystem in the conceptual framework of the City Mirror

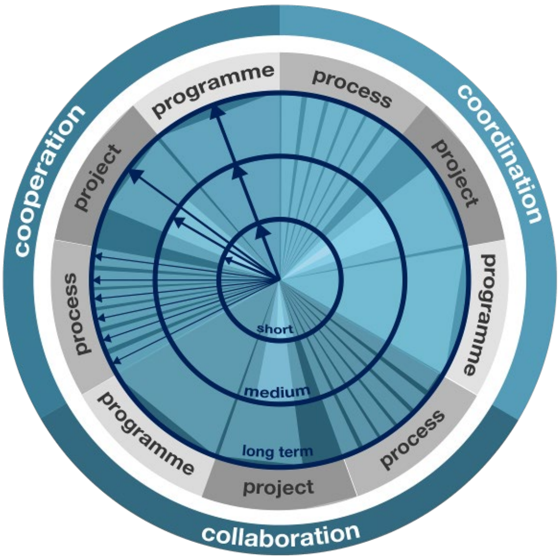


Figure 3: Schema of the forms of support of technologies in local actions within the conceptual framework of the City Mirror

The design proposal of the City Mirror had been used in this approach as a tool critically constructed for investigating the problem under study in its empirical and design aspects concerning:

- the interdependence between users' representations, urban context, city activities and role of technology in between
- the structure and management of the design process of a City Mirror considering the challenges of addressing the needs of multiple stakeholders, multiple domains, and multiple scales of actions to formulate a coherent solution to them.

The conceptual framework associated with the proposal of the City Mirror worked as a knowledge infrastructure to bind real phenomena and design solutions, empirical and theoretical findings. From an operational perspective, this framework allowed the organisation of the empirical and design findings coming from field activities in an organic way, despite the diversity of settings, goals, contexts addressed and analysed by the research.

3 Research Strategy

The City Mirror proposal had been studied by structuring three case studies intertwined to the design process of three web-based technologies focused on city applications with local development aims: a civic social network, a collaborative governance platform and a city open data portal. Each one of these technologies instantiated the design proposal of a multi-actor, multi-purpose and multi-scale digital environment to mirror the structure and nature of city dynamics in local actions.

The strategy to investigate City-Mirror-like technologies had been developed as a continuous transversal activity within and across the three case studies, by keeping a research agenda partially independent by the design and development process of the three platforms and exploiting these design processes to explore in-depth and in different setting the possibility of defining alternative web-based technologies for cities.

This balancing between research explorations and design management was based on overlapping the conceptual framework of the City Mirror to the “contingencies grid” of each case study, given by the goals of the projects to which it was associated, the context of intervention, the involved partners and stakeholders, the scope of the technology in itself, the design phase for the activities to be performed.

For each case study, the exploration space was the results of the overlapping areas between the layers and axes of the conceptual framework that the specific project would allow investigating and the specificities of each project, design process and context of intervention. In other words, each case study had been used to explore the nature of interactions in one city system and its adjacent “in-between spaces”, to analyse the needs and implications of representing a specific subset of users ‘identities in urban actions, to identify the constraints of the preferential forms of support expected by the specific technologies in the applicative scenarios associated to the case study [Fig.4]. The exploration of all the components of the conceptual framework along the three axes of users, city and technologies had been covered project after project, and case study after case study by covering a subset of its components at the time.

As regarding the axis of the City context, the first case study primarily covered the interactions with the physical system of the city taking into account also the resources and values associated to it, while the second and third case study had been respectively focused on the functional and social system of the city. This does not mean that in the research activities we do not considered the totality of city systems as a whole, but that most of the knowledge generated within one case study is traceable back to the constitutive elements of one city system because of the specific goal of the platform, its functionalities, its interfaces, its applicative scenarios and so on.

Similarly, as regarding the layers of user’s identities, the first case study focused on groups, communities and networks, while the second case study addressed mainly the needs of organisations and local communities, and the third case study allowed to analyse groups, organisations and network of organisations. As regarding the form of prevalent forms of technology support, the three case studies provided the opportunity to investigate respectively constraints and schema of coordinative, cooperative and collaborative activities in local actions.

By looking at the three design processes of the case studies, it is important to highlight that the research activities implemented within each case study covered primarily one of the macro-phases of the design process of the technologies under study: pre-design, design, or evaluation phase. Indeed, as indicated by Wulf et al. [2011], one of the major limitations of research concerning the design of digital artefacts is the focus on one only phase of their design process because of the timing of projects, funds availability, resources and opportunities to continue the research for an indefinite time. Building on this awareness, the research strategy to carried out this work tried to overcome this limitation by using the three case studies as distinct units covering the entire design process. The fact of dealing with proof of concepts, working prototypes, and consolidated tools had also been used for gathering more insights on the design constraints in the three situations.

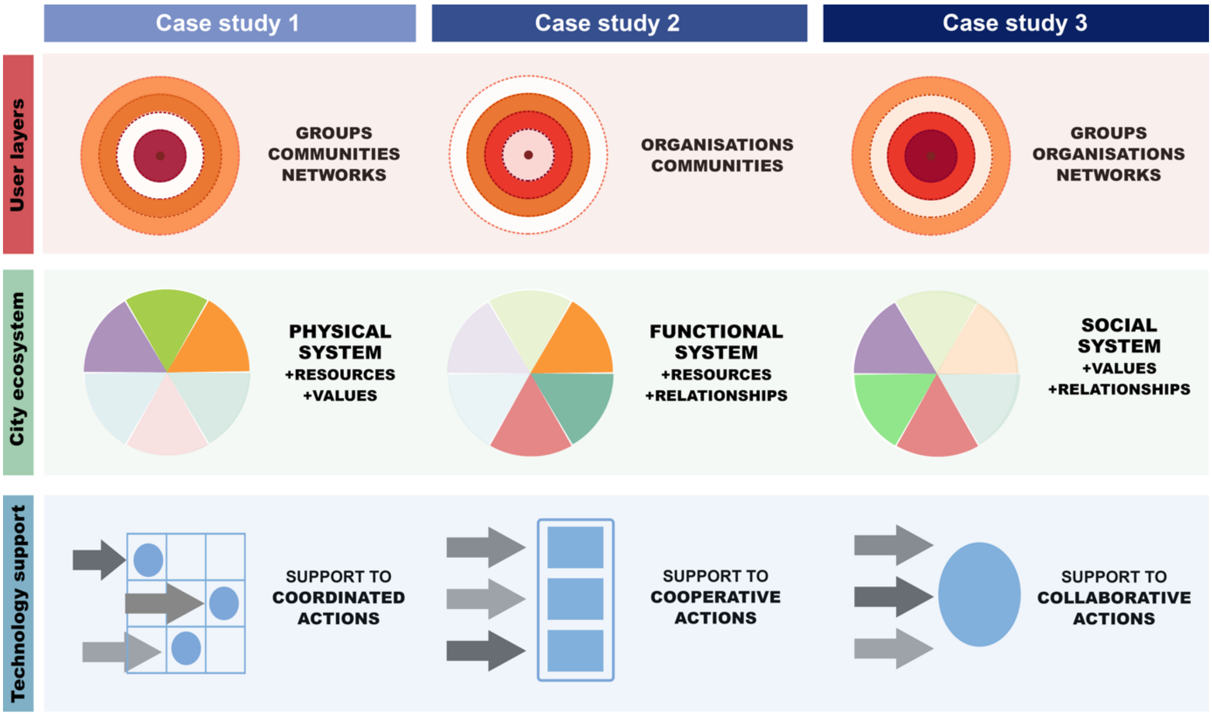


Figure 4: synoptic view of the case studies

The three case studies respectively provided the opportunity to study:

- the intrinsic constraints of the socio-technical context in which the artefact should be integrated within a pre-design phase (third case study)
- the difficulties of balancing contrasting requirements coming from contrasting goals and applications during an on-going design activity (first case study)
- the issues of finding appropriate evaluation criteria for assessing the compatibility between the potentialities of the artefacts and the goals of local development actions in a post-design phase (second case study).

4 Case studies

Case study 1 is associated with the design process of FirstLife, a civic social network developed and tested mainly in the City of Turin, Italy. Its scope was to create a new type of social network aimed to support civic activities, public participation, co-production of services by enhancing spatial interactions among users, especially proximity interactions, such as at the neighbourhood scale [Lupi et al. 2016a]. This principle had been translated into the design of a platform in which the main interface and way to access to contents was through the map, a spatial representation of users' activities, traced by the user-generated contents they create on the platform. The ambition of FirstLife as a civic social network was to find a way for breaking the mechanisms fostered by global online social networks (e.g. Facebook), such as the extended user profiling for commercial purposes, the segregation of like-minded users (filter bubble phenomenon), or the engagement-for-engagement (social network addiction). On the contrary, FirstLife wanted to enhance diversity and plurality of interactions as they happen in real life and contribute to the active use of a digital tool for implementing concrete social innovation and local development actions in the city [Lupi et al. 2016b]. In doing so, the design process moved into an unexplored domain in which meanings and practices were to be established on different logics that the existing mass social networks, and these logics required to be discovered, in particular as regards the framing of users as "agents of change" and the city not as space but as "container of actions" shaping places.

The field activities for the first case study relied on the involvement of local institutions, privates, and non-profit organisations in workshops, seminars, contextual enquiries, joint-initiatives and branch projects, for three years, mainly in the city of Turin and in the Piedmont Region (Italy). By using the work-in-progress prototype of FirstLife in real settings, the exploration of the design space of web-based technologies for local development had been conducted across several scenarios including: community and participatory mapping initiatives, urban regeneration projects, management of distributed events in the city, consolidation of sectorial networks at territorial level, service design for local enterprises, public engagement in urban transformations. Beyond the analysis of users 'needs in several different settings, these scenarios allowed us to study the pragmatic of interactive maps in multi-actor, multi-scale and multi-purpose digital environments. They also highlighted the issues associated to map-based interfaces concerning the representation of local coalitions, power relationships, formal and informal hierarchies among city organisations and groups outlining a set of complex constraints to consider in the design process.

Case study 2 had been developed within the project of WeGovNow, a platform for supporting collaborative governance processes in the city [Boella et al. 2018]. Its scope was moving from the paradigm of the e-gov to the one of the we-gov. In other words, from using technology to intermediate the relationship between Public Administration and Citizens, to use technology for building new collaborative relationships between public and private actors to improve the local governance. The proposal of WeGovNow was to implement this paradigm shift by integrating in a unified platform a set of digital tools already existing, such as a deliberative platform, a community mapping tool, a reporting application, a crowd-mapping system, and test the new platform in two Italian cities (Turin and San Dona' di Piave) and in the London Borough of Southwark (UK). The main challenge of designing WeGovNow as a collaborative governance platform was not just to work on technology, but on outlining new governance models through the use of technology. Working on existing platforms for new purposes and new applicative scenarios deeply questioned assumptions and logics under their design, pointing toward alternative solutions and meanings of the available functionalities. At the same time, working on defining new governance models and collaborative services by using technology as a frame helped the partners involved in the process in building a greater awareness of the political, social, and practical implications of design choices.

In this case study, the design space of web-based technologies for local development had been explored by working with the institutional stakeholders of two of the cities involved in the project (Turin and San Dona' di Piave, Italy) on a set of sub-projects and by conducting interviews, workshops, and contextual enquiries with various offices of the local administrations. These activities were aimed to analyse with the stakeholders how aligning the forms of support provided by the WeGovNow platform to the way city management processes are actually implemented. Building on that, we constructed with the partners four collaborative governance scenarios refactoring the logics of existing tools (without altering their core functionalities) in order to enable, through the new unified platform, new ways of organising and managing public spaces, services, projects.

Case study 3 accompanied the development of a proposal for refactoring MK:Insight, the Open Data portal of the City of Milton Keynes (UK). The main goal of the design exploration for MK:Insight2X was to overcome the underuse of the existing platform by outlining new design solutions to transform the data portal into a tool effectively addressing the needs of different stakeholders operating in the city. The limited use of Open Data portals is a well-known problem affecting this typology of technology [Janseen et al. 2012], and not only the Milton Keynes data portal. This problem is recently becoming more critical at an urban scale where the availability of data tend to be associated with high expectations for data-driven local development processes and, at the same time, with rising tensions related to redistribution of the benefits generated by the access and elaboration of city data [Kitchin 2014]. In order to address this mismatch between increasing requests of data publicly available and the limited use of existing Open Data, the redesign process of MK:Insight2X started from rethinking the components of an Open Data portal, revealing assumptions and practices embodied or hidden in its functioning, or simply not covered by the current functionalities of Open Data Portal. This process had also been grounded on the idea that an Open Data portal requires to be "open" to the needs and practices of people that could make a positive use of data in the activities they implement into the city.

The exploration of new functional configurations for the Open Data portal to support data practices for local development actions had been developed entirely in the pre-design phase of the new portal, driven by the purpose of moving from the idea of a {Open Data} PORTAL to the idea of an OPEN {data portal}. In other words, from a data portal as a catalogue of open data products and centred on the needs of one data producer, to a data portal opened to a plurality of "data activators" and reframing data as a relational medium among local stakeholders. The proof of concept and preliminary prototype of the OPEN {data portal} had been developed as a result of the engagement process that involved city council, public agencies such as health and environmental agencies, businesses, academia, non-profit organisations and grass-roots groups. The representatives of these local stakeholders had been called to explore the design space of an OPEN {data portal} through the construction of visual artefacts outlining a plurality of real scenarios connecting Open Data to local actions. These visual artefacts, built by using cultural probes and storytelling techniques, provided a rich understanding of the relational patterns associated to the production and use of data in the city, as well as on the boundaries and internal rules expected from a multi-actor, multi-scale and multi-purpose city data portal.

5 Recomposing the design space across the three case studies

The implementation of the multi-case study strategy had been based on the sequential development of the three case studies advancing through a double helicoidal process, in which every convolution of the primary helix corresponds to the development cycle of one case study that internally progresses through local cycles combining action, analysis, design, and conceptualisation of contextualised findings [Fig.5].

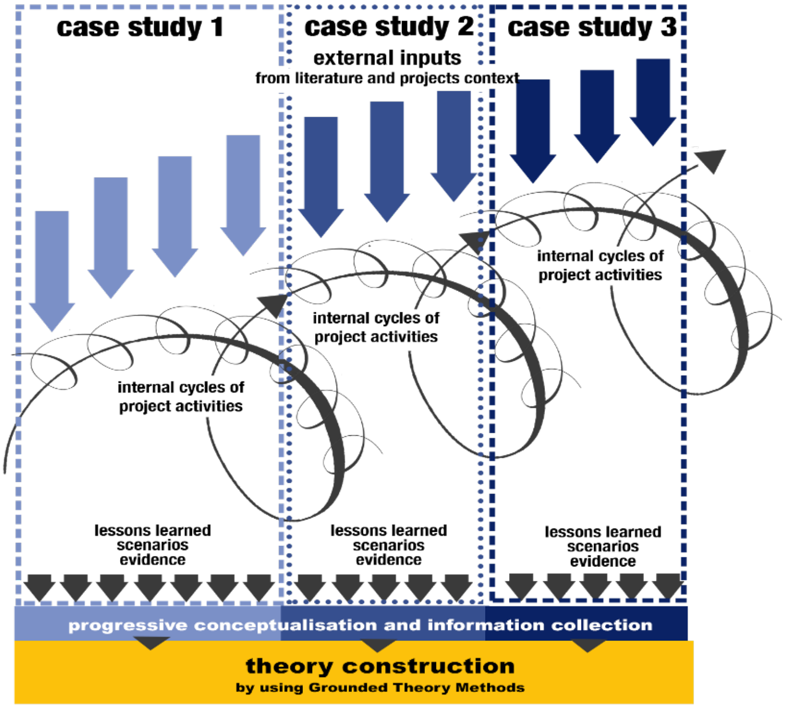


Figure 5: Development process of the case studies

The sequence of the three case studies allowed to progressively move the focus of the research from the analysis of the contextual factors impacting on the connection between web technologies and city dynamics, to the analysis of the processes to be supported, and then to the rules to put in place to make these technologies socially acceptable into a complex relational environment. Similarly, the object of design expanded from the platform functionalities, to the services build on and around the use of these technologies in city activities, and lastly to the more abstract level of the nature of information and relationships activated through the information exchange [Fig.6].

Leveraging on the diverse operational settings of the case studies and the peculiarities of the three platform under development, the recomposition of the design space of city-mirror-like technologies had been progressively done by using the conceptual framework as infrastructure for articulating the different pieces of knowledge coming from the three case studies, as anticipated in section 2. The components of the model of the City ecosystem [Fig. 2] had been linked to the ones of the model of the users' identities and the forms of technology support.

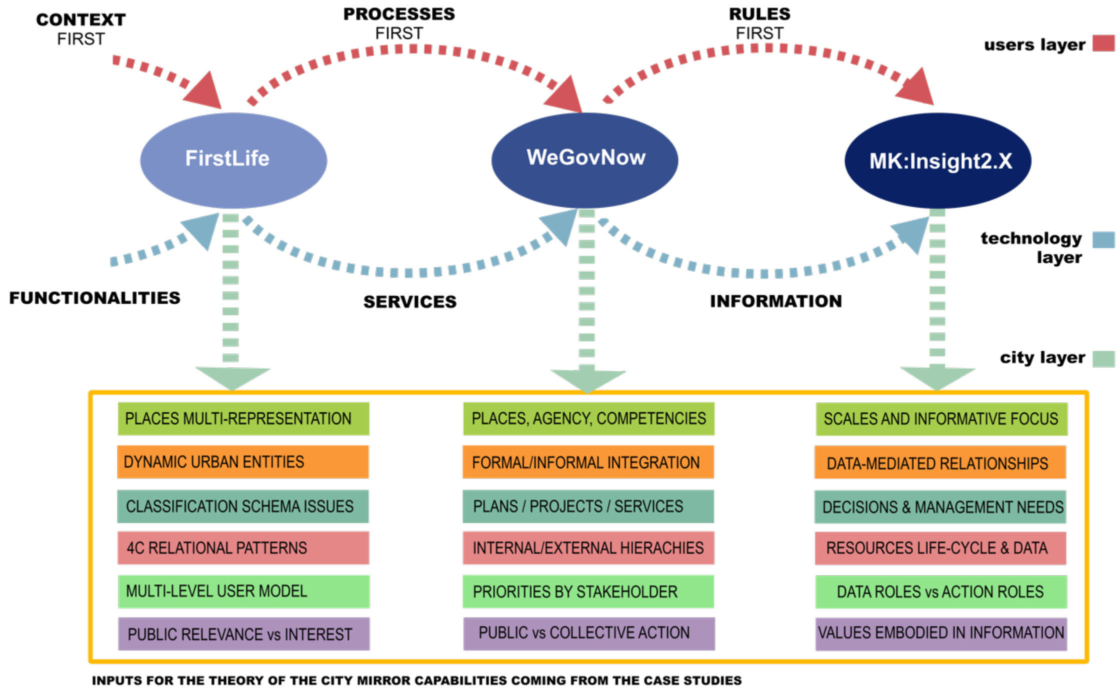


Figure 6: Exploration of the connection between people and technologies in the city across the three case studies

For instance, the representation of the physical system of the city started to be analysed in relation to the different perceptions and languages of different users to understand how to enable the coexistence of multiple representations of places, experimenting and testing various solutions with users and consolidating the insights on this aspect. Then, in the second case study, the analysis of the representation of the physical system of the city explored the aspects related to the ownership and competencies over places, established both formally or informally, and how these affect the online and offline agency of users over these places. In the third case study, the representation of the physical system of the city had been investigated by focusing on the types of information able to communicate the characteristics of these space with a focus appropriate to the scale of action of users. Thus, the sum of the three case studies allowed to explore the representation of the physical system of the city in relation to the perception of the urban environment mediated by technology, the link between online and offline actions in the city implemented by users, and the barriers or tactics to facilitate the communication about the urban environment and actions in the city at different scales providing a deep understanding of this specific aspect. Analogously, the same approach had been followed for the functional and social systems of the city, as well as for the in-between zones of the needs and resources, values and identities, and relationships, as shown in fig. 6.

The lessons learned from the design processes, applicative scenarios and pieces of evidence progressively gathered and analysed had been stratified and systematised by using grounded theory techniques in a coherent theory binding concepts, requirements, and evaluation criteria to inform the design of web technologies reflecting city dynamics by creating a multi-actor, multi-scale, multi-purpose environment [Fig. 7]. The resulting theory organises the capabilities of web-based technologies intended to support local development actions accordingly to the components of the City Ecosystem. In particular, the resulting theory focuses on the technology capabilities of enabling city stakeholders in:

- "reading the city" by lighting on the richness of places where they live
- "observing the city change" by monitoring shared material and immaterial resources
- "dialoguing with others" beyond organisational boundaries to known what is going on
- "understanding the city functioning" by navigating across practices, services, and interdependences of city activities
- "taking care of the city" by being aware of the evolving local needs
- "transforming the city" by creating a dialogue space opened to competing values.

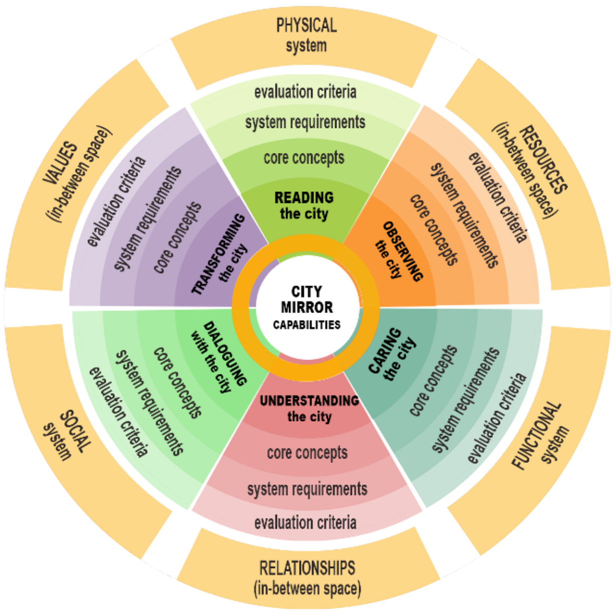


Figure 7: Dimensions of the preliminary theory on the City Mirror capabilities

The ultimate goal of developing a design theory based on the iterative exploration of a design space reflects a common practice in design-driven research, and in particular in Research through Design approaches in the field of technology design [Gaver 2012, Zimmerman et al. 2010]. In this framework, it is assumed that the resulting theory is always provisional [Gaver 2012] and opened to further integrations.

The adoption of a design-driven approach in the exploration of the City Mirror proposal provided the opportunity to combine the three forms of Interaction Design research indicated by Fallmann [2008] for generating knowledge about an alternative future (the possible), the users' needs (the true) and the constraints of the operational context given by the design process in itself (the real).

The presented design-driven approach applied to investigate how web-based technologies could support local development actions reflects also the three canonical roles of researchers in the practice of design-driven research as "constructors of the world they desire” [Zimmerman & Forlizzi 2014], scholars engaged in tracing how knowledge is generated by intervening in the context through artefacts [Zimmermann et al. 2007] and as “glass-boxes” on the connection between design choices and implications in the applicative context of the artefacts [Jones 1980].

6 Concluding Notes

The value of the design-driven research approach presented in this paper is proposing an example of the exploration of the connections between technology and people in urban contexts coherently pursued across multiple projects, settings, artefacts. The double-core of this approach is in the design proposal of the City Mirror and the conceptual framework based on the three axes of Users’ representation, City Ecosystem and forms of technological support. Both are aimed to envisions and analyse the practical implications of proposing alternatives to current technologies under their explanatory and prescriptive aspects.

The strategy implemented to systematically explore the design space of these future technologies across multiple case studies also reflects other two distinctive characteristics of a design orientation to problems. Firstly, the attempt to address complex problems such as local development dynamics in a holistic way, while abstracting, selecting or generalising the multitude of factors impacting on the definition of the problem [Jones 1980]. Secondly, the integration of inputs from a plurality of theories and methods from different disciplines by identifying conceptual and operational convergences, as it had been done in this work bridging the domain of Interaction Design with theories, models, methods of the research in urban planning, urban design and urban studies.

In conclusion, the role of design in this type of exploration is enabling the discovery of new phenomena (not observable without intervening in the context), but also providing support to bring out the tacit knowledge embodied in the practices of city actors. In this way, the adoption of a design-orientation to study digital technologies in cities made possible to outlining new needs [Fu et al. 2011], understanding how pragmatically address conflicts and competing goals of different practices and actors, and tracing new paths for future technologies.

7 References

Aurigi, A. (2016). Making the digital city: the early shaping of urban internet space. Routledge.

Boella, G., Francis, L., Grassi, E., Kistner, A., Nitsche, A., Noskov, A., ... & Tsampoulatidis, I. (2018). Wegovnow: a map based platform to engage the local civic society. In Companion of the The Web Conference 2018 on The Web Conference 2018 proceedings (pp. 1215-1219).

Concilio G., Rizzo, F. (2016). Human Smart Cities: Rethinking the Interplay Between Design and Planning. Springer.

Cross, N. (2006). Designerly ways of knowing. Springer.

Deming, W. E. (2018). The new economics for industry, government, education. MIT press.

Fallman, D. (2008). The interaction design research triangle of design practice, design studies, and design exploration. Design Issues, Volume 24, Issue 3 (pp. 4-18).

Fernandez-Anez, V., Fernández-Güell, J. M., & Giffinger, R. (2018). Smart City implementation and discourses: An integrated conceptual model. The case of Vienna. Cities, Volume 78, (pp. 4-16).

Finck, M., & Ranchordás, S. (2016). Sharing and the City. Vanderbilt Journal of Transnational Law, Volume 49, (pp. 1299-1369).

Fu, Z., Zimmerman, J., Wu, J., Kirwan, C. M., & Zhao, C. (2011). The role of design in Ubicomp research and practice. In Proceedings of the 13th international conference on Ubiquitous computing (pp. 629-630). ACM.

Gaver, W. (2012, May). What should we expect from research through design?. In Proceedings of the SIGCHI conference on human factors in computing systems (pp. 937-946). ACM.
Gleasurea, R. (2015). When is a problem a design science problem?. Systems, Signs & Actions, Volume 9, Issue 1, (pp. 9-25).
Janssen, M., Charalabidis, Y., & Zuiderwijk, A. (2012). Benefits, adoption barriers and myths of open data and open government. Information systems management, Volume 29, Issue 4, (pp. 258-268). Taylor & Francis.
Jones, J. C. (1980). Design Methods: Seeds of human futures. 1980 ed., John Wiley and Sons Publications.
Joshi, S., Saxena, S., & Godbole, T. (2016). Developing smart cities: An integrated framework. Procedia Computer Science, Volume 93, (pp. 902-909). Elsevier.
Kitchin, R. (2014). The data revolution: Big data, open data, data infrastructures and their consequences. Sage.
Lara, A. P., Da Costa, E. M., Furlani, T. Z., & Yigitcanlar, T. (2016). Smartness that matters: towards a comprehensive and human-centred characterisation of smart cities. Journal of Open Innovation: Technology, Market, and Complexity, Volume 2, Issue 2. MDPI
Lee, J. H., Hancock, M. G., & Hu, M. C. (2014). Towards an effective framework for building smart cities: Lessons from Seoul and San Francisco. Technological Forecasting and Social Change, Volume 89, (pp. 80-99), Elsevier.
Lupi, L., Antonini, A., Boella, G., Schifanella, C., Sanasi, L. (2016a) Back to public: rethinking the public dimension of institutional and private initiatives on an urban data platform. Trento: IEEE. 2016 IEEE International Smart Cities Conference (ISC2).
Lupi L., Antonini A., Boella G., Mason E., (2016b) Real society in virtual space: a platform to share responsibilities in urban regeneration processes, in G. Colombo, P. Lombardi, G. Mondini (edited by), 9th International Conference on Innovation in Urban and Regional Planning INPUT 2016, Conference Proceedings Book “e-agorà/e-ἀγορά for the transition toward resilient communities”, Turin (IT)
Lim, C., & Maglio, P. P. (2018a). Data-driven understanding of smart service systems through text mining. Service Science, Volume 10, Issue 2, (pp.154-180).
Lim, C., Kim, K. J., & Maglio, P. P. (2018b). Smart cities with big data: Reference models, challenges, and considerations. Cities, Volume 82, (pp. 86-99). Elsevier.
Manzini, E. (2015). Design, when everybody designs: An introduction to design for social innovation. MIT press.
Nam, T., & Pardo, T. A. (2011). Conceptualizing smart city with dimensions of technology, people, and institutions. In Proceedings of the 12th annual international digital government research conference: digital government innovation in challenging times (pp. 282-291). ACM.
Neirotti, P., De Marco, A., Cagliano, A. C., Mangano, G., & Scorrano, F. (2014). Current trends in Smart City initiatives: Some stylised facts. Cities, Volume 38, (pp. 25-36). Elsevier.
Schaffers, H., Komninos, N., Pallot, M., Trousse, B., Nilsson, M., & Oliveira, A. (2011). Smart cities and the future internet: Towards cooperation frameworks for open innovation. In The future internet assembly (pp. 431-446). Springer.
Stolterman, E. (2008). The nature of design practice and implications for interaction design research. International Journal of Design, Volume 2, Issue 1.
Wulf, V., Rohde, M., Pipek, V., & Stevens, G. (2011). Engaging with practices: design case studies as a research framework in CSCW. In Proceedings of the ACM 2011 conference on Computer supported cooperative work (pp. 505-512). ACM.
Yigitcanlar, T., Kamruzzaman, M., Buys, L., Ioppolo, G., Sabatini-Marques, J., da Costa, E. M., & Yun, J. J. (2018). Understanding ‘smart cities’: Intertwining development drivers with desired outcomes in a multidimensional framework. Cities, Volume 81, (pp.145-160). Elsevier.
Zimmerman, J., Forlizzi, J., & Evenson, S. (2007). Research through design as a method for interaction design research in HCI. In Proceedings of the SIGCHI conference on Human factors in computing systems (pp. 493-502). ACM.
Zimmerman, J., Stolterman, E., & Forlizzi, J. (2010). An analysis and critique of Research through Design: towards a formalization of a research approach. In Proceedings of the 8th ACM Conference on Designing Interactive Systems (pp. 310-319). ACM.
Zimmerman, J., & Forlizzi, J. (2014). Research through design in HCI. In Ways of Knowing in HCI (pp. 167-189). Springer.

About the Authors

Lucia Lupi: PhD candidate in "Urban and Regional Development" at the Polytechnic of Turin, working since 2015 as design researcher in Urban Informatics, specialised in Participatory Design, Requirements Analysis and City Modelling. She collaborated with the "Social Computing" research group of the Department of Computer Science of the University of Turin (IT) from 2015 to 2017. Since 2018, she is a visiting PhD researcher at the Knowledge Media Institute of The Open University (UK), collaborating with the research groups “Intelligent Systems & Data Science" and "Collective Intelligence 4 Common Good". Her research interests are focused on the design of multi-stakeholder collaborative systems for city, civic and urban technologies.

Design and Implementation of Wearable Devices to Enhance Aquatics Physical Education

Han, Barron

Shanghai American School, Shanghai, China
barron.han@gmail.com

The digital revolution has enhanced traditional in-class learning through countless hardware and software solutions that allow teachers and students to collaborate more effectively. However, physical education is still taught in the same way as hundreds of years ago, only using "small data" collected by coaches and teachers without technological assistance. This paper examines current solutions to aquatics physical education, proposes a unique wearable device for swimmers, and outlines the design process behind the creation of this device, as well as future steps and intended implementation of this product. The device presented in this paper is capable of gathering and processing biometric and motion data and generating recommendations that can benefit swim training at all competency levels. It combines the benefits of integrated hardware and management software solutions and is cost competitive against similar commercial products

Keywords: aquatics physical education; machine learning; artificial intelligence; big data; motion analysis; educational equality

1 Introduction

Aquatics training is a vital part of primary education, teaching children about maintaining physical fitness and safety in and around the water. Lack of proper water safety instruction can lead to injury and drowning. In fact, drowning is currently the "second leading cause of childhood unintentional death" (CDC 2012). The Canadian Red Cross learn-to-swim program is offered to 1.2 million children. The USA Swimming Foundation offers swimming classes at 800 nationwide centers, educating over 4 million students (American Red Cross, 2009). However, in less economically developed countries, lack of proper swim training is concerning (Brenner, 2009).

In addition to the safety benefits of learning to swim, more than 330,000 United States students pursue the sport competitively, racing for over 2000 clubs (USA Swimming, 2016). Swimmer enrolment in the United States has increased drastically since 2007, making aquatics education even more relevant in this decade.

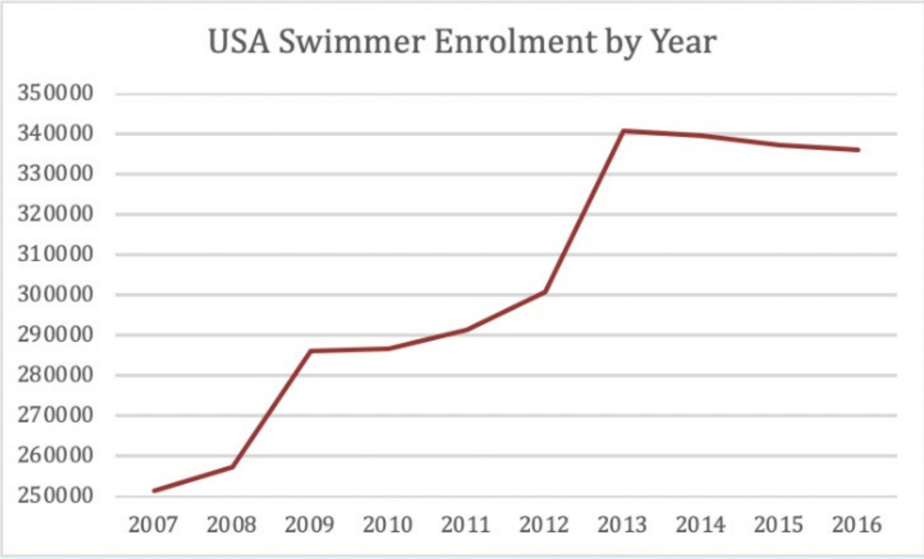


Figure 1: Competitive swimmer enrolment from 2007-2016. Source: adapted from USA Swimming 2016

However, traditional aquatics instruction is limited to “small data”, the information instructors can collect by using their own senses. This primarily consists of visual information that the instructor uses to communicate areas for improvement to their swimmers. However, this method has two primary limitations: it requires focused attention on a single student, and it is difficult to make wider conclusions about students’ improvements during a course. First, “small data” collection is highly inefficient. Most water safety classes have an average of five students per instructor, while competitive club training sessions might have a student to coach ratio of as high as 30. In such a setting, it becomes largely impossible for an instructor to give quality attention to each individual and make valuable comments to students. Second, since there is no way of synthesizing information over the course of a few lessons, it is difficult to gauge student progress and make adjustments accordingly. Most water safety learn-to-swim courses last for a duration of six to seven classes. Over this short period, instructors must rely solely on intuition and experience to understand how students are progressing through the course and whether adjustments are necessary. In club swimming, a competitive season can last up to three months, and in such an environment, swimmer-specific alterations are also nearly impossible.

Figure 2: Left: In most club settings in developed nations like the United States, it is impossible for a coach to give attention to all swimmers because there are too many swimmers in the pool at any given time. Right: Swimmers in poorer areas lack specialized coaches who are trained in proper technique and safety. There is a problem that needs to be addressed in both developing and developed countries. Source: Poireier-Leroy and Farah Abdi Warsameh

2 Research background and competitive product analysis

Wearable devices are any technological device that “can be worn by individuals” and include the “ability to track information related to the individual wearer” (Sandall, 2016). These devices are often used to track the motions of the user and generate real-time feedback. Since 2014, the wearable technology industry has skyrocketed, with newer companies such as Fitbit creating fitness trackers that monitor the users step count, walking distance, and heart rate (Sandall, 2016). More recently, established high-tech companies such as Apple, Samsung, Google, and Huawei have developed smart-wearables that are more powerful with features such as integrated GPS and high-speed cellular connectivity. These devices are beneficial as fitness trackers that encourage users to be more active in their daily lives. They have a few primary purposes: 1) set exercise goals, 2) monitor user’s activity, 3) share data with other users.

Some start-up companies are creating advanced products driven by artificial intelligence that use multiple sensors that can “classify which exercise the user is doing” and “correct the user’s exercise pattern”, two functions conventional fitness trackers cannot perform (Zhang, 2013). These devices are similar to the product functions this paper is outlining. Using accelerometer and gyroscopic data, the Microleap2 can detect common issues in running form that can cause injury or inflammation. It then notifies the user in real-time to correct their form. Currently, these devices are limited to running, basketball, golf, and baseball (Mardonova and Choi, 2018).

Recently, companies have incorporated aquatics features into their fitness trackers. However, all of the existing products have fundamental limitations.

For example, the Apple Watch contains an electrocardiogram (ECG) heart rate sensor that is accurate underwater, along with computer algorithms that can detect the type of stroke, and distance swam. Similar to their running functions, these devices fail to provide more specific swimming metrics or provide useful insights on form improvement.

Some professional clubs have adopted specialized hardware and software solutions to improve training efficiency. Team organization apps such as *CommitSwimming* can track training sets and athlete progression, but they require manual input of timing and set information. Biometric sensors such as heart rate straps, lactic acid monitors, and muscle oxygen monitors can gauge training intensity but are often bulky and impede the movement of athletes. “Integrated” software and hardware solutions are the current pinnacle of wearable technology in aquatics physical education, reducing the amount of data coaches need to collect. *MySwimPro* and *TritonWear* are two examples of this technology. *MySwimPro* is a software solution that can be paired with smartwatches from Apple, Garmin, Fitbit, and Google. It provides a personalized training schedule based on a user’s ability and goals, using sensors in the smartwatch to generate data on stroke rate, stroke efficiency, and heart rate. *MySwimPro* is limited to personal use as it does not have team management features for coaches of large club or professional teams. *TritonWear* is a powerful ecosystem that monitors the swimming of up to 50 swimmers on a team. It generates profiles for each swimmer during a training session, giving coaches access to motion data such as acceleration and swimming specific metrics such as breath count and stroke efficiency. Each swimmer is equipped with a small “Triton Unit” containing basic motion sensors. The information collected by the unit is then transferred to a smart device via a “Triton Connect” hub for the coach to review.

While some professional teams do invest in products such as *TritonWear*, the cost of hardware solutions is prohibitive for non-professional club teams and learn-to-swim programs. For example, each “Triton Unit” and “Triton Connect” Hub costs $299 USD at the time of publication. Including the annual subscription cost of the program, the total initial investment for a 20-student swim program can be as high as $6500 USD. Even less powerful solutions, such as specialized sensors, e.g. heart rate, accelerometer, gyroscope, can cost hundreds of dollars and require a steep learning curve for operators and instructors.

Product	Apple Watch	Specialized Sensors	CommitSwimming	MySwimPro	TritonWear	Our Device
Type	Hardware	Hardware	Software	Software	Integrated	Integrated
Stroke Detection	Accelerometer	N/A	N/A	N/A	Accelorometer	Accelerometer referenced with IR sensors
Stroke Improvement	N/A	N/A	N/A	N/A	N/A	Under Development
Biometric Data	Heart Rate	One-type	N/A	N/A	N/A	Heart rate
Training program	Self Generated	N/A	Manual Input	Manual Input	Self Generated	Self Generated with motion and biometric data attached to each training set
Team management	N/A	N/A	Available	Available	Available	Available
Data output	6 axis accelerometer - gyroscope and Heart rate	One-type	N/A	N/A	6 axis accelerometer and gyrosocope	9 Axis accelerometer - gyrosocope - compass with two IR bands and Heart Rate
Cost per Unit	400 USD (For 40mm model)	100 USD	N/A Subscription Service	N/A Subscription Service	299 USD	150 USD (Aim to reduce to 90 USD when manufacturing in bulk)
Cost for 20 person team	**8000 USD**	2000 USD	1200 USD	120 USD	**6500 USD**	**~3000 USD**

Figure 3: Function comparison chart. Source: Author

3 Design process and prototypes

3.1 Field Research

This project began in May 2018. A questionnaire was drafted and sent to swim coaches and swimmers. No coaches that were interviewed have used wearable devices for their swimmers, but a majority believed that a well-developed device can benefit their training. These coaches were then surveyed to determine the necessary features such a device should include.

Interviews were conducted with six athletes and three coaches of different calibres to determine the use case and proper implementation of features.

The consensus among elite swimmers and coaches including the Hong Kong national team head coach, former Chinese National Team directing coach of technique, and a Chinese national champion, was that a competitive, integrated solution for aquatics physical education in learn-to-swim programs, in a club setting, and at the professional level must include the following features:

1. A Comprehensive array of sensors that can measure motion and biometric data
2. Algorithms capable of analysing motion and stroke
3. Ability to synthesize and combine information that is easily accessible for coaches
4. An Easy-to-operate user interface for coaches and swimmers
5. Non-obtrusive for swimmers
6. Accessible to a broader audience with a non-prohibitive price

Table 1 Coach and Swimmer Questionnaire

	Coaches	Swimmers
Background	a. What information about the athlete during training would you like to know about that you currently cannot collect? (heartrate, stroke rate, breaths/length, turn speed, reaction time, blood oxygen) b. What sensors have you currently tried to collect data on the athlete during training? c. To what extent do those sensors affect your training in a positive or negative way? d. When do they become obtrusive, and how? e. What information would you like the athlete to know while training (HUD, recommended stroke rate) that will benefit their training? f. What equipment have you used to ensure this? g. To what extend do they affect the training in a positive/negative way? h. Have you tried using an all-in-one solutions for the above? i. If so, how well did they work? j. If not, would you consider beginning to use one?	a. How are your training sessions organized (e.g. private lessons, group setting, club or team setting)? b. How much attention does your coach give you during each training session? c. Do you wish your coach gave you more attention, if so in what aspects? d. Have you ever tried an sensors, under water earphones, or other accessories to complement your training? e. How well have these worked? Were they comfortable?
After Use	a. How has your training changed after using this device? b. What benefits does it bring you that are most significant and/or important? c. Would you consider using this system long term?	a. Did this device negatively affect your stroke and training? Was it comfortable to wear? Did it restrict your motion? b. Was there a change to how much individual attention your coach gave you after you started using this system and has his/her coaching style changed? c. Would you consider using this device long term? d. What changes would you make to this device? What else do you wish it did?

3.2 Device Objectives

A smart, wearable device must be comfortable for the wearer and placed in an optimal location for data collection. In order to maintain balance, keep a hydrodynamic form, and collect data on head-position and the position of the user's arms, the hardware should be placed in a compact wedge on the wearer's head, parallel to the elastic goggle straps.

A primary concern with smartwatches, sensor bands, and other traditional data collection hardware is that they affect the swimmer's natural movement through the water. Since smartwatches are only worn on one hand, they slightly imbalance the swimmer, affecting their stroke. Uncomfortable heart rate bands can restrict an athlete's breathing and movement. These concerns also apply to less experienced swimmers who are still perfecting their stroke. A smart wearable device should be placed on the axis that traverses the athlete's center of buoyancy. It should be slim, limiting the resistance it enacts on the swimmer's movement. It should be in a comfortable, easily accessible location.

To accurately measure motion and biometric data, sensors must be strategically placed. A swimmer's motion can be measured by several important variables: the movement of the athlete's head, the arm position relative to the axis of rotation, and the swimmer's acceleration, velocity, and rotation. The sensors must also be able to detect a swimmer's heartbeat to collect data on training intensity.

3.3 Physical Design

The athlete's head is an optimal location for sensors. In each competitive swimming stroke, both arms pass over the ears in a single stroke cycle. In the short axis strokes (butterfly and breaststroke), both arms pass this point simultaneously, while in the long axis strokes (backstroke and front crawl), the arms alternate. By placing sensors on the sides of the athlete's head, distance data on both arms can be collected. Second, while swimming, an athlete's head remains relatively stationary; the head only moves when the swimmer breathes or turns at the end of the pool. Placing motion sensors on the head streamlines data output and reduces the need for advanced data processing to eliminate noise generated when sensors are placed on a swimmer's hand or chest. In both of these locations, subtle movements such as breathing or rotations of the hands can cause data to be unreliable. Third, heart rate sensors must be placed near large arteries where heartbeat is easier to detect. Since both movement and distance sensors are on the swimmer's head, a single unit is sufficient to collect all necessary data.

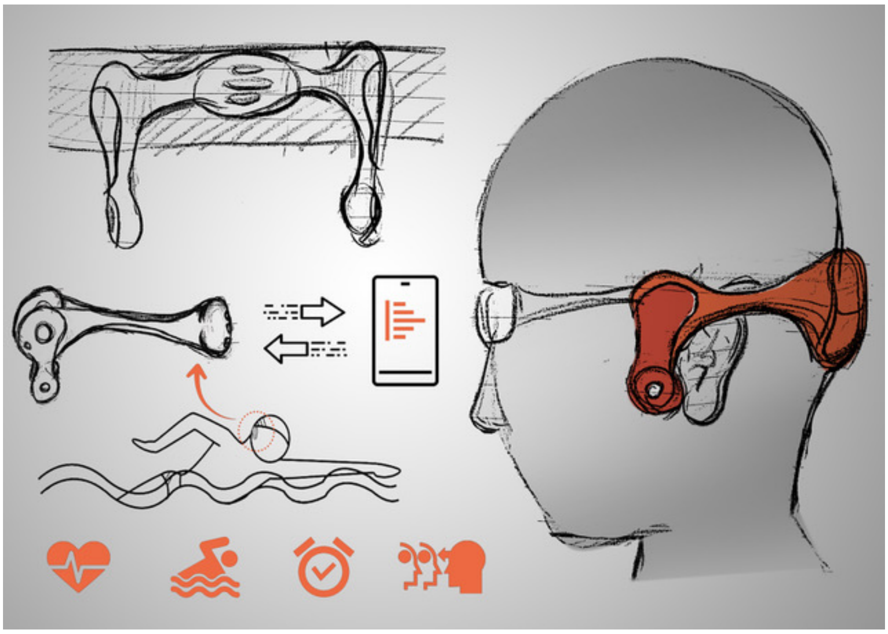


Figure 4: Initial product design concept drawings reveal a form factor that can accurately determine biometric data, swim stroke and other metrics, timing, and allow coaches to communicate with swimmers in real time. Source: Author

Sensors are laid out in a horseshoe on half of the back of the user's head as shown in Figure 5. Motion sensors are placed near the base of the swimmer's skull while two distance sensors and the heart rate sensor are placed on the sides of the athlete's head.

1 – Battery
2 – Power Delivery
3 – Bluetooth Antenna
4 – IMU
5 – SD Card Reader
6 – Curie SOC
7 – Power input
8 – Left Infrared
9 – Right Infrared
10 – Heart Rate Sensor

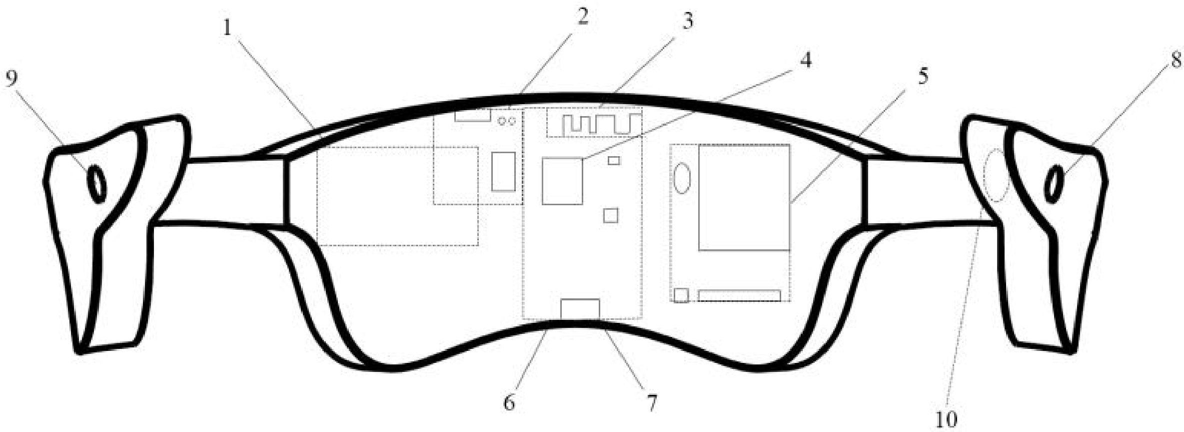


Figure 5,6: Technical drawing and render of the product casing. Source: Author

3.4 Hardware Implementation

To be competitive with existing solutions, effective hardware must be highly accurate, reliable, and low-cost. The initial model implements a modular system with good compatibility, using The Arduino ecosystem with Intel libraries for the first prototypes.

When measuring the effectiveness of training sessions, it is important to consider the following variables:

- Motion data including position, velocity, and acceleration on 3 axes
- Rotation (3 axes) and heading of the swimmer’s head
- Arm position in relation to head
- Heart rate (measured from the head)

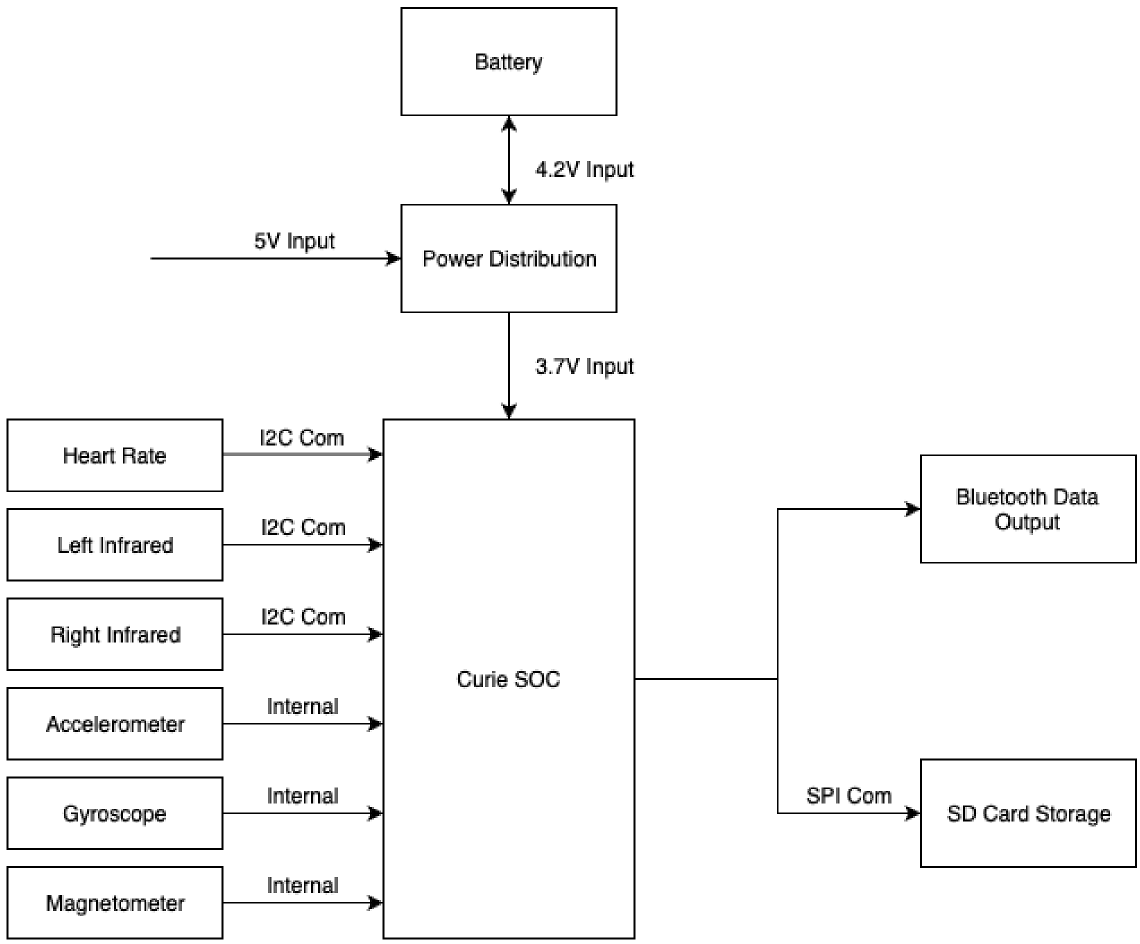


Figure 7: Hardware Configurations. Source: Author

First, an Intel Curie SOC was used for data processing and motion data collection. This board includes various functionalities such as a built-in digital compass, accelerometer, and gyroscope. Raw data from the digital compass can determine a swimmer's heading. The integral of accelerometer data fused with other metrics for orientation calculates a swimmer's position and velocity at any given time. All other sensors and equipment are connected through the Curie Nano chip, which is placed at the center of the device, sitting above the base of the swimmer's head. This location's symmetry also allows accurate headings to be calculated since the board stays parallel to the ground during exercise.

Second, a pair of infrared sensor modules were used to determine the location of the swimmer's arms. The sensors were symmetrically placed on the side of the athlete's head so that the infrared beams were perpendicular to the swimmer's motion.

Third, a single heart rate sensor was placed on the inside of the horseshoe-shaped exterior in order to be in contact with the swimmer's skin. This allows it to receive reasonably clean heart rate data from the large arteries near the temples. This prevents the noise that is generated from placing sensors on high-movement areas of the body such as the neck or the wrists.

Fourth, a single microSD (tf) card reader is used to write and store data. The current capacity of the drive is 16 gigabytes. The device outputs approximately 30 bytes of data every 20 milliseconds, and the sd card can store approximately 2 hours of data.

Finally, the device is powered by a single 1200 mah battery. The battery and protection boards are located adjacent to the Curie Nano for easier wiring and cable management.

All electrical components within the casing were applied with a waterproof resin. Special attention was given to the battery and protection board which were entirely sealed. The microSD card slot is also completely sealed as future data transfer will happen via Bluetooth or USB. Micro USB ports for charging and data transfer were replaced by magnetic induction contact points. Finally, the entire plastic outer casing is wrapped for insertion into the casing.

4 Data Processing

4.1 Models of Swim Ability

The main goal for swim training is to reduce the time needed to complete a specific event through improved reaction time, start time, velocity, and turn time. Therefore, the time to complete an event can be modelled by the following:

$$t_{total} = t_{reaction} + \frac{d}{v} + t_{turn}$$

Where the total time taken is the sum of the reaction time, turn time, and the swim time. The swim time can be calculated by calculating the quotient of total distance and swim velocity. The swim velocity at any time t is equal to the integral of a function of acceleration as follows:

$$v = \int_0^n a(t)\ dt$$

However, in the real world, a Riemann sum of each outputted acceleration point will be used as no smooth curve can be easily approximated. A left bound Riemann sum will be calculated using the following formula:

$$v = t_{interval}(\sum_{t=0}^{n-1} a(t))$$

and

$$d = t_{interval}(\sum_{t=0}^{n-1} v(t))$$

With an identified initial position and orientation.

Swim velocity is related to the product of stroke rate and stroke efficiency in the following relationship:

$$v = f * \eta$$

Stroke rate is calculated using the number of strokes per second; efficiency is calculated using distance per stroke. Stroke efficiency can be maximized through technical improvements to reduce drag and improved strength to power through each stroke. Velocity in all four competitive strokes is maximized with a unique combination of a high stroke rate and consistent but lower stroke efficiency (Craig and Pendergast, 1979).

The final data output of the device must allow swimmers to optimize this model and improve their time in the target event.

4.2 Software Implementation

The software's primary purpose is processing raw data to generate useable information that can be easily viewed by coaches and swimmers. The data processing is done in two parts. First, raw motion and biometric data is read from the SD card and processed to give swimming information. Next, using the outputs from the previous step, algorithms identify areas of improvement for coaches and swimmers to focus on.

The first step of data processing is done with a lightweight Python script. Using functional programming, raw data is converted to data that reflects efficiency of training by the subsequent steps: first, reading the CSV file and creating data structures that sort information by lap; second, processing each swim variable per lap and saving it to a separate list; and third, combining all data and writing to a separate file. The data structures are displayed in Figure 9.

Time

$$\begin{pmatrix} t_1 & r_1 \\ \vdots & \vdots \\ t_n & r_n \end{pmatrix}$$

Accelerometer

$$\begin{pmatrix} t_1 & Ax_1 & Ay_1 & Az_1 \\ \vdots & \vdots & \vdots & \vdots \\ t_n & Ax_n & Ay_n & Az_n \end{pmatrix}$$

Gyroscope

$$\begin{pmatrix} t_1 & Gx_1 & Gy_1 & Gz_1 \\ \vdots & \vdots & \vdots & \vdots \\ t_n & Gx_n & Gy_n & Gz_n \end{pmatrix}$$

Infrared

$$\begin{pmatrix} t_1 & l_1 & r_1 \\ \vdots & \vdots & \vdots \\ t_n & l_n & r_n \end{pmatrix}$$

Heading

$$\begin{pmatrix} t_1 & h_1 \\ \vdots & \vdots \\ t_n & h_n \end{pmatrix}$$

Figure 9: Sensor type data structures for head and relative arm positions

Thirteen data channels are outputted at a rate of approximately 10 hertz. Data is imported into the processing script as a csv file and conclusions are outputted as a csv file with all focused metrics for data visualization. This process can be done in real time via a low energy Bluetooth connection. The final output of the script separates each lap that a swimmer has swum, with swim-specific metrics including stroke rate, distance per stroke, average velocity and breath count, along with a classification label for the type of stroke swum. Please refer to the appendix for a more detailed description of the methodology.

4.3 Machine Learning Algorithm for Stroke Improvement

An optional advanced data processing package allows the device to generate conclusions on technique and possible areas of improvement by identifying common mechanical errors. By collecting data on athletes doing the correct and incorrect movements, an algorithm can be trained to identify incorrect technique and provide the necessary feedback to the swimmer. Currently, the following common errors are being trained; these mistakes can be identified with data that the sensors on the device output:

1. Front Crawl:
    a. Shoulder over-rotation: Occurs when the swimmer rotates his arms past his center of rotation, causing arms to reach in front of the opposite shoulder. This increases the risk of shoulder injury and causes additional drag.

    b. Head misalignment during breathing: Occurs when the swimmer shifts his head off the streamline position, causing body position in the water to suffer, increased frontal area and greater drag.
2. Backstroke:
    a. Incorrect head position: Occurs when the swimmer tilts his head forward too much during the backstroke, harming body position and causing the lower body to sink in the water, increasing drag.
    b. Incorrect arm position: Occurs when the swimmer's arms are too close or too far away from the ears when the arms are raised above the swimmer's head. Can cause shoulder strain and decreased stroke efficiency.
3. Breaststroke:
    a. Improper head movement during breathing: Occurs when an inexperienced swimmer throws his head up and down during the stroke, negatively impacting the body's streamline in the water and increasing drag.
    b. Weak streamline: Occurs when the swimmer's arms are not tightly tucked during the recovery portion of the stroke, causing increased frontal area and drag.
4. Butterfly:
    a. Late breaths: Occurs when the swimmer breaths at an incorrect time in the stroke.
5. All
    a. Late stroke or incorrect rhythm: Occurs when the swimmer pauses at incorrect positions during his stroke, decreasing stroke efficiency, and stroke rate, especially in butterfly.
    b. Mismatched kick and pull: Occurs when the kick is not done in conjunction with the pool so that the body is not able to return to a natural position in the water. This causes increased drag and lower speed in the water.

5 Applications

5.1 Application in Learn-to-Swim Programs

In many learn-to-swim programs, coaches may not have the proper training to use the processed data from the sensors. The device will be able to provide feedback on technique with very little human guidance. Incorrect posture or poor stroke mechanics while swimming can often lead to injuries. These are especially prominent in a club setting with inexperienced coaches who do not pay proper attention to correct technique.

Table 2 Common Swimming Injuries

Injury	Cause and Solutions
Neck and Shoulder Injuries: Inflammation, tendonitis and rotator cuff tears, shoulder impingement syndrome.	Extended periods of competitive swim training can wear out the rotator cuffs (Dischler, 2017). The primary causes of shoulder and neck injuries are poor breathing and shoulder rotation (UPMC Sports Medicine). The device will be able to detect the rotating motions of the head and match it with accelerometer data to determine if breathing is done at the appropriate time to prevent stress in the shoulders and neck. Second, over-rotation of the shoulders when the arms cross the center of rotation can cause inflammation or shoulder impingement syndrome in the long term.
Knee injuries: MCL tear, tendonitis, inflammation	Excessive breaststroke kick training puts extra pressure on the insides of the knees, leading to possible injury. If the device detects a large amount of breaststroke swam combined with sudden decreases in a swimmer's kick strength it can generate recommendations that allow a swimmer to recover

After analysing the data, the device can provide feedback that is displayed in the companion app to remind the swimmer. The app can then guide the swimmers to online resources on injury prevention and proper technique. In addition, the data from these swimmers can be sent to high-level coaches remotely, matched with video footage, allowing swimmers to be coached remotely by a specialist. This device will be a resource for students in rural or poorer areas who aim to swim competitively and promote equality in aquatics education.

5.2 Application in Competitive Programs

By using big data and machine learning, this product can improve the swimming capabilities of students at any level.

At the competitive level, the data collection device described has benefits for team management and individual feedback. First, all key information is saved to an easily accessible document. Coaches can keep track of all training plans that were written and whether deviations were made during the actual training session. Second, in many professional clubs, coaches will no longer have to spend so much their time measuring their swimmers' splits. An automated timing system will reduce their workload and allow coaches to concentrate on stroke and technique improvement instead. Finally, this data collection device can give coaches and swimmers access to swim metrics that are otherwise impossible to obtain, such as heart rate, stroke efficiency, and stroke rate. Data processing algorithms can then determine trends in these and other variables enabling targeted feedback for swimmers. For athletes, the device is non-obtrusive, allowing them to swim normally while learning from specific data about their performance.

This device can give athletes higher quality coaching by providing conclusions on stroke and technique. The stroke recognition function can also determine if strokes were done correctly. By matching sensor data of inexperienced swimmers with those of experienced ones the algorithm has learned, the device can notice errors and communicate them to swim instructors. For example, in a short axis stroke, if the program registers an extremely high count of non-zero outputs, it can conclude that the swimmer's stroke is asymmetrical and provide the necessary feedback. Similarly, the acceleration graphs of learn-to-swim students can be compared to those of professional athletes. Using this comparison as well as video analysis, areas of improvement can be identified.

Figure 10: On-land testing using first low-fidelity working prototype. Source: Author

6 Market Feedback Analysis

Between December 2018 and April 2019, two rounds of testing were conducted using this device with 6 swimmers and 3 club-level coach. Recommendations were taken into account for future development. Feedback after testing was as follows:

1. Comfort: Swimmers who used this device for training said it did not impact their training in a negative way and got used to the device on their heads quickly. Only one swimmer complained of too much clamping pressure on the sides of his head and downwards pressure on his ears. When worn correctly, additional drag was not noticeable even during high-intensity sets where the swimmer was swimming with great speed.
2. Effectiveness: Most coaches were impressed by the amount of data that this device could generate. However, they requested a more elegant method to visualize the data through an app instead of through a text output. This will be a primary area of improvement. One coach asked for audio feedback to be integrated either as a beeping sound for swimmers or voice feedback that is linked either to the program or to a microphone that the coaches can use.
3. Price: The current price is acceptable for most of the elite teams that were interviewed (details on price reduction are mentioned in the "Improvements" section).

7 Summary

7.1 Current Development

Currently, multiple low fidelity prototypes have been created for beta testing with a few athletes at an international high school in Shanghai, China. Hardware and firmware development is mostly finished with the software capable of outputting all eleven channels of data accurately. Stroke identification software and basic swim metric outputs are complete with software and the stroke improvement package under development.

The latest medium fidelity prototype improves upon the existing form factor, allowing for better usability. First, the total volume of the device was decreased. Second, components were shifted to reduce the clamping force on swimmers' and also remove obstructions present in previous models that prevented swimmers from achieving the best streamline position. Figure 11 shows a side-to-side comparison of the two models.

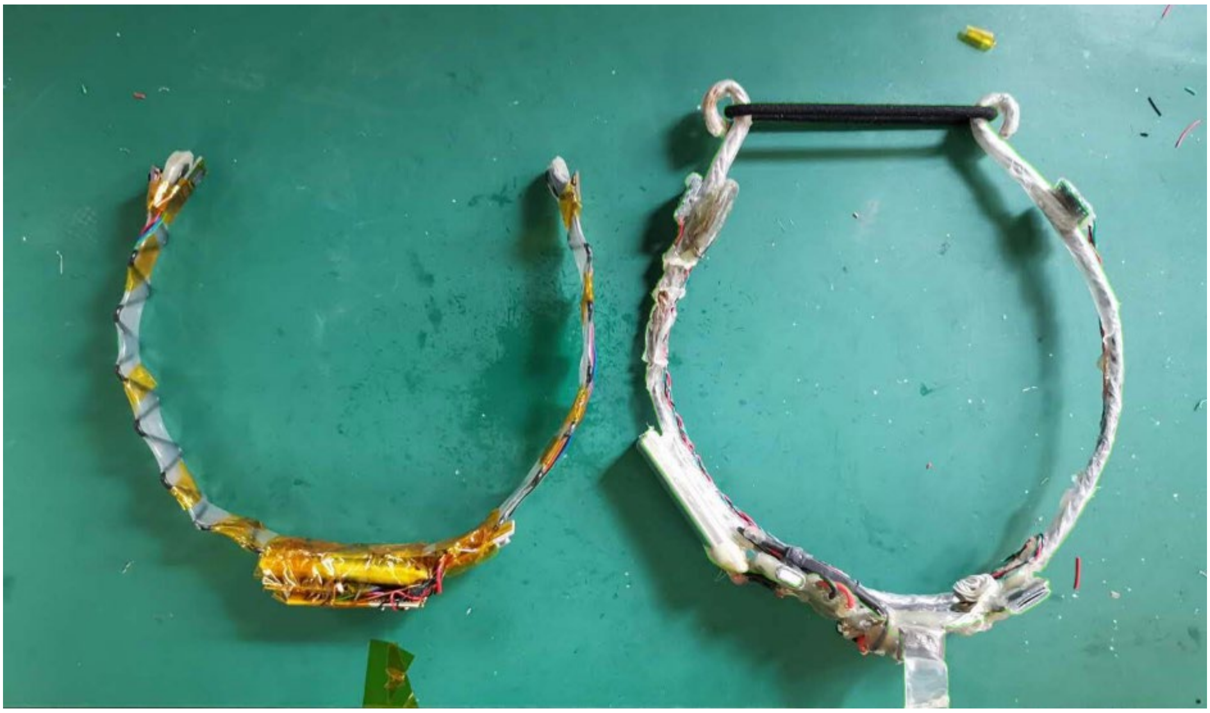


Figure 11: Medium fidelity prototype (left) and low fidelity prototype (right). Source: Author

7.2 Improvements

Future improvements for the device should focus on increased usability, functionality, and accessibility. Regarding hardware, next generation prototypes will use a more flexible material for additional comfort and more effective waterproofing. A replacement for the Curie platform will be used as it has been discontinued by Intel. Since the current firmware already outputs all necessary raw data, very little improvement is necessary. Only slight revisions may be required for compatibility with new hardware modules.

The second stage of data processing must be addressed: identifying areas of improvement for swimmers. A deep learning algorithm will be incorporated, combining swimming videos and motion data to give recommendations on stroke. This requires data collection from professional and amateur swimmers of all age levels. To improve usability, both recommendations and processed swimming metrics must be presented in a readable format through data visualization techniques. The current document output only consists of a table of values with category headers. It is difficult to gauge trends throughout a training session or season. Cumulative graphs and tables will be used to display data in a more user-friendly way.

Next, a mobile app and cloud ecosystem will be established. A mobile app will allow coaches to access data in real time via Bluetooth connection with the device. Coaches can use this information to give timely feedback to swimmers. Users can then opt to upload their training data to the cloud where it can be compared to datasets from high-level athletes. All data on the cloud can then be used to train and improve algorithms.

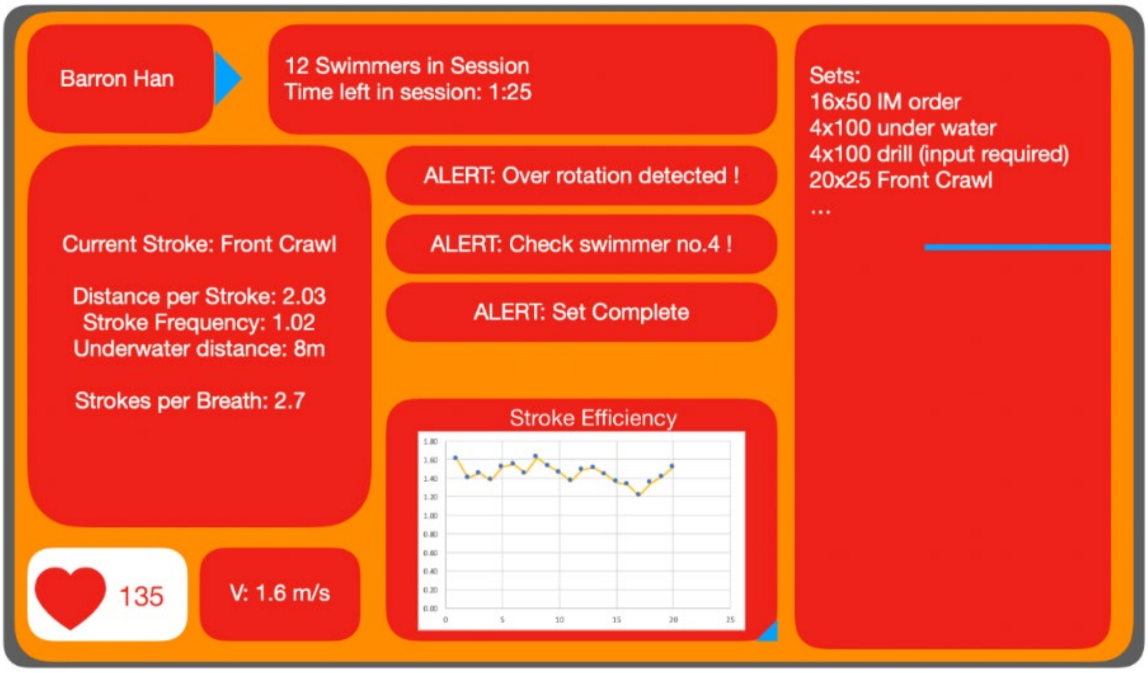


Figure 11: Sample App Interface. Source: Author.

Finally, the price of the product must be reduced to make it viable for learn-to-swim clubs and students in economically developing nations. A primary concern when designing this device is price. This device uses only off-the-shelf components making broken parts easily replaceable. Currently, the market price of a single prototype is around $150 USD, which is already considerably less than other high-tech aquatics education solutions valued at around $300 USD. While this is already appealing to many competitive institutions, the price can be further decreased to less than $100 USD per unit when a larger quantity of product casings are ordered at once.

The vision is to create a tool that can provide high-quality aquatics physical education for all students, from a learn-to-swim level to the professional level. This device will first be pushed to competitive swimmers and professional teams for development and feedback. Ultimately, it has the capacity of transforming physical education on a basic level, changing the vague, inaccurate “small data” ideology to incorporate the benefits of big data and machine learning for all swimmers.

8 References

American Red Cross. (2009). Red Cross Swim News: Overview. Retrieved February 4, 2019, from **https://www.redcross.org/content/dam/redcross/atg/PDF_s/SwimmingWaterSafety.pdf**

Apple Watch Series 4. (n.d.). Retrieved from http://www.apple.com/apple-watch-series-4/

Brenner R.A., Taneja G.S., Haynie D.L., Trumble A.C., Qian C., Klinger R.M., Klebanoff M.A. Association between swimming lessons and drowning in childhood: A case-control study. Arch. Pediatr. Adolesc. Med. 2009;163:203. doi: 10.1001/archpediatrics.2008.563

Craig, A. B., & Pendergast, D. R. (1979). Relationships of Stroke Rate, Distance per Stroke, and Velocity in Competitive Swimming. *Medicine and Science in Sports, 11*(3), 278-283. Retrieved April 15, 2019, from http://www.teamtermin.com/docs/Relationships_of_Stroke_Rate_Velocity_and_Distance_Per_Stroke_Pendergast_Craig_1976.pdf

Sandall, Brian K. (2016) "Wearable Technology and Schools: Where are We and Where Do We Go From Here?," *Journal of Curriculum, Teaching, Learning and Leadership in Education: Vol. 1 : Iss. 1 , Article 9.*

Centers for Disease Control and Prevention Unintentional Drowning: Get the Facts. [(accessed on 20 October 2019)]; Available online: https://www.cdc.gov/homeandrecreationalsafety/water-safety/waterinjuries-factsheet.html.

Dischler, J. D., Baumer, T. G., Finkelstein, E., Siegal, D. S., & Bey, M. J. (2017). Association Between Years of Competition and Shoulder Function in Collegiate Swimmers. *Sports Health: A Multidisciplinary Approach, 10*(2), 113-118. doi:10.1177/1941738117726771

Hall, James G., "Aquatic strategies and techniques and their benefit on children with autism" (2013). *Theses and Dissertations @ UNI. 6.* Retrieved February 16, 2019, from: https://scholarworks.uni.edu/etd/6

Mardonova, Mokhinabonu & Choi, Yosoon. (2018). Review of Wearable Device Technology and Its Applications to the Mining Industry. Energies. 11. 547. 10.3390/en11030547.

MySwimPro. (2018). Elite. Retrieved from https://myswimpro.com/elite/.

Poirier-Leroy, Olivier. Crowded Warm Up Pool. https://www.yourswimlog.com/swim-meet-warm-up/.

UPMC Sports Medicine. (n.d.). Swimming Injuries: Tips, Prevention, and Treatment. Retrieved from https://www.upmc.com/services/sports-medicine/for-athletes/swimming.

USA Swimming. (2016). 2016 Membership Demographics Report. Retrieved from https://www.usaswimming.org/docs/default-source/default-document-library/statistics-2016.pdf

Warsameh, F. (2015, February 3). Somali children splash around in a swimming pool at the Mogadishu Guest House [Digital image]. Retrieved July 4, 2019, from https://www.news24.com/Africa/News/Mogadishu-kids-playground-joy-amid-violence-20150203

World Health Organization. (n.d.). Drowning. Retrieved from https://www.who.int/news-room/fact-sheets/detail/drowning

Xiaoyi Zhang, Ming-Chun Huang, Fengbo Ren, Wenyao Xu, Nan Guan, and Wang Yi. 2013. Proper running posture guide: a wearable biomechanics capture system. In *Proceedings of the 8th International Conference on Body Area Networks*. ICST (Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering), 83–89. http://dx.doi.org/10.4108/icst.bodynets.2013.253700

Xu, Lei. (2018, April 14th). Personal Interview.

About the Author:

Barron Han: A junior at Shanghai American School, Barron is a competitive swimmer who's interest in engineering, computer science, and product design inspired him to create a wearable device to enhance training for all swimmers.

Acknowledgement: Thank you to the people at IvyMaker for guiding me through the product design process and giving me advice on hardware, and thank you to Dr. Sean Bradshaw and Gao Bo for reviewing my work and giving me feedback for this paper.

Appendix

Summary of Data Processing

Laps were sorted using the "heading" variable outputted by the electronic compass. The script uses a running sum on the change in heading of the swimmer to determine when a 180-degree turn is made. It then uses the "time" variable of these points as an index value to split the data into separate lists per lap. This allows future functions to reference specific intervals (laps), calculating the necessary swimming metrics for each lap. A simple filter removes slight changes in a swimmer's head position while breathing to increase the accuracy of turn detection. The indexes outputted by this function can also be used to calculate lap count and distance in a given session.

The following functions were calculated on a lap to lap basis using the outputs from the first lap separation function: heart rate, stroke detection and count, stroke rate and efficiency, and breath count.

Heart rate is calculated using turning point detection. The raw data from the heart rate sensor is mapped on an interval from 0 to 1023. The data is first filtered for irregularities that could be registered as false maximums. Then, the algorithm compares adjacent points to locate turning points, counting the number of maximums within a single lap interval. Using the time stamps and the calculated number of turning points, the heart rate can be calculated.

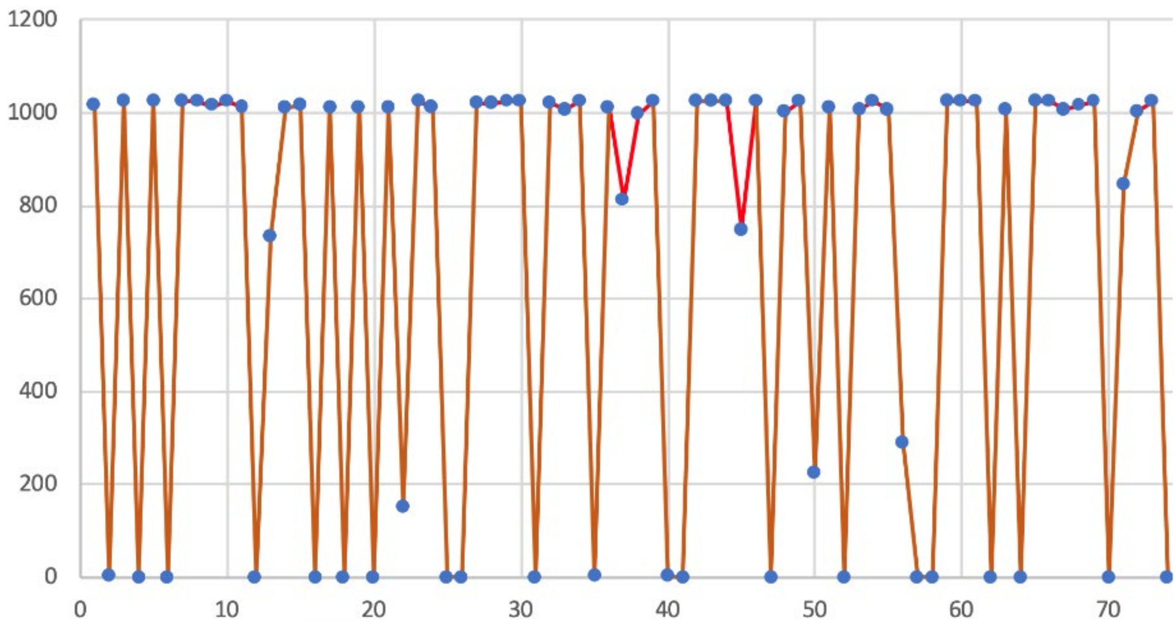


Figure 10: Sample Underwater Heartrate Data with false maximum detection (red segments were judged as inaccurate and eliminated from the total heart-beat count)

Stroke recognition is done in two parts. First, the algorithm detects whether the swimmer's stroke is a "long-axis" or "short-axis" stroke. The long-axis strokes (front crawl and backstroke) involve alternating arm rotation while the short-axis strokes (breaststroke and butterfly) are symmetric. The data from the infrared sensors have a range of 0 to 4494 millimetres. For the purpose of stroke recognition, this data must be standardized for the algorithm to process it more accurately. The distance variable from the left and right sensors are combined and standardized through a comparison function. This function compares the distance between the left and right arm. If the difference is statistically significant, and not the result of a slight imbalance in a swimmer's stroke, the function outputs an integer of either "1" or "-1" depending on which value is larger. If the difference is not statistically significant, a "0" is outputted. Using this method, each raw data value is determined to be part of a short-axis stroke, where the output is "0", or a long-axis stroke, where the output is either "1" or "-1".

A separate filter determines sudden changes between short and long axis strokes that are most likely the result of data collection errors, concluding whether the stroke is short or long axis during a given target lap. Using this output, a separate algorithm distinguishes between the two strokes for each type. The distinction between backstroke and front crawl is straightforward. The acceleration value in the z-axis is retrieved to determine whether the gravitational acceleration is positive or negative. A positive gravitational acceleration indicates that the Curie Nano module is reversed and the swimmer is facing upwards. A negative gravitational acceleration indicates the opposite. Using this method, the orientation and thus the type of long-axis stroke can be determined. The two short-axis strokes are more similar so the distinction algorithm is more complex. There are two possible approaches. First, a guided algorithm can be used to determine the difference in the y-axis acceleration graphs of the two strokes. The acceleration graph for butterfly should have two maximums per stroke cycle that are created by the two kicks done per stroke. Breaststroke only has one maximum generated by a continuous pull-and-kick motion for each stroke cycle. Second, a machine learning algorithm can be used without human guidance to distinguish the difference using classification. However, the first approach is preferable since it does not require resource-intensive python machine learning libraries such as *sci-kit learn*. This will be beneficial for the final application which will be installed on mobile devices that must process data in real time at roughly 50 times a second.

Stroke detection is used to determine when a stroke cycle is completed—as the swimmer's arms return to the streamline position next to the head. Only the left infrared data output is used for this purpose. When the hand crosses the sensor, the data is at its minimum, usually at a distance between 0 and 20 millimetres. A turning point detection algorithm (similar to the one used for heart rate) is used to determine the number of minimums and thus the number of strokes. The time indexes are used to calculate related metrics such as stroke rate. Acceleration data can also be used to calculate distance per stroke, a unit to measure stroke efficiency.

The breath count algorithm utilizes the output of the stroke recognition program and utilizes a specific function based on stroke type. For backstroke, no breath count is outputted. For front crawl, the gyroscope is used to determine when a significant head rotation occurs. By integrating the accelerometer data, the zeroes of the angular velocity function can be determined. These points indicate when a breath was taken. This function allows metrics such as breath count and strokes per breath to be calculated.

IASDR 2019

International Association of Societies of
Design Research Conference 2019
DESIGN REVOLUTIONS

Manchester School of Art
Manchester Metropolitan University
02-05 September 2019

Design Considerations for Explanations Made by a Recommender Chatbot

Park, Sunjeong *; Lim, Youn-kyung

Dept. of Industrial Design, KAIST, Daejeon, Korea, Republic of
* sunny0414@kaist.ac.kr

Self-explanatory features of intelligent agents have been emphasized in terms of helping users build mental models. While previous studies have revealed what traits an agent's explanations should have, investigations on how to design such explanations from a dialogue perspective (e.g., through a conversational UI) have not been addressed. Thus, the purpose of this work is to explore the roles of explanations in recommender chatbots and to suggest design considerations for such chatbots' explanations based on a better understanding of the user experience. For this study, we designed a recommender chatbot to act as a probe. It provides explanations for its recommendations, based on service customization in recommender systems that reflect how it learns and evolves. Each participant experienced the recommender chatbot for 5 days and underwent a semi-structured post-interview. We discovered three roles of explanations in user mental model development. First, each user rapidly built a mental model of the chatbot and became more tolerant of unsatisfactory recommendations. Second, users willingly gave information to the chatbot and acquired a sense of ownership towards it. Third, users reflected on their own habitual activities and used the chatbot reliably. Based on these findings, we suggest three design considerations for chatbot explanations. First, the explanations should be grounded by data from diverse channels. Second, the explanations should be logical and distinguish between personal and generic data. Third, the explanations should gradually become more complete through inferences made from comprehensive information.

Keywords: recommender system; explanations; user mental model

1 Introduction

Intelligent agents are defined as “computer programs whose behaviour only becomes fully specified after they learn from an end user's training data” (Kulesza, 2012). In this role, intelligent agents have become increasingly complex and diverse, and self-explanatory features have become important.

Recent studies have emphasized the benefits of explanations by intelligent agents (Herlocker, 2000; Johnson, 1993; Lim, 2009; Sinha, 2002). In addition, many studies exist that focus on how intelligent agents should offer explanations to end-users (Lim, 2009; Tintarev, 2007; Stumpf, 2009; Herlocker, 2000). These papers studied what characteristics such explanations should have and how they can be made more reasonable based on the underlying algorithm or model. Focusing more on users, some studies examined how an intelligent agent’s explanations affect user mental models (Kulesza, 2012; Tullio, 2007). However, studies regarding "how to *design* explanations to help users develop mental models regarding an intelligent agent" are still limited.

Based on this gap in the existing research, our purpose in this study is to perform an explorational investigation of how chatbot explanations can be designed to help users build mental models of the agent, specifically regarding the chatbot explanations in recommendation services. We focused on a chatbot interaction-based recommender system that provides explanations in the context of a dialogue (i.e., a recommender chatbot). Because customization is an essential aspect of recommendation services, explanations on the customization process should be provided to the users during their interactions with the recommender chatbot. Therefore, we designed a recommender chatbot that provides explanations intended to provide transparency regarding its customization principles.

The user study was conducted with a chatbot designed by the Wizard of Oz method. User opinions and experiences regarding its explanations were collected during post-interviews. The study revealed three major findings concerning the roles that explanations have in user mental model development. Based on these findings, the considerations for designing explanations in conversational UI-based (e.g., chatbot based) recommendation services were suggested to emphasize the positive roles of such explanations. The outcomes from this study can be baselines of the explanation design that emphasize the positive roles of intelligent agents' self-explanations. It can be helpful in conversation design or user interface design of intelligent systems, not only in practice but also in future researches in the field of human-computer interaction (HCI).

2 Background

The importance of building user mental models for intelligent agents has been emphasized recently (Tullio, 2007; Kulesza, 2012; Kulesza, 2013). Mental models can be considered as “internal representations that people build based on their experiences in the real world. [...] The mental-models must be sound (i.e., accurate) enough to support effective interactions” (Kulesza, 2012). However, many intelligent agents fail to build accurate mental models, since the term intelligent raises the user expectations too much on the agents' ability. Also, the intelligent agents including recommender chatbots are based on machine learning technology which is perceived as black box algorithms. It is often ambiguous to users on what service the agent can provide, and why those services are provided. Therefore, to build a proper mental model which should be based on user understandings on what and why of intelligent agents, transparent explanations play a critical role (Tintarev, 2007; Sinha, 2002; Johnson, 1993; Herlocker, 2000). Explanations remove the "black box" aspect that typically surrounds an intelligent agent and allow the agent to justify its actions, increase user involvement, help users build mental models about the agent’s processes, and raise the acceptability of the agent’s actions (Herlocker, 2000).

Previous studies have investigated the crucial factors of explanations. Based on the importance of explaining inner logic (Sinha, 2012), some studies have suggested approaches to explaining why (Lim, 2009) and how (Kulesza, 2012) the agent makes recommendations. Other studies revealed some features that explanations should include: the user context (Tintarev, 2007) and the source of the explanations (Kulesza, 2012; Tintarev, 2007). These studies suggested traits that explanations should possess to improve users' understanding of the agent. Although previous studies investigated the effects of explanations on user satisfaction or the degree to which users correctly understood the agent, research on the users' experiences during the mental-model building process is still lacking. Along with the previous study, which emphasized that the way an explanation is communicated is the most important aspect of helping users understand the agent (Stumpf, 2010), we narrow down our perspective on providing explanations in the context of a dialogue in a conversational UI such a chatbot format, which is the most basic and familiar type of interaction that people have with intelligent agents, to lower the barriers for understanding the agent.

3 Method

3.1 Designing a Recommender Chatbot Transparent on the Principles of Service Customization through Explanations

The purpose of this study is to investigate user experiences with a chatbot that provides explanations about its recommendations. We designed a preliminary recommender chatbot to probe user experiences on this topic and explored the roles that explanations take in building users' mental models of the recommender chatbot. To help users develop mental models and to undergo an engaged experience, we designed a recommender chatbot whose explanations transparently revealed the principles of its service customization from two aspects, which are well-known requirements for service customization, i.e., learning and evolving (Lee, 2009; Kim, 2016; Kim, 2019).

The first principle of customization applied to the recommender chatbot is that it learns about the user based on user-provided data. To reveal this aspect in the explanations, our chatbot specified the user-provided data that was associated with each recommendation using constructions such as "I learned about your information from…". After each recommendation, the chatbot collected user feedback by asking "How was my recommendation?" Then, during subsequent recommendations, the chatbot reflected the user's feedback by statements such as "by considering your feedback on…".

Another principle of customization is that the chatbot evolves its recommendations based on accumulated data regarding a user. As user data accumulate, the nature of inferable information changes: fragments become patterns; subsequently, the depth of the patterns deepens. Our chatbot revealed this deepening knowledge in its explanations by making references—first, to the initial fragmented data, and over time, to the user's activity patterns.

Following the recent research trend on recommender systems in the domains of physical activity and personal health care (Fernandez-Luque, 2009; Wiesner, 2010; Kumar, 2014; He, 2014; Otsuki, 2017), we selected health care as our chatbot's domain; the chatbot provides recommendations on diet and exercise. We chose this domain because of its convenience for providing personalized recommendations and because it is familiar, easily understood, and of interest or concern to everyday users.

3.2 Participants

For this study, twelve people were recruited as participants. We attempted to recruit people who were interested in exercise and diet, placing them in the target group for our health recommender chatbot. Based on the purpose of qualitative studies (Leedy & Ormrod, 2005), the goal of this study was not to identify the tendencies of a specific type of users but to understand the various users' perceptions and experiences from their own perspectives. Therefore, we considered the diversity of prior knowledge and experience with chatbots when recruiting participants. The participants judged their own prior knowledge and experience to reflect their own perspectives by selecting among four options: 1) very familiar with chatbots and have prior knowledge and experience (majored in or working in a related field and used one steadily for more than a month); 2) have chatbot knowledge but little experience (know what one is but have used one for less than a month); 3) have chatbot knowledge but no experience (know what one is but have not used one); and 4) have neither chatbot knowledge nor experience. Detailed information on each participant is provided in Table 1. Among the 12 participants, 9 were male. The average age of the participants was 25.75 years, and the median was 25.00 years.

Table 1 Prior user knowledge on and experience with chatbots

Participant number	Prior knowledge on and experience with chatbots
P1	Very familiar in both knowledge and experience
P2	Have knowledge, but no experience
P3	Have knowledge, but no experience
P4	None
P5	Have knowledge but little experience
P6	Have knowledge but little experience
P7	Have knowledge but little experience
P8	Very familiar in both knowledge and experience
P9	Very familiar in both knowledge and experience
P10	Have knowledge, but no experience
P11	Have knowledge, but no experience
P12	Have knowledge, but no experience

3.3 Procedure

3.3.1 Experiencing the Recommender Chatbot

We used the Wizard of Oz method to develop the recommender chatbot based on the strategy described in Section 3.1. The researchers acted as a recommender chatbot, producing health recommendations and the explanations on each recommendation. The recommendations were based on each participant's schedule data and physical data (e.g., number of steps over time, travel paths and distances), and the explanations were designed based on the basic principles we described in Section 3.1. To track participants' personal daily activities and log their physical activities, the researcher provided each user with a smartphone health app (e.g., iPhone health app, Pacer) or an activity tracker (e.g., Mi band, Jawbone). We collected the participants' schedule data for the 5 days of the study period by accessing their calendar apps. The participants were aware of the types of data provided to the researchers and that the recommendations would be provided based solely on these data. The participants experienced this health recommender chatbot over 5 days.

Each participant received personalized daily health recommendations concerning their exercise and diet from the recommender chatbot. For the chatbot system, we utilized an instant messenger app (KakaoTalk) because that app is domestically widespread; thus, users could chat in a familiar environment. Furthermore, because KakaoTalk supports many business chatbots, most of the users already had some experience conversing with a chatbot via this app (even when they were not aware that it was a chatbot). We did not tell the participants that our chatbot was a roleplay performed by a human wizard: the chatbot provided recommendations at fixed times as if they were provided by a non-human system.

At the beginning of the experiment, the recommender chatbot sent an introductory message to introduce the service, as shown in Table 2.

Table 2 Introductory message sent by the chatbot at the start of conversation with the participants

Purpose of the message	Sample message content
Greet the user and set an exercise goal	“Hello John, the weather is bright today. I will introduce myself first. I am a chatbot who recommends exercise and diet based on your exercise goals. Would you please set your exercise goals by choosing among 1) reducing body fat, 2) improving balance, or 3) building muscle?”
Explain recommendation service in detail and get confirmation on data collection	“Your exercise goal is body fat reduction. I will recommend exercises and meals related to body fat reduction. I will provide daily recommendations regarding your exercise and diet. To give you a better quality of recommendations, I need to learn a little about you. May I access your schedule data and health tracking data?”

After the introduction, the recommendations were provided to each user via instant messenger twice a day: one recommendation for exercise and one recommendation for diet. After each recommendation, the chatbot asked, “How was my recommendation?” to collect user feedback; subsequently, it could reflect the feedback as another aspect of user information. The recommender chatbot mentioned the source of its data using words such as "learned," "based on," "considering" and "feedback" in the explanations to reflect the first principle of customization (learning). As time passed, the learned user information became more abundant, and the recommender chatbot considered the accumulated information to enhance the recommendations. The inferences from this accumulated information were reflected in the explanations over the study period of 5 days, reflecting the second principle of customization (evolving). Examples of the detailed explanations provided on each day are listed in Table 3.

Table 3 Base data reflected in the recommendations and examples of explanations

Days	Base data reflected on recommendation	Example of recommendation with explanation
Day 1	Based on exercise goal	(participant whose exercise goal is to reduce body fat) “How about oatmeal and boiled eggs to help you lose body fat today?”
Day 2	Schedule was additionally considered	“Good morning, John. Based on your schedule from 10 am to 3 pm today, you will be tired. I recommend you have chicken soup for lunch, a high-protein meal.”
Day 3	Daily activity data additionally reflected	“It's raining today. I learned about your activities yesterday, and your activity level came up a little short compared to the recommended amount. I recommend that you have a low-fat tofu salad today.”
Day 4	User feedback to prior recommendations additionally considered	(a participant who wanted the chatbot to recommend meals that can be eaten at restaurants near his school) “Good morning, John. Today's meal is recommended by considering your diet feedback. I recommend a turkey sandwich, which is a balanced meal that can be eaten near your school.”
Day 5	Users' routine patterns analysed from daily activity data over the previous four days additionally considered	“Looking at the pattern of your recent activity, you seem to prefer high-intensity exercise at the appointed time. Based on the feedback you provided, I recommend the Tabata routine today at 8 PM, which will help you improve your strength and reduce your body fat. I will provide the workout video as you requested last time.”

3.3.2 User Interviews

After 5 days of experience with the recommender chatbot, a post-interview was conducted with each participant. This interview focused particularly on probing users' thoughts and experiences with the explanations from various aspects. The interview questions are listed in Table 4. Each interview lasted a maximum of one hour and was voice-recorded.

Table 4 Intent of the interview questions and sample interview questions

Intent of the interview question	Sample interview question
To relax the participants and allow them to freely communicate their overall impressions	"How was your experience with the health recommender chatbot?"
To understand participants' expectations at the outset	"What expectations did you have right after the initial chatbot greeting?"
To recall experiences related to the participant's satisfaction with the explanations	"What was the most satisfactory explanation? Why?" and "What was the most unsatisfactory explanation? Why?"
To gain participants' detailed impressions of the explanations based on two principles of customization	"Did you feel that the chatbot was learning about you? If yes, when and why? If not, why not?" "Did you feel that the chatbot was evolving? If yes, when and why? If not, why not?"
To understand participants' opinions about the transparency of the explanations	"Did you think that the chatbot provided transparent explanations about its recommendations? If yes, can you give an example of when and why? If not, why not?"
To understand participants' overall levels of trust and satisfaction with the chatbot in relation to its transparency	"Regarding your impressions of transparency, how did this impact your overall trust of and satisfaction with the chatbot?"

After asking these questions, we showed each participant their full conversation with their own recommender chatbot and asked them to freely provide any additional impressions about the conversations.

The collected interview data were transcribed, and similar comments were grouped. To categorize the comments, we tagged each comment based on the purpose of this study. This open-coding process was performed while keeping in mind the detailed factors of explanations and their effects on the users' experiences. The coding was individually performed by the four researchers, and five researchers (including the four researchers who performed the open-coding) discussed the results. This process of open-coding and discussion was performed iteratively to extract agreed-upon findings. In this way, we were able to identify the three findings concerning the roles of explanations in recommender chatbots for user mental model development.

4 Findings: The Roles of Explanations in User Mental Model Development

4.1 Users rapidly built a mental model on the recommender chatbot and became more tolerant of unsatisfactory recommendations

Users were able to discover what the recommender chatbots knew and understood about them through the explanations. The chatbots provided explanations regarding the data on which the recommendations were based along with the content. Therefore, the users were able to understand how the chatbot processed data and consequently, to build mental models on it. This process helped users feel that the recommender chatbot understood them, which ultimately led to an increase in trust. "*I used the chatbot for only a few days, but it was nice to know that it [chatbot] knew those various things about me. I felt understood.*" [P9]

The increased user trust in the recommender chatbot made the users more likely to actively try the recommended diet or exercise. "*I was motivated to perform the recommended exercise because it [the chatbot] explained the reason why it was suggesting that to me. Whether the recommendation was good or not, I was willing to try.*" [P11]

In addition, when the recommender chatbot made an unwanted or improper recommendation, users thought it occurred because they had not given the chatbot enough information; therefore, providing an incorrect recommendation was a reasonable mistake. Users tried to convince themselves that a lack of information was the reason why the recommendation was wrong, which caused them to adopt a more tolerant attitude towards the recommender chatbot. *"I know that it needs to learn about my activities or preferences for a long time to make totally fitting recommendations. It can give inappropriate recommendations sometimes since it does not have enough information about me.*" [P10]

The explanations provided with the recommendations helped users gain trust in the recommender chatbot and be more tolerant of unsatisfactory recommendations, which can potentially reduce the abandonment rate.

4.2 Users willingly gave information to the recommender chatbot and acquired a sense of ownership towards it

Users felt intimate with the recommender chatbot when it mentioned social issues or referenced personal information concerning the user's daily life in the explanations. From the explanations, users thought that the recommender chatbot felt sympathy for them. *"I felt intimate because the chatbot said things such as 'Since you have been to Jeju [...].' I felt that it was thinking specifically about me.*" [P9]

As users built their mental models on the recommender chatbot and felt increasing intimacy, they tried to provide more detailed feedback to obtain better recommendations. "*From this point on, I explained in more detail [not only giving feedback on whether I liked it or not] when giving feedback. For example, 'I like this recommendation, but I do not want to try it right now.' I was trying to give more information*." [P12]

The recommender chatbot provided increasingly customized recommendations and used phrases that were increasingly specific to each user by collectively reflecting the user feedback and activity data. Users were able to experience the recommender chatbot's development in a more customized direction through the explanations and felt themselves becoming engaged with the chatbot. As a result, users gained a sense of ownership from thoughts such as 'the recommender chatbot is only for me'. "*At first, the chatbot felt like a teacher who teaches 30 students, but as it became more personalized, I felt a one-to-one relationship [of teacher-student].*" [P4]

The user-chatbot relationship and the feeling of ownership helped users to provide information steadily and willingly to the recommender chatbot. The ownership helped the participants trust the chatbot's recommendations. This positive feedback can be a cornerstone in building long-term relationships.

4.3 Users reflected on their own activity habits and reliably used the recommender chatbot

Users were deeply impressed by the explanations when the recommender chatbot analysed their cumulative exercise data and made reports from a comprehensive viewpoint. Existing activity trackers or personalized health care apps merely sort and display users' activity data.

However, in our study, the recommender chatbot interpreted the data and described it conversationally when delivering recommendations to the user. In particular, the parts in which the chatbot analysed the activity over several days and discovered lifestyle patterns caused users to recognize the chatbot as a customized information source that reinterprets their personal objective data. *"I think it was good that it discovered my life pattern and let me know. I liked the comprehensive evaluations such as 'You enjoy exercise through in-life activities rather than high-intensity exercise'. [It explained] aspects that are difficult to understand when looking at the data by myself."* [P11]

From the provided analysis, users felt they were understood by the recommender chatbot and used it more reliably. Users self-checked their lifestyle and patterns through the customized reports provided by the chatbot. *"It was very good in terms of the chatbot understanding my life pattern. It gave me a chance to do a self-check."* [P7], Furthermore, users became self-motivated to change their life patterns, and they were more likely to actively accept the recommender chatbot's recommendations. *"I started to trust the chatbot's recommendations more, and my attitude changed—I became more likely to try the recommendations to change my life pattern in a better way.*" [P12]

These interview results imply that explanations that interpret the user's behaviour patterns increase the perceived reliability of the recommender chatbot and can self-motivate users. Fostering self-motivation has the potential to have a continuing impact on the user's life and improves the probability of long-term use of the recommender chatbot.

5 Design Considerations to Emphasize the Positive Roles of Explanations

We extracted three considerations for designing explanations that emphasize their positive roles in helping users develop mental models. These considerations were proposed based on the user experience instances when they expressed positive influences regarding the explanations. These design considerations can be applied as strategies for recommender chatbots in future studies and should be discussed deeply so they can be developed in forms more feasible for designers.

5.1 Explanations should be grounded by data from diverse channels

When giving a recommendation to a user, the chatbot should explain why this content is recommended and which data are the basis for the recommendation. From our study, we discovered that users trust the recommendations more when the content is grounded by the data from diverse channels.

For example, suppose a user who set an exercise goal of muscle-building has a below-average daily step count and mentioned in feedback that he does not cook. To this user, the recommendation could be given as follows, considering his dinnertime schedule: "Looking at your activity data for a few days, your step count is a little short compared to the average. I recommend that you eat dinner at a restaurant approximately a 15-minute walk from work, based on your feedback and activity data. Today, I recommend the XX sushi restaurant, which is famous for its high-protein brown rice sushi." This explanation includes data from four channels: 1) the step-counting channel, 2) the user's feedback channel, 3) the user's schedule channel, and 4) the user's exercise goal channel. The 15-minute-distant restaurant was recommended because the user's *number of steps* was below average. Reflecting the *feedback* that the user cannot cook, the chatbot recommended a restaurant rather than a specific meal to cook. The chatbot recommended a suitable dinnertime based on the *user's* *schedule*. The reason for recommending that particular restaurant (sushi) was because sushi is high-protein food, which is related to the user's *exercise goal*.

In this way, the recommender chatbot lets the user know that it has learned personalized information through various channels and that it considers these data when making recommendations. This not only helps users trust the recommendations but can also positively affect the user-chatbot relationship by revealing that the chatbot is actively accepting and learning from the provided information and feedback.

To be more specific about the source channel of the data, users felt more intimate with the recommender chatbot when it considered data from the user's context. This context included both public social issues and personal situations that had occurred in the user's daily life. To provide explanations considering the user context, it is important to collect information about the user's overall lifestyle. Even when that information is not directly related to the recommender chatbot’s service domain (e.g., exercise and diet), explanations that demonstrate an understanding of the user's lifestyle will help users feel more intimate towards the recommender chatbot. For example, prior to recommending diets, information should be collected not only on users' diet goals and food allergies but also their living environments (whether the user can cook) and typical travel ranges.

5.2 Explanations should be logical and distinguish between personal data and generic data

Users gain trust in the recommender chatbot and its recommendations when it provides explanations that have a logical flow. To provide a logical explanation, the content of the recommendation should be connected to the data on which the recommendation is based. Additionally, the source of the data should be clarified by distinguishing two data types: "personal" data, which is specific to the user, and "generic" data, which is obtained from big data. For example, a logical explanation can be used to highlight a user's personal data (less than 5,000 steps per day) compared with objective indicators from generic data (average step per day for an adult in their 20 s): “You have walked less than 5,000 steps per day for the last three days, which is only half of the recommended average step per day for an adult in their 20s”. This explanation is more convincing to users than an explanation such as “Looking at your activity patterns during the last three days, your step count is insufficient”.

Furthermore, the explanations should include the reasons why a particular content was recommended so that the users build trust on the recommender chatbot. For example, when sending a workout link, it is good to provide the reason why a video of a specific trainer was selected (e.g., this trainer’s videos are the most popular among home-oriented trainers). If the explanation is insufficient, users may suspect that the content may have been selected for advertising purposes, which can erode trust in the recommender chatbot.

Through the logical explanation mentioning the source of the data, users were able to perceive what the chatbot had learned about them. Therefore, users were more tolerant of unwanted or improper recommendations in the initial stages of use because they understood what information was insufficient for the chatbot. Users’ understanding of the data that the chatbot had learned about them made it easier for them to provide detailed feedback. Moreover, the higher quality of user feedback made it possible for the chatbot to provide increasingly customized recommendations with explanations that referred to prior feedback. During this process of users giving feedback and getting it back in future recommendations, users felt themselves becoming engaged with the chatbot and felt ownership of it.

5.3 Explanations should gradually become more complete through inference from comprehensive information

The longer a user interacts with the recommender chatbot, the more data it accumulates. Instead of showing the accumulated user data in a piecemeal fashion (e.g., using a list or chart), the chatbot should make a comprehensive judgement by deducing patterns and referring to them in explanations.

For example, our recommender chatbot provided explanations on the user's recent activity patterns at specific times of the day. "Looking at your *activity patterns* during the last three days, your step count *during work hours* is insufficient. Since you have a meeting until 5 PM, I recommend stretching during office hours for 10 minutes at 5 pm." This explanation reflected a user pattern determined by the chatbot from the user's activity data. Then, it recommended an exercise to augment the user's insufficient activity level.

As another example, our recommender chatbot recommended specific exercises (e.g., squats, lunges, Pilates, stretching at work, walking, etc.) through a video link, and the chatbot could discover what types of exercise each user preferred based on the accumulated user feedback. This knowledge was then expressed in the recommendations based on exercise classifications. "You seem to prefer exercise through *normal life activities* rather than high-intensity exercise at some specific time. Based on your feedback on the recommended exercises, I recommend moderate-intensity exercise. Try home-Pilates for 15 minutes after 9 pm."

As the amount of data accumulated, the participants in our study expected not only to obtain more satisfying recommendations but also to obtain analysed information on their comprehensive lifestyle patterns. In other words, providing data for an extended period allowed users to expect that the recommender chatbot would monitor their lives and activities. This suggests that it is important to meet users' expectations regarding both satisfactory recommendations and acknowledgements of the data users provide. Comprehensively inferring data and providing reports to users can positively affect the continuous use of the recommender chatbot by meeting users' expectations.

6 Conclusion and Future Research

By designing a recommender chatbot that provides explanations on its customization directions, we exploratively investigated user's experiences with the explanations and their development of mental models on the recommender chatbot. The user study revealed the findings on the roles of the explanations in the users' mental model development. We then suggested three considerations for designing explanations made by recommender chatbots based on the analysis of positive instances from the user studies. First, the explanations should be grounded on data from diverse channels rather than responding to data from only a single channel. Second, the explanations should be logical, which can be accomplished by the chatbot stating the types of data on which its recommendations are based. Third, not only the recommendations themselves but also the explanations should evolve in a direction customized to the user by gradually becoming more comprehensive through inferences.

Since all of the recruited participants were Asian, the activity patterns or lifestyles of users can be biased. Despite that, the key design considerations for explanations proposed in this paper will be the seeds for further research that generate specific design outcomes. This user-centred approach for designing explanations in recommender chatbots will lead to users developing more effective mental models, eventually resulting in users building trust and being more satisfied with the recommender chatbot. We hope that future studies demonstrate the influences of these considerations on people's service experiences regarding the intelligent agent, not just in the health care domain but also in other domains.

7 Acknowledgements

This work was supported by Institute of Information & Communications Technology Planning & Evaluation (IITP) grant funded by the Korea government (MSIT) (No.2016-0-00564, Development of Intelligent Interaction Technology Based on Context Awareness and Human Intention Understanding).

8 References

Fernandez-Luque, L., Karlsen, R., & Vognild, L. K. (2009, August). Challenges and opportunities of using recommender systems for personalized health education. In MIE (pp. 903-907).

He, Q., Agu, E., Strong, D., & Tulu, B. (2014, November). RecFit: a context-aware system for recommending physical activities. In Proceedings of the 1st Workshop on Mobile Medical Applications (pp. 34-39). ACM. doi:10.1145/2676431.2676439

Herlocker, J. L., Konstan, J. A., & Riedl, J. (2000). Explaining collaborative filtering recommendations. Proceedings of the 2000 ACM Conference on Computer Supported Cooperative Work - CSCW '00. doi:10.1145/358916.358995

Johnson, H., & Johnson, P. (1993). Explanation facilities and interactive systems. Proceedings of the 1st International Conference on Intelligent User Interfaces - IUI '93. doi:10.1145/169891.169951

KakaoTalk, http://www.kakao.com/services/8

Kim, D. J., Lee, Y., Rho, S., & Lim, Y. K. (2016, May). Design opportunities in three stages of relationship development between users and self-tracking devices. In Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (pp. 699-703). ACM. doi:10.1145/2858036.2858148

Kim, D. J., & Lim, Y. K. (2019, May). Co-Performing Agent: Design for Building User–Agent Partnership in Learning and Adaptive Services. In Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems. ACM.

Kulesza, T., Stumpf, S., Burnett, M., & Kwan, I. (2012, May). Tell me more?: the effects of mental model soundness on personalizing an intelligent agent. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (pp. 1-10). ACM. doi:10.1145/2207676.2207678

Kulesza, T., Stumpf, S., Burnett, M., Yang, S., Kwan, I., & Wong, W. K. (2013, September). Too much, too little, or just right? Ways explanations impact end users' mental models. In Visual Languages and Human-Centric Computing (VL/HCC), 2013 IEEE Symposium on (pp. 3-10). IEEE.

Kumar, G., Jerbi, H., Gurrin, C., & O'Mahony, M. P. (2014, December). Towards activity recommendation from lifelogs. In Proceedings of the 16th International Conference on Information Integration and Web-based Applications & Services (pp. 87-96). ACM. doi:10.1145/2684200.2684298

Lee, M. K., & Forlizzi, J. (2009). Designing adaptive robotic services. Proc. of IASDR'09.

Leedy, P. D., & Ormrod, J. E. (2005). Practical research (pp. 139-140). Pearson Custom.

Lim, B. Y., Dey, A. K., & Avrahami, D. (2009, April). Why and why not explanations improve the intelligibility of context-aware intelligent systems. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (pp. 2119-2128). ACM. doi:10.1145/1518701.1519023

Otsuki, R., Sugiyama, O., Matsumura, K., Tada, M., Noma, H., & Kuroda, T. (2017, October). When should the Health Promotion Agent Recommend the User to Walk?: Approach for Searching an Appropriate Walking Pattern for the User. In Proceedings of the 5th International Conference on Human Agent Interaction (pp. 469-472). ACM. doi:10.1145/3125739.3132589

Sinha, R., & Swearingen, K. (2002, April). The role of transparency in recommender systems. In CHI'02 extended abstracts on Human factors in computing systems (pp. 830-831). ACM. doi:10.1145/506443.506619

Stumpf, S., Rajaram, V., Li, L., Wong, W. K., Burnett, M., Dietterich, T., ... & Herlocker, J. (2009). Interacting meaningfully with machine learning systems: Three experiments. International Journal of Human-Computer Studies, 67(8), 639-662. doi:10.1016/j.ijhcs.2009.03.004

Stumpf, S., Wong, W. K., Burnett, M., & Kulesza, T. (2010). Making intelligent systems understandable and controllable by end users.

Tintarev, N., & Masthoff, J. (2007, October). Effective explanations of recommendations: user-centered design. In Proceedings of the 2007 ACM conference on Recommender systems (pp. 153-156). ACM. doi:10.1145/1297231.1297259

Tullio, J., Dey, A. K., Chalecki, J., & Fogarty, J. (2007, April). How it works: a field study of non-technical users interacting with an intelligent system. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (pp. 31-40). ACM. doi:10.1145/1240624.1240630

Wiesner, M., & Pfeifer, D. (2010, November). Adapting recommender systems to the requirements of personal health record systems. In Proceedings of the 1st ACM International Health Informatics Symposium (pp. 410-414). ACM. doi:10.1145/1882992.1883053

Design research, eHealth, and the convergence revolution

Pannunzio, Valeria*; Kleinsmann, Maaike; Snelders, Dirk

Delft University of Technology, Delft, the Netherlands
* v.pannunzio@tudelft.nl

The Quadruple Aim is a framework which prioritizes four 'aims', or dimensions of performance, for innovating in the healthcare domain, respectively: 1) enhancing the individual experience of care; 2) improving the work life of health care clinicians and staff; 3) improving the health of populations; and 4) reducing the per capita cost of care. In this contribution, recent literature providing examples of design research in the eHealth domain is reviewed to answer the research question: 'in which measure has design research contributed to each of the 'four aims' of eHealth innovation in the past five years?'. The results of the review are presented and employed to draw three main observations: 1) design researchers in eHealth seem to be largely focused on improving experiences of care, either patients' or health professionals'; 2) design researchers' contribution on reducing per capita costs of care appears to be less pronounced, which is outlined as a point for improvement; and 3) in a considerable amount of reviewed contributions, design researchers appear to be contributing to multiple 'aims' at once. In this sub-group of reviewed contributions, several disciplinary areas and types of stakeholders interact and integrate through design research activities.
The latter observation leads to a reflection on the strategic role of design research in the contexts of the convergence revolution and of the non-communicable disease crisis. Implications of this reflection for design researchers are recognized in the opportunity and timeliness to develop eHealth-specific ways to orchestrate design integration. A direction for further research in this sense is identified in the use of sensory and self-monitored data as a boundary object for eHealth innovation. The prospective value of this direction is finally exemplified through the case of blood pressure.

Keywords: design research; eHealth; Quadruple Aim; convergence revolution

1 Introduction

1.1 Design research in eHealth

eHealth is defined as the 'the application of information and communications technologies (ICT) across the whole range of functions that affect health' (Silber, 2003). In this paper, we set out to explore recent literature reporting design research case studies in the eHealth field, with the aim of understanding the specific effects and influences afforded by design researchers in this domain. Specifically, we collected eHealth-related examples of design research in the two acceptations of what Horvath (2007) calls *Research in Design Context (RiDC)* and *Design-Inclusive Research (DIR),* while discarding examples of *Practice-Based Research (PBR)* (ibid.).

For instance, literature describing usability tests conducted on eHealth proposition for design purposes (RiDC) was included in this review, as well as literature providing accounts of eHealth-relevant findings obtained through design activities (DIR). Conversely, literature providing heuristics and guidelines for designing eHealth propositions domain (PBR) was excluded from the review. This was chosen because, in this stage, our interest lies in understanding effects and influences afforded by design research in eHealth, rather than in exploring the practical aspects of designing in the eHealth domain.

1.2 The Quadruple Aim framework

The framework here employed to distinguish between *kinds* of influences afforded by design research in eHealth is the 'Quadruple Aim', a widely adopted prioritization of four dimensions of performance for improving the quality of healthcare systems. The four dimensions are depicted in Figure 1.

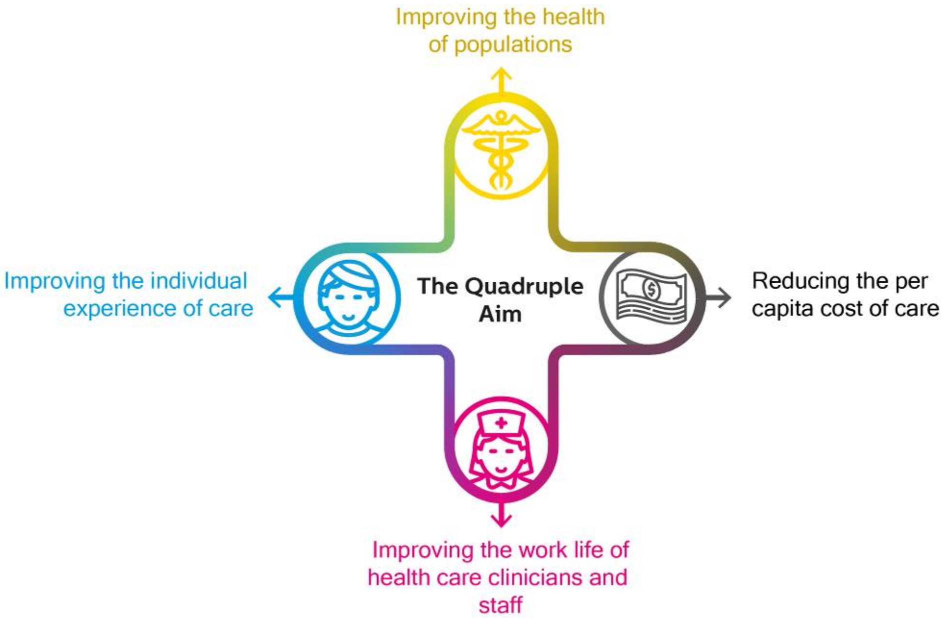


Figure 1. The Quadruple Aim framework (authors' own illustration).

The framework arises from a recognition of the intrinsic interconnectedness of the four dimensions; specifically, improving the health of populations is seen as the primary measure of performance of any part of a healthcare system, and the other three dimensions are seen as secondary measures of performance, all instrumental in the achievement of the former (Sikka, Morath, & Leape, 2015). The framework is recognized as pertinent to the eHealth domain, and has been successfully employed to assess the impact of specific eHealth innovations (Liddy & Keely, 2018). Exploring the impact of design research processes on each of these four aims is intended to be an exercise which is deemed useful both to stimulate awareness and self-reflection for design research practitioners working in this domain, and to serve transdisciplinary eHealth teams, whose members might not always know which kind of value to expect from design research expertise.

The overall research question is formulated as; in which measure has design research contributed to each of the 'four aims' of eHealth innovation in the past five years?

2 Methods

The literature review is executed as follows;

- Step 1. Advanced searches were performed in three academic databases, namely IEEExplore Digital Library, Elsevier Science Direct, and ACM Digital Library, using a combination of keyword developed iteratively and reported in Table 1. This set of databases was chosen in reason of its coverage of multiple 'flavours' of eHealth literature, including the medical-oriented (represented by sources such as the International Journal of Medical Informatics) and the computer science-oriented ones (represented by sources such as or Pervasive and Mobile Computing). We focused on the past five years, so the search is performed on papers from 2014 onwards. This step resulted in a first selection of 785 papers.

Table 1. Keywords used for database searching.

eHealth keywords	"e-health"; "eHealth";"digital health"; "health IT"
Design Research keywords	"design research";"user centered design"; "patient centered design"; "user experience"; "user research"

- Step 2. We scanned the abstracts of the papers found in Step 1 in order to exclude contributions irrelevant to the research question.
- Step 3. The remaining contributions were read in full text and excluded if deemed by the authors that; a) the contribution does not describe a single case study; b) the contribution content is not to be regarded as an example of design research as defined in the introduction; c) none of the four goals of the Quadruple Aim framework are explicitly mentioned as an objective or as an achievement of the design intervention described in the contribution. Additionally, during the review and selection process, it was decided to exclude d) four contributions that were deemed to be only indirectly health-related (e.g. describing design projects aimed at designing a website accessible for user with disabilities), thus unfit to be scrutinized through the Quadruple Aim framework; and e) one contribution that was not fully written in English. An overview of the number of contributions excluded during each of these steps is provided in Figure 2.

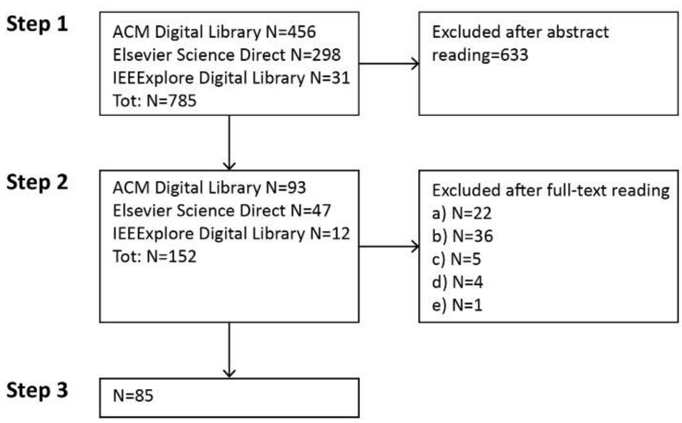


Figure 2. Diagram summarizing the first three steps of the literature review process.

- Step 4. The remaining 85 contributions were re-read and labelled depending on their mention of design objectives or achievements pertaining to one or more of the four dimensions of the Quadruple Aim framework. For instance, contributions mentioning ‘improved patient satisfaction’ as a goal or a result of an intervention supported by design research were labelled as pertaining to the first dimension, ‘enhancing the individual experience of care’; contributions mentioning ‘quantifiable improvements on the Healthy Eating Index’ were labelled as pertaining to third dimension, ‘improving the health of populations’, and so on. Each contributions could be labelled on multiple dimensions.

3 Results

An overview of the raw results from the literature research is offered in Figure 3.

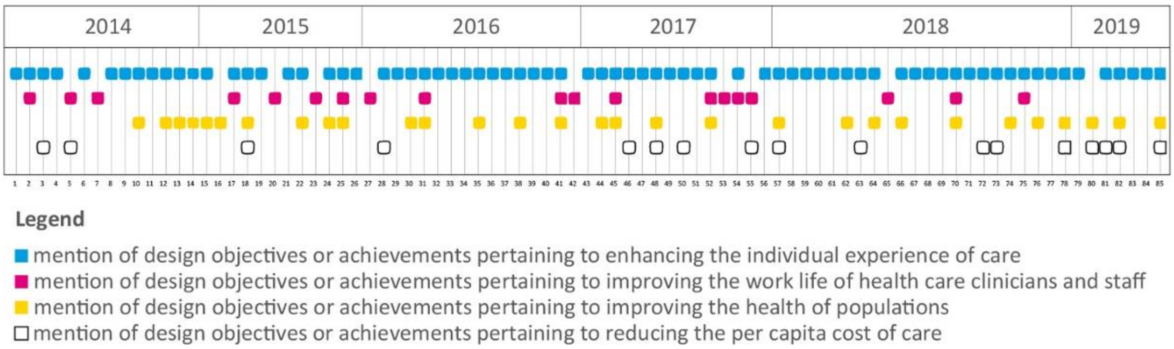


Figure 3. Each one of the 85 contributions, represented as a vertical line, is labeled depending on the categories of aim mentioned as a design objective or achievement.

To better understand the interconnectedness between the four aims, the contributions were also grouped based on their labels (Figure 4).

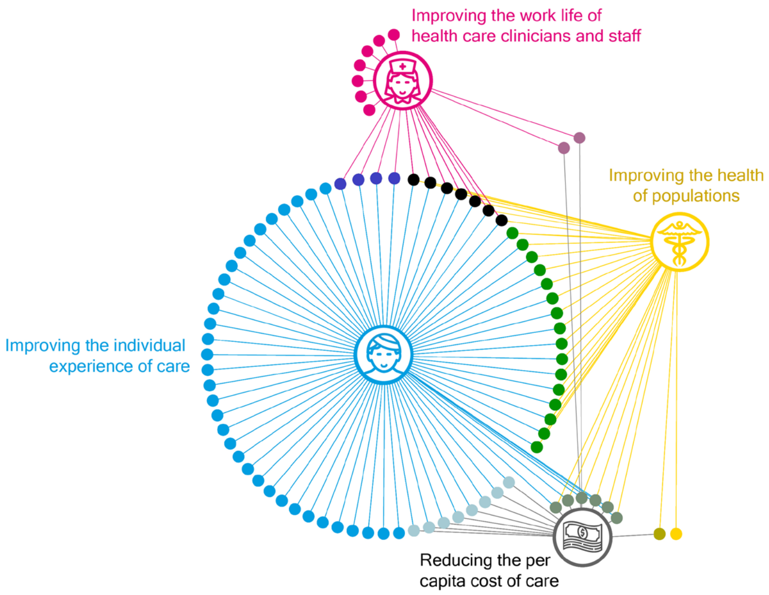


Figure 4. The 85 contributions, represented as a coloured dot, are linked to the relevant aims (each depicted by a coloured icon). Dots are coloured depending on their connections; contributions only mentioning improved individual experiences of care are coloured in blue, contributions only mentioning improved health of populations are coloured in yellow, contributions mentioning both are coloured in green, and so on. Authors’ own illustration.

4 Discussion

Figures 3 and 4 collectively provide an impression of the kinds of benefits authors mention as related to design research in eHealth, and can lead us to a number of reflections.

4.1 Design research as the enabler for improved eHealth experience

Observing Figure 3, we can see how almost all reviewed contributions contain explicit mentions of the aim of enhancing the individual experience of care. The few contributions not mentioning individual experience-related goals tend to be the ones that do mention improving the work life of health care clinicians and staff *instead* (as it is the case of contribution 5, 7, 20, 23, 27, 42, 53, 55, and 65). This effect of mutual exclusion is easily explained by looking at target users; some design research processes are simply situated in contexts in which healthcare staff members are intended to be the primary users of the innovation - see e.g. the case of Zarabzadeh et al (2016), who investigates the utility of an electronic Clinical Prediction Rules (eCPR) amongst physicians. Altogether, thus, a first element that stands out from the overview is the strong focus on user *experiences* in eHealth design research literature, whether patients' or healthcare staff's.

The second most-often mentioned benefit of design research activities in the eHealth domain relates to improving the health of populations. A considerable number of contributions indicate specific improvements in term of health outcomes reached through or supported by design research activities. Crucially, these contributions almost never mention improved health outcomes as the *only* kind of benefit afforded, but rather as one that is coupled with improved experiences of care. As we can see in Figure 5, green dots (contributions mentioning both improved individual experiences of care and improved health of populations) appear to be fairly common cases in the reviewed literature. Reading through these contributions, two main kinds of mechanisms emerge in the way design research connects improvements in individual experiences and improvements in care outcomes, respectively;

1. Design research activities that set out to promote individual experiences of care for existing eHealth propositions, and end up impacting on care outcomes in the process - see for instance the case reported by Bakker, Kazantzis, Rickwood & Rickard (2018), in which the effort to develop an easy-to-use and engaging application resulted in a eHealth innovation which was, then, deemed to deserve its own Randomized Clinical Trial.
2. Design research activities that set out to promote improved individual experiences *so that* new, disruptive eHealth innovations that are already known to present health benefits become 'good enough' to be used - see for instance the case reported by Calvillo-Arbizu et al., (2019), in which a user-centered design process is followed so to 'maximize user acceptance' of an otherwise defined eHealth innovation.

The existence of both mechanisms, which we could refer to as 'experience-driven' and 'experience-enabled' care improvements, represent firstly a confirmation of the insights that lie at the very basis of the Quadruple Aim framework, such as the realization that care outcomes and experiences of care are inextricably linked; and secondly, a confirmation of the value of doing design research in the eHealth domain as a way to generate both 'pull' and 'push' care innovations. This last consideration aligns to theoretical models of design impact in healthcare systems, in which a distinction is drawn between a) design approaches in which design-generated knowledge is employed to develop a product or service, and b) design approaches in which design-generated knowledge is employed to develop a product or service *and* to trigger new health research (Pannunzio, in press).

4.2 Cost-awareness in eHealth design research: a point for improvement

Yet, the presented results should not only provide reassuring confirmations to design researchers working in the eHealth domain, but also raise puzzling concerns. The relative disinterest of design research practitioners in reducing per capita costs of care through eHealth innovations shown in Figure 3, if indeed representative of the larger eHealth scene, would be particularly alarming. In the current context of aging population and increasing prevalence of resource-intensive chronic diseases (Bloom et al, 2012), lack of cost-awareness would represent a regrettable missed opportunity for design researchers working in the eHealth domain - a field born with the very promise of providing cost-effective solutions to modern health challenges (see e.g. Stroetmann, Jones, Dobrev & Stroetmann, 2006). If eHealth becomes no more than another way to develop expensive care propositions, no matter how desirable and impactful in terms of care outcomes, the unsustainable economic burden put on modern health systems by current epidemiological trends stands few chances to be relieved.

4.3 Multiple-aim and multi-disciplinary design research: an ally for the convergence revolution

A conclusive reflection can be conducted on the overall landscape of design research in eHealth and its disciplinary implications. eHealth is, in fact, a realm described as inherently interdisciplinary (Pagliari, 2007; Van Velsen, Wentzel, & Van Gemert-Pijnen, 2013), in which diverse branches of knowledge - medicine, engineering, computer science, social sciences - come together and occasionally collide. Example of such ‘collisions’ are, for instance, the newborn fields of;

- infodemiology - described as ‘ the science of distribution and determinants of information in an electronic medium, specifically the Internet, or in a population, with the ultimate aim to inform public health and public policy’ (Eysenbach, 2009), and
- synthetic biology, the field of study in which engineers and biologists come together to re-engineer living organisms (Khalil & Collins, 2010).

In the eHealth realm, design research can form different kinds of disciplinary bonds, some of which can be observed in the results of the literature research. Specifically, observing the overview provided in Figure 4, and keeping in mind our precedent observations, we can operate a division of the overall eHealth design research scene into three main ‘zones’ of transdisciplinary integration (Figure 5);

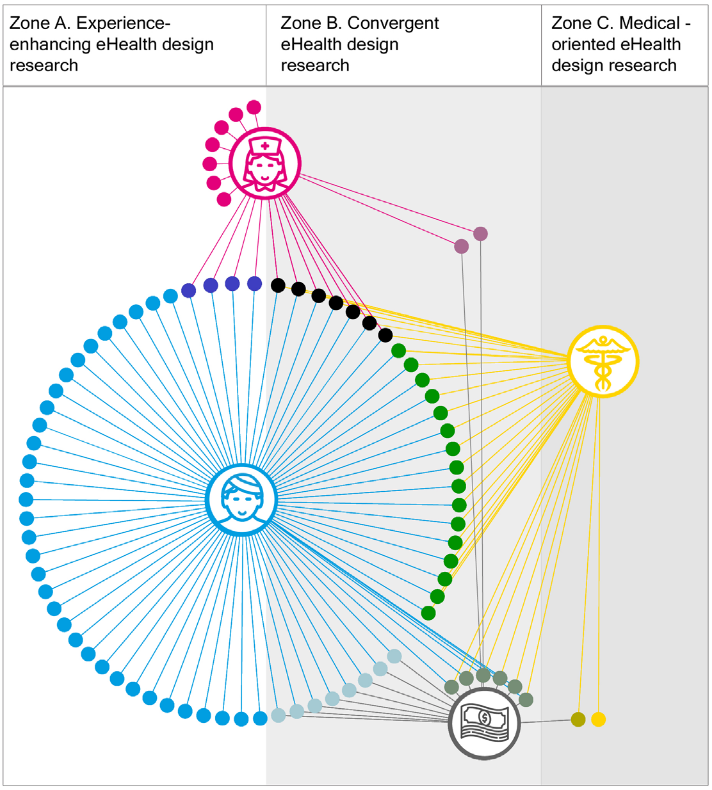


Figure 5. eHealth design research map, distinguishing three 'zones' of design research in the eHealth field. Authors' own illustration.

- Zone 1, in which eHealth challenges are tackled mainly from the user experience perspective (either patients', healthcare staff's, or both). Here, space for relevant transdisciplinary integration is identified between design research and disciplines such as Human Factors Engineering and Psychology.
- Zone 2, in which eHealth challenges are tackled in an integrated fashion. Here, space for relevant transdisciplinary integration is identified between design research and disparate disciplines, such as Health Service Research, Business Strategy, Industrial and System Engineering, and Computer Science.
- Zone 3, in which eHealth challenges are tackled mainly from the health outcomes perspective. Here, space for relevant transdisciplinary integration is identified between design research and medical disciplines.

This last snapshot of the eHealth design research scene is, possibly, the most intriguing one to look at to surmise upcoming developments in the field. The existence in literature - and outside of it - of a number of examples in which design research is used to address diverse sets of care goals *at the same time* through the development of eHealth innovations, as we see happening in Zone 2, allows us to recognize the strategic relevance of design research in a future perspective of convergence.

Convergence, according to Sharp, Hockfield & Jacks (2016), is the 'integration of historically distinct disciplines and technologies into a unified whole that creates fundamentally new opportunities for life science and medical practice'. Some scholars have written of the 'convergence revolution' as a third revolution in the health sciences after the discovery of DNA and the sequencing of the human genome (Ranganathan, 2017).

The Convergence Revolution, which is described as ongoing, is however not enabled by one breakthrough discovery, but rather arises from an integrated approach to the pursuit of health innovation.

4.4 Exploring the need for integrated approaches to health innovation: the non-communicable disease crisis

The value and timeliness of adopting an *integrated* approach on health innovation can be best understood by looking at large-scale healthcare modern challenges such as the non-communicable disease crisis. On a global level, non-infectious, or non-communicable diseases (NCDs) have been on the rise for decades, largely as a result of historical successes in the fight against infections (Figure 6).

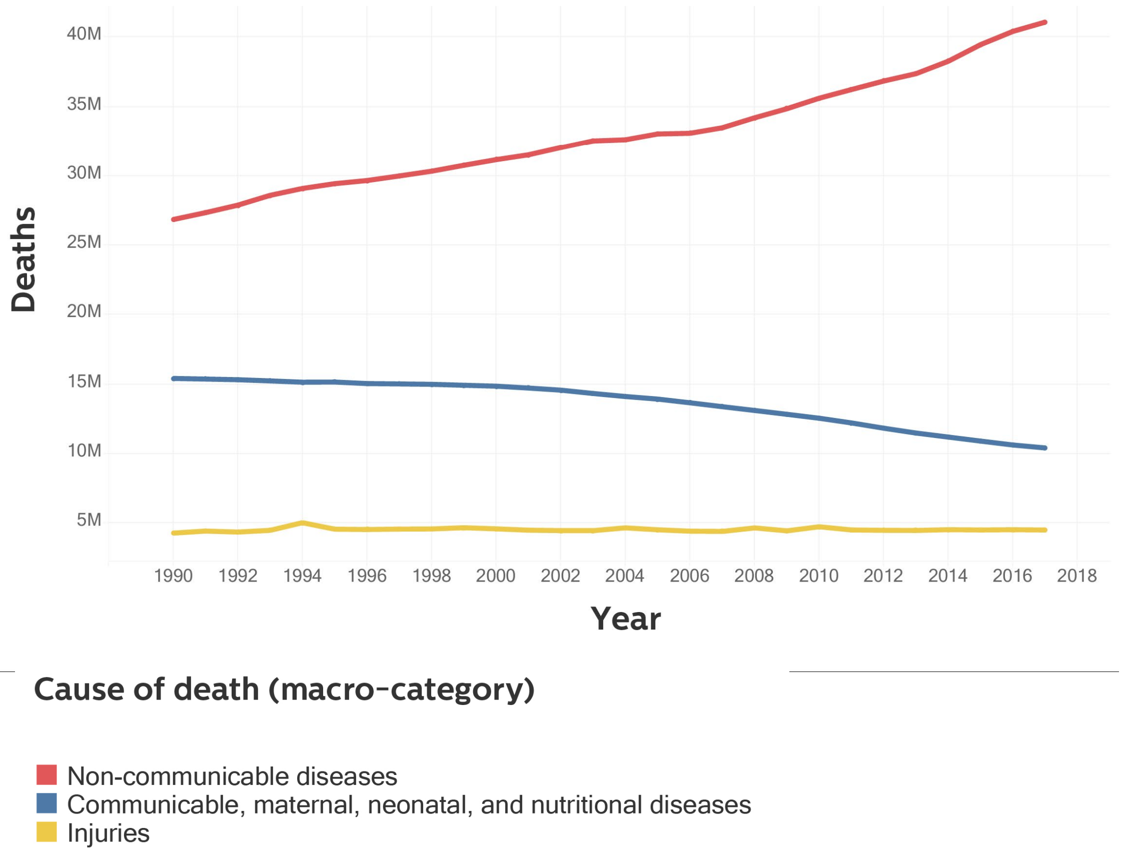


Figure 6. Causes of death globally from 1990 to 2017 (latest data available). Authors' own illustration. Data source; Institute for Health Metrics and Evaluation, 2019a.

Among these NCDs, four disease categories stand out (Figure 7.); cardiovascular disease, cancer (and other neoplasms), diabetes, and chronic respiratory diseases.

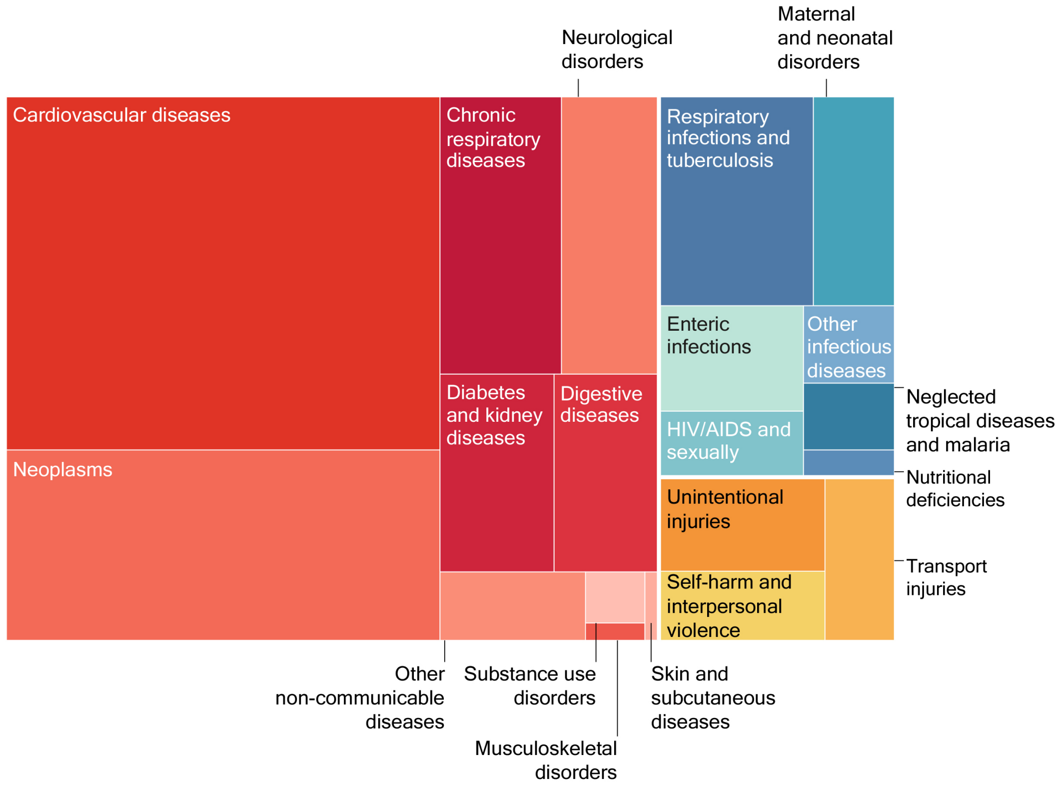


Figure 7. Causes of death globally in 2017 (latest data available) per disease category. Non-communicable diseases are depicted in shades of red; communicable, maternal neonatal and nutritional diseases are depicted in shades of blue; and injuries are depicted in shades of yellow. Authors' own illustration. Data source: Institute for Health Metrics and Evaluation, 2019b.

The economic impact of the non-communicable disease crisis is staggering; it is forecasted that the total cost of these conditions between 2012 and 2022 will exceed 30 trillion US dollars, damaging global GDP growth and 'pushing millions on people below the poverty line' (Bloom et al., 2012). The rise of NCDs also determines an increased demand for social and healthcare which contributes to the global shortage of health workforce, projected to result in a potential deficit of 18 million health workers by 2030 (World Health Organization, 2016). In 2011, the United Nations acknowledged in a resolution adopted by the General Assembly that 'the global burden and threat of non-communicable diseases constitutes one of the major challenges for development in the twenty first century' (United Nations, 2011). The same resolution states that prevention 'must be the cornerstone of the global response' to NCDs. Prevention is not only recognized as 'the only approach that will ensure future generations are not at risk of premature death' (Beaglehole et al., 2011a), but also as the strategy with the greatest potential to alleviate NCDs unbearable costs and workforce toll - since 'once an NCD develops, the burden on health systems (...) is substantial' (Beaglehole et al., 2011b). Following the UN high-level meeting in 2011, the World Health Assembly set a target of a 25 percent relative reduction in overall mortality from the four deadliest NCDs by 2025 (World Health Organization, 2013). However, the latest progress monitor, covering data up until 2017, reported that 'progress has been insufficient and highly uneven' (World Health Organization, 2017).

The insufficient progress should not surprise; preventing NCDs on a population level is a challenge that presents unprecedented difficulties for health systems. NCDs, in fact, tend to develop as results of a complex interplay of concurrent causes, or risk factors. As we can observe in Figure 8., typical risk factors for NCDs include dietary, physical activity or smoking behaviours.

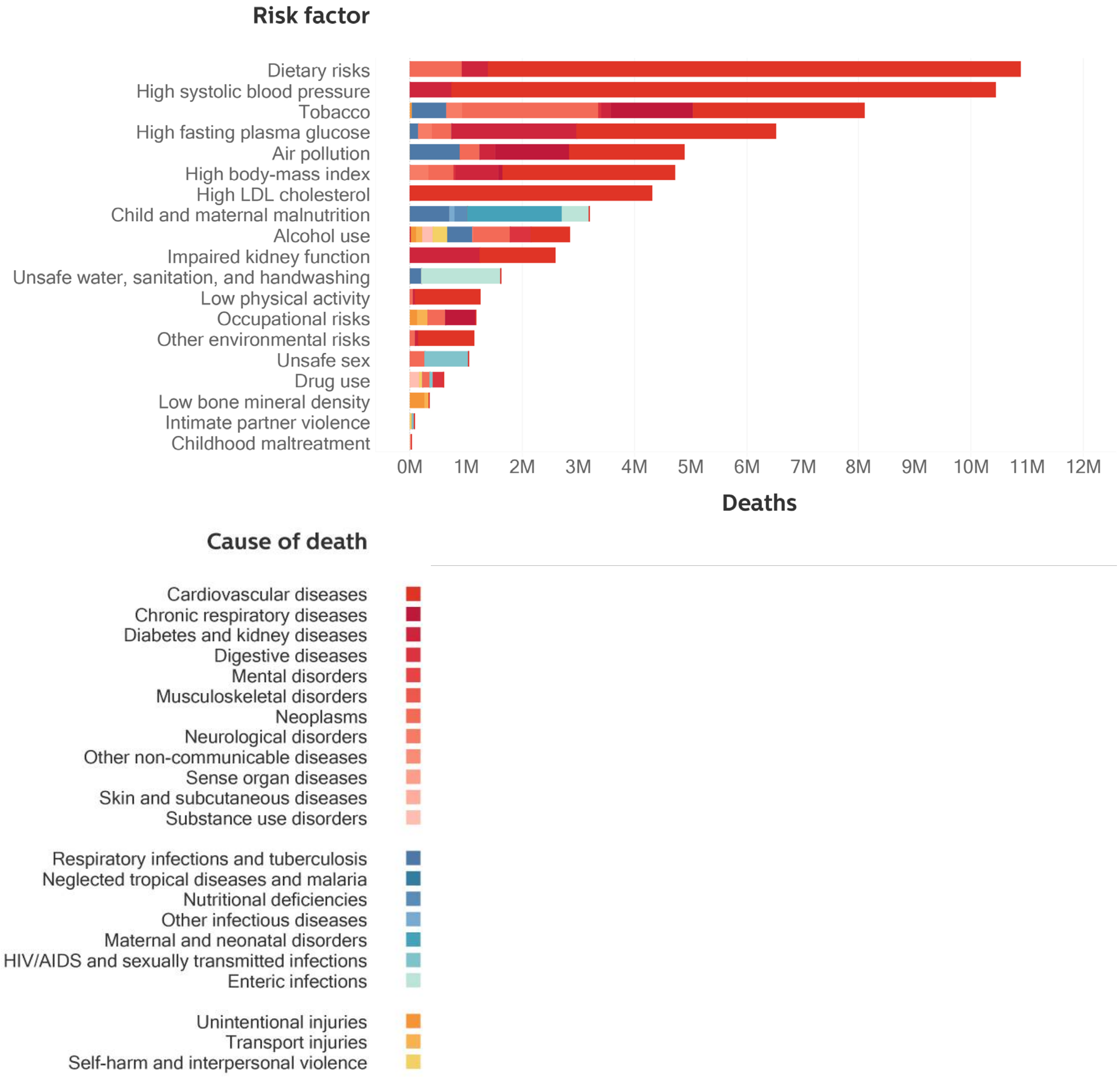


Figure 8. Risk factors linked to causes of death globally for 2017 (latest data available). Authors' own illustration. Data source: Institute for Health Metrics and Evaluation, 2019c.

Preventing NCDs through reduction of these kinds of risk factors means, in practice, getting individuals who do not have a disease to adopt healthier behaviours - for consistent amounts of time. Healthcare-specific capabilities find themselves ill-prepared to cope with a similar task; after all, both clinical disciplines and material systems of health practice evolved in rather different conditions and responding to the needs of *sick* individuals. Widespread, direct healthcare interventions towards *non-sick* individuals can be extremely efficient from a clinical point of view, but clash into problems that are beyond healthcare's disciplinary reach, and are more closely linked to historical, cultural, political and contextual factors. Worrisome, for instance, is the example of vaccination campaigns, one of the greatest achievements of public health, and yet among the interventions that generate the most long-lived controversies within subsets of the public (Dubé, Vivion & MacDonald, 2015).

To cope with such 'externalized' health challenges, effective integration - of capabilities, contexts, and functions –is crucial. One good example of this principle can be found in the case of tobacco consumption: the reduction of smoking habits in a number of high- and middle-income countries is regarded as one the biggest successes so far in the control of NCDs risk factors (Ezzati & Riboli, 2013). Such result is deemed to have been driven by measures such as restrictive taxation, smoke-free policies in public spaces, warning labels, and bans on advertising promotion and sponsorship (Gravely et al., 2017). The implementation of these measures is described as a successful integration of achievements from different disciplines - production of clear scientific evidence regarding the harms tobacco consumption, execution of careful cost-effectiveness estimations, and innovative developments in legislation (Shibuya, 2003).

In other areas of NCD risk, examples of effective integration are yet to be found; the lack of effective measures for improving diet and exercise, in particular, led some to define overweight, obesity, and high blood glucose as the 'wild cards' of global NCD risks, and to call for 'bold, creative policies that address harmful alcohol consumption, improve diet, and increase physical activity' (Ezzati & Riboli, 2013). Others advocate the need for an "interdisciplinary social and behavioral approach, including the cultural aspects of nutrition" (Bousquet et al., 2011). Convergence, with its promise of integrating 'historically distinct disciplines and technologies', presents itself as an ideal approach for exploring 'what it means to be well, to function at the peak of our physical and mental capabilities, as well as to prevent or deal with illness' (Sharp et al., 2016).

5 Directions for further research

5.1 Design integration through digital data

The ability to integrate and connect different contexts and specialized disciplines is identified as a core design capability in design literature (Kleinsmann & Valkenburg, 2008). Buchanan, for instance, (1992) elaborates on design as an integrative discipline, which connects knowledge from the arts and sciences in ways that are appropriate to the problems and purposes at hand. Dorst (1997) provides a detailed account of integration as a design activity, which he identifies as 'a reasoning process building up a network of decisions (part of the design problem or the design solution) while taking account of different contexts (distinct ways of looking at the problem or solution)'. Still recently, the integrative power of design and its specific value in the health domain has been examined by Romm & Vink, (2018), who elaborate on the 'in-betweenness' of service design practitioners working in healthcare.

This integrative power appears to be especially necessary in a context of increasing convergence, in which health innovation is expected to arise from stakeholders afferent to different disciplines - each one with their own 'ways of looking'. We observe this design ability in action in the results of the present literature review, and specifically in the examples that populate 'Zone 2' (Figure 5.).

Doing design research in convergent eHealth scenarios becomes, thus, not only a matter collecting and producing knowledge, but also a matter of reconciling different types of knowledge and orchestrating their contribution in the design process. Orchestrating service co-creation for the purpose of planning and carrying out knowledge integration activities was, indeed, recently recognized as a strategic design ability for integrated care innovation (Durón, Simonse & Kleinsmann 2019).

A designerly way in which this orchestration can be managed is through the use of boundary objects, or artefacts that are 'both plastic enough to adapt to local needs and constraints of the several parties employing them, yet robust enough to maintain a common identity across sites' (Star, 1989). Carlile (2002) identifies three characteristics of 'effective' boundary objects in new product development, being;

1. (The boundary object) establishes a shared syntax or language
2. (The boundary object) provides a concrete means for individuals to specify and learn about their differences and dependencies across a given boundary
3. (The boundary object) facilitates a process where individuals can jointly transform their knowledge (p.451).

Boundary objects can be embodied in a wide array of formats, both material and immaterial. Mortier, Haddadi, Henderson, McAuley and Crowcroft (2014) elaborate on the use of *digital data* as a boundary object in ubiquitous computing settings, in reason of the capacity of these data to be 'open to multiple interpretations and the concern of many stakeholders'. Indeed, in the eHealth domain, a unique opportunity of design-led integration is constituted by the possibility of using data (and especially sensory and patient-reported data) as a boundary object which satisfies each of the previously specified condition for effectiveness. Respectively;

1. Sensory and patient-reported data can be employed as a way to 'establish a shared syntax or language' in reason of their capacity to generate *syntheses* of complex, cross-contextual networks of meanings within eHealth design research. In one of the papers populating Zone 2. (Figure 5.), for instance, we observe how 'data-driven' medical consultations are enabled by a eHealth intervention in which clinicians can prescribe '10,000 steps a day' to patients who wish to improve their physical activity levels (Kim et al., 2017). Here, a shared syntax for doctor-patient conversation is generated by collapsing the complexity of physical activity (both a clinician-understood health metric and a patient-understood everyday life behavior) into a quantified goal that can be easily recognized by both parties.
2. Sensory and patient-reported data can 'provide concrete means for individuals to specify about their differences and dependencies across a given boundary', in reason of their capacity to surface *antitheses* in stakeholders' needs and purposes regarding a eHealth proposition. In van Kollenburg, Bogers, Rutjes, Deckers, Frens and Hummels (2018), for instance, we learn of an exploration of the value of parent-tracked baby data in interactions with healthcare professionals. Starting from parents-reported data, the design researchers could identify specific differences in how parents and health professionals envisioned a preferred care workflow (e.g. parents favoured richer data overviews while GPs preferred simpler data summaries).

3. Sensory and patient-reported data can ‘facilitate a process where individuals can jointly transform their knowledge’, in reason of their capacity to introduce *changes* in the knowledge bases themselves. For instance, the introduction of glucose self-monitoring devices for diabetic patients, which enabled more frequent measurements than previous technology, is described to have ‘shifted the value’ of the information about glucose levels, ‘challenging the numerical standards for “normalcy”’ (Mol & Law, 2004 as cited in Fiore-Gartland & Neff, 2015).

The use of sensory and patient-reported data as a boundary object in eHealth design research is identified as a promising strategy for design integration in a context of convergence. The entire field of medical-grade wearable sensors, specifically, which is recognized by Mertz (2016) to ‘rely on’ the convergence revolution, is a domain in which design researchers can effectively apply this strategy. Next, future opportunities for design research in this direction are illustrated through the case of blood pressure.

5.2. The blood pressure example

Unobtrusive wearable technologies for the self-monitoring of blood pressure, a crucial metric for cardiovascular health, are being developed and will become more and more common in the next decades. In January 2019, the first wristwatch able to take clinically accurate blood pressure readings was released in the American market (Omron Healthcare, 2019). According to the manufacturer’s website, the product went almost immediately sold out, and to the moment in which this paper is written, aspiring customers can, at most, enrol in a waiting list.

This innovation opens new, uncharted eHealth scenarios: the early market success of the product indicates the existence of a robust demand for consumer-facing blood pressure wearable monitors, but does not help envisioning how will we, as consumers, use these wearables and the data they collect. How will this change our habits, routines and lifestyles? What opportunities will this technology afford us?

To investigate these questions, we intend to explore the use of self-monitored blood pressure data as a boundary object for the development of integrated services propositions for cardiovascular prevention. As observable in Figure 8., high blood pressure is a prominent risk factor for several NCDs, and in particular for cardiovascular diseases, the class of conditions responsible for most deaths worldwide. The development of measurable and cost-effective ways to control blood pressure in a large enough subset of the population would constitute a ‘quadruple-aimed’ innovation, able to;

1. improve individual experiences of care by enabling personalized, meaningful ways of managing one’s own cardiovascular health
2. improve the work life of health care clinicians and staff by reducing chronic care workloads and promoting the availability of data useful for population health management
3. reduce the per capita cost of care by preventing or delaying the development of chronic, non-communicable conditions
4. Improve the cardiovascular health of populations by reducing the incidence of hypertension, especially through the adoption of healthier behaviours such as a low-sodium diet and active lifestyle, which would have preventive effects on the other main NCDs as well.

Of course, this is easier said than done; in such a challenge lie numerous, multifaceted complexities, most of which are not for design researchers to solve. Yet, it is a challenge for design researchers to surface these complexities, so that the relevant disciplines and stakeholders may use them as a way to create shared understandings, to face misalignments, or to advance themselves.

6 Conclusions

In this contribution, recent examples of design research in the eHealth domain were reviewed to answer the research question: 'in which measure has design research contributed to each of the 'four aims' of eHealth innovation in the past five years?'. The research results provided a snapshot of the contemporary eHealth design research scene which led the authors to three main conclusions;

1. design researchers in eHealth seem to be largely focused on improving experiences of care, either patients' or health professionals';
2. design researchers' contribution on reducing per capita costs of care appears to be less pronounced;
3. In a considerable amount of reviewed contributions, design researchers appear to be contributing to multiple 'aims' at once. In this sub-group of reviewed contributions, several disciplinary areas and types of stakeholders interact and integrate through design research activities.

From these conclusions, key contributions to the field were identified, namely; 1) a solicitation for design research working in eHealth to reserve increased attention to cost-effectiveness aspects; and 2) a call for design researchers in eHealth to embrace their strategic role in the contexts of the convergence revolution, particularly by developing new, eHealth-specific ways to orchestrate design integration. A direction for further research in this regard was identified in the use of sensory and self-monitored data as a boundary object; finally, the prospective value of this direction was exemplified through the example of blood pressure.

7 References

Bakker, D., Kazantzis, N., Rickwood, D., & Rickard, N. (2018). Development and Pilot Evaluation of Smartphone-Delivered Cognitive Behavior Therapy Strategies for Mood- and Anxiety-Related Problems: MoodMission. *Cognitive and Behavioral Practice*, 25(4), 496–514. doi:10.1016/j.cbpra.2018.07.002

Beaglehole, R., Bonita, R., Alleyne, G., Horton, R., Li, L., Lincoln, P., … Stuckler, D. (2011b). UN High-Level Meeting on Non-Communicable Diseases: addressing four questions. *The Lancet*, 378(9789), 449–455. doi:10.1016/s0140-6736(11)60879-9

Beaglehole, R., Bonita, R., Horton, R., Adams, C., Alleyne, G., Asaria, P., ... & Cecchini, M. (2011a). Priority actions for the non-communicable disease crisis. *The Lancet*, 377(9775), 1438-1447.

Bloom, D. E., Cafiero, E., Jané-Llopis, E., Abrahams-Gessel, S., Bloom, L. R., Fathima, S., ... & O'Farrell, D. (2012). *The global economic burden of noncommunicable diseases* (No. 8712). Program on the Global Demography of Aging.

Bousquet, J., Anto, J. M., Sterk, P. J., Adcock, I. M., Chung, K. F., Roca, J., ... & Abdelhak, S. (2011). Systems medicine and integrated care to combat chronic noncommunicable diseases. *Genome medicine*, 3(7), 43.

Buchanan, R. (1992). Wicked Problems in Design Thinking. Design Issues, 8(2), 5. doi:10.2307/1511637

Carlile, P. R. (2002). A Pragmatic View of Knowledge and Boundaries: Boundary Objects in New Product Development. *Organization Science*, 13(4), 442–455. doi:10.1287/orsc.13.4.442.2953

Dorst, K. (1997). *Describing design: a comparison of paradigms*. Unpublished doctoral Dissertation, Technische Universiteit Delft.
Dubé, E., Vivion, M., & MacDonald, N. E. (2014). Vaccine hesitancy, vaccine refusal and the anti-vaccine movement: influence, impact and implications. *Expert Review of Vaccines*, 14(1), 99–117. doi:10.1586/14760584.2015.964212
Canales Durón, R., Simonse, L., & Kleinsmann, M. (2018). Strategic Design Abilities for Integrated Care Innovation. *Service Design and Service Thinking in Healthcare and Hospital Management*, 211–232. doi:10.1007/978-3-030-00749-2_13
Eysenbach, G. (2009). Infodemiology and Infoveillance: Framework for an Emerging Set of Public Health Informatics Methods to Analyze Search, Communication and Publication Behavior on the Internet. *Journal of Medical Internet Research*, 11(1), e11. doi:10.2196/jmir.1157
Ezzati, M., & Riboli, E. (2013). Behavioral and Dietary Risk Factors for Noncommunicable Diseases. *New England Journal of Medicine*, 369(10), 954–964. doi:10.1056/nejmra1203528
Fiore-Gartland, B., & Neff, G. (2015). Communication, mediation, and the expectations of data: Data valences across health and wellness communities. *International Journal of Communication*, 9, 19.
Gravely, S., Giovino, G. A., Craig, L., Commar, A., D'Espaignet, E. T., Schotte, K., & Fong, G. T. (2017). Implementation of key demand-reduction measures of the WHO Framework Convention on Tobacco Control and change in smoking prevalence in 126 countries: an association study. *The Lancet* Public Health, 2(4), e166–e174. doi:10.1016/s2468-2667(17)30045-2
Horváth, I. (2007), Comparison of Three Methodological Approaches of Design Research, Proceedings of ICED 2007, the 16th International Conference on Engineering Design, Paris, 28.-31.08.2007, The Design Society 2007, Glasgow, 1-11.
Institute for Health Metrics and Evaluation (2019a). GBD Compare Data Visualization. Seattle, WA: *IHME, University of Washington*. Available at http://ihmeuw.org/4u6h (accessed on 11/07/2019)
Institute for Health Metrics and Evaluation (2019b). GBD Compare Data Visualization. Seattle, WA: *IHME, University of Washington*, 2019. Available at http://ihmeuw.org/4u6i (accessed on 11/07/2019)
Institute for Health Metrics and Evaluation (2019c). GBD Compare Data Visualization. Seattle, WA: *IHME, University of Washington*, 2019. Available at http://ihmeuw.org/4u6j (accessed on 11/07/2019)
Khalil, A. S., & Collins, J. J. (2010). Synthetic biology: applications come of age. Nature Reviews Genetics, 11(5), 367–379. doi:10.1038/nrg2775
Kim, Y., Heo, E., Lee, H., Ji, S., Choi, J., Kim, J.-W., … Yoo, S. (2017). Prescribing 10,000 Steps Like Aspirin. *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems* - CHI '17. doi:10.1145/3025453.3025570
Kleinsmann, M., & Valkenburg, R. (2008). Barriers and enablers for creating shared understanding in co-design projects. *Design Studies*, 29(4), 369–386. doi:10.1016/j.destud.2008.03.003
Liddy, C., & Keely, E. (2018). Using the Quadruple Aim Framework to Measure Impact of Heath Technology Implementation: A Case Study of eConsult. *The Journal of the American Board of Family Medicine*, 31(3), 445–455. doi:10.3122/jabfm.2018.03.170397
Mertz, L. (2016). Convergence Revolution Comes to Wearables: Multiple Advances are Taking Biosensor Networks to the Next Level in Health Care. *IEEE Pulse*, 7(1), 13–17. doi:10.1109/mpul.2015.2498475
Mortier, R., Haddadi, H., Henderson, T., McAuley, D., & Crowcroft, J. (2014). Human-Data Interaction: The Human Face of the Data-Driven Society. *SSRN Electronic Journal*. doi:10.2139/ssrn.2508051
Omron Healthcare. (2019) (2019, January the 16th). Omron HeartGuide™, the First Wearable Blood Pressure Monitor, a Top Award-Winner at CES 2019. Retrieved on the 10th April 2019 from https://omronhealthcare.com/2019/01/omron-heartguide-first-wearable-blood-pressure-monitor-top-award-winner-ces-2019/.
Pagliari, C. (2007). Design and Evaluation in eHealth: Challenges and Implications for an Interdisciplinary Field. *Journal of Medical Internet Research*, 9(2), e15. doi:10.2196/jmir.9.2.e15
Pannunzio, V., Kleinsmann, M., Snelders, D., (in press). Three approaches to design engineering in the health domain: a systemic perspective. *Proceedings of ICED 2019, the 22nd International Conference on Engineering Design*, Delft, 05.-08.2019, Cambridge University Press.
Ranganathan, B. (2017). Convergence Revolution – Piloting the Third Scientific Revolution through Start-Ups for Breast Cancer Cure. *Cancer Science & Research: Open Access*, 4(1), 1–6. doi:10.15226/csroa.2017.00130

Romm, J., & Vink, J. (2018). Investigating the “In-betweenness” of Service Design Practitioners in Healthcare. *Service Design and Service Thinking in Healthcare and Hospital Management*, 117–135. doi:10.1007/978-3-030-00749-2_8
Sharp, P., Hockfield, S., Jacks, T. (2016), *Convergence: the future of health*. The Convergence Revolution. Cambridge, MA.
Shibuya, K. (2003). WHO Framework Convention on Tobacco Control: development of an evidence based global public health treaty. *BMJ*, 327(7407), 154–157. doi:10.1136/bmj.327.7407.154
Sikka, R., Morath, J. M., & Leape, L. (2015). The Quadruple Aim: care, health, cost and meaning in work. *BMJ Quality & Safety*, 24(10), 608–610. doi:10.1136/bmjqs-2015-004160
Silber, D. (2003). The case for eHealth. Maastricht, The Netherlands: European Institute of Public Administration.
Star, S. L. (1989). The Structure of Ill-Structured Solutions: Boundary Objects and Heterogeneous Distributed Problem Solving. *Distributed Artificial Intelligence*, 37–54. doi:10.1016/b978-1-55860-092-8.50006-x
Stroetmann, K. A., Jones, T., Dobrev, A., & Stroetmann, V. N. (2006). *eHealth is Worth it. The economic benefits of implemented eHealth solutions at ten European sites*. Luxembourg: Office for Official Publications of the European Communities
United Nations. (2011). *Political declaration of the high-level meeting of the general assembly on the prevention and control of non-communicable diseases*. New York: United Nations.
Van Kollenburg, J., Bogers, S., Rutjes, H., Deckers, E., Frens, J., & Hummels, C. (2018). Exploring the Value of Parent Tracked Baby Data in Interactions with Healthcare Professionals. *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems - CHI ’18*. doi:10.1145/3173574.3173871
Van Velsen, L., Wentzel, J., & Van Gemert-Pijnen, J. E. (2013). Designing eHealth that Matters via a Multidisciplinary Requirements Development Approach. *JMIR Research Protocols*, 2(1), e21. doi:10.2196/resprot.2547
World Health Organization (2016). Global strategy on human resources for health: workforce 2030. Geneva: World Health Organization.
World Health Organization. (2013) *Global action plan for the prevention and control of noncommunicable diseases 2013-2020*. Geneva: World Health Organization.
World Health Organization. (2017) *Noncommunicable Diseases Progress Monitor 2017.* Geneva: World Health Organization.
Zarabzadeh, A., McDonnell, R., Berrios, S. P., Dempsey, J., Harrington, E., Smith, S. M., & Fahey, T. (2016). Utility of Electronic International Register of Clinical Prediction Rules Relevant to Primary Care. 2016 *IEEE 29th International Symposium on Computer-Based Medical Systems (CBMS)*. doi:10.1109/cbms.2016.26

About the Authors:

Valeria Pannunzio: Currently a Ph.D. researcher in the CardioLab at the IDE faculty of the Delft University of Technology, Valeria holds a master's degree in Design for Interaction and previously worked at Philips Healthcare as a service designer.

Maaike Kleinsmann: Associate Professor in design-driven innovation at the IDE faculty of the Delft University of Technology, Maaike is also the head of the CardioLab, an initiative of the IDE faculty, De Hartstichting and Philips Design.

Dirk Snelders: Head of the section Methodology and Organisation of Design at the IDE faculty of the Delft University of Technology, Dirk has a background in psychology and marketing, where he has developed his research interest on the role of design in business.

Acknowledgement: We gratefully acknowledge the anonymous peer reviewers for the valuable support.

Developing a Design Guide for Consistent Manifestation of Conversational Agent Personalities

Kim, Hankyung*[a]; Koh, Dong Yoon[a]; Lee, Gaeun[b]; Park, Jung-Mi[b]; Lim, Youn-kyung[a]

[a] Department of Industrial Design, KAIST, Daejeon, Republic of Korea
[b] Samsung Research, Seoul, Republic of Korea
* hkkim31@kaist.ac.kr

Consistency in a personality of a conversational agent plays a crucial role in forming user expectations towards interaction and determining the quality of user experience. For an agent personality to be manifested consistently, designers should be able to communicate the personality they designed clearly and concretely to multiple dialogue designers so that the same understanding of the intended personality is shared among them. This paper proposes a design guide to support such communication to ensure consistent manifestation of an agent personality throughout conversations crafted by multiple designers. In reference to a conversational agent personality framework and the speech act theory, we developed the guide that supports designers to grasp how an agent personality was designed as well as how to manifest it in various conversational situations. While we evaluated the guide in a Wizard-of-Oz-based user study, we also explored what should be considered in order for designers to maintain consistency of manifested personality in conversational interactions. The findings related to users' perception of a consistent agent personality were threefold: users perceived roles and functions of an agent as its personality; cross-situational consistency in style of providing services and contents mattered; and users were tolerant for inconsistency in verbal and physical modalities. We conclude the paper with discussion on potential benefits of the guide.

Keywords: agent personality; consistency; conversational agent; design guide

1 Introduction

As advances in the fields of artificial intelligence and natural language processing brought about widespread commercialization of conversational agents such as Siri, Alexa, Google, and Cortana, efforts in research and practice have been made to craft their personalities. For instance, Alexa is attributed with a "friendly, upbeat, and helpful" personality, while Siri is described to be "friendly and humble, but also with an edge." (Danielescu & Christian, 2018). Likewise, designers are vying to craft unique personalities of CAs with care as they can influence users' perception of CAs, satisfaction of interaction, and brand identities.

However, while much attention is devoted to what kinds of personalities CAs should have, how to ensure consistency of designed personalities in conversations remains underexplored. Though the importance of consistency in CAs' personalities was emphasized in prior work, achieving it seems to be challenging in a practical conversation design process.

In such a process, creators of a CA personality are not always in charge of designing all conversations of the agent. Instead, multiple designers write dialogue lines individually by referring to the descriptions or design guidelines created already. Given this situation, it is crucial for the conversational designers to form a clear consensus on a single, originally intended personality. Failure of this would lead to inconsistent personalities conveyed in various conversations, undermining overall user experience and expectations towards how to interact with the agent (Cassell, 2000; Callejas, 2014). While research on making consistent CA personalities exist, most work leans towards technical solutions drawing heavily on computational linguistics (Mairesse & Walker, 2007; Bouchet & Sansonnet, 2012; Li, 2016; Qian, 2018), and few designerly attempts were made to solve the conundrum of sharing the same conceptual image of the CA personality among various designers.

In consideration of this issue, we propose a design guide to facilitate multiple designers to design and share the same understanding of a CA's personality, thereby aiding them to manifest the personality consistently in separately created conversations. Building upon an existing CA personality framework and a speech act taxonomy, our guide was designed to inform designers to understand how a CA's personality has been designed and how it can be manifested via various channels in specific conversational cases. We examined the effectiveness of this guide by conducting a Wizard-of-Oz user study, which also uncovered factors associated with perceived consistency of a CA's personality from a user's perspective. Our work contributes to the field of HCI research field by providing designers with pragmatic guidelines and user-perspective design considerations for maintaining consistency in the process of constructing and manifesting CAs' personalities.

2 Background and Related Work

With our focus on consistency of CA personalities, we position this paper with respect to prior work on CAs and their personalities, along with discussions on existing design guidelines for popular conversational agents.

2.1 Conversational Agents

A conversational agent refers to a system that interacts with users by means of human-like natural language (Kopp, 2005; Vassallo, 2010). To achieve natural interaction with a user, the agent should be capable of comprehending linguistic and non-linguistic inputs to generate corresponding responses, carrying out basic conversational behaviours such as turn-taking, and understanding contexts to generate its own opinions (Davis, 2001).

While much past CA research leans to technical contributions, recent work has been increasingly exploring user experience of CAs. Studies have scrutinized opinions from users of various CAs to identify the discrepancy between user expectation and actual experience (Luger & Sellen, 2016) and infrequent users of CAs to disclose pragmatic issues that led to the termination of their usage (Cowan, 2017). Another study investigated people's experiences of actual in-home usage of a CA (Sciuto et al., 2018). Although limited in an office context, a line of studies has also explored user experiences of CAs throughout in-the-wild deployment of a prototype such as an assistant chatbot on an instant messaging tool (Liao, 2016), a Q&A chatbot (Liao, 2018), and a journaling bot (Kocielnik et al., 2018). While these studies collectively point towards technical problems as well as CAs' actual intelligence and capability as prevailing issues in current stage of CA research, they also highlight opportunities for designing human-like features such as personalities or playfulness as they affect users' mental models of CAs.

2.2 Consistency in Personalities of Conversational Agents

As natural language has no longer been the preserve of humans, CAs can socially interact with humans, which leads users to endow human-like personalities to such agents (Nass, 1995). Accordingly, many studies emphasized the significance of CAs' personalities by identifying significance of personality regarding satisfaction of interactions with an agent (Xiao, 2005), its effect on whether the user decides to continue interacting with the agent (Callejas, 2014), as well as its role as the determining factor of the overall image of the brand which a CA belongs to (Cohen, 2004).

Recognizing of the necessity of designing an agent's personality, studies addressing how an agent's personality should be designed abound. Studies proposed that a friendly and authoritative yet inordinately passive personality of an agent is liked (Selker, 1994; Dryer, 1999). Other studies revealed that users preferred agent personalities that were similar to their own (Tapus, 2008; Mairesse & Walker, 2010; Nass, 2012) or that match task contexts (Goetz, 2003). While such prior work was crucial to adding knowledge about agent personalities, researchers have glanced over subjects on consistent manifestation of an agent personality. Indeed, consistency is even highlighted in the very definition of personality. Psychology's definition of personality in itself shows us how closely the quality of a personality is tied to its consistency, as personality is described as a continuous and consistent behavioural or emotional pattern that characterizes an individual, making it possible for others to anticipate how the individual will act in certain situations (Cattell, 1970; Goldberg, 1990). A study (Bouchet & Sansonnet, 2012) applied the same notion of personality and explored the gravity of a consistently conveyed agent personality, identifying the personality's role in allowing users to predict what agent capabilities.

While current studies concerning the consistency of agent personalities exist, their focus tends towards automation of personality design and dialog generation processes. For instance, a study (Mairesse & Walker, 2007) proposed the PERSONAGE system that generated CAs' personalities by quantitatively manipulating extraversion-introversion levels. Other studies created mathematical models for an agent persona that tailors the agent's linguistic style to its users (Li, 2016) or for generating consistent responses (Qian, 2018). Bouchet & Sansonnet (2012) also proposed a method based on the FFM/NEO PI-R personality model that translated personality traits into specific actions. While such automation does provide a means to a uniform and coherent agent personality, as the mechanical process exploits existing taxonomies of broadly classified personality traits and uses strict algorithms to standardize the design and expression of personality, it leaves little room for designers' efforts that can imbue CAs with more characterful personalities. Instead, our works aims to suggest a design-oriented solution on the problem of inconsistent personality, offering findings on how to design and manifest CAs' personality and how to assure consistency in them along with considerations on an end-user perspective.

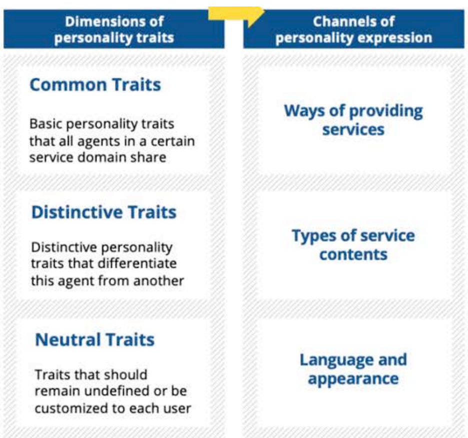
2.3 Design Guides for Conversational Agents in Practice

Despite the necessity for a practical guidance for designing and manifesting a personality in a consistent manner, existing design guidelines for commercialized CAs on do not present a structural approach to this issue. While publicly accessible guidelines for popular CAs such as Alexa (2019), Cortana (2019), or Bixby (2018) provide details to the configuration of the conversations or on the development of a dialog system, there seemed to lack sufficient instructions on consistent manifestation of intended personalities of CAs. These documents provide detailed descriptions of their own agent's personas, principles on how the personalities are expressed in key usage situations, and directions on how to build compatible 'skills' for their respective devices, only to lack applicability of such guidance on other CAs in general. While personality design principles and guidelines for Google Assistant in Google Conversation Design (2019) seem apt for expanded application, little focus is laid on how specifically a designed personality can be reflected in dialogues, not to mention the issues with communication between the personality designers and dialog writers as well as the considerations on expression channels of a personality other than the verbal modality. Accordingly, our work aims to develop a new design guide that resolves the prevailing issue of inconsistent personalities of CAs manifested in actual dialogues caused by the current practice where multiple designers work separately.

3 Developing the Guide for Agent Personality Manifestation

We developed a guide to support personalities of conversational agents to be shared among multiple designers as intended and therefore be consistently manifested. Our guide draws upon prior work (Kim et al., 2019) that suggests a new conceptual framework for designing and communicating agent personalities as shown in Figure 1. According to the framework, a conversational agent has three dimensions of its personality and three channels for them to be expressed. We chose this framework as a reference as it identifies recent considerations distinctive for designing CA personalities instead of relying on human personality models.

Our guide also builds on speech act theory (Austin, 1962; Searle, 1969) which states that when people is participating in a conversation, they not only produce utterances but also perform actions. This notion is applied to CAs as well, leading our guide to describe how an agent personality is expressed for possible speech acts, that is, for possible conversational behaviours that an agent makes. We chose Dialog Act Markup in Several Layers (DAMSL) (Allen & Core, 1997) as a reference (Figure 1). Being one of the widely used taxonomies for processing computational conversations, DAMSL is a domain-independent type of taxonomy that categorized types of speech acts based on their communicative functions. Therefore, it was considered as a suitable scheme to make our guide describe ways of manifesting a CA personality in diverse conversational situations regardless of its domain.



Code	Speech acts based on DAMSL
A	Providing general statement
B	Asking user for answer/information
C	Asking user to do something
D	Expressing will to perform function/services
E	Opening/closing
F	Expressing emotion
G	Declaring change in status
H	Expressing acceptance/confirmation/refusal
I	Expressing understanding
J	Answering to user's information request

Figure 1. Two references used for the guide: the framework for personalities of conversational agents (left) (Kim et al., 2019) and the list of communicative functions from the DAMSL taxonomy (right) (Allen & Core, 1997)

Based on the aforementioned references, we developed the guide for designing and manifesting an agent personality as in Figure 2 and Figure 3. The guide is comprised of two parts: the first part describing personality traits of an agent and the second part describing how such personality traits should be actually manifested via expression channels for each conversational situation. Reflecting the personality framework, the first part includes *common traits* that all agents in a certain service domain share, *distinctive traits* that are unique to this very agent, and *neutral traits* that should remain undefined or customizable by users. Each personality adjective is clarified with specific actions that the adjective implies. Also, to facilitate grasping of the overall personality, we added a space for a representative keyword summarizing various personality traits. The second part guides designers on how the personality in the first part can be manifested through various expression channels with regards to a certain speech act, or a conversational situation, with a dialogue example.

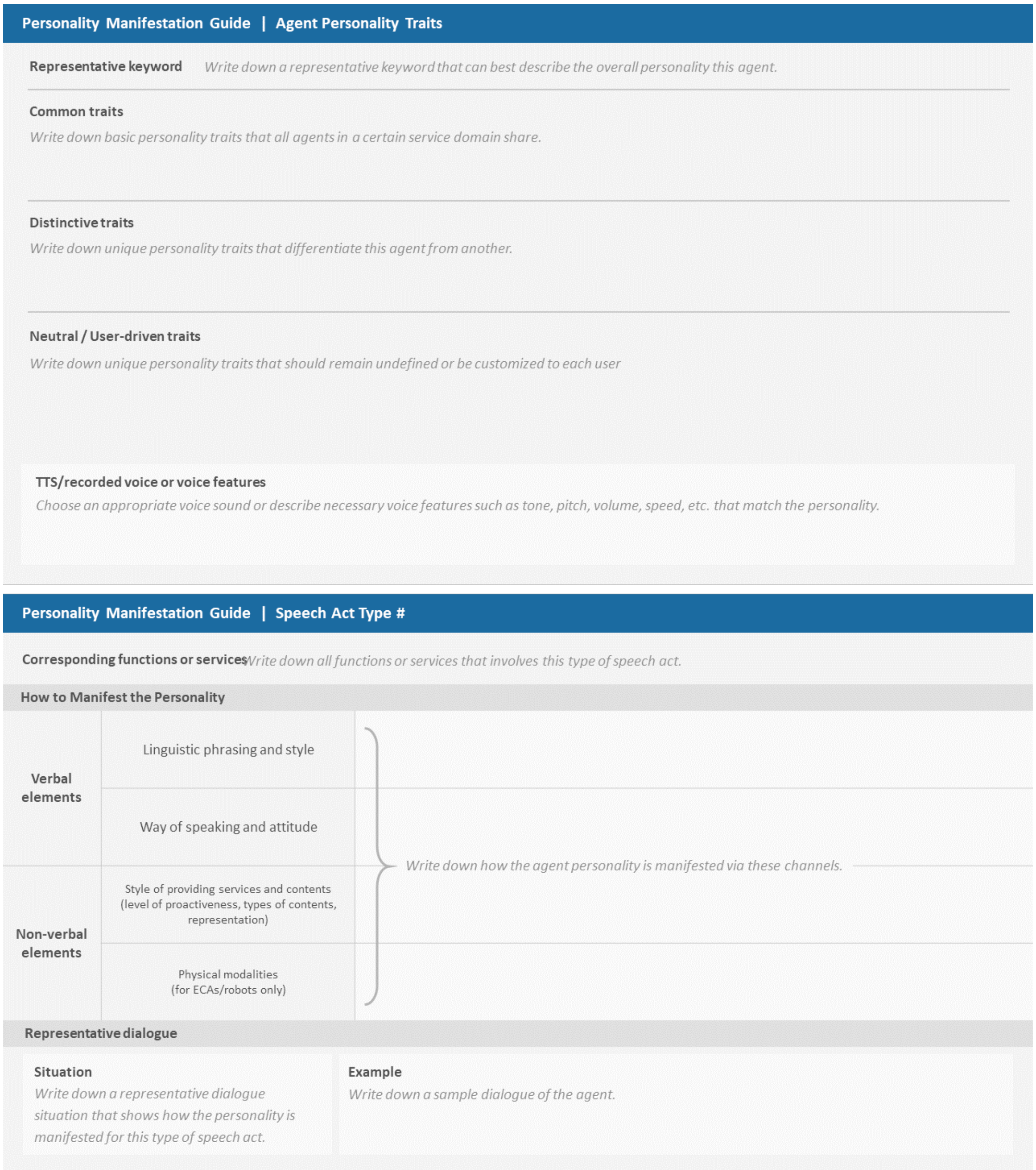


Figure 2. The overall composition of the guide: the first part (top) and the second part (bottom)

Personality Manifestation Guide | Agent Personality Traits

Representative keyword	*Strict Instructor*

Common traits

Accurate – Never makes mistakes. Punctual to the minute. Strictly avoids grammar errors, misspelling, and euphemism. Enunciate without slurring words at the end.
Trustworthy – Explains reasons for actions. Avoids excessive rhetoric, overreaction, and bluffing. Laughs and smiles confidently.
Friendly – Avoids using jargons. Says things that cheer users up. Always listens to users. Proactively helps users.

Distinctive traits

Uptight – Speak necessary words only. Relies on facts and numbers instead of emotion. Does not tolerate users' mistakes. Strictly sticks to a policy.
Flawless – Tries to control every detail about its users. Always checks and manages users' health in a proactive and thorough manner.
Charismatic – Has gestures and voice that hold users' attention. Give instructions without being condescending. Always pushes ahead and never gives up.

Neutral / User-driven traits

- Older than its user
- Having no particular hobbies or preferences

TTS/recorded voice or voice features
(voice sample embedded)

Personality Manifestation Guide | Speech Act Type C. Asking user to do something

Corresponding functions or services	*Medication reminder, Blood pressure check request, Exercise recommendation*

How to Manifest the Personality

Verbal elements	Linguistic phrasing and style	*- Delivers only the most important information concisely.* *- Uses directive language to clearly articulate what the agent wants the user to do.*
	Way of speaking and attitude	*- Pushes the user to ensure that he/she actually does what the agent asks him/her to do.*
Non-verbal elements	Style of providing services and contents (level of proactiveness, types of contents, representation)	*- Always be proactive in suggesting services.* *- Chooses the single best option of its own accord so that the user can perform it right away.* *- Offers relevant information as evidence from reliable sources (e.g. from the web).*
	Physical modalities (for ECAs/robots only)	*- Displays a facial expression in accordance with what it is suggesting/asking the user to do.*

Representative dialogue

Situation	Example (This speech type underlined)
Recommending workout after detecting low daily step count	*Agent: "Today's daily step count is 4532, which is 1000 steps lower than the recent average."* *Agent: "<u>(With a determined look on its face) Stretch your body for 10 minutes before going to sleep! (Offers the most viewed 10-minute stretching Youtube video)</u>"* *User: "OK. Thanks."*

Figure 3. An example of the written guide

4 Study Method for Examining the Guide

We conducted a Wizard-of-Oz (WoZ) user study (Dahlbäck, 1993) to explore whether end users would perceive an agent personality to be consistent in conversations designed based on our guide, thereby evaluating the effectiveness of the guide in allowing multiple designers to manifest an agent personality consistently in a conversation design process. As we could not decide on a single representative guide to compare ours with, we aimed to let users to experience conversations with two agents with distinctive personalities designed by our guide and to examine whether they would perceive each personality to be consistent and as intended.

The study consisted of two parts: making agent prototypes and conducting a user study with the prototypes. In the following section, we describe the processes of each part.

4.1 Making Agent Prototypes

For our WoZ study, we created agent prototypes comprised of various dialogues which multiple designers individually created using the guides, as done in actual design practice. We started with designing two agent personalities to complete two guides to be provided for other conversation designers. Three researchers conducted a design workshop to create two different healthcare agent personalities (Table 1) and complete the guides accordingly. A healthcare domain was selected for our study as the three researchers all had experiences of using relevant services and were interested in designing them.

Table 1. Personality descriptions of Agent Type 1 and Type 2

	Agent Type 1	**Agent Type 2**
Representative keyword	Strict Instructor	Golden Retriever
Common Traits ***(Shared by both agents)***	Accurate, Trustworthy, Friendly	
Distinctive Traits ***(Unique to each agent)***	Uptight, Flawless, Charismatic	Emotional, Youthful, Humorous
Neutral Traits ***(Undecided or tailored to users)***	Older than its user Having no particular hobbies or preferences	Of a similar age as its user Sharing hobbies and preferences with the user

After designing the agent personalities, we aimed to collect dialogues that other designers would create by referring to the contents in the given guides. We recruited 16 participants with either design or computer science background and experiences in CA-related research. The average age of participants was 26 (SD=4.4, MIN=21, MAX=37), and 10 were female.

We assigned each half of the 16 participants with the two agents we designed: eight for Agent Type 1 and another eight for Agent Type 2. Adapting the common conversational design process in practice, we asked participants to work individually online. Each participant received a link for a Google Drive Spreadsheet (Figure 4) containing an overall introduction, an instruction on how to write dialogues on the sheet, a description of agent service concept, and the contents of the personality guide.

Each participant was asked to write 26 lines in a given user scenario. The scenario included various healthcare-related situations, such as sleep report, medication reminder, and recipe recommendation, as well as several non-task conversations including greetings and small talk, ensuring that the contents in the guide for all ten speech acts were utilized at least once.

Throughout this, 8 variations of a single dialogue line for a conversational situation were created, resulting in 208 dialogue lines in total for each agent. From these dialogues, non-verbal behaviours associated with physical modalities were converted to animations using Microsoft PowerPoint. Verbal dialogues were converted as audio files using a TTS generator and embedded in corresponding slides. In this way, one dialogue line was transformed as one slide as in Figure 5, resulting in two .pptx files as two agent prototypes.

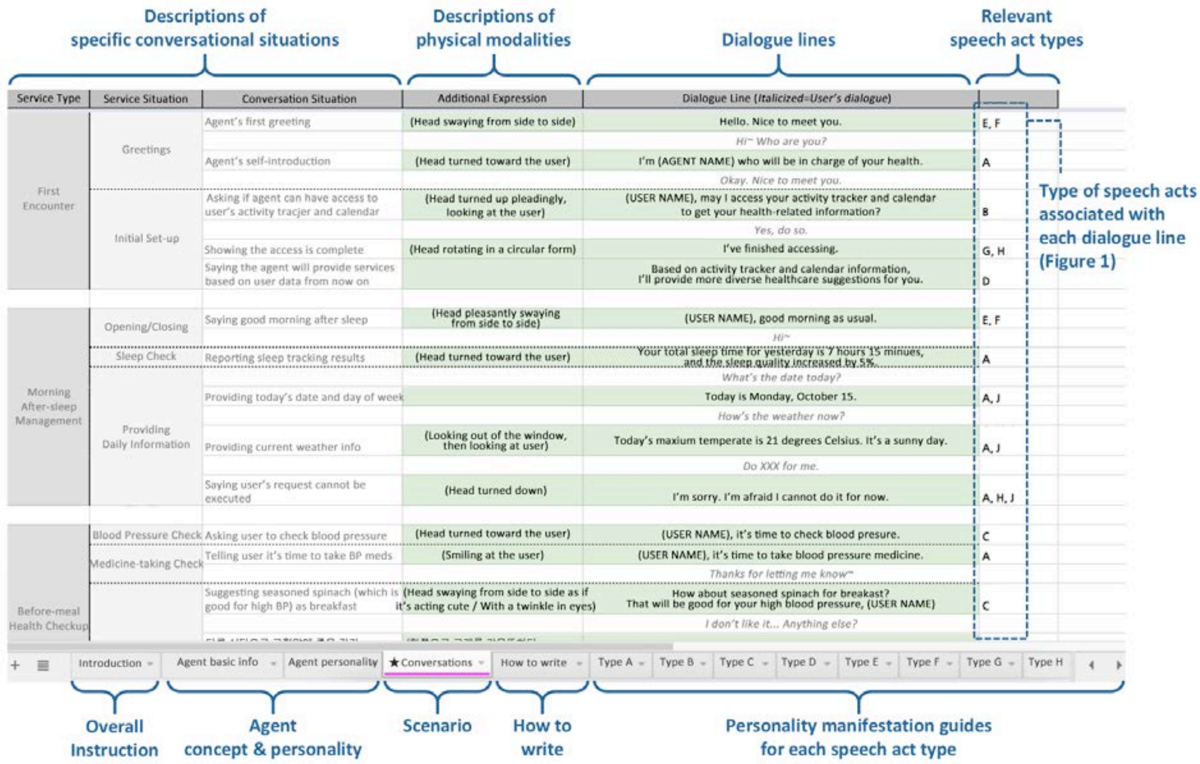


Figure 4. An example of conversations designed by a participant (in green cells; translated to English)

Figure 5. Process of making agent prototypes from dialogues collected

4.2 Wizard-of-Oz User Study

Using the agent prototypes, we conducted a WoZ user study to explore how end users would perceive the designed agent personalities and what would be factors affecting such perception during conversational interactions. We recruited 30 participants who had basic understanding of CAs and experiences of using them. The average age of participants was 25 (SD=2.9, MIN=20, MAX=32), and 14 were female.

Figure 6 shows the study process and set-up. After introduction, a participant was given with a set of tip cards about agent concept, possible commands and functions of the agent, tasks to be completed, and hypothetical user characteristics set up for the participant. We expected the cards to work as a boundary for minimizing conversational situations that deviate from our database of dialogues and expressions.

Based on the cards, participants were asked to freely converse with each agent prototype until they were sure how each agent personality was perceived to be. With sufficient training in advance, the first wizard played with nimbleness appropriate dialogues by referring to the database. Also, he played various dialogues randomly to ensure that conversations designed by different writers were mixed. The second wizard transcribed all conversations real-time so that participants could review the logs after interaction. We did not control interaction time or sequence as we expected experiences to be natural and realistic. To compensate the effect by order of interactions, half of the participants interacted with Agent Type 1 first and then Agent Type 2, and vice versa.

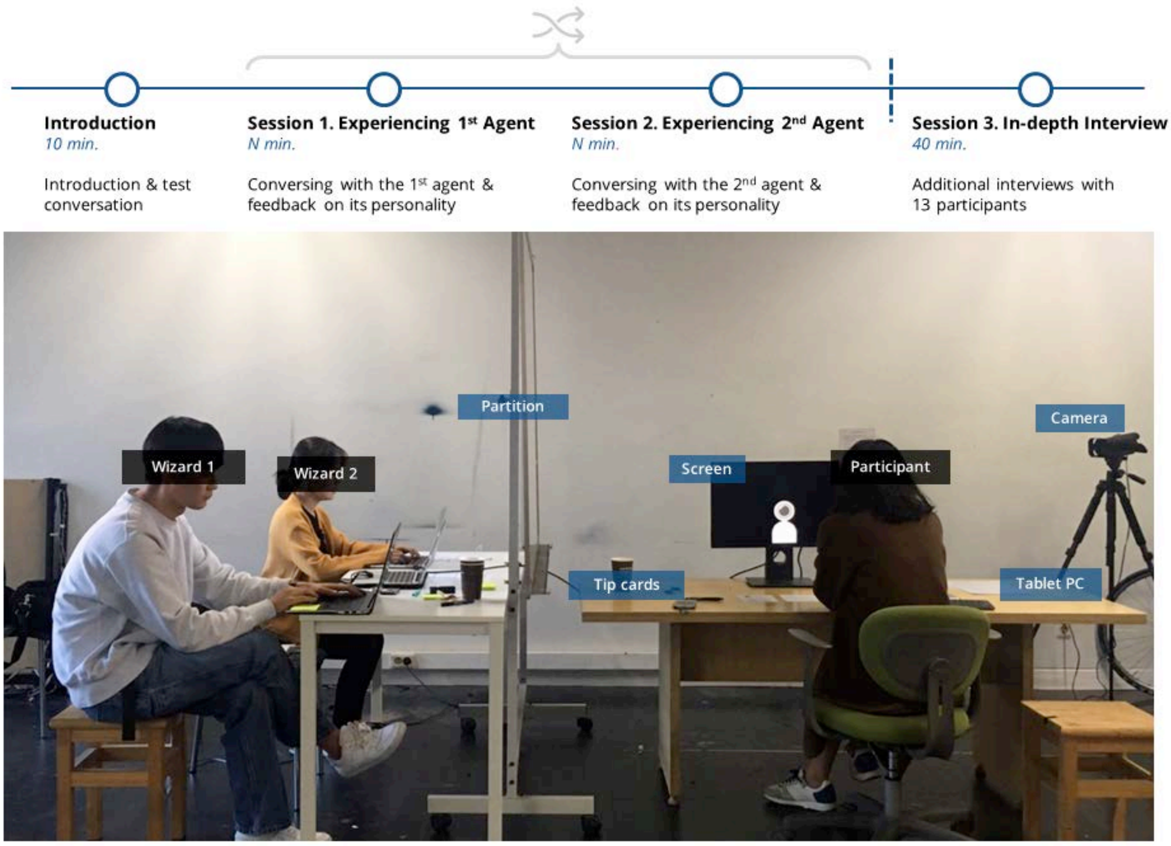


Figure 6. Study process (top) and set-up (bottom)

After interacting with each agent, participants evaluated how the personality traits of the agent were perceived based on 7-point semantic differential questions (Figure 7). Each item included a pair of all personality traits of both agents (Table 1) and their opposite adjectives. The order of the semantic differential questions was randomized to compensate possible bias. Also, participants commented with detailed reasons on how each personality was perceived to be and whether or not they perceived each personality to be consistent.

Among 30 participants, we conducted in-depth interviews with seven who evaluated the personalities of both agents correctly and six who did less correctly. Along with discussions on overall interaction experiences, the interview questions focused on understanding what affected participants' perceived personalities of agent as well as their consistency. Each interview lasted about 40 minutes. All interviews were audio-recorded and transcribed.

For data analysis, three researchers examined the transcribed interview logs of and participants' comments on each agent. Iterative open-coding analysis was conducted in search of emergent themes and patterns regarding users' perception of a CA's personality and its consistency during conversational interactions. We repeated this analysis process until we reached consensus on three factors related with consistent personalities of CAs.

5 Findings

In this section, we first report on the result of quantitative analysis regarding the effectiveness of the guide on maintaining consistency of agent personalities. We then present three factors that affected perceived consistency in agent personalities identified from the qualitative data, the main interest of our data analysis.

5.1 Evaluation of the guide

We implemented basic quantitative analysis to validate the effectiveness of the guide. From the answers regarding whether or not the overall personality of each agent was perceived consistently throughout the WoZ session, we found that in general participants perceived the overall expression of the agent personality to be consistent. For Agent Type 1, 27 out of 30 participants answered that they perceived its personality to be consistent. For Agent Type 2, 28 out of 30 participants answered that they perceived its personality to be consistent.

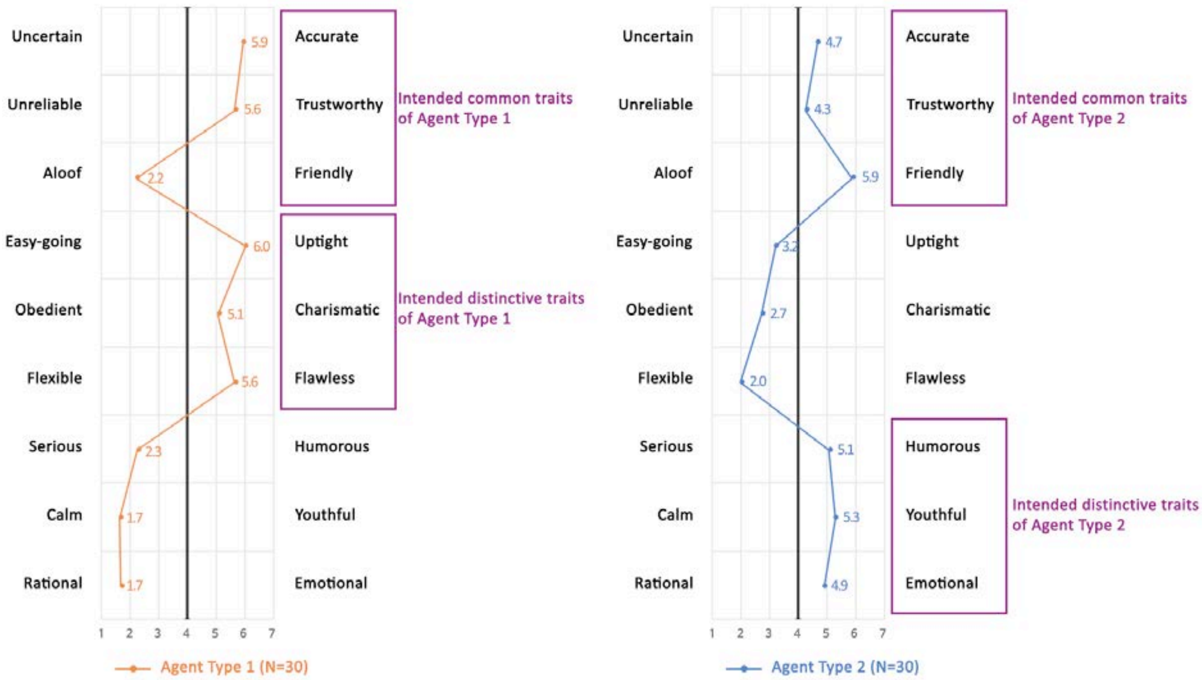


Figure 7. Average scores on each personality trait of Agent Type 1 (left) and Type 2 (right)

By calculating the average of the scores participants gave for each common and distinctive personality traits of the agents, we found that participants perceived all personality traits as intended except the *friendly* common trait of Agent Type 1. While Agent Type 1 should have embodied the *friendly* common trait as a healthcare agent, participants actually identified Agent Type 1 closer to aloof, scoring only an average 2.2 out of 7 on the 'aloof-friendly' item (Figure 7, left). One reason for this might be that while *common traits* were what every agent designer pursued at first, *distinctive traits* played a stronger role in giving distinctive individuality to the agent, consequently being a more dominant influence on users' perception of CA personalities. For Agent Type 1, we think that its *uptight*, *charismatic*, and *flawless* distinctive traits overrode the *friendly* common trait. This can also account for the average scores of the *accurate* and *trustworthy* common traits for Agent Type 2 being closer to the midpoint; for Agent Type 2, its *humorous*, *youthful*, and *emotional* distinctive traits lessened such common traits while strengthening the *friendly* common trait. These unexpected interactions among the traits will be an interesting area for future research for designing agent personalities.

5.2 Factors Related to Perceived Consistency of Agent Personalities

Qualitative analysis of the data unveiled three factors associated with users' perception of consistent agent personalities. We report each in the following.

5.2.1 Roles and Functions of an Agent as Personality

Participants perceived the roles and functions of an agent as its personality. The nature of such roles and functions connoted stereotypical images or behaviours, thereby setting expectations on personality traits implicitly associated with those stereotypes. For instance, P1 felt Agent Type 1 as not extremely uptight due to the inherent limitation set by its role as an assistant: "*An agent is an assistant anyway, so it does not feel like talking so harsh. It is in a position to take care of me, so it's difficult to think it to be so rigid.*" As for personalities implied by certain functions, P6 and P7 mentioned that although Agent Type 2 was basically perceived to be friendly and youthful, it was also flawless to some degree because of the functions such as medication reminder and low step count warning.

As such, an agent's role and functions seemed to set up a ground personality or a boundary that limits the agent to have certain personalities. As a CA in practice is usually first equipped with functions and features by engineers and then rendered a personality, our findings motivate designers to begin a sketch of personality considering readily assigned functional purposes or roles of a CA. However, pre-existing user expectations regarding roles and functions are not concrete foundations on which its personality must be laid, but just one of the preliminary triggers that guide designers who need to start from scratch. For example, P3 mentioned that he would clarify the perceived role of an agent based on its perceived personality: "*If the agent acts proactively, it will be a trainer, and if it is passive, it will be a butler*." Initial predictions based on an agent's role and functions can be defied by actual perception of its personality.

So as to maintain consistency of a CA personality throughout varied ways of manifestation, these findings suggest that not only the expressed personality should be in line with functions or services that the agent is performing, but also the types of such functions and services should also fall into an analogous category. For instance, P4 mentioned that her expectations on a CA personality stemming from its functions were the key to the perceived consistency of the personality for her: "*I think consistency depends not on how it speaks but on whether or not it goes beyond my expectations during interactions. For example, I always use Siri strictly for the purpose of setting morning alarms, but if it suddenly tries a small talk and asks me how my meeting was, it will be a little awkward (because that is too tender).*" The dissonance between expectations set by one function and another can create perceived inconsistency of a CA personality.

In light of these findings, we suggest future CA designs reconsider whether or not a CA should have its personalities varied based on the functions and services it provides, or even whether or not a single multi-purpose agent is an appropriate choice. While how to manifest a personality consistently is an issue that badgers a multiple-domain CA, it can be resolved by adopting a different approach: designing multiple domain-specific agents such as a meta-chatbot (Maturi, 2016) or a conversational Internet-of-Things system. Prior work (Jung et al., 2017) has suggested that users tend to endow IoT products with typical roles matching mental models. Retaining such mental models can be supported by multiple discrete agents each focusing on performing one or a few particular tasks, reducing chances for their personalities to lose consistency across diverse situations.

5.2.2 Cross-situational Consistency in Services Style and Contents

Participants also perceived agent personalities from ways the agents provide services. For example, P9 felt uptight and flawless traits of Agent Type 1 in a conversation about diet recommendation service: "*The first most impressive moment was when it didn't allow me to change the menu. I had no choice other than spinach… I thought it was rigid because it didn't offer me any alternatives.*" Also, P1 thoughts Agent Type 2 to be friendly and emotional when the agent additionally suggested her what to wear along with weather information. From each separate conversational moment as such, participants got an inkling of how an agent offered a certain service as well as what types of service contents it provided, and such inklings led to form a perception towards a personality as a whole after experiencing various dialogues through multiple turn-takings.

As a result, keeping consistency in ways of providing services and types of contents across various situations was crucial in consistency of agent personalities. P6, P7 and P20 perceived the consistent personality of Agent Type 1 because of its repeated attempts to push users: "*It was kind of pushing me when it was talking about medication. The words like 'right now,' too. When I asked for alternatives, it said no. Also, when I was in the bed, it kept asking my permission to turn off the light in 30 minutes*." (P7) Also, P3 said Agent Type 2 was friendly and emotional all the time because it always proactively took care of his health: "*When I said 'good morning,' I expected a report on my sleep patterns at most, but the agent actually even asked me if I was tired or not. And here, (when it was providing weather information) it even told me to put warm clothes and a mask. And also… it proactively asked me if I was thinking about the breakfast menu.*" While these examples show how agent perform various services in a similar manner, P4 said the personality of Agent Type 2 was perceived consistent due to similarities in service contents: "*(The agent) said it supports my healthy life, and everything it said and every service it provided were all related to healthcare. (…) The services were all about health, so I thought it was consistent.*"

Indeed, inconsistency in a personality was noticed when such style of providing services or contents types varied across different situations. P18 commented that he was talking with two different agents when Agent Type 1 offered services in both strict and caring ways: "*It seemed uptight when it reminded me of taking medication, provided date and weather information, and tried to manage my lifestyle, but it acted friendly and humorous when it suggested me to do stretching exercises, told me some news about my favourite musician, and tried small talks at night.*" Also, P3 and P7 said Agent Type 1's sudden attempt on light-hearted chit chat baffled them: "*The topic [a casual chat on daily schedule] was a little inappropriate. (…) When I told the agent that I was bored, I was expecting things like a suggestion on stretching exercises*." (P7) As these illustrate, similarity in style of providing services and contents types was key to consistent personalities of CAs.

5.2.3 Tolerance for Inconsistency in Verbal and Physical Modalities

Aligning with findings from prior work (Dryer, 1999; Neff et al., 2010; Hwang et al., 2013; Schuller & Batliner, 2013), our study also found that verbal, facial, and gestural modalities, such as detailed linguistic phrases, way of talking, and visual appearance, render an agent personality: "*It mentioned the exact number of steps, and regarding weather information, I saw some numbers like 13 degrees Celsius and 30% chance of rain (on the facial display). That made it [Agent Type 1] very meticulous, trustworthy, but at the same time a bit rigid.*" (P9) "*It had various facial expressions. It was smiling and crying… That seemed quite emotional.*" (P12)

However, participants were relatively tolerant towards stylistic inconsistency of such verbal and physical modalities across varying situations. For instance, P5 did not pay attention to specific linguistic phrasing or way of speaking while interacting with Agent Type 2: "*I did not care how it spoke so much. People sometimes say like this, and sometimes say like that.*" Also, P4 mentioned that the inconsistency of Agent Type 2's language actually strengthened its youthful personality: "*Even if someone first stays calm and later talks so cheerfully, you do not think that as personality disorder. That inconsistency is the personality itself. You don't think the personality changes.*" Such tolerance was pointed out by other participants who also described "*unpredictable"* as "*characterful*" (P2) and even "*consistency of interactional modalities*" as "*a cause of abandoning a longer-term relationship development with the agent*." (P11)

Instead, participants tended to figure out more veiled meanings from what met the eyes and ears, interpreting them as style of providing services. Reading between lines, P6 distinguished between two different styles of providing services by Agent Type 1 and 2 based on how they spoke: "*Type 2 was more gentle. By saying 'why don't you do this?' it was more like making a suggestion. The second one [Type 1] was more like rushing me, but this Type 2 was softer. Compared to Type 1's saying 'do this right now!', Type 2 was much tenderer.*" Therefore, with regards to an agent's modalities, concerns should lie on sub-textual nuance conveyed as a cue for service styles instead of merely ensuring whether their explicit appearance and linguistic phrasing stays consistent.

6 Conclusion and Future Studies

This paper presented how we developed and evaluated a design guide for consistent manifestation of CAs' personalities by multiple conversation designers. Throughout a WoZ user study, we confirmed that the guide supported multiple designers to share the same understanding on how a CA's personality has been designed and how it has been intended to be manifested in conversation. The findings from this study also shed light on design of clear agent personalities by identifying factors associated with users' perception on such personalities and its consistency: the roles and functions of an agent as its personality; cross-situational consistency in style of providing services and contents; and tolerance for inconsistency in verbal and physical modalities. Grounded on the problem occurring in real design processes of CAs' personalities and conversations, our guide is believed to have high applicability in design practice. With further refinement, the guide is expected to work as pragmatic guidelines empowered by both designer- and user-centred perspectives regarding consistency of CAs' personalities.

7 References

Alexa Design Guide. (2019). Retrieved April 4, 2019, from https://developer.amazon.com/docs/alexa-design/get-started.html

Allen, J. F., & Core, M. (1997). Draft of DAMSL: dialog act markup in several layers. The Multiparty Discourse Group. University of Rochester, Rochester, USA.

Astrid, M., Krämer, N. C., Gratch, J., & Kang, S. H. (2010). “It doesn’t matter what you are!” Explaining social effects of agents and avatars. Computers in Human Behavior, 26(6), 1641-1650

Austin, J. L. (1962) *How to Do Things with Words*. Oxford: Oxford University Press.

Bixby Design Guides. (2018). Retrieved from https://bixbydevelopers.com/dev/docs/dev-guide/design-guides

Bouchet, F., & Sansonnet, J. (2012) Intelligent Agents with Personality. Cognitively Informed Intelligent Interfaces: 177-200. doi:10.4018/978-1-4666-1628-8.ch011

Callejas, Z., Griol, D., & López-Cózar, R. (2014). A framework for the assessment of synthetic personalities according to user perception. I*nternational Journal of Human Computer Studies* 72(7), 567 – 583

Cassell, J. (2000). Embodied conversational agents. Cambridge, Mass: MIT Press, 392-395.

Cattell, R. B., Eber, H. W., & Tatsuoka, M. M. (1970). *Handbook for the Sixteen Personality Factor Questionnaire (16PF)*. New York: Plenum.

Cohen, M. H., Giangola, J. P., & Balogh, J. (2004). *Voice user interface design*. Boston, Mass.: Addison-Wesley.

Cortana's Persona. (2019). Retrieved from https://docs.microsoft.com/en-us/cortana/skills/cortanas-persona

Cowan, B.R., Pantidi, N., Coyle, D., Morrissey, K., Clarke, P., Al-Shehri, S., Earley, D., & Bandeira, N. (2017). "What can I help you with?": Infrequent users' experiences of Intelligent Personal Assistants. In *Proceedings of the 19th International Conference on Human-Computer Interaction with Mobile Devices and Services (MobileHCI '17)*. ACM, New York, NY, USA, Article 43, 12 pages. DOI: https://doi.org/10.1145/3098279.3098539

Dahlbäck, N., Jönsson, A., & Ahrenberg, L. (1993). Wizard of Oz Studies — Why and How. Knowledge-Based Systems, 6(4), 258-266. doi:10.1016/0950-7051(93)90017-n

Danielescu, A., & Christian, G. (2018). A Bot is Not a Polyglot: Designing Personalities for Multi-Lingual Conversational Agents. In Extended Abstracts of the 62 2018 CHI Conference on Human Factors in Computing Systems (CHI EA '18). ACM, New York, NY, USA

Davis, M. (2001). Engines of Logic: Mathematicians and the Origin of the Computer. WW Norton & Co., Inc.

Dryer, D. C. (1999). Getting Personal with Computers: How to Design Personalities for Agents. Applied Artificial Intelligence, 13(3), 273-295.

Dwoskin, E. (2016). The next hot job in Silicon Valley is for poets. Washington Post. Retrieved from https://www.washingtonpost.com/news/the-switch/wp/2016/04/07/whypoets-are-flocking-to-silicon-valley/?noredirect=on&utm_term=.692302b00703

Goetz, J., Kiesler, S., & Powers, A. (2003). Matching Robot Appearance and Behavior to Tasks to Improve Human-Robot Cooperation. In *Robot and Human Interactive Communication*, 55-60.

Goldberg, L. R. (1990). An Alternative "Description of Personality": The Big-Five factor structure. *Journal of Personality and Social Psychology*, 59(6), 1216-1229. doi:10.1037//0022-3514.59.6.1216

Google Conversation Design. (2019). Retrieved April 4, 2019, from https://designguidelines.withgoogle.com/conversation/conversation-design/welcome.html

Güzeldere, G., & Franchi, S. (1995). Dialogues with Colorful “Personalities” of Early AI. Stanford Hum. Rev. 4, 2 (July 1995), 161-169.

Hwang, J., Park, T., & Hwang, W. (2013). The Effects of Overall Robot Shape on the Emotions Invoked in Users and the Perceived Personalities of Robot. *Appl Ergon* 44(3):459–471. doi:10.1016/j. apergo.2012.10.010

Jung, J., Nam, H., Lim, Y., & Lee, K. (2017). Beauty and the Beast. In *Proceedings of the 2017 ACM Conference Companion Publication on Designing Interactive Systems (DIS '17 Companion).* ACM, New York, NY, USA, 61-66. DOI: https://doi.org/10.1145/3064857.3079120

Kim, H., Koh, D., Lee, G., Park, J., & Lim, Y. (2019). Designing Personalities of Conversational Agents. In *Extended Abstracts of the 2019 CHI Conference on Human Factors in Computing Systems (CHI EA '19).* ACM, Glasgow, UK, Paper LBW1321, 6 pages. DOI: https://doi.org/10.1145/3290607.3312887.

Kocielnik, R., Avrahami, D., Marlow, J., Lu, D., & Hsieh, G. (2018). Designing for Workplace Reflection: A Chat and Voice-Based Conversational Agent. In *Proceedings of the 2018 Designing Interactive Systems Conference (DIS '18)*. ACM, New York, NY, USA, 881-894. DOI: https://doi.org/10.1145/3196709.3196784

Kopp, S., Gesellensetter, L., Krämer, N. C., & Wachsmuth, I. (2005). A conversational agent as museum guide–design and evaluation of a real-world application. In *International Workshop on Intelligent Virtual Agents*. pp. 329-343. Springer Berlin Heidelberg.

Li, J., Galley, M., Brockett, C., Spithourakis, G., Gao, J. and Dolan, B. (2016). A Persona-Based Neural Conversation Model. In *Proceedings of the 54th Annual Meeting of the Association for Computational Linguistics (Volume 1: Long Papers)*. doi:10.18653/v1/p16-1094

Liao, Q. V., Davis, M., Geyer, W., Muller, M., and Shami, N. S. (2016). What Can You Do?: Studying Social-Agent Orientation and Agent Proactive Interactions with an Agent for Employees. In *Proceedings of the 2016 ACM Conference on Designing Interactive 63 Systems (DIS '16)*. ACM, New York, NY, USA, 264-275. DOI: https://doi.org/10.1145/2901790.2901842

Liao, Q.V., Hussain, M. M., Chandar, P., Davis, M., Khazaeni, Y., Crasso, M.O., Wang, D., Muller, M., Shami, N.S., and Geyer, W. (2018). All Work and No Play?. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems (CHI '18)*. ACM, New York, NY, USA, Paper 3, 13 pages. DOI: https://doi.org/10.1145/3173574.3173577

Luger, E. and Sellen, A. (2016). "Like Having a Really Bad PA": The Gulf between User Expectation and Experience of Conversational Agents. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (CHI '16)*. ACM, New York, NY, USA, 5286-5297. DOI: https://doi.org/10.1145/2858036.2858288

Mairesse, F., and Walker, M. (2007). PERSONAGE: Personality Generation for Dialogue. In *Proceedings of the 45th Annual Meeting of the Association of Computational Linguistics*, Association for Computational Linguistics, 496–503

Mairesse. F., and Walker, M. (2010) Towards personality-based user adaptation: psychologically informed stylistic language generation. User Model User-Adap 20(3):227–278. doi:10.1007/s11257-010-9076-2

Maturi, H. (2016). Meta Chatbot: Enabling collaboration between chatbots. Retrieved April 4, 2019 from https://www.linkedin.com/pulse/meta-chatbot-enabling-collaboration-between-chatbots-hareesh-maturi/

McKenzie, S. (2017). Artist who worked on Pixar's Brave giving Google AI 'personality.' BBC News. Retrieved from https://www.bbc.com/news/uk-scotland-highlands-islands39513019

Mctear, M., Callejas, Z. and Griol, D. (2016). *Introducing the Conversational Interface*. Springer. doi:10.1007/978-3-319-32967-3_1

Moore, R. K. (2013). Spoken Language Processing: Where do we go from here?. In *Your Virtual Butler* (pp. 119-133). Springer Berlin Heidelberg.

Murad, C., Munteanu, C., Clark, L. and Cowan, B. R. (2018). Design guidelines for hands-free speech interaction. In *Proceedings of the 20th International Conference on Human-Computer Interaction with Mobile Devices and Services Adjunct (MobileHCI '18)*. ACM, New York, NY, USA, 269-276. DOI: https://doi.org/10.1145/3236112.3236149

Nass, C., Moon, Y., Fogg, B. J., Reeves, B., & Dryer, C. (1995). Can computer personalities be human personalities? In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '95)*, 228-229. ACM, New York, NY, USA.

Nass, C., and Lee, K. M. (2012). Does computer-generated speech manifest personality? An experimental test of similarity-attraction. In *Proceedings of the SIGCHI conference on Human Factors in Computing Systems (CHI '00)*. ACM, New York, NY, USA, 329-336. DOI=http://dx.doi.org/10.1145/332040.332452

Neff M, Wang Y, Abbott R, Walker M, (2010) Evaluating the effect of gesture and language on personality perception in conversational agents. In: Allbeck J, Badler N, Bickmore T, Pelachaud C, Safonova A (eds) *Intelligent virtual agents* 6356. Springer, Berlin, pp 222–235. doi:10.1007/978-3-642-15892-6_24

Pavlus, J. (2016), 'The next phase of ux: Designing chatbot personalities'. URL: https://www.fastcodesign.com/3054934/the-next-phase-of-ux-designing

Qian, Q., Huang, M., Zhao, H., Xu, J., & Zhu, X., Assigning Personality/Profile to a Chatting Machine for Coherent Conversation Generation. In *Proceedings of the Twenty Seventh International Joint Conference on Artificial Intelligence*. doi:10.24963/ijcai.2018/595

Reeves, B. & Nass, C. (1996). *The media equation: how people treat computers, television and new media like real people and places*, Cambridge University Press, New York.

Schuller, B., & Batliner, A. (2013) *Computational paralinguistics: emotion, affect and personality in speech and language processing*. Wiley, Chichester. doi:10.1002/9781118706664
Sciuto, A., Saini, A., Forlizzi, J., & Hong, J. I. (2018). "Hey Alexa, Whats Up?": A Mixed-Methods Studies of In-Home Conversational Agent Usage. In *Proceedings of the 2018 Designing Interactive Systems Conference (DIS '18)*. ACM, New York, NY, USA, 857-868. DOI: https://doi.org/10.1145/3196709.3196772
Selker, T. (1994). COACH: a teaching agent that learns. Communications of the ACM, 37(7), 92-99.
Searle, J. (1969) *Speech Acts*. Cambridge: Cambridge University Press.
Tapus, A., Ţăpuş, C., and Matarić, M. J. (2008). User-robot personality matching and assistive robot behavior adaptation for post-stroke rehabilitation therapy. Intelligent Service Robotics, 2, 169-183.
Vassallo, G., Pilato, G., Augello, G. & Gaglio, S. (2010). Phrase Coherence in Conceptual Spaces for Conversational Agents. In Sheu, Yu, Ramamoorthy, Joshi & Zadeh.(eds). *Semantic Computing*. IEEE: 357-371. DOI: 10.1002/9780470588222.ch18
Weizenbaum, J. (1966). ELIZA: A Computer Program for the Study of Natural Language Communication between Man and Machine. In Communications of the ACM. 9,1:36-45. DOI: 10.1145/365153.365168
Wilks, Y. (2010). Is a companion a distinctive kind of relationship with a machine? . In *Proceedings of the 2010 Workshop on Companionable Dialogue Systems (CDS '10)*. Association for Computational Linguistics, Stroudsburg, PA, USA, 13-18.
Xiao, H., Reid, D., Marriott, A. & Gulland, E. (2005). An Adaptive Personality Model for ECAs. In: Tao, J., Tan, T., & Picard, R.W. (eds). *Affective Computing and Intelligent Interaction*. ACII 2005. Lecture Notes in Computer Science, vol 3784. Springer, Berlin, Heidelberg
Acklin, C. (2010). Design-Driven Innovation Process Model. *Design Management Journal*, *5*(1), 50-60.

About the Authors:

Hankyung Kim: Hankyung Kim is a Ph.D. student in the Department of Industrial Design at KAIST. She is interested in designing human-centered user experience for AI-powered products and systems.

Dong Yoon Koh: Dong Yoon Koh is a master in the Department of Industrial Design at KAIST. He is Interested in the design of aesthetically pleasing interaction and the user-led exploration of novel interface.

Gaeun Lee: Gaeun Lee is a UX/UI designer at Samsung research with an academic background in the study of ergonomics and Industrial information design. She is passionate about research in HRI and Human factors.

Jung-Mi Park: Jung-Mi Park is a UX/UI designer at Samsung research with an academic background in the study of Industrial Design. She is passionate about research in HRI and Human factors.

Youn-kyung Lim: Youn-kyung Lim is a professor in the Department of Industrial Design at KAIST, where she leads the Creative Interaction Design (CIxD) lab. Her research interests have been in the areas of experience-centered design and prototyping in HCI, with a design-oriented perspective, especially focusing on enabling creative interaction design. Lim received her Ph.D. in design from the Institute of Design at the Illinois Institute of Technology in Chicago.

Acknowledgement: This work was primarily supported by Samsung Research Project “Humane AI: Implementation and Evaluation for HRI Adaptation” and partially supported by Institute of Information & Communications Technology Planning & Evaluation (IITP) grant funded by the Korea government (MSIT) (No.2016-0-00564).

Enabling self-determination through transformative service design and digital technologies: studying mobility experiences of people with disability

Sartori do Amaral, Carla*[a]; Chamorro-Koc, Marianella [a]; Beatson, Amanda[b]; Tuzovic, Sven[b]

[a] School of Design, Queensland University of Technology, Brisbane, Australia
[b] Business School, Queensland University of Technology, Brisbane, Australia
* carla.amaral@hdr.qut.edu.au

People with disabilities face many barriers for active participation in the workforce. One of the major obstacles that impact access to employment opportunities is mobility-related issues. Commuting to work and being able to navigate physical barriers is a crucial skill for people with physical disabilities to gain and maintain employment, as well as to exercise their self-determination. The evolution of digital technologies and the offerings of services online can facilitate journeys to work by enabling self-determination strategies to empower people in their everyday mobility dependent activities. However, difficulties often occur during self-directed interactions because of fragmented and disconnected information, causing service users to have little control over their journeys, which can negatively impact their wellbeing. This paper reports research that takes a transformative service design approach to identify areas where design can improve the interaction between people and digital technologies to enable self-determination of users in the context of planning and undertaking journeys to work. We present findings from eight critical incident-style interviews with people living with mobility-related impairments, highlighting barriers and enabling strategies that impact their self-determination in the context of journeys and how digital platforms assisted them in these situations. Five areas for design interventions are identified: planning and decision making, transport options, technology, policy and standards, and communication. These findings are indicative of key areas where service design can unlock the potential of digital technologies and play a transformative role in enabling self-determination for people with disabilities in their daily journeys to work.

Keywords: digital technologies; mobility; disability; self-determination; transformative service design

1 Introduction

One in five people lives with a disability in Australia. Those with a disability of working age (15-64 years) face barriers to employment, which result in significantly lower participation in the workforce compared to those without a disability (Australian Bureau of Statistics, 2016). Globally, the number of people with disabilities in working age is about 15% of the world's population, or 1 billion citizens (World Health Organization, 2011). Among the many obstacles people with a disability experience, mobility limitations and physical barriers are crucial factors that can restrict participation in employment-related activities (Boyce, Malakar, Millman, & Bhattarai, 1999; Raja, 2016). For example, to gain and maintain employment, it is often necessary to be able to go from home to work daily. The ability to effectively navigate from one place to another is, therefore, an essential skill to support employment and self-determination of people with disabilities (LaGrow, Wiener, & LaDuke, 1990; Moore Sohlberg, Fickas, Lemoncello, & Hung, 2009; Shogren et al., 2009). Self-determination is the principle of self-direction and choice (Ryan & Deci, 2017), which directly impacts the feeling of wellbeing (Schalock & Verdugo, 2002; Wehmeyer, 2005).

Beyond participation in the workforce, navigating physical spaces can also represent barriers in social, economic, and community participation, especially for people with a physical disability (Raja, 2016). For this reason, when a person with disability experiences limitation to effectively navigate to work, their self-determination is impacted, and their sense of wellbeing is negatively affected. The problem is that, in Australia, current services and infrastructure do not enable effective commute to work for people with mobility-related impairments (Chamorro-Koc, Stafford, & Adkins, 2015) which limits self-determination and positions them in a situation of inequality.

Digital technologies can potentially enhance self-determination by making the journey to work more seamless (Adkins, Chamorro-Koc, & Stafford, 2015; Chamorro-Koc et al., 2015). Information and communication technologies (ICT) can help people with mobility-related disabilities to plan for their journeys, make sure they have access to the support they need to undertake the commute effectively, and also find strategies to manage issues that disrupt mobility during the trip (Chamorro-Koc et al., 2015). These evolutions in ICT allow people to be able to access services independently (Matthew L. Meuter, Ostrom, Bitner, & Roundtree, 2003), giving them more choice and control. The issue is that when there are disruptions to self-directed service interactions, self-determination can be limited and consequently generate a negative impact on users' wellbeing.

Design can play a transformative role in this complex system because it brings a human-centred approach to create transformational service experiences that improve wellbeing (S. Anderson, Nasr, & Rayburn, 2018). This transformative lens is vital in the context of this study because it recognises service users as experts of their experiences (Cottam & Leadbeater, 2004; Lundkvist & Yakhlef, 2004) and therefore, allows them to propose an agenda for change. In this paper, we investigate the experience of people with mobility-related impairments in Brisbane, Australia, about the use of digital technologies to prepare for and during journeys from a transformative service design perspective. Our focus is to identify opportunities from users' perspectives to propose areas for potential intervention where design can play a transformative role in enhancing self-determination in their journeys to work.

2 Digital technologies and self-determination

Technology can help people with physical disabilities overcome mobility problems, which are frequently the issues preventing their participation in the workforce (Boyce et al., 1999; Raja, 2016). However, while technology has brought many advancements and improvements to the lives of people with disabilities, they do not always enable their self-determination.

For example, in the context of online support services for people with disabilities, the National Disability Insurance Scheme (NDIS) is an initiative that the Australian government is putting in place to have a significant online presence to help people achieve their desired goals and achieve social inclusion (National Disability Insurance Agency, 2018). The NDIS provides funding to support services such as mobility equipment and employment activities that people can access through an online portal (National Disability Insurance Agency, 2018). However, there is fragmentation in service delivery because how this amplification in access and connection with other governmental programs, such as disability employment services, is going to work is still being resolved (Stafford, Marston, Chamorro-Koc, Beatson, & Drennan, 2017). In addition, research has identified that people supported by the scheme and registered service providers reported issues with the online portal and difficulties in the access to care and resources (Mcloughlin, Mcnicoll, Beecher Kelk, Cornford, & Hutchinson, 2019). These problems limit users' self-determination because they cannot have full control and access to relevant information and support services.

There are digital platforms that are contributing to overcoming some of the informational gaps and lack of choice for participants of the NDIS programme. One example that enhances the self-determination of people with disabilities in the care sector is Clickability. This web-based platform enables service users to rate and review disability support services to assist their peers in making informed decisions about which services to contract (Clickability, 2019). The platform works in a peer-to-peer (P2P) format facilitating the connection between users and service providers. This kind of P2P flow is one of the approaches to empower users by challenging power inequalities and moral order (Mcloughlin et al., 2019). Figure 1 shows an example of an online search for transport services in the West End suburb of Brisbane, Australia, using Clickability's service directory. The results show the organisations that provide the service and include rating and reviews from other users that have previously contracted the service.

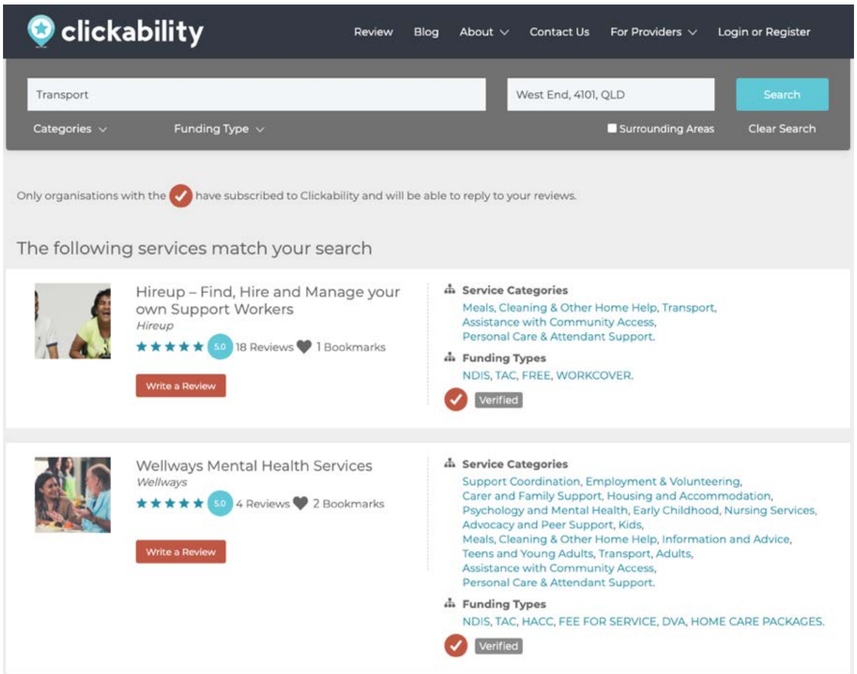


Figure 1. Example of Clickability's interface. Source: Clickability. (2019). Transport search. Retrieved from https://clickability.com.au/listing/?keyword=Transport&council=518&search_location=West+End%2C+4101%2C+QLD

In the mobility area, a Sydney based start-up is developing a mobile application called Navability to support navigation for wheelchair users. This app uses data crowdsourcing to create maps based on users' fitness, travel ability, and the physical accessibility of the route (Briometrix, 2017). This kind of personalised approach enhances people's confidence to undertake their journeys. Figure 2 shows an example of a map that Briometrix created for the city of Sydney 2017 New Year's Eve celebrations that offers information on accessible routes for wheelchair users based on the analysis of the gradients, pathways and users' travel effort (which is indicated by the colours on the map).

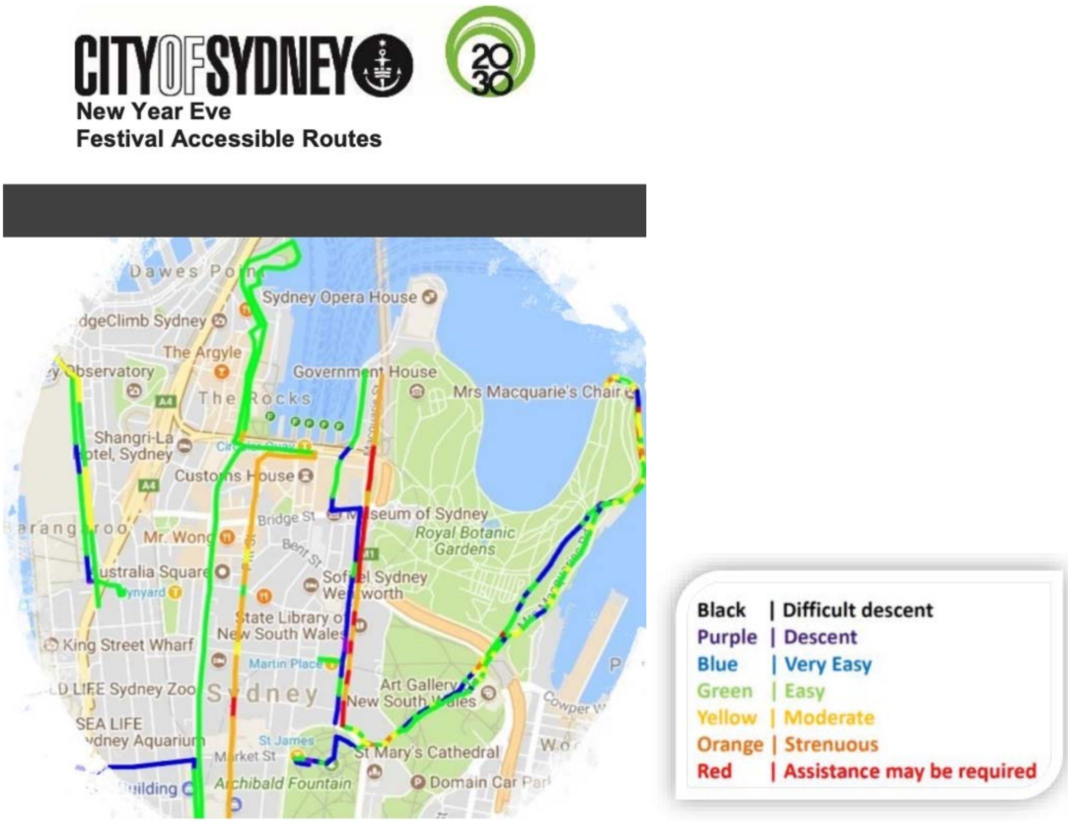


Figure 2. Accessible routes map for wheelchair users (left) and the travel effort colour legend (right). Source: Briometrix. (2017). Retrieved from https://www.briometrix.com/wp-content/uploads/2018/10/City_of_Sydney_New_Year_Eve_Accessibilty_Effort_Mapping.pdf

These two examples indicate that user-generated content is critical to producing information that is relevant and helpful for those accessing online services. In the Clickability example, the P2P approach of user reviews gives a voice to the consumer of services to express their opinion and experiences, and in turn, the platform allows service providers to learn more about their customer needs. While in the Navability example, data to create the maps is generated by other wheelchair users, meaning that the route information provided is based on the mobility experience of people in similar situations, which makes the information more accurate.

This study incorporates the approach of these examples, which is to consider service users the experts of their experiences and therefore position them in the centre of the service system. In addition, we aim to extend the findings from previous work that highlighted the need for improvement in service delivery and the potential of using digital platforms to improve the mobility experience of people with disability (Adkins et al., 2015; Chamorro-Koc et al., 2015) by contributing with insights to inform new services. Therefore, to investigate further ways in which design can unlock the potential of digital technologies in enabling self-determination for people with disabilities in their journeys to work, we applied a transformative service design approach which is unpacked in the next section of this paper.

3 Design as a transformative approach

The concept of transformation design, was introduced by Burns, Cottam, Vanstone, and Winhall (2006), and is associated with social change, and also with companies adopting a human-centred design culture into their practices. Sangiorgi (2011) analysed this concept tracing a connection between transformation design and service design suggesting that services are not the outcome but a tool for societal transformations thus also being able to help to build a more equitable society.

In the context of this research, we acknowledge that people's interaction with online services can have both a positive or negative impact on wellbeing (L. Anderson et al., 2013). One way of making sure online services improve the quality of life of users is by designing services that enhance self-determination and facilitate the connection between users and service providers (S. Anderson et al., 2018). This way, service providers are more familiar with users' needs and expectations and can respond accordingly.

Service design is a human-centred, integrative and transformative approach to the development of services (Sangiorgi et al., 2019). As human-centred, service design plays a role in understanding and mapping people's experiences (Meroni & Sangiorgi, 2011), as integrative it incorporates multidisciplinary knowledge to map complex systems, and as transformative, the design of services has the potential to enhance the collective feeling of wellbeing (Sangiorgi et al., 2019). For this reason, S. Anderson, et al. (2018, p. 110) propose that services can be "transformative by design" to enhance people's wellbeing.

Transformative service design (TSD) encompasses the human-centred vision of design with the service design approach of capturing users' perspectives and providing companies capabilities to better understand their customer needs (Iriarte, Alberdi, Urrutia, & Justel, 2017). We consider users the experts of their experiences as they play a key role in transformative service design by proposing an agenda for the improvement of their wellbeing (Cottam & Leadbeater, 2004; Lundkvist & Yakhlef, 2004). In this research, we employed critical incident-style interviews to helps us have a deep understanding of people's mobility experiences to investigate current and potential service user needs. The findings generated from these interviews contribute with insights to inform transformative service design for digital technologies.

4 Method

In this research, we define journeys to work as the activities that people perform before and during a commute, including planning, familiarisation with the route, getting from one place to another, and any other activities included in this process. Following a transformative service design approach to understand users' experiences, we selected the Critical Incident Technique (CIT) as the method of data collection as it positions participants at the centre of inquiry and gives them agency to raise relevant events that impact their journeys.

4.1 Critical Incident Technique (CIT)

CIT is an inductive method of inquiry that supports the observation of human behaviour by triggering participants to recall stories that can be positive or negative experiences, which can then be categorised to address practical problems (Flanagan, 1954). Since its introduction to the social sciences, CIT has been applied to a variety of contexts and adopted by the service research field, including subject areas related to this study such as, service research (Bitner, Brooms, & Tetreault, 1990), autonomous self-service encounters (Matthew L Meuter, Ostrom, Roundtree, & Bitner, 2000), and dis/satisfaction in the online service environment (Holloway & Beatty, 2008). This method suits this research because it "obtains a record of specific behaviors from those in the best position to make the necessary observations and evaluations" (Flanagan, 1954, p. 355), which is aligned with our vision that service users the expert of their experiences.

CIT is a flexible and inductive technique (Flanagan, 1954), and it generates an in-depth record of events and a rich set of data (Gremler, 2004). However, it has received some criticism from the academic community. As the method relies on participants' recollections of events that happened in the past, reports may be subjected to personal bias or lack of memory (Michel, 2001). Also, because of its flexibility, the method has been inconsistently applied, and therefore, researchers should use it thoughtfully and acknowledge its weaknesses (Marcella, Lockerbie, & Baxter, 2013).

We made conscious effort to follow Flanagan's (1954) approach with minimal adaptations to be thoughtful and consistent in the application of CIT by having a clear aim and recording all details from participant's reports of critical incidents which are further detailed in the following section. For this research, a critical incident is defined as: *limiting situations as well as supporting strategies perceived by participants to cause disturbances or to improve their self-determination in the use of digital platforms to prepare for or during journeys.*

4.2 Data Collection

We conducted semi-structured interviews with eight people with a physical disability living in Brisbane, Queensland, Australia. Brisbane is the third most populous city in Australia (Australian Bureau of Statistics, 2019). Transport options include travelling by road, rail, river, footpaths, bikepaths, and air (Department of Transport and Main Roads, 2019). Public transport is delivered by buses, ferries, and train (Brisbane City Council, 2019). This purposive sample of participants were people with various levels of mobility abilities and familiar with using digital technology to plan for or during daily journeys. All the participants but one were also employed at the time of the interview. We distributed a link to a screening questionnaire via social media post and email for people to self-identify whether they were interested in participating. We used the Gross Motor Classification System (GMFCS) (CanChild, 2019) as a guide to describing different levels of mobility and asked participants to self-report which level corresponded to their movement abilities. This information provided a helpful understanding of the diversity of mobility located under the broad category of physical disability. However, no preference was given to the GMFCS level as selection criteria. Another relevant selection criterion was the participant's familiarity with the use of digital technology during commute because of the nature of the study. Table 1 shows participants' profiles according to the answers they provided in the screening questionnaire.

Each interview lasted on average forty minutes and took place at an agreed location between the researcher and the participant. One interview was conducted via Skype because of the participant's geographical location at the time of the study. Before the interview, each participant received by email a copy of the study's description, purpose, use of data and a copy of the consent form to become familiar with the research. When meeting in person, the researcher explained the study's objectives again, clarified questions and obtained informed consent before beginning.

Following Flanagan's (1954) advice, we had a clear aim for the interview, which was based on the critical incident definition. We asked participants to describe memorable examples of limiting situations or support strategies that impacted their self-determination during journeys and the role digital technology played during those incidents. In order to establish rapport, we started by asking participants to describe a typical journey that they usually undertake. The participants described their journeys in detail in sort of a timeline format, from the moment they prepare to leave, to the moment they arrive at their destination. They were also asked to describe how they adapted or dealt with unexpected events during journeys and if online services or digital platforms helped them to prepare for or during the journey. The interviews were conversational and participant-led with the researcher asking opportunistic questions when appropriate.

Because of the semi-structured, participant-led nature of the interviews, participants reported critical incidents not only about their journeys to work but also about other recollections of moments when they felt like their mobility was limited and self-determination was impacted, for example when going to restaurants and booking hotels. These reports have raised interesting perspectives not only about mobility but also about social participation in society. All the interviews were audio-recorded to include all the details of the incidents reported and to avoid data collection bias. The audios were later transcribed verbatim to prepare for data analysis.

Table 1. Participant's profiles.

ID	Age	Gender	Commuting frequency	Transport type	Movement ability levels
P1	25-30	Male	2-3 times a week	Bus, train, own car	Level 4
P2	25-30	Male	Daily	Own car	Level 4
P3	25-30	Female	Rare occasions	Train, taxi	Level 4
P4	25-30	Female	Rare occasions	Taxi	Level 4
P5	25-30	Female	Rare occasions	Bus, train, taxi, own car	Level 4
P6	25-30	Female	2-3 times a week	Bus, train, taxi, own car	Level 2
P7	25-30	Male	Rare occasions	Bus, train, taxi, own car	Level 5
P8	25-30	Male	Daily	Own car	Level 3

4.3 Data Analysis

An inductive approach to data analysis was followed with the support of the ATLAS.ti software. Interview transcripts were uploaded to the software, and thematic analysis was conducted to categorise relevant incidents. In order to initially select critical incidents, we read the transcripts multiple times to become familiarised with the data.

To address the criticism that CIT has been inconsistently applied (Marcella et al., 2013), we generated a diagram with criteria for incident inclusion and exclusion containing key questions to guarantee a consistent selection of incidents. This step helped us to filter the transcripts and identify the critical incidents, which were later thematic analysed. The diagram (Figure 3) was created based on the research aims and definition of a critical incident. In order to determine if a critical incident was usable or not, we followed the diagram starting at the top and moving down following the arrows according to the response for each question. The diagram also assisted us in dividing critical incidents into three groups, which are described in Table 2.

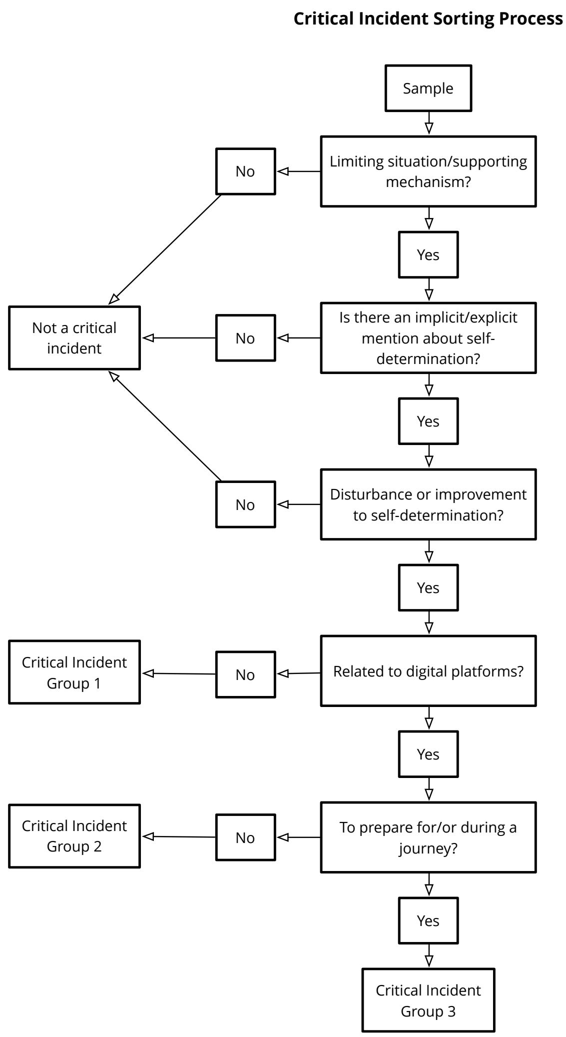


Figure 3. Critical incident sorting process diagram developed specifically for this research. Source: Authors.

In total, 54 usable incidents were identified using the sorting process. Table 2 describes each group, presents the number of critical incidents in each group, and provides examples of the content of the incidents within each group.

The groups demonstrate that participants' reports of critical incidents can be separated in three groups: group 1, when they only refer to impacts to their self-determination; group 2, when there is an interaction with a digital platform in addition to impact to their self-determination; and group 3 when they mentioned interaction with digital platforms during journeys that helped in situations where their self-determination was hindered, or when digital platforms improved self-determination. In the context of this study, digital platforms represent websites or applications that offer services or information that can be accessed by users through a computer, tablet or smartphone both online or offline, such as Facebook and Google.

Table 2. Critical incidents divided by group.

Group description	Number of Critical Incidents and %	Examples
Group 1 – Limiting situations as well as supporting mechanisms perceived by participants to cause disturbances or to improve their self-determination.	**24** (44.4%)	Issues with train ramps not being brought out by guards. Good reports about accessibility overseas. Problems with the accessibility of footpaths, hotel rooms, restaurants, event venues. Ability to problem solve and frustration of having to ask for help. Difficulties with taxi drivers. Blocked footpaths and broken lifts.
Group 2 - Limiting situations as well as supporting mechanisms perceived by participants to cause disturbances or to improve their self-determination in the use of digital platforms.	**11** (20.3%)	The importance of websites to have realistic photos of their venues. NDIS website provides vague information. Conflicting information about accessibility (online vs. reality). Problems with many different understandings of accessibility. Advantages of online peer support networks. Online reviews of services and venues (making informed decisions). Gaming and the feeling of equality. Issues around booking transport or accommodation for wheelchair users online.
Group 3 – Limiting situations as well as supporting mechanisms perceived by participants to cause disturbances or to improve their self-determination in the use of digital platforms to prepare for or during daily journeys.	**19** (35.2%)	Advantages and disadvantages of ride-share services like Uber. Booking alert could help with train ramp issues. The necessity to call venues to double check or confirm online information about accessibility to plan for a journey. Online platforms assist in finding a plan B for journeys. More accurate and consistent online information on accessibility can help to plan for journeys. Virtual tours of journeys could facilitate the decision-making process before the journey. Communication with public transport provider is difficult. Vagueness or lack of update of online public transport information.

5 Initial Findings

A thematic analysis of the 54 critical incidents generated 5 categories and 24 sub-categories. Open coding was conducted initially using the research's critical incident definition as the unit of analysis. Continuous re-examination was performed to refine the codes and group them into themes. Table 3 shows the classification system of all categories and sub-categories identified in the analysis process.

Table 3. Critical incidents divided by categories and sub-categories.

Category	%	Sub-categories	%
Planning and decision making (23)	**29.1%**	The need to contact the service provider to check information provided online (9)	11.4%
		Relying on others (5)	6.3%
		Planning for journeys (4)	5.1%
		Online support to problem-solve (2)	2.5%
		Skills and confidence (2)	2.5%
		Decision making (1)	1.3%
Transport options (21)	**26.6%**	Taxi (6)	7.6%
		Public transport accessibility (5)	6.3%
		Rideshare (4)	5.1%
		Public space accessibility (4)	5.1%

		Overseas experience (2)	2.5%
Technology (15)	**19%**	Suggestions for improvement (8)	10.1%
		Online peer support (3)	3.8%
		Online reviews (2)	2.5%
		NDIS (1)	1.3%
		Virtual environments (1)	1.3%
Policy and standards (12)	**15.2%**	Providing feedback to service providers (4)	5.1%
		Lack of understanding of user needs (3)	3.8%
		Accessibility information (2)	2.5%
		User as the expert (2)	2.5%
		Local council engagement (1)	1.3%
Communication (8)	**10.1%**	Photographs (4)	5.1%
		Inaccurate online accessibility information (3)	3.8%
		Outdated online information (1)	1.3%
Total: 79 codes			

Initial findings show that the largest category of limiting situations and support strategies impacting participants' self-determination in the use of digital platforms during journeys is planning and decision making (29.1%), followed by transport options (26.6%), technology (19%), policy and standards (15.2%), and communication (10.1%). Table 4 presents definitions of the 6 main categories, as well as sample quotes for both limiting situations that represent barriers for participants and supporting strategies that enable self-determination. Following the table, we discuss each of these categories.

Table 4. Categories definitions and examples from interview transcripts.

Category	Definition	Examples	
		Barriers	Enablers
Planning and decision making	Strategies employed to problem-solve in order to overcome barriers or unexpected events. Planning to avoid unnecessary risks.	I've become more conscious of asking people to stand up and let me have that seat because I obviously can't, I don't feel stable enough to stand on a moving train or bus and sitting sideways is painful and sitting backwards is also very painful. […] It's so weird because I'm so independent and having to ask for help, it's not in my nature. (P6, relying on others)	Yeah, genuinely if a problem pops up I'll then rely on online services to help me problem solve that issue. […] I think for the most part, like I'll potentially use Google Maps sometimes to not so much plan the trip but to see how long it'll take, just to ensure everything runs efficiently and timely and smoothly. (P7, online support to problem-solve)
Transport options	Positive and negative aspects of public transport, taxi and rideshare companies.	I would often get on the train and the guard who normally brings the ramp would often forget and I'd be left on the train. There was probably around, I'd say six times, that I was waiting for someone to get around and I tried to call them and they didn't	I'm lucky that I found a couple of regular drivers that I use quite a lot but the issue is that obviously because they're, because I like them, they are popular amongst all my mates as well, so they get used regularly, so I might only

		listen and the train just left. And I was stuck on the train. (P1, public transport accessibility)	get them for particular drives. (P7, taxi)
Technology	Digital platforms that provide accurate and relevant information as well as peer support networks that help people with disability.	But yeah there is no like travel page for disabled people to connect and like – no, don't go here, do this, do that. (P4, online peer support)	People doing reviews. People doing video blog reviews and stuff like that. […] That's what I try to do. So, I find that's very helpful for people. (P5, online reviews)
Policy and standards	People have different understandings of accessibility success, and therefore the information provided or solutions offered do not correspond to the actual needs of users.	Some people have very different ideas of what's successful or not. So, it was last weekend, a friend who's also in a wheelchair, we were going up to Noosa for two nights and he booked a place and he was real happy with it. He said, Yep. Accessible. They got it. We booked it fine and then when he got there, um, their understanding of what accessible was, was completely different to what he needed. (P2, accessibility information)	Because I've had this unfortunate incident it has made me very wary of trying X, Y, Z and the same thing is for medication. A lot of doctors, they will say do this, but I'll often get a reaction. So, I'm allergic to codeine so a lot of pain relief has that in it. Yeah, it feels some days that the odds are so stacked up, but for me, being a bit of a risk assessor, for me it's really about continuing to minimising things that I don't need to have to come in contact with. Just to make my life easier. (P6, user as the expert)
Communication	Communication through digital platforms and differences between what is available online vs. reality.	It can get annoying sometimes because in my head versus what they say can be totally different […] it's not updated. Like I'll know this where I am going, but the app is there saying take four busses, and I am there I only need to take one or two I mean, that's ridiculous. (P6, outdated online information)	I check Tripadvisor because they normally have realistic pictures of rooms and stuff. Where you get your hotel, the pictures of the rooms on the hotel website, they use wide angle lenses, which distorts everything and makes it look wider than it actually is. So, I always use Tripadvisor to see real pictures. (P1, pictures)

5.1 Planning and decision making (29.1%)

Learning how to find strategies to overcome barriers during journeys makes a big difference in people's decisions about whether or not they believe they can commute to a particular location. Participants explained that this decision-making process is directly related to their travel skills and confidence. However, it can also be influenced by the accessibility information they can find online. If they can independently find a way to plan for the journey or solve problems during a journey they can act with self-determination, on the other hand, it can be frustrating if they do not succeed.

Participants also mentioned that if they cannot independently solve a problem, asking for help to other people is used as a problem-solving strategy. In most of the cases relying on others to overcome barriers during journeys has been reported as a limiting situation that they experience. However, to avoid this situation and to prevent unnecessary risks or tricky situations, participants talked about the importance of planning journeys in advance.

Planning was the most relevant sub-category within problem-solving strategies. According to participants, it is quite hard to do things spontaneously because planning requires time and it usually starts hours, if not days before the actual commute takes place. It was mentioned that part of the planning process is the necessity to contact service provides to double-check information provided online. Contacting service providers was presented both as a supporting strategy because it gives people more confidence about the information provided online, but also a limiting situation because sometimes what is said online is not accurate or is outdated.

5.2 Transport options (26.6%)

The physical accessibility of buses and trains were described as an issue. Participants described critical incidents in public transport where, for example, they would not be able to get on or off the train because the ramp for the wheelchair would not be brought out for them. Some participants described that train stations in other countries they have visited were accessible, and they did not have to rely on guards or other people to bring a ramp for them. These overseas experiences were mentioned as a positive impact on their self-determination because they felt confident to go everywhere because they would know that every transport facility would be accessible.

Most of the reported incidents of experiences with taxi services were negative. Participants explained that they do not feel they have much control of where they are going during journeys. Another example was that some drivers charge more than what they are supposed to charge because they start the meter before loading the wheelchair into the car. It is rare to find a driver that they can trust, and when they do, they might only get them for particular drives because other people might request the same driver.

The experiences with rideshare companies were reported as both positive and negative. Some participants endorsed companies like Uber for their reliability in having drivers that can assist wheelchair users, while others said that this service does not work for them because they have different needs and the cars are not suitable. Security concerns were also raised in terms of the lack of security measures compared to taxi companies.

5.3 Technology (19%)

Social media provides the opportunity for people with mobility-related disability and other people in similar situations to have a voice, connect and build networks of peer support. Participants expressed that these networks are enabling strategies that help them in many situations, such as travel tips, updates on public transport (e.g. if a train track is out), and support services recommendations. The importance of these networks is the opportunity they give for people to make informed decisions about what services to use or what routes to take to make their journeys more seamless.

Participants also provided many insights on potential ways in which digital technologies could support them on their journeys. Some of the comments were around the possibility of restaurants, bars, hotels and other venues to have standard guidelines to follow in order to provide more specific, accurate and consistent information about the accessibility of their spaces on their websites. Another comment related to public transport was to have some app to alert train guards on platforms to bring the ramp out for people that use wheelchairs.

Virtual environments were reported as spaces where participants feel empowered and equal. An example is when a participant reported being able to perform really well on an online game and to feel like the other participants were unaware of their physical differences.

5.4 Policy and standards (15.2%)

Finding within this category demonstrated that people have different understandings about accessibility success. Participants explained that in many occasions, they have read or received information about accessibility that did not correspond to their specific needs, resulting in the venue actually not being accessible to them. Because people with mobility-related disabilities are the ones having to adapt to different physical barriers during journeys, they have an expert perspective on what is best for them. Some participants expressed that sometimes having access to ramps and lifts is not sufficient to supply their needs, and there is a need for venues to consider accessibility facilities that go further than providing ramps and lifts. For this reason, some participants engage in providing feedback to service providers with suggestions on how to improve the physical space or the information that they give online. However, sometimes the response is positive, but on other occasions, it is not even possible to establish contact with service providers.

In this category, participants also commented about the lack of action from local councils after engaging with the disability community. Others talked about the NDIS online platform and its problems with vague information. There were also comments about mobility issues related to public space accessibility, such as steep ramps, limited accessible parking and pathways blocked for construction.

5.5 Communication (10.1%)

Participants mentioned that on many occasions, the information provided online about transport facilities and accessibility does not correspond with reality.

For example, in some situations, the information about public transport is outdated, and that can influence whether or not a participant decides to undertake a journey. This inaccuracy also happened with accessibility information, especially in hotel websites, where they say they can provide accessible rooms, and when the guest arrives, they see the room cannot accommodate them. One common mistake that hotels, restaurants and other venues make is to provide photographs of their space that were taken with wide-angle cameras, which distorts some of the dimensions of door widths, for example. Participants said that they usually try to access digital platforms that provide realistic photos of spaces, such as Tripadvisor, to make their assessment of whether or not space is accessible to them.

6 Design implications

These preliminary results provide insights into five key areas that can be explored for the design of new services from the end-user perspective. However, further investigation is also required to understand the challenges of service providers involved in the service delivery system. This initial investigation is the first stage of broader research, which envisages the application of findings in the development of digital platforms that would enable people with disabilities the ability to plan and problem solve their daily or routine journeys beforehand. Based on the initial findings, we suggest that a transformative service design approach to the design of such service or enhanced P2P digital platform should address the following:

- A Digital Strategy Toolbox (of planning and decision-making strategies): this will comprise delivery strategies that combine existing support services with successful problem-solving practices of people with lived experience of disability.
- An online collaborative platform for up to date users' rating of transport options.
- A co-produced tool or communication channel that allows end-users and service providers to communicate and share accessibility problems and solutions. This tool will help increase stakeholders understanding of accessibility by improving communication channels between service users and service providers for users to be able to communicate their needs.
- A Reality Map or Viewer, based on end-users' input, and that display consistent and relevant information about accessibility online.

7 Conclusion

This paper has reported research that undertakes a transformative service design approach and a critical incident method to identify areas where design can improve the interaction between people and digital technologies to enable self-determination in everyday journeys. The critical incident interviews have allowed the identification of issues that people with mobility-related impairments face in their journeys to work and in other aspects of their lives and how they manage to overcome these barriers. Participants mentioned barriers and enabling strategies and, in some cases, pinpointed how technology assisted them during these critical moments. This study is the first phase of broader research and therefore the ideas and design implications presented will continue to evolve as the study progresses. Future research steps will involve engagement with service providers and focus on applying the findings in the development of guidelines supporting the design of digital platforms that enable self-determination for people with mobility-related disabilities.

8 References

Adkins, B., Chamorro-Koc, M., & Stafford, L. (2015). New Mobilities for Accessible Cities: Toward Scenarios for Seamless Journeys. In D. Araya (Ed.), *Smart Cities as Democratic Ecologies* (pp. 200-218). New York, NY: Palgrave Macmillan.

Anderson, L., Ostrom, A. L., Corus, C., Fisk, R. P., Gallan, A. S., Giraldo, M., . . . Williams, J. D. (2013). Transformative service research: An agenda for the future. *Journal of Business Research, 66*(8), 1203-1210. doi:10.1016/j.jbusres.2012.08.013

Anderson, S., Nasr, L., & Rayburn, S. W. (2018). Transformative service research and service design: synergistic effects in healthcare. *The Service Industries Journal, 38*(1-2), 99-113. doi:10.1080/02642069.2017.1404579

Australian Bureau of Statistics. (2016). Disability, Ageing and Carers, Australia: Summary of Findings, 2015. Retrieved from http://www.abs.gov.au/ausstats/abs@.nsf/0/C258C88A7AA5A87ECA2568A9001393E8?Opendocument

Australian Bureau of Statistics. (2019). 3218.0 - Regional Population Growth, Australia, 2017-18. Retrieved from https://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/3218.0Main+Features12017-18?OpenDocument

Bitner, M. J., Brooms, B. H., & Tetreault, M. S. (1990). The Service Encounter: Diagnosing Favorable and Unfavorable Incidents. *Journal of Marketing, 54*(1), 71-84.

Boyce, W., Malakar, S., Millman, R., & Bhattarai, K. (1999). Physically disabled children in Nepal: a follow up study. *Asia Pacific Disability Rehabilitation Journal, 10*(1).

Briometrix. (2017). Navability accessible navigation. Retrieved from https://www.briometrix.com/navability/

Brisbane City Council. (2019). Public transport. Retrieved from https://www.brisbane.qld.gov.au/traffic-and-transport/public-transport
Burns, C., Cottam, H., Vanstone, C., & Whinhall, J. (2006). *Transformation Design*. London: Design Council.
CanChild. (2019). GMFCS. Retrieved from https://www.canchild.ca/en/resources/42-gross-motor-function-classification-system-expanded-revised-gmfcs-e-r
Chamorro-Koc, M., Stafford, L., & Adkins, B. (2015). *Seamless journeys enhancing accessibility to work through digital technologies for people with mobility-related impairements*. Paper presented at the IASDR2015 Interplay, Brisbane, Australia.
Clickability. (2019). What is Clickability? Retrieved from https://clickability.com.au/about/
Cottam, H., & Leadbeater, C. (2004). *Red paper 1 health: co-creating services*. Retrieved from London: https://www.designcouncil.org.uk/sites/default/files/asset/document/red-paper-health.pdf
Department of Transport and Main Roads. (2019). Travel and Transport. Retrieved from https://www.tmr.qld.gov.au/Travel-and-transport
Flanagan, J. C. (1954). The Critical Incident Technique. *Psychological Bulletin, 51*(4), 327-358.
Gremler, D. D. (2004). The Critical Incident Technique in Service Research. *Journal of Service Research, 7*(1), 65-89. doi:10.1177/1094670504266138
Holloway, B. B., & Beatty, S. E. (2008). Satisfiers and Dissatisfiers in the Online Environment. *Journal of Service Research, 10*(4), 347-364. doi:10.1177/1094670508314266
Iriarte, I., Alberdi, A., Urrutia, E., & Justel, D. (2017). Beyond customer satisfaction. Supporting organisational change through Service Design. A case study in the insurance industry. *The Design Journal, 20*(1), S424-S434. doi:10.1080/14606925.2017.1352950
LaGrow, S., Wiener, W., & LaDuke, R. (1990). Independent travel for developmentally disabled persons: A comprehensive model of instruction. *Research in Developmental Disabilities, 11*(3), 289-301. doi:10.1016/0891-4222(90)90014-Y
Lundkvist, A., & Yakhlef, A. (2004). Customer involvement in new service development: a conversational approach. *Managing Service Quality: An International Journal, 14*(2/3), 249-257. doi:10.1108/09604520410528662
Marcella, R., Lockerbie, H., & Baxter, G. (2013). *Critical incident technique as a tool for gathering data as part of a qualitative study of information seeking behaviour.* Paper presented at the Qualitative Market Research: An International Journal.
Mcloughlin, I., Mcnicoll, Y., Beecher Kelk, A., Cornford, J., & Hutchinson, K. (2019). A 'Tripadvisor' for disability? Social enterprise and 'digital disruption' in Australia. *Information, Communication & Society, 22*(4), 521-537. doi:10.1080/1369118X.2018.1538382
Meroni, A., & Sangiorgi, D. (2011). *Design for Services*: Gower.
Meuter, M. L., Ostrom, A. L., Bitner, M. J., & Roundtree, R. (2003). The influence of technology anxiety on consumer use and experiences with self-service technologies. *Journal of Business Research, 56*(11), 899-906. doi:10.1016/S0148-2963(01)00276-4
Meuter, M. L., Ostrom, A. L., Roundtree, R., & Bitner, M. J. (2000). Self-service technologies: Understanding customer satisfaction with technology-based service encounters. *Journal of Marketing, 64*(3), 50-64. doi:10.1509/jmkg.64.3.50.18024
Michel, S. (2001). Analyzing service failures and recoveries: a process approach. *International Journal of Service Industry Management, 12*(1), 20-33. doi:10.1108/09564230110382754
Moore Sohlberg, M., Fickas, S., Lemoncello, R., & Hung, P.-F. (2009). Validation of the Activities of Community Transportation model for individuals with cognitive impairments. *Disability and Rehabilitation, 31*(11), 887-897. doi:10.1080/09638280802356260
National Disability Insurance Agency. (2018). About us NDIS. Retrieved from https://www.ndis.gov.au/about-us
Raja, D. S. (2016). *Bridging the disability divide through digital technologies*. Retrieved from http://pubdocs.worldbank.org/en/123481461249337484/WDR16-BP-Bridging-the-Disability-Divide-through-Digital-Technology-RAJA.pdf
Ryan, R. M., & Deci, E. L. (2017). *Self-Determination Theory : Basic Psychological Needs in Motivation, Development, and Wellness*. New York: The Guilford Press.
Sangiorgi, D. (2011). Transformative Services and Transformation Design. *International Journal of Design, 5*(2), 29-40.
Sangiorgi, D., Lima, F., Patrício, L., Joly, M. P., Favini, C., Sangiorgi, D., . . . Favini, C. (2019). A Human-Centred, Multidisciplinary, and Transformative Approach to Service Science: A Service Design Perspective. In *Handbook of Service Science, Volume II* (pp. 147-181): Cham : Springer International Publishing : Imprint: Springer.

Schalock, R. L., & Verdugo, M. A. (2002). *Handbook on quality of life for human service practitioners*. Washington, DC: American Association on Mental Retardation.
Shogren, K., Bradley, V. J., Gomez, S. C., Yeager, M. H., Schalock, R. L., Borthwick-Duffy, S., . . . Wehmeyer, M. L. (2009). Public policy and the enhancement of desired outcomes for persons with intellectual disability. *Intellectual and Developmental Disabilities, 47*(4), 307-319. doi:10.1352/1934-9556-47.4.307
Stafford, L., Marston, G., Chamorro-Koc, M., Beatson, A., & Drennan, J. (2017). Why one size fits all approach to transition in Disability Employment Services hinders employability of young people with physical and neurological disabilities in Australia. *Journal of Industrial Relations, 59*(5), 631-651. doi:10.1177/0022185617723379
Wehmeyer, M. L. (2005). Self-Determination and Individuals with Severe Disabilities: Re-Examining Meanings and Misinterpretations. *Research and Practice for Persons with Severe Disabilities, 30*(3), 113-120. doi:10.2511/rpsd.30.3.113
World Health Organization. (2011). *World report on disability*. Retrieved from Malta: https://apps.who.int/iris/bitstream/handle/10665/70670/WHO_NMH_VIP_11.01_eng.pdf;jsessionid=0E86EE58CFBDE72F8D76CDBE78DF0E91?sequence=1

About the Authors:

Carla Sartori do Amaral: is a PhD candidate interested in the area of transformative service design. Her current research focuses on improving the mobility experience of young people with physical disabilities by developing a peer-to-peer framework for digital platforms.

Dr Marianella Chamorro-Koc: current research in on People Sustained Engagement with Technologies in two distinctive areas: Design for Health Innovation, and Viable Futures through Design. Marianella leads the QUT Design Lab Program of Design for Health and Wellbeing.

Dr Amanda Beatson: research focus is on optimising customer value; particularly how to create and maintain positive service experiences and organisational image. She publishes broadly including, Journal of Business Ethics, Journal of Marketing Management and The Service Industries Journal.

Dr Sven Tuzovic: is Senior Lecturer of Marketing at QUT Business School. Prior to QUT, he was Associate Professor at Pacific Lutheran University, USA. His research focuses on services marketing, customer experience management, and the adoption of service technologies.

Acknowledgement: The research team would like to thank all participants for their support and for sharing their stories and experiences. Their contribution was central to the insights presented in this paper.

Ethics through Design: Medical data systems, chronically ill data subjects, and all the invisible things in between.

Luján Escalante, Maria[*a]; Büscher, Monika[a]; Tsekleves, Emmanuel[a]; Andersen, Mads[b]; Nielsen, Laura[b]; Selinas, Paris[a]; Moffat, Luke[a]; Robins, Jessica[a]

[a] Lancaster University, Lancaster, UK
[b] Alexadra Institute of Technology, Aarhus, Denmark
* m.lujanescalante@lancaster.ac.uk

Ethics of medical data practices and technologies are becoming the focus of growing research that intersect several fields, including Design. In this paper we posit that Ethics through Design offers a pragmatic approach to creatively address ethical impact assessment challenges in the medical domain. Through a case study of an EU-funded research project (SODA) that explores multiparty computing in medical contexts, such as dementia, we explore the idea of contextual and participatory ethics, as a way of *doing* ethics together with vulnerable data subjects and system end-users. We present the project research methodology and findings that drove us to more deeply understand data subjects' perceptions of own data practices and how they influence their wellbeing, in contrast with values and interests of system end-users' practices. Those groups are not usually studied in connection, however we are proposing that their intersection opens a spectrum of possibilities for future design research practice in the area of trustee systems that contributes to ethics of technology.

Keywords: Ethics, Technology, Multiparty Computing; Dementia; Data, Ethics through Design.

1 Introduction and Project Context

Digital technologies are becoming central to health and care practices. They mediate complex socio-technological systems and people whose data is being collected and used, known as data subjects. On a social level, data mediations can support development of structures of health services and public policy; while at the individual level, they are affecting care experience and ultimately, identities and narratives of health and illness. Interests in collecting, sharing, analysing and comparing medical data vary, and are shared by data subjects and professionals to improve medical knowledge, public health, clinical care, health devices, products and services.

Multiagency data interoperation renders individual invisible transactions and intimate negotiations– data subjects and informal caregivers who often unintentionally work at generating, interpreting, and at times misusing measurements — with clinical situated practices and pre-programmed algorithms. Data transactions, far from neutral, are subjected to gender, class, nationality, personal history and contextual politics. Data subjects may or may not understand when and how they are providing data, what data sharing implies or even what data is or means for them. At the same time, data subjects have conceptions, ideas and rights on their data. As these intersect, a range of frictions arise.

Clinical and medical data collected through digital devices (e.g. insulin pumps) may usefully converge to form Biomedical Big Data (BBD). The 'datafication' (Van Dijck, 2014) of medical systems may yield new insights through machine learning and algorithmic categorisation, data might be repurposed to great effect to inform medical research more widely. However, currently, this processing is highly obstructed by incompatible data sets and systems that cannot interoperate across countries, neither agencies, eg. hospitals, private companies, general practitioners and care organisation. National and local data regulations place responsibility on data controllers and system end-users that spend significant time (weeks, months, even years) before information can be shared and become beneficial. Challenges also arise, because the "benefits" of data sharing may not directly impact data subjects, the promise is of a better healthcare future that does not belong to them.

Medical datafication may even imply a "trade off" of values, rights and freedoms. In the European Union fundamental rights regarding the protection of personal data, non-discrimination and the presumption of innocence are supported by values of dignity, freedom, democracy, equality and the respect of human rights (Büscher et al., 2018). The challenges of technological responsible innovation in alignment with human rights are formidable; in part because they are complex, in part because they are distributed across organisations, cultures and countries, but also because they conceal data practices and intimate negotiations. In the medical domain ethical tensions arise in particularly significant ways, the "trade off" in caring systems entails disparate power relations, vulnerable data subjects and fragile spaces and temporalities.

1.1 Multiparty Computing System in the Medical Domain

The overall aim of SODA project is to explore secure uses of Multiparty Computation (MPC) in the medical domain, focusing on chronic illnesses. MPC has the potential to offer data usage and multiagency interoperability without *actually* sharing data. Instead, processing is done on encrypted data, making it an efficient privacy preserving technique in which different parties never have to handle each other's data. This paper describes one of SODA studies; SODA-Lancaster lead by ImaginationLancaster in collaboration with Centre for Mobilities research Cemore (Lancaster, UK) and Alexandra Institute of Technology (Aarhus, Denmark) and particularly engages with the case of dementia data practices.

We used Collaborative Design processes to explore spaces and knowledges that emerge from the engagement with data subjects living with dementia and their caregivers as well as system end-users; clinicians, data scientists and BBD systems controllers. The aim was *not* to co-design artefacts, services nor products, but to inform an idea of collaborative contextual ethics. The aim was to *do* Ethics through Design (EtD). This paper discusses MPC ethical challenges and opportunities in the dementia domain emerging from EtD research approach.

1.2 The Challenge: Let's talk about data

For certain chronic diseases such as diabetes and renal disorders, data practices are very important part of controlling, coping and making sense of data subjects' own illnesses. In such cases, data interface with one's own body, social aspects of the disease and even, community making. In SODA studies with diabetics[1], stories about "managing front and backstage of data" emerged; for example, it was common to volunteer data in forums and communities where they can be helpful ("to myself or others"), but also hiding it in contexts in where data about illnes could be stigmatizing. We are calling these sort of decisions, intimate negotiations, and they are affected by and affecting trust.

Data practices for people living with dementia are radically different. Neither data subjects, nor their caregivers, are in direct control of dementia data practices. The clinical monitoring is not mediated by personal or clinical devices, there are not any numbers to follow. The sporadic monitoring is purely qualitative, caregivers and clinicians follow aspects that indicate ability to keep up with everyday activities; managing bank accounts, visiting pharmacy, ability to drive, to make a meal.

In addition, the profile of a SODA participant living with dementia, is of a person who has grown older with very little contact and familiarity with personal digital devices, neither health devices nor personal computers or social media platforms.

In the specific case of the UK, the National Health System (NHS) owns patient's medical data. A culture of keeping one's own personal records - exam results, analysis, diagnostics, medical histories - has not been cultivated. Within the NHS system, personal medical data operates only at a local level. Data subjects rarely have access to their own records and in many places, medical data is still collected and stored physically. The NHS system is rapidly changing with current projects on a national scale of digital data repositories.

In contrast, BBD scientists and users of medical systems such as NHS, embrace a data epistemology that sets apart data subjects. It relies on knowledge produced by the analysis of patterns (Kitchin, 2014), in which the individual (its personal context, needs, data practices) is discarded in favour of data volume, significant enough to become a pattern. This has two consequences, the de-individuation of data subjects and the presumption of data as objective, anonymous and interoperable. The latter manifested in ideas such as, the more data is collected the nearer to reality data brings us, or, data sets can be added together, cross-analysed and used with different purposes. Such dataism (Van Dijck, 2014) can 'introduce machinic forms of reasoning into human affairs in ways that are difficult to align with human rights and values' (Büscher et al., 2018, p. 257).

The combination of individual data practices and system data practices opens up a relation rarely explored. In our investigation, the combination of digital divide and NHS data culture, means that ideas such as, personal medical data sharing, and the mere idea of data, are very unfamiliar, even abstract for data subjects. This lack of touch with one's own data accentuates digital inequalities of the system. Before exploring forms of given consent, perceived fears or benefits of data sharing and trustful systems, our study had to step back and start with questions of data; what is data? when or how do people living with dementia, often treated as *patients*, become *active* data subjects? what is the matter of data systems and how do data matter for subjects? The task was to design a methodology that explored that relation and bring together(apart) two perspectives within the system that data mediates; data subject's intimacy and the system's top-down vision.

[1] Still work in progress, publication follow later this year.

2 Our Approach

The project premise is that co-design processes have the potential to create spaces for knowledge exchange in which the development of participants' own voice and agency are nurtured and supported. The aim of co-designing contextual ethics was to open up a relation that is usually flattened down or hidden - within datafied infrastructures of data pattern and data volume - by including the perspectives of; 1) data subjects and 2) system end-users.

In the case of people living with dementia, co-design also has the potential to directly benefit participants, as creative activities with peers and professionals constitute a much-needed opportunity to socialize, boost well-being and quality of life (Luján Escalante et al. 2017, Rodgers, 2018). Dementia involves neurophysiological symptoms such as loss of memory, mental agility, balance, mobility, and although there is no cure for it, cognitive and behavioural interventions can be most beneficial at improving life quality and slowing down the decline (Forbes at al., 2013).

The research methodology followed a design-led, cross-disciplinary, approach (participatory action research) (Büscher et al., 2004; Chevalier et al., 2013) inspired by the field of social futures research (Urry, 2016). It used creative methods including, play (Luján Escalante et al. 2017, Tsekleves et al. 2018), persona and scenarios (Wärnestål et al., 2014, Nielsen 2011), music, props and participatory storytelling (Kankainen et al., 2012; Morrissey, 2016)

In the case of end-users, we experimented with methods such as value scenarios (Nathan et al. 2007), controversy mapping and public experimentation (Marres, 2009) were part of co-design workshops used for 'infrastructuring' debate of diverse interests (Dantec and DiSalvo 2013).

2.1 Ethics through Design

In both cases, co-design methods were used to collect, assess, validate and contrast rich descriptions of participants' ideas, practices and perceptions. We posit this as Ethics through Design (EtD).

In Sanders and Stappers' (2008) seminal definition, co-design refers to 'the creativity of designers and people not trained in design working together in the design development process' (p. 6). EtD is not concerned with what is designed, but strictly with the value that emerges in co-design processes, conceived as a *milieu*, as a site that catalyses affections, knowledge and creative, generative, encounters. Co-design as *site of emergence* is then, temporary, fragile, heterogeneous and in conflict. (Luján Escalante, 2019).

EtD is a pragmatic approach to creatively address ethical challenges. It draws on Value Sensitive Design (Friedman, 1996), disclosive ethics (Introna, 2007), ethical impact assessment (Petersen et al., 2016, CEN CWA SATORI project 2016), responsible research innovation (von Schomberg 2013, Liegl et al., 2016) and principles and values to design IT systems in radically careful and carefully radical ways (Büscher et al. 2014). The EtD approach aims to be transformative as participants become responsible for innovation, having a much higher stake in its design, making and understanding (Hartswood et al., 2002; Couvreur & de Goossens, 2011) socio-technological knowledge that is always political, as it is concerned with the power of hiding or offering visibility, inclusion and respect to the individual.

EtD follows the idea that attention to the social and ethical is not a constraint on IT innovation, but, on the contrary, the key to creating high quality IT for human empowering. The initiative asks how more ethically, socially circumspect and flexible IT research and innovation can be achieved if design can support accessibility to better drawn an inclusive “bigger picture”, with detailed attention to capacity of balancing benefits and losses (Büscher et all. 2018). EtD aims to put values and ethics into practice, to explore aspirations, visions and ideas about data practices.

3 Research Design

3.1 Data Subjects

Partnered with Neurodropin Center and their support group in Lancaster, UK, 3 sessions were designed and facilitated with 6 participants living with dementia, 2 caregivers, 2 researcher co-designers, one ethical facilitator, a cartoonist and one storyteller. Sessions lasted around 2 hours. Participants arrived and settled in the space over tea and biscuits, sessions started with a music game, as an ice breaker and ended with a community lunch.

3.1.1 Exploring issues of Consent creatively

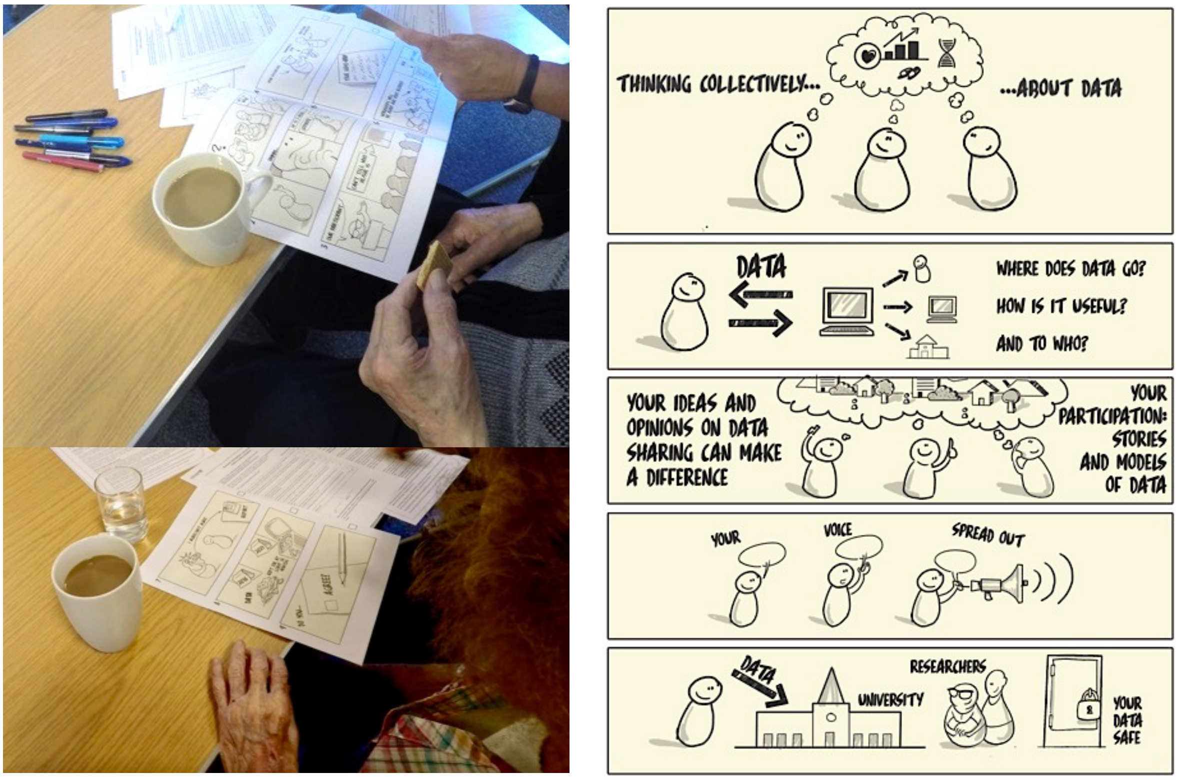


Figure 1: In the right, an extract of the Project Information Sheet. In the left, participants engaging with EtD consent tool, that included Participant Ethical Approval, Research Participation Consent and Project Information.

Experience from past co-design projects with people living with dementia (Luján Escalante et al. 2017, Tsekleves et al., 2018, Luján Escalante 2019), made evident that processes of obtaining participant consent was not satisfactory, as caregivers and researchers had to read and explain point by point the documents, defeating the process of independent consent.

EtD proposes ethical consent as a collaborative and creative process, moving beyond box ticking to explore consent as an opportunity for trust building via creative encounters and meaningful conversations. A tool was designed to collaboratively engage with an informed consent process. Ethical forms were ‘translated’ into visual media (See Figure 1), using comic strip format, and were used as tools to mediate our first encounter with participants and engaging them. The cartoons provided light relief from the written word, they illustrated and opened up debate about serious and sensitive topics. Furthermore, as a ‘visual form they are simple but ideas rich’ (Barlett, 2013), and worked as a boundary object (Star & Griesemer, 1989).

3.1.2 Participatory storytelling, Music and Props.

Figure 2: Props-as-probes: In the left, participatory storytelling character building. In the right, bottles and pharmacy paper bags, as props to facilitate conversations about medical data practices. Also, props to facilitate movement and participation.

Probes are commonly deployed in dementia projects (Wallace et al., 2013a and 2013b). With a shorter project duration, we used ‘props-as-probes’ (Morrisey et al., 2016) prioritizing quick and creative action in situated contexts. Props served as scaffold of design responses open but bounded; emphasizing the tangible and interlinked relation between creativity, communication and connection, constituting both the ends and the means of our iterative co-design process. The combination of props and music, allowed participants to be playful, to connect with the workshop activities, and to create social bonds. Props also were used to dress-up fictional characters in participatory story-telling, or to represent ideas such as personal medical data, data systems, money, time, medical treatments (See Figure 2).

By using participatory story-telling we drawn on ‘performative experience design’ (Kankainen et al., 2012) and story-telling in service design (Spence et al., 2013). The approach explored spontaneous performance and participation in narrative. It provided a platform from where different roles and rehearsals of self-expression, including verbal or non-verbal dialogue, sprung. Participants co-designers shifted from role to role, from one story node to other, creating a sense of freedom – from patient to doctor, from baby to elderly, from famous singer to young dancer, from story-teller to spectator. This method gave value to the creation of active participative environments, and the possibilities for ways of being of people living with dementia can multiply beyond the *patient* identity.

3.1.3 Co-creating Personas & Scenarios

The first and second sessions were dedicated to co-creating (Tsekeleves et al. 2018) Persona and Scenarios (Wärnestål et al., 2014) respectively. Personas captured conversations about objects, stories, things and numbers that matter for individuals. Role shifting interplayed as well in the co-creation process, at times participants identified with Personas, at others, Personas represented a relative or a character in the story. Personas then, were mobilised into an interconnected 'datafied' medical context, the Scenario. Relating everyday activities with data generation, data sharing and data purpose. The Scenarios represented "a day in town" and were inspired by participatory story-telling.

Figure 3: Personas and Scenarios. In the top line, examples of Personas co-created by people living with dementia as co-designers. In the bottom, examples of Scenarios, inspired by a day of the Personas in town.

3.1.4 Visual Conversations and Constant Communication with Participant Co-designers

Sessions regarded participants as experts rather than patients. The last tool to facilitate co-design was used in a dynamic that emulated "an expert interview". Answers were recorded visually on the wall. Participants expressed pride and fulfilment at their voices being taken seriously.

Each session was followed by a postal correspondence with each participant. Postcards featured pictures of the workshop designs were sent with a personal note. Postcards worked as reminder for following sessions and as a souvenir or memento. Participants showed great enthusiasm receiving their postcards. At the end of the three sessions, a visual report was shared among participants, caregiver organisations and family members over a community lunch, however not many of the participants could attend as health conditions worsened.

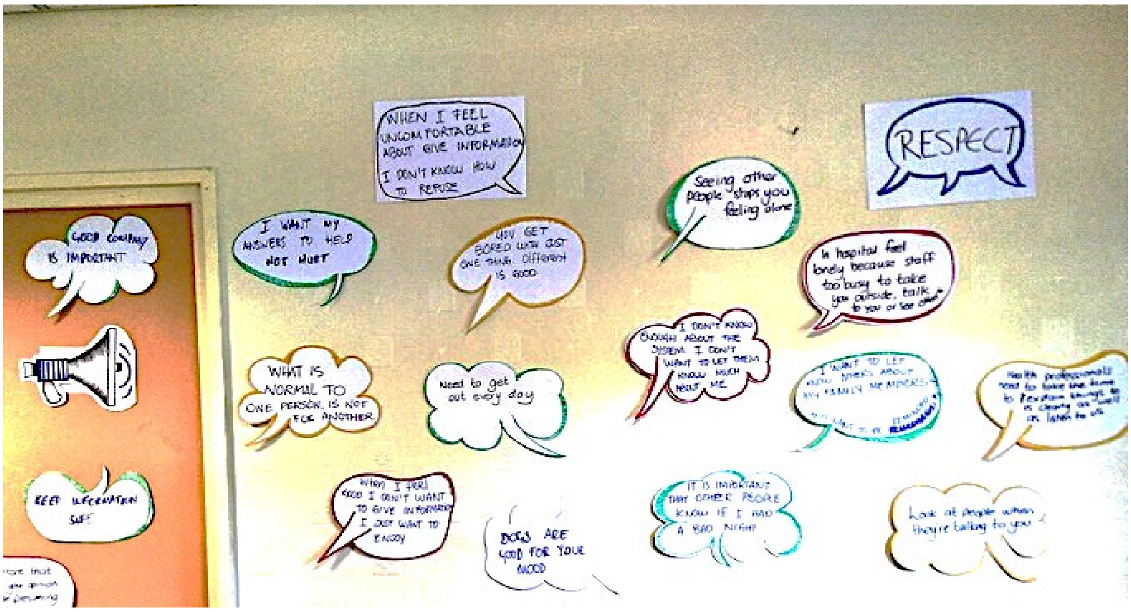


Figure 4: We called them ‘visual conversations’, because facilitators visually recorded conversations of people living with dementia playing the "data expert" role. Extracts of the interview filled the walls of the room and make it easier for participants to remember and for facilitator to go back to a certain aspect of the conversation.

3.2 End-Users

An EtD day-long session was designed and facilitated for NHS clinicians, academic and non-academic medical data scientists, NHS Business Intelligence, data regulatory body officers and Lancaster City Council policy officers from the Information Office.

3.2.1 Value Case Mapping

A method developed to collaboratively map data journeys and practices in Lancaster (UK), Building a complex picture from the data subjects out. The map made accessible the relation of data subjects and end-users. This exercise inspired by Nathan et al. (2007) aimed to expand and thicken a relation that is usually narrated along a thin line: I give consent to share my data, my data will be used for the benefit of others. This exercise wanted to visit, explore, inhabit the journeys of medical data, identify gate keepers, and understand practices of system end users, not just visualizing coincidences but also conflicts of opinions among participants.

The exercise allowed knowledge exchange supporting breaking silos of each participant’s data disciplines by understanding responsibilities, values and interests. It offered participants to locate themselves and their own practices on the map, and to identify own practices challenges and opportunities. The exercise support reflection upon how to make systems more beneficial, in terms of end-users and data subjects, and guidance were written in hexagons that cover the places in the maps showing ethical issues.

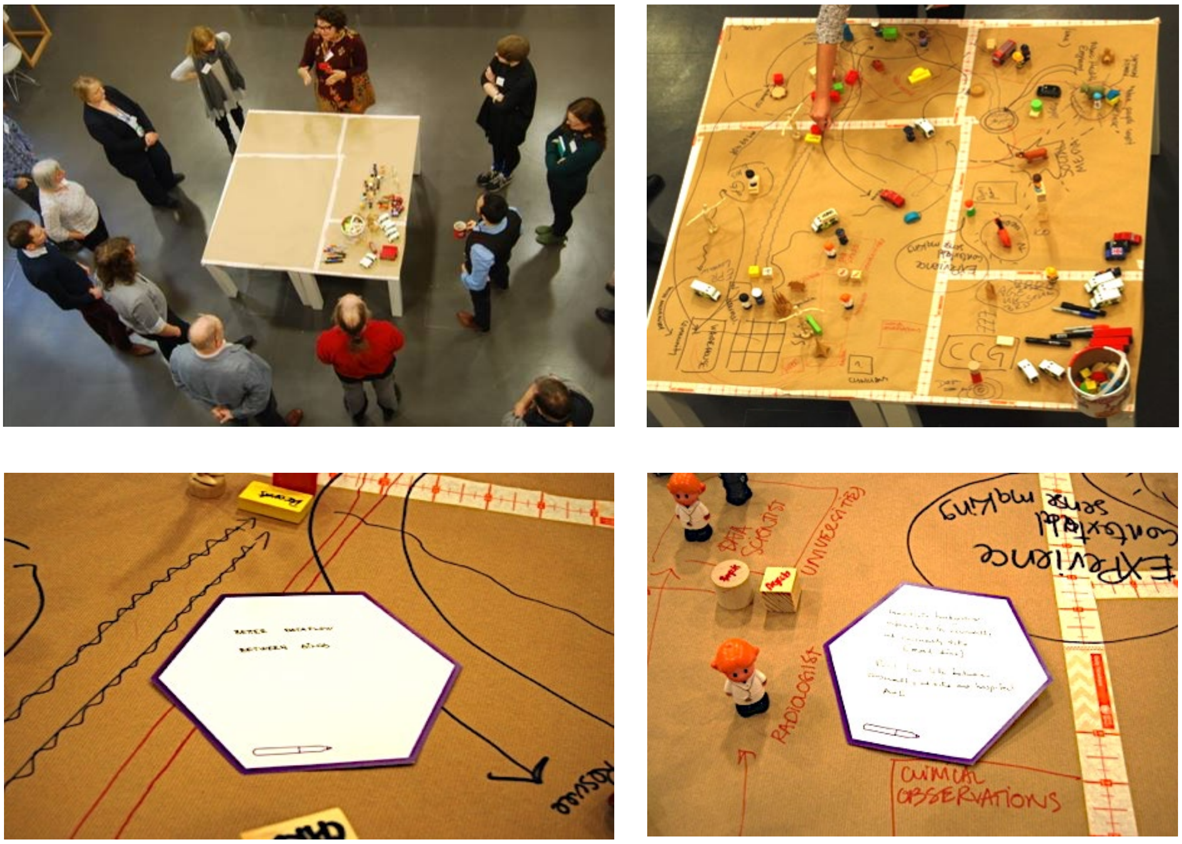


Figure 5: Value Case Mapping in the top and Practice-led Ethical Guidance in hexagons at the buttom.

3.2.2 *Creative ethical impact assessment.*

After an MPC technical discussion and its potential for privacy preserving in the medical domain, participants in teams rapidly co-designed plausible data scenarios in which MPC is used in Lancaster. In this exercise we used a co-design tool, part of the Etikit, that supported participants to co-design, discuss, imagine and ethically assess (Büscher et al. 2018) each of the plausible data scenarios. The exercise is also supported by the *IsITethical?* Key Term Playing Cards

Figure 6: EtD co-design tool for rapid co-design speculative data scenarios and ethically asses them. They bring about ethical challenges and opportunities in a visual, contextual manner.

4 Findings and Discussion

4.1 Foreseen Benefits

4.1.1 On the principle of Responsible Research Innovation

- Case M. - Business Intelligence Manager from NHS.

At NHS local council level, our collaboration with academic data scientists has started to show patterns that allow us to propose hypotheses. For example, we noticed that stroke patients who are obese, if they are still alive after 30 days in hospital, they have a greater likelihood to survive than patients who have a normal weight. We speculated, this is because they have greater bodily resources to survive the hardships of hospitalisation. MPC could be useful to contrast and corroborate those patters at national level and even beyond.

4.1.2 On the principles of Accountability and Non-discrimination

- Case S. - Emergency Planner from Public Health England: herding cats in a crisis, or working with a list of lists.

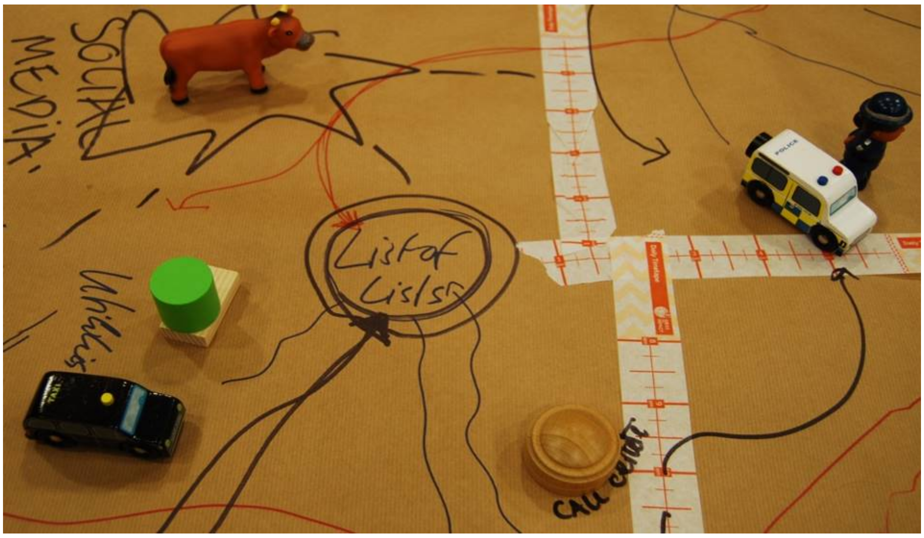


Figure 7: The 'list of lists' was thoroughly discussed at many moments of the day, it originally emerged during the value case collaborative mapping exercise, as the Lancaster Council Health planner was sharing some of the most pressing obstacle of her practice.

Imagine you are faced with a rapid onset flood. My job is to identify vulnerable people with urgency. There are many places where vulnerabilities are captured, there are records at local authorities, utility companies, aid charities. Not all vulnerable people are on one list, because some people do not feel vulnerable or do not want to be categorised as such. Additionally, personal devices, such as fitbit or mobility aid scooter, may constitute commercial data sets that identify vulnerable people. MPC could be potentially useful, to create an integrated list of vulnerable people in the specific street in which the flood occurred, a 'list of lists' that identifies names and addresses.

4.1.3 On the principles of Dignity and Respect

- Case D. – Does he take sugar?

Since I have been diagnosed, I have disappeared. At clinics and care centres, doctors, nurses and caregivers no longer address me directly, all questions about me are not to me, they are to my wife. Those may be questions such as, did he have a good night? does he *take sugar in his tea? How could MPC be useful to preserve my dignity? Can it share data that is important to me, and that is going to affect my wellbeing, so people have information and do not ask others like if I am not present*.

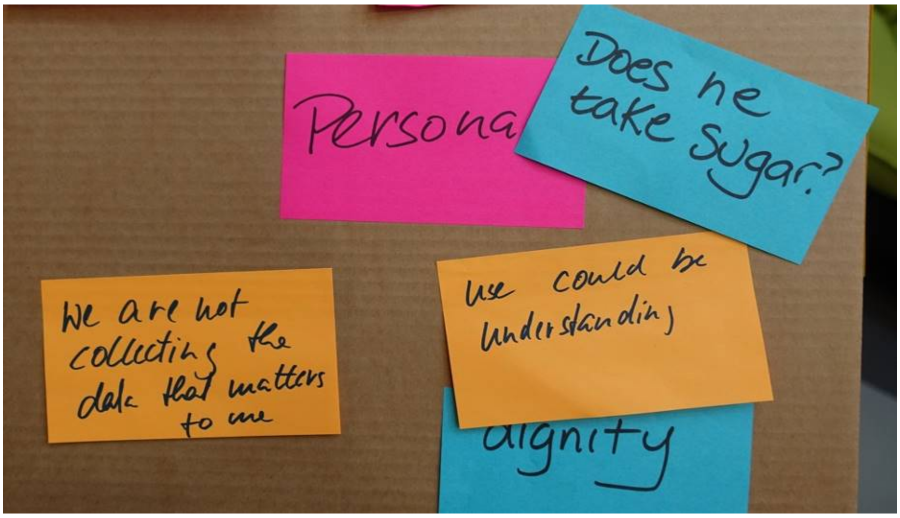


Figure 8: The 'does he take sugar?' story emerged in one of the exploratory workshops (Lancaster Nov 2018), it stayed with the project and informed many of the methods that were emerging.

4.1.4 On the principles of Proportionality and Humanity

- Case J. – Living with dementia in a care home, used to be a baker.

If during my everyday activities such as collecting my prescription at the pharmacy, visiting doctors and care centre, I am sharing information, such as my name and address with so many agencies and organisations, because my data is may be useful for them, how is it that MPC cannot be designed so my data is also useful to me? I usually forget my own address. How could this MPC work both ways? How could MPC be useful to me?

4.2 What would make MPC difficult: Challenges and Design Opportunities.

4.2.1 On the principles of Governability and Stewardship

- The issues of making MPC accessible and 'getting the questions right'

A premise of MPC is that all parties involved agreed on what the system can compute, which questions can be "asked". However, the process of deciding questions, how they should be asked, how data is collected and managed to support beneficial use of MPC techniques, present issues of governability and system stewardship.

Discussions with end-users speculated on the introduction of a certified trusted party such as NHS or Public Health England to act as arbiter and translator, policing and administrating the MPC. This raises all sorts of different questions: How often could questions change? What happens to old questions and answers? What if someone wants to leave or join the system? Will that affect guidelines for questions and data input? How trusted arbiter's transparency and accountability are guarantee? Who is allowed to ask what questions? What is allowed to do what with results?

Furthermore, end-user discussions evidenced a need for structuring a system that afford a widest range of questions, the system cannot be an "oracle", as every question asked will leak information about the combined data sets, introducing then issues of privacy, purpose binding and data minimization.

Questions above show structuring an MPC system in the health domain presents interoperability challenges but also design opportunities. They also show a need for sufficient information about MPC and its limitations. The conversation about the introduction of trustee third party, partly would defeat one of the main purposes of MPC: to avoid human arbitrary. The EtD workshops show that participants may not trust nonhuman governability of sensible data.

4.2.2 On the principles of Transparency, Fairness and Justice

- How can data work for me? Losing the data subject

The process of retrieving information (asking questions) to an MPC system is very opaque. How can data be designed to be accessible, palpable and to be just and inclusive. Can data systems help people living with dementia to remember, their addresses and personal information? How can data systems be designed to benefit data subjects in fair data transactions? How can the data subject's interests, values and needs be preserved in the design of operability of data systems? Can MPC be useful to create a data culture that preserve ownership and self-determination, or is it always going to be about agencies and organisations?

4.2.3 On the principle of Trust

EtD conversations informed a variety of values; respect, dignity, interoperability, transparency, accountability, privacy. However, the discussion on trust, was one of the richest, not just among participants but also among researchers who constantly discussed trust exercised at various levels.

Institutional Trust emerges from the relationship between people and trusted institutions. We noticed how relations with partner organisations trust researchers because of the connection with a public university. We also noticed that care organisations - home, care centres and NGO's - trust each other and trust is shared and transferred from one to another, i.e, both end-users and data subjects trusted NHS. The idea that there are institutions that can be trust with the most vulnerable was a constant during the project.

The study also experienced other aspects of trust, that even linked with institutional trust, relates to research and innovation, the idea that researchers mediate trust. People living with dementia and their caregivers, offered us unlimited trust and trusted the research and the co-design process with very few questions or doubts. They trust researchers for no reason with one's own sensible data and creating trustee bonds in which sensible stories were shared.

Co-design processes open spaces of trust, and trust exercised in co-creative spaces put co-design researchers in debt, where *indebtedness* is not about a debt that follows from a transaction but, rather, a debt that is the condition of possibility (Barad, 1998, p. 7); the possibility to contribute to responsible research innovation. We thought about trust as ongoing practice beyond transactions or associations; it is to voluntarily open oneself up to risk, vulnerability and to receive responsibility. It is supported by intellectual honesty and awareness of one's own limitations.

Trust in technology emerges when expectations are regularly met and grows as technologies become more dependable. Trust in information transactions is encouraged by doing what it says it does (and not less or more) and demonstrating repeatability, predictability, dependability, and, thus, reliability (Clarke et al., 2006; Büscher et al., 2009).

4.2.4 On the principle of Response-ability: Co-designing with vulnerable participants in fragile spaces.

Advancements in BBD techniques such as 'personalisation' and algorithmic profiling, make it easy for people to be treated 'not as persons but as mere temporary aggregates of data processed at an industrial scale' (EDPS, 2018). Hence, the need for revisiting and revitalising the principle of dignity is even more important. Looking for the lost vulnerable data subject in the complex obscure big data system, was a way to respond to the dignity call. The experience of co-designing ethics with people that are feeling unwell and whose health is deteriorating quickly, make of the space of affections that co-design opens, a very fragile one, that call for care, for care informing research practices and care informing relationships.

We are joining the sortilege of Haraways's neologism *response-ability* (1997, p.71). We propose a process of technology innovation fuelled by ethics, dependent upon trust that emerges and exercises within the fragility of creative encounters. It is simultaneously about staying responsible with the co-design process, loyal to its subjects and matters, and about taking care of one's abilities to respond to it.

5 Ethics through Design: A mode of conclusion

Technological Innovation methodologies, including medical and care technologies, move violently away from the perspective of the subject and towards relying on data analytics that tend to conceal the social to highlight patterns (Kitchin, 2014). They are assumed to yield new forms of knowledge embedded in data understood as synonymous with knowledge. However, data, more than patterns, are practices situated in organisational, political and fragile contexts.

EtD departs from the premise of co-design processes as a site of emergence (Luján Escalante, 2019), that build generative spaces, not just of designs or prototypes but of relations and values; ethical values. EtD builds on the idea of contextual and participatory ethics, more than theorising, it requires *doing* ethics together in the context of data practices. It moves away from the idea of ethics as a barrier to innovation, towards an understanding of ethics as highly contested, on-going processes that offer creative opportunities for responsible innovation. EtD reconceptualises ethical impact assessments, going beyond the legality or morality, (that are not necessarily ethical). It is building capacities for anticipating, noticing and addressing ethical tensions through co-creative methods to facilitate high quality IT research and innovation that that goes beyond box ticking. EtD does not just reconceptualise ethics but also design methods by asking questions like; what sort of things, tools, processes do we use to meaningfully collaborate with participants in ethical processes? How do these methods constrain, frame and generate certain ethical practices and not others?

EtD is engaging different stakeholders in the medical data interoperability systems, allowing SODA to explore the spaces and knowledges emerging from thinking together, realising and making real, medical data in the wider ecology of the social and material worlds of practicing wellbeing. SODA designed and re-purposed new and existing co-design tools and activities that facilitated the co-design process informed by the specificities of SODA contexts and participants, and allowed us to develop a deeper understanding of data subjects' perceptions of their own data sharing and how it influences their wellbeing.

6 References

Barad, K. (1998). Getting real: Technoscientific practices and the materialization of reality. *Differences: a journal of feminist cultural studies*, *10*(2), 87-91.

Bartlett, R. (2013). Playing with meaning: using cartoons to disseminate research findings. *Qualitative Research*, *13*(2), 214-227.

Büscher M., Mogensen P., Agger Eriksen M., Friis Kristensen J. (2004) 'Ways of Grounding Imagination'. *Proceedings of the Participatory Design Conference* (PDC), Toronto, Canada, 27-31 July 2004, pp. 193-203.

Büscher, M., Mogensen, P.H. and Kristensen, M. (2009). 'When and how (not) to trust IT? Supporting virtual emergency teamwork'. *International Journal of Information Systems for Crisis Response and Management* (IJISCRAM), 1(2): 1-15.

Büscher, M., Liegl, M., Rizza, C., & Watson, H. (2014). How to do IT more carefully? Ethical, Legal and Social Issues (ELSI) in IT Supported Crisis Response and Management. *IJISCRAM*, 6(4): iv-xxiii.

Büscher, M., Easton, C., Kerasidou, C., Luján Escalante, M., Petersen, K., Bonnamour, M.C., Lund, D., Baur, A., Ammicht, R. and Quinn, J.H. (2018) 'The IsITethical? Exchange: Responsible Research and Innovation for Disaster Risk Management.' *Proceedings of the 15th ISCRAM Conference.* Rochester, USA May 2018.

Clarke, K., Hardstone, G., Rouncefield, M., Sommerville, I. (2006). *Trust in Technology: ASocio-Technical Perspective* (Computer Supported Cooperative Work). New York: Springer-Verlag.

CEN CWA SATORI Project Draft: Document type: Ethics assessment for research and innovation — Part 1: Ethics assessment unit and Part 2: Ethical Impact Assessment Framework.

Couvreur, L., De Goossens, R. (2011). Design for (every)one: co-creation as a bridge between universal design and rehabilitation engineering. CoDesign: International Journal of CoCreation in Design and the Arts. 7:2. 107-121.

Chevalier, J. M., & Buckles, D. J. (2013). *Participatory action research: Theory and methods for engaged inquiry*. Routledge.

Dantec, C. A. L., & DiSalvo, C. (2013) 'Infrastructuring and the formation of publics in participatory design.' *Social Studies of Science* , 43(2). pp. 241–264. http://doi.org/10.1177/0306312712471581

Friedman, B. (1996). Value-sensitive design. *interactions*, *3*(6), 16-23.

EDPS (European Data Protection Supervisor) (2015) Towards a new digital ethics: Data, dignity and technology. Accessed at: https://edps.europa.eu/sites/edp/files/publication/15-09-11_data_ethics_en.pdf

Haraway, D. 1997. 'Modest_ Witness @Second_ Millenium.FemaleMan_ Meets_Onco Mouse', *Feminism and Technoscience*. NewYork: Routledge.

Hartswood, M.; Procter, R.; Slack, R; Voß, A.; Büscher, M.; Rouncefield, M.; Rouchy, P. (2002). Co-realisation: Towards a Principled Synthesis of Ethnomethodology and Participatory Design. *Scandinavian Journal of Information Systems*, Vol. 14(2), pp. 9-30.

Introna, L. D. (2007). Maintaining the reversibility of foldings: Making the ethics (politics) of information technology visible. *Ethics and Information Technology*, *9*(1), 11-25.

Kankainen, A., Vaajakallio, K., Kantola, V., & Mattelmäki, T. (2012). Storytelling Group–a co-design method for service design. *Behaviour & Information Technology*, *31*(3), 221-230.

Kitchin, R. (2014). Big Data, new epistemologies and paradigm shifts. *Big data & society*, *1*(1), 2053951714528481

Liegl, M., Boden, A., Büscher, M., Oliphant, R., & Kerasidou, X. (2016). Designing for ethical innovation: A case study on ELSI co-design in emergency. *International Journal of Human-Computer Studies*, *95*, 80-95.

Luján Escalante, M. A., Tsekleves, E., Bingley, A. F., & A. Gradinar (2017) 'Ageing playfully: a story of forgetting and remembering' *Design for Health*, *1*(1), 134-145.

Luján Escalante, M. (2019) 'Framework of Emergence: From Chain of Value to Value Constellation.' *CoDesign: Vol 15, No 1.* Taylor & Francis Online.

Marres, N. (2009) 'Green Living Experiments, the Ontological Turn and the Undoability of Involvement', *European Journal of Social Theory*, 12(1), 2009. pp. 117–133.

Morrissey, K., Wood, G., Green, D., Pantidi, N., and J. McCarthy (2016) " 'I'm a rambler, I'm a gambler, I'm a long way from home': The Place of Props, Music, and Design in Dementia Care." In *Proceedings of the 2016 ACM Conference on Designing Interactive Systems*, pp. 1008-1020. ACM.

Nathan, L. P., Klasnja, P. V., & Friedman, B. (2007). Value scenarios: a technique for envisioning systemic effects of new technologies. In *CHI'07 extended abstracts on Human factors in computing systems* (pp. 2585-2590). ACM.

Nielsen, L. (2011). Personas in co-creation and co-design. In *Proceedings of the 11th Human-Computer Interaction Research Symposium* (pp. 38-40).

Petersen, K., R. Oliphant and M. Büscher (2016) 'Experimenting with Ethical Impact Assesment'. Proceedings of the ISCRAM 2016 Conference – Rio de Janeiro, Brazil, May 2016. Tapia, Antunes, Bañuls, Moore and Porto, eds.

Rodgers, P. A. (2018). Co-designing with people living with dementia. *CoDesign*,*14*(3), 188-202.

Sanders, EB-N. and Stappers, PJ (2008) Co-creation and the new landscapes of design. *CoDesign* 4:5–18

Spence, J., Frohlich, D., and S. Andrews (2013) 'Performative experience design'. In *CHI '13 Extended Abstracts on Human Factors in Computing Systems* (CHI EA '13). ACM, New York, NY, USA, 2049-2058.

Star, S. & Griesemer, J., (1989). 'Institutional Ecology, `Translations' and Boundary Objects: Amateurs and Professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39'. *Social Studies of Science*, 19(3), pp.387–420.

Tsekleves, E., Bingley, A., Luján Escalante, M and A. Gradinar (2018) 'Engaging people with dementia in designing playful and creative practices: co-design or co-creation?' in *Dementia Journal*. Sage.

Urry, J. (2016). What is the future? London: Routledge.

Van Dijck, J. (2014) Datafication, dataism and dataveillance: Big Data between scientific paradigm and ideology, Surveillance & Society, 12 (2), pp. 197-208.

Von Schomberg, R. (2013). A vision of responsible innovation. In R. Owen, J. Bessant, & M. Heintz (Eds.), *Responsible innovation*. London: Wiley, 51-74.

Wallace, J., McCarthy, J., Wright, P., an P. Olivier (2013a) 'Making design probes work. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI '13). ACM, New York, NY, USA, 3441-3450.

Wallace, J., Wright, P. C., McCarthy, J., Green, D. P., Thomas, J., & Olivier, P. (2013b). A design-led inquiry into personhood in dementia. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 2617-2626). ACM.

Wärnestål, P., Svedberg, P., & Nygren, J. (2014). 'Co-constructing child personas for health-promoting services with vulnerable children'. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 3767-3776). ACM.

IASDR 2019
International Association of Societies of Design Research Conference 2019
DESIGN REVOLUTIONS
Manchester School of Art
Manchester Metropolitan University
02-05 September 2019

From Fore-thinker to Facilitator: The Role of Design in the 4th Industrial Revolution

Zhenyuan, Liu *; Tianren, Deng

Tongji University, Shanghai, China
* l_zhenyuan@tongji.edu.cn

The purpose of this paper is to provide and explain a vision of the changing role of design in the 4th industrial revolution. By looking at the sustainability crisis caused by our previous industrial and economic development through a F-P-N(Forethought-Production-Needs) model, the paper explains the problem that the previous three industrial revolutions tended to solve and the strategies that industrial development adopted, it explains why and how design has played a role as fore-thinker and why the previous industrial paradigm failed to be sustainable. The authors assert that Industrial revolutions are not ends but means to realize more efficient and resilient industry capacity to interact with the dynamic and constant change of the market, which represents the individual and collective human needs. In such light, the emerging 4th industrial revolution and the role of design are expected to enable the shift of our industry paradigm from “what we manufacture” with the focus of production efficiency and rhetoric strategy of design, to “why we manufacture” with the focus of production effectiveness and dialectic strategy of design. In order to realize such paradigm shift, the paper points out that it is critical to realize that design being as fore-thinker will no longer be helpful enough in a network-based industry. Instead, formations of design cultures throughout all aspects of a networking industry are needed. The knowledge of design should no longer be mastered among the few, but blend into the network of innovation and production communities of the future industry by the facilitator of design culture. The paper concludes that, in the coming 4th industrial revolution, the role of design is not to be discovered nor predicted, but to be shaped through increasing dialectic research and practice to facilitate a more resilient and sustainable future industry and economy.

Keywords: industrial revolution; the role of design; industrial design

1 Introduction

Why do we need another industrial revolution? What the next industrial revolution is expected to realize? One reasonable answer is that it should set out to solve the problems of our existing industry and economy. Otherwise, what is the point if we just accelerate the capacity together with its side effects of our current industry model? The world is not lack of sexy or cool looking automobiles anymore but is longing for innovative approaches to tackle complex sociotechnical problems such as intelligent urban mobility or healthcare, government policy, and environmental protection (Donald A. Norman, 2015). One of the reasons that human society is faced with today’s sustainability crisis is the linear model of industry in which a product is designed, mass-produced, delivered, sold, used and discarded.

This whole production model is based on the “forethought” (Richard Buchanan, 2009) and competition about what the markets or users might want with the available technology environment. The role of design during the past three industrial revolutions is deeply involved at such “forethought” stage.

Industrial revolutions are not ends but means to realize more efficient and resilient industry capacity to interact with the changing dynamic needs of the market. The previous three industrial revolutions focused on the upgrade of manufacture efficiency through the invention of mechanized production, flow line production and automated production. The result is that more products will be produced more efficiently to be sold and replaced more quickly. However, production growth on our planet fundamentally cannot be infinite due to the limited natural recourse for production. Sustainability crisis caused by existing industry model is becoming more and more serious. With such reality and problems, we assert the emerging 4th industrial revolution and the role of design are expected to enable the shift of our industry paradigm from “what we manufacture” with the focus of production efficiency and rhetoric strategy of design, to “why we manufacture” with the focus of production effectiveness and dialectic strategy of design.

2 The F-P-N Model and the previous industrial revolutions

Industry is defined as the companies and activities involved in the process of producing goods for sale. The purpose of industry production is to meet the needs of people and make better life. It is necessary to make a schedule before production otherwise it is impossible to decide what to produce and how to produce. Therefore, design plays the role of forethink needs before production. From the perspective of time, the whole process can be described as: 1. Design makes **forethought**. 2. Goods are put into **production**. 3. **Needs** get satisfied. (F-P-N model) The three steps are in chronological order and the model is so-called ‘linear model’, in which design is at the front-end of the whole process.

For a long time, industry has been pursuing efficient production to meet people's different needs as well as maximize profits. The prominent events are the previous industrial revolutions. After each revolution, driven by economic factors or interests, industry constantly upgrade technology, thus the efficiency of production is greatly improved, and people's needs are better satisfied.

2.1 The 1st Industrial Revolution

During the 1st industrial revolution, steam-powered mechanized production was invented to replace human-powered manual production, which indicated the arrival of the industrial era in human history. Design and manufacture were closely integrated at that stage. In order to make products accessible to more customers, and to avoid accidents in the mechanized production, it was necessary to plan and coordinate various types of work and processes before mass production and integrate the restrictions and interests from the manufacture side and the market side including manufacture feasibility, assembly and transportation efficiency. Although the technology revolution enabled dramatic production efficiency increase, the users' choices from available products were still limited, and there was a long-time span from the forethought to the market, as shown in Figure 1.

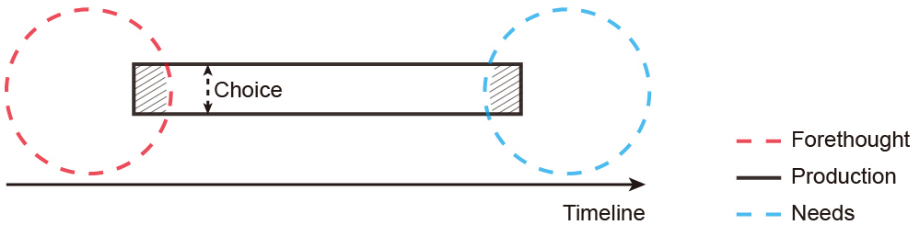


Figure 1. Model during the 1st Industrial Revolution

The Thonet chair, as shown in Figure 2, was a good example of that period. It was partially mechanized production and partially assembled by manual with standardized parts, which can be used in different styles. The design of Thonet 14 is especially suitable for the serialization of production in factories. It is designed into serval simple parts, which is convenient for disassembly, transportation and assembly. It reflects the whole system integration of product design from material processing to production circulation.

Figure 2. Thonet chair No.14. Source: Google

2.2 The 2nd Industrial Revolution

During the 2nd industrial revolution, the flow line production model of production management and organization further improved productivity, and the choice of products increased and the time span between product forethought to delivery was corresponding shorten, as shown in Figure 3. People can choose between different products to meet a certain demand. This drove design to consider the coordination of function with aesthetics and economy, which improved the value and competitiveness of products. At that time, the primary role of design was to plan and forethink mass produced products with increasing consideration on emotional interaction between products and users. The contents of industrial design were also gradually enriched with the pursuit and creation of style and fashion. Design was also recognized as future-oriented and played a role as fore-thinker of new choices.

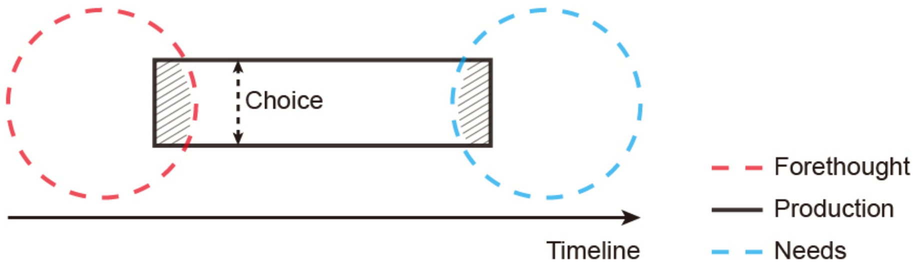


Figure 3. Model during the 2nd industrial revolution

Model T was the first automobile produced through flow line production. The average assembly time of chassis was shortened from 12.5 hours to 1.5 hours. (History of Ford) Flow line production allowed the price of the touring car version to be lowered from $850 in 1908 to less than $300 in 1925. At such prices the Model T at times comprised as much as 40 percent of all cars sold in the United States. On such basis, Ford designed different body styles of Model T including a five-seat touring car, a two-seat runabout, and a seven-seat town car to meet different needs. Design still playing a role as fore-thinker helped to make products more competitive in the markets. Meanwhile, design is not just about how to adapt to the requirement of high-speed production, but to take consideration of customers' segmentation needs even aesthetic judgement.

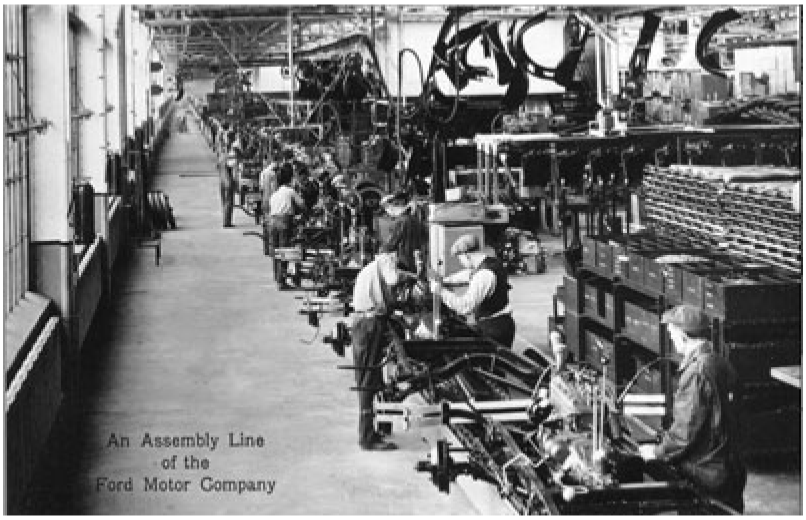


Figure 4. Flow line production of Model T. Source: Ford

2.3 The 3rd Industrial Revolution

During the 3rd industrial revolution, the invention of integrated circuit promotes the emergence of automatic production line, which further improved the level of production capacity and efficiency, as shown in Figure 5. The industry entered the era of automated production. During this period, benefit from the breakthrough of production efficiency and accuracy, mass production based industry gained more resilience and began to be able to respond according to customer orders. Consumers could customize products to satisfy personalized needs. The back-end of industry chain began to participate in the decision-making stage which was exclusive to front-end before. Meanwhile, design began to integrate elements of vision and meaning of product experience as well as the establishment of brand image and brand culture. During this period, designers started to play the role of creators and fore-thinkers of product experience. There also started a trend that design gradually became a dominant factor in some companies.

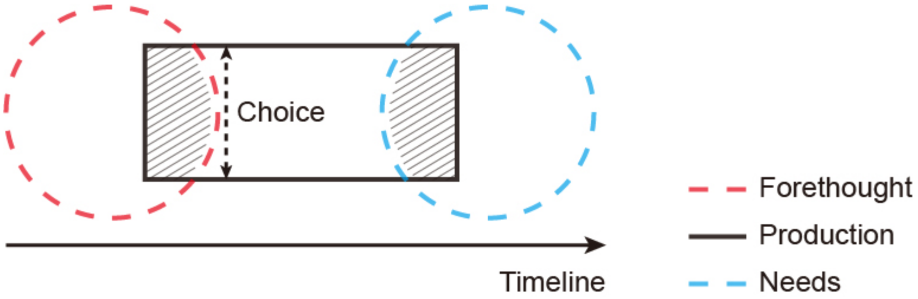


Figure 5. Model during the 3rd industrial revolution

Honeywell T86 circular thermostat is a typical example which combines product function with user experience. The designer Dreyfuss focused on ergonomics, and his design used a unique circular appearance rather than a conventional rectangular one. The overall shape has no redundant keys, and is similar to the appearance of the dial, which facilitates consumers to be familiar with the use mechanism. T86 thermostat reflects the design at that time not only to meet the realization of basic functions, but also pay attention to better user experience.

Figure 6. Honeywell T86. Source: Google

2.4 The summary of previous three industrial revolutions

During the previous three industrial revolutions, design has played a role of forethinking final needs in most cases and conceive products and their plans for manufacture as well as strategies for marketing competition. However, there is a time lag between designers' forethoughts and their final deliveries to the market. Overall, after each industrial revolution, the manufacture efficiency was greatly improved. The time lag in the industrial chain was shortened, and the choices provided by design and manufacture were increased, as shown in Figure 7.

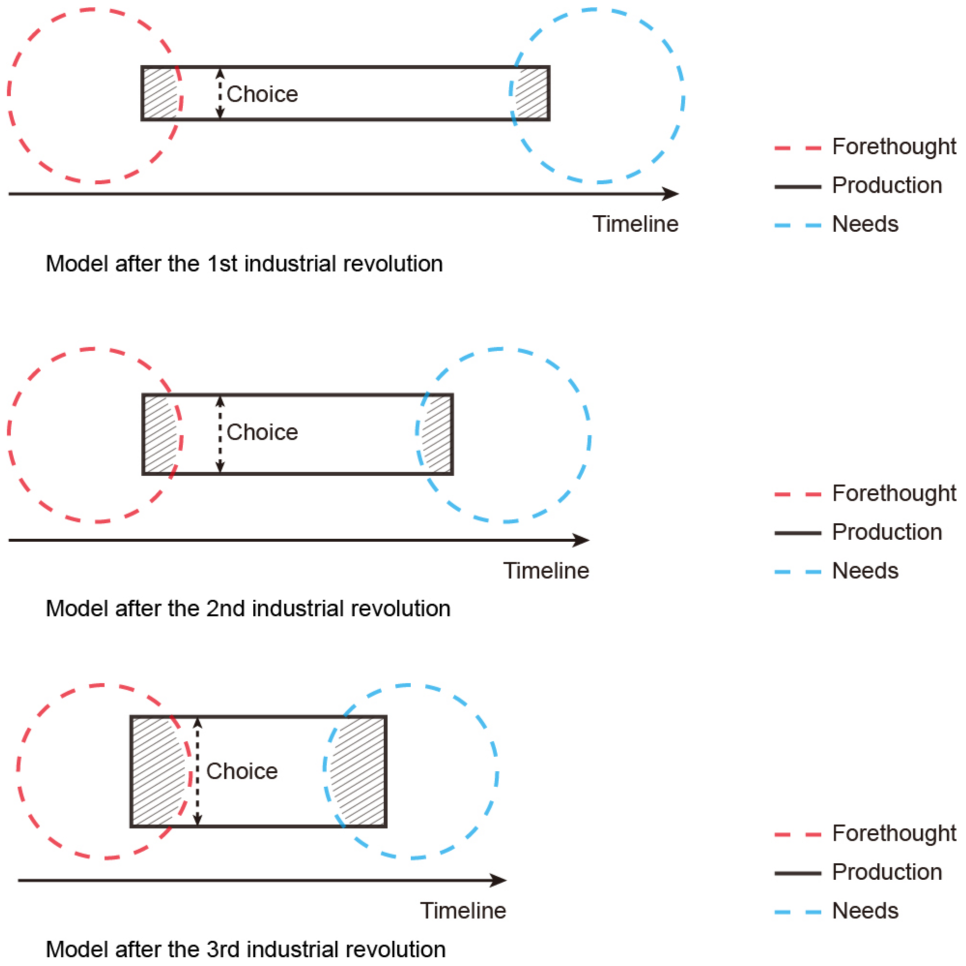


Figure 7. Evolution of three industrial revolutions

From such perspective, design is located at the front-end of the whole industrial chain with a linear model at its nature. The reason behind such model was that a centralized paradigm of manufacture was necessary to provide more efficient production and logistic, as well as more competitive cost due to the available technological environment. But why do we want our industry to be more efficient at the first place? The answer lies at the gap and uncertainty between what the market might want and what we should produce. In Figure 7, the shaded parts represent the user's needs that were satisfied through proper forethought and production. The blank area in the left circle represents the forethought that cannot be fulfilled by production or the inaccurate prediction. The blank area in the left one represents the needs that are not met. The degree of the satisfaction of user needs may be understood as being increasing while the shaded part gets bigger. To conclude, during the last three industrial revolutions, the key of industrial development was to increase efficiency throughout the industrial chain within a linear paradigm, and design has been located at front-end of such chain and playing a role of fore-thinker to help with conceiving and creating the plans for what to manufacture, and predicting what might be popular.

3 The Problem that the previous three industrial revolutions tended to solve

3.1 The knowledge of needs and production

The fundamental problem that our industry and economy have always been longing to solve is the disconnection between the incondensable knowledge of needs and the concentrated knowledge of production. The knowledge of needs never exists in concentrated or integrated form but solely as the dispersed bits of incomplete and frequently contradictory knowledge which all the separate individuals possess (Hayek. F. 1945). The external performance of the discrete knowledge may be the costumer's pursuit of product diversity. Demand for variety may arise from a taste for diversity in individual consumption and/or from diversity in tastes even when each consumer chooses a single variant (Kevin Lancaster, 1990). The knowledge is constantly changing and unpredictable and users' pursuit of product variety is also hard to measure.

On contrast, the knowledge of production is concentrated in the individuals and organizations that control the means of production. In such situation, though the knowledge of needs is not capturable, our industry still tried its best to produce and sale what might be needed by consulting individuals or organizations whose work involved forethought in the conception and planning of the humanmade world (Richard Buchanan, 2009) to “make sure” the mass-manufactured products will realize their economic and social values. However, such kind of forethought has its limitation of resilience in front of the unpredictable changing personal needs and severe global competition. As long as the fundamental problem exists, the failure of forethought and its consequent unsustainable environmental impact will also co-exist.

3.2 The strategy that industrial development adopted

Industrial revolutions are not ends but means to realize more efficient and resilient industry capacity to interact with the dynamic and constant change of the market, which represents the individual and collective needs. In order to remedy the fundamental problem, the existing model of our industry tries to improve production efficiency and velocity through technology upgrading. In this way, the time lag between forethought and market is constantly shortened. Such strategy can indeed satisfy needs to a certain extent through offering more choices to more potential customers in less time. But it inevitably comes with the result that products will be produced more efficiently and to be sold and replaced more quickly. The root of such problem lies at the heart of the linear production models in which the communities representing the knowledge of needs in most of the time are excluded as feedback givers. In such context, design plays the role as fore-thinker to explore and conceive possible needs of individuals before manufacture. As the result of technology constraints, the existing linear model has its historical necessity and significance. Relied on design to forecast needs of customers, the centralized manufacture mode was the most effective way to tackle dynamic needs. The previous three industrial revolutions have promoted the evolution of society from traditional manual production to advanced automated production. The user's choice has experienced three times of upgrade: from scratch, from less to more, from more to better.

3.3 The consequence of the strategy

Obviously, there does not exist an omnipotent status, so the forethought from design sometimes could deviate from real needs. Together with the time lag between production and market, this deviation could cause improper production and resource waste, which takes responsibility for sustainability crisis. Nowadays, the sustainability crisis brought by the linear model has become more and more evident. Price volatility, increasing material demand, degradation of ecosystems, decreasing lifetime of products, all these problems cause attention on paradigm transformation. The fundamental cause of the current crisis in sustainability is the industrialization that followed the industrial revolution and the rapid economic growth it fostered. (Hiroshi. K., Kazuhiko T.,2006) Any system based on continual extraction and consumption will eventually experience limits to growth. Consequently, there is an urgent need for innovation to meet these challenges, by redesigning our economy to be one that creates rather than extracts value, keeping finite technical resources in flow within the economy and protecting and regenerating biological systems. (Ellen Macarthur Foundation, 2019) With the rise of the 4th industrial revolution, emerging technology such as interconnection, informatization, big data, enable opportunities for paradigm transformation. Existing linear models and corresponding roles of design will also convert. We finally have a chance to set our production model into a web-based system. Which enables the spontaneous interaction between the knowledge of the needs and the knowledge of the production.

4 The emerging 4th industrial revolution

On the basis of an advanced digitalization within factories, the combination of Internet technologies and future-oriented technologies in the field of “smart” objects (machines and products) seems to result in a new fundamental paradigm shift in industrial production (Lasi, H., Fettke, P., Kemper, HG. Feld T., Hoffenmann M. 2014). This is the trend of “4th industrial revolution”. It will exert profound influence on all aspects of the society.

4.1 The changing nature of customer demand

Digital technology, especially the Internet, have ensured customization which was the province of the wealthy historically available to a wider range of customers. Chris Anderson (2006) described the phenomenon in his book *The Long Tail*: an increased shift away from mainstream products and markets at the head of the demand curve, replaced by a gravitation toward multiple ever-expanding niches that constitute the curve’s “long tail”. In addition to the growing interest in customization, consumers are increasingly apt to engage in the creation of the products they buy as well. At base, this phenomenon represents a shift in identity from passive recipient to active participant—a blurring of the line between producer and consumer (Deloitte, 2015).

4.2 The changing nature of products

The drive for customization is prompting some manufacturers to reshape their products as physical platforms. This change is not only merely adding software to physical objects, but also allowing for broad customization, and encouraging third-party partners to strengthen the underlying products with additional value. Another transformation is from product to service. Manufacturing firms not only seek manufacturing technique innovation, but are also beginning to focus on induction and impetus of service (Jay Lee, Hung-An Kao, Shanhu Yang, 2015). When products become "smart", interconnected, and even transformed into services, it is obsolete of the concept of creating value by merely manufacture and selling more products. In the future, value will come from connectivity, data, collaboration, feedback loops and learning.

4.3 The changing economics of production

The profound change in the field of manufacture mode is the application of additive manufacture which benefits from the exponentially developing digital infrastructure. Compared with subtract manufacture, the cost of small batch production with additive manufacture is lower, so additive manufacture is more suitable for customization requirements. Meanwhile, the waste caused by additive manufacture is less, the utilization rate of materials is higher, and it fits the requirements of sustainable development. Another great impact of exponentially developing digital infrastructure is its ability to break barriers and offer opportunities to newcomers. It's easier than ever to learn a new skill or connect with experts in any field. These benefits, first apparent in the digital world, are now trickling down to real world and are likely to inspire both growth and change.

4.4 The changing economics of the value chain

The boundaries between manufacturers and retailers are becoming increasingly blurred. The softening of this role is meaningful not only for companies longing for changing, but also for any intermediaries holding inventory. Under this circumstance, many hardware start-ups abandon the traditional entity retail channels and directly contact consumers through online platforms.

5 From fore-thinker to facilitator

5.1 The keys of the 4th industrial revolution

The previous industrial revolutions upgraded capacity of interacting with the changing dynamic market through the invention of efficiency driven technology. In the age of the 4th industrial revolution, the fundamental problem between the knowledge of needs and the knowledge of production still exists. The knowledge of needs is still discrete and cannot be precisely predict. The difference between the 4th industrial revolution and the precise three ones will be the strategy to tackle such fundamental problem. The previous linear model provided users with more choices through efficiency-oriented technology upgrades, increasing the variety of products and production speed. The 4th industrial revolution will take a different approach. The arrival of the fourth industrial revolution will not only be demonstrated as the improvement of production efficiency, but also the paradigm transformation of effective production web system. The key is to achieve a problem-oriented, real-time, dynamic capability, which means that the design cannot and should not play the role of a fore-thinker in the front-end of manufacture chain as before.

5.2 From fore-thinker to facilitator

If we to realize the reversal of the economic growth paradigm in the coming 4th industrial revolution, to realize the real transformation of industrial development from "efficiency" to "effectiveness" and to achieve circular and sustainable economic growth, the role of design needs to be changed from the previous "fore-thinker" who planned in advance to the "facilitator" who will help to build an new innovative culture. From the historical perspective, design grows from a trade activity to a segmented profession to a field for technical research and to what now should be recognized as a new liberal art of technological culture (Richard Buchanan, 1992). The fundamental change is that the role of design changes from the front-end of production line to the center of the innovation community, from the planning of products and services to the facilitation and curation of innovation communities. The knowledge of design will no longer belongs to a few groups of people but will be sewed through the creative community network of the entire future industry through design culture, as demonstrated in Figure 8.

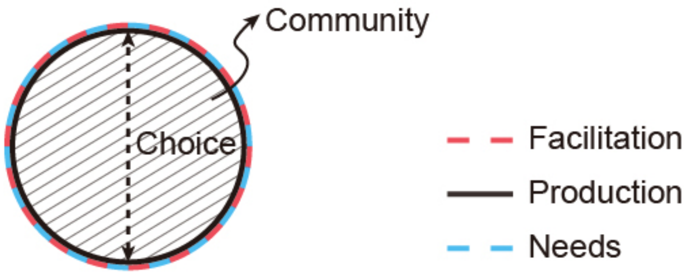


Figure 8. Ideal model for the 4th industrial revolution

In the ideal model, there is no clear front-end and back-end distinction. The parties associated with the product life cycle -- customer, design, manufacture, logistics, etc. -- are closely integrated and exist in the form of an innovation community in which design plays a central role. This user-centred innovation processes offer great advantages over the manufacturer-centric innovation development systems that have been the mainstay of commerce for hundreds of years (Eric von Hippel, 2005). Integration of users in open innovation community can improve the ability of organizations to access external innovation sources and enhance innovation efficiency. In this model, design should open itself to enable the human power of conceiving, planning, and making products that serve human beings in the accomplishment of their individual and collective purposes (Richard Buchanan, 2006).

5.3 The Emerging Practices

The facilitation of a design culture may not only help to balance the knowledge of needs and the knowledge of production, but also may have a chance to solve the problems left by previous linear model. Nowadays, besides the ecological crisis, there are social crisis, political crisis, cultural crisis, moral crisis, as well as the crisis of democratic ideology and capitalist system (Ernst von Weizsaecker, Ander Wijkman. 2018). Behind the great challenges we face, there is a cultural gap between the artificial world and the ecosphere (John Thackara, 2018). This is closely related to the previous linear development model.

However, there are already emerging practices that have a strong focus of facilitating design culture to tackle global issues by community-based and effectiveness-driven innovation, such as Mozilla for network security; Ellen Macarthur Foundation for circular economy; The Ocean Cleanup for marine ecology; Highline for urban renewal; Nice 2035 for community co-creation. These ongoing projects and practices are not only focusing on design of new products or services, but also on solving complex sociotechnical problems and facilitating a vital, meaning and value creating, and design driven community.

The Ocean Cleanup is non-government engineering environmental organization based in Netherlands, that develops technology to extract plastic pollution from the oceans. The organization use the natural oceanic forces to catch and concentrate the plastic and investigate how to reuse the material. By adopting design thinking and selling branded material for reuse, the organization aims to eventually make the Cleanup self-sustainable. The Ellen MacArthur Foundation is a charity registered in the UK which aims to inspire a generation to re-think, re-design & build a positive future through the framework of a circular economy. It is committed to building circular economy based on three principles:1 design out waste and pollution. 2 keep products and materials in use. 3 regenerate natural systems. Nice 2035 is a complex space and ecosystem which integrates product research, development laboratory, innovative education space, physical prototype store, multi-creation center, incubator and other functions. Nice 2035 regards community as an important source of innovation in cities, and community residents as an important force of social innovation. It emphasizes the wisdom of ordinary people based on daily life and relies on design colleges' resources and ecology.

The three cases above support our argument that in the forthcoming 4th industrial revolution, design will be involved in a transformation from the "fore-thinker" at the front-end of the original production line to the "facilitator" of design culture widely spread in the future production network. The facilitation of task-driven and community-based design culture might be the key to solve the problems left over from the past industrial revolutions and help us achieve a sustainable development model in the forthcoming 4th Industrial Revolution.

6 Conclusion

This paper puts forward the role that design should play in the coming new industrial revolution and the shift of the focus of research strategies (Buchanan, 2007) that design inquiry and practice should take. The fundamental change the paper tries to promote is that design being at the front of providing ideas for products and services becomes the center of facilitating design cultures for innovation communities.

In order to facilitate such shift, design education institutions and design research communities will continue to pioneer to explore new topics and methods of meaning and vision driven design and innovation research and practice. How can design curate technology cultures to enhance the production and economic adaptability of change? How should design help to connect advanced manufacture and everyday life? How can design and creativity unlock the potential of Industry 4.0 technologies? How we will prepare a new generation of design students who will rise to the challenge of such shift?

7 Reference

Chris Anderson. (2006). The Long Tail: Why the Future of Business Is Selling Less of More. New York: Hyperion.

Deloitte. (2015). The future of manufacturing: making things in a changing world. Retrieved from https://www2.deloitte.com/us/en.html

Donald A. Norman. (2015). DesignX: Complex Sociotechnical System. *She Ji: The Journal of Design, Economics, and Innovation,1*(2), 83-106. doi: 10.1016/j.sheji.2016.01.002

Ellen Macarthur Foundation. (2019) Artificial Intelligence and the Circular Economy: AI as a Tool to Accelerate the transition. Retrieved from https://www.ellenmacarthurfoundation.org/publications

Eric von Hippel. (2005). Democratizing Innovation: The Evolving Phenomenon of User Innovation. *Management Review Quarterly, 55*(1), 63-78. doi: 10.1007/s11301-004-0002-8

Ernst von Weizsaecker, Ander Wijkman. (2018). Come On! Capitalism, Short-termism, Population and the Destruction of the Planet. doi: 10.1007/978-1-4939-7419-1

Hayek, F. (1945). The Use of Knowledge in Society. *The American Economic Review, 35*(4), 519-530. Retrieved from http://www.jstor.org/stable/1809376

Hiroshi Komiyama, Kazuhiko Takeuchi (2006). Sustainability science: building a new discipline. *Sustainable Science, 1*(2), 1-6. doi: 10.1007/s11625-006-0007-4.

History of Ford. (n.d.). Retrieved from https://corporate.ford.com/history.html

Jay Lee, Hung-An, Shanhu Yang. (2014). Service Innovation and Smart Analytics for Industry 4.0 and Big Data Environment. Procedia CIRP, 16, 3-8. doi: 10.1016/j.procir.2014.02.001

John Thackara. (2018). How to Thrive in the Next Economy: Designing Tomorrow's World Today. Shanghai: Tongji University Press.

Lasi, H., Fettke, P., Kemper, HG. et al. (2014). Industry 4.0. Business & Information Systems Engineering,6(4), 239-242. doi:10.1007/s12599-014-0334-4

Kelvin Lancaster. (1990). The Economics of Product Variety: A Survey. *Marketing Science, 9*(3), 189-206. doi: 10.1287/mksc.9.3.189

Richard Buchanan. (1992). Wicked Problems in Design thinking. *Design Issues, 8*(2), 5-21. doi: 10.2307/1511637

Richard Buchanan. (2006). Design Research and the New Learning. *Design Issues, 17*(4), 3-23. doi: 10.1162/07479360152681056

Richard Buchanan. (2007). Strategies of Design Research: Productive Science and Rhetorical Inquiry. *Birkhäuser Basel,* 55-66. doi: 10.1007/978-3-7643-8472-2_4

Richard Buchanan. (2009). Thinking about Design: An Historical Perspective, *Philosophy of Technology and Engineering Sciences*, 409-453. doi: 10.1016/B978-0-444-51667-1.50020-3

About the Authors:

Zhenyuan Liu: Associate Professor, College of Design and Innovation, Tongji University. Main research directions are design theory and methodology, design education and design management.

Tianren Deng: Postgraduate, College of Design and Innovation, Tongji University. The discipline is industrial design. Main research direction is design for mass customization.

Geometry vs Realism: an exploration of visual immersion in a synthetic reality space

Lawrence, Abbie*; Loudon, Gareth; Gill, Steve; Pepperell, Robert; Baldwin, Joe

Cardiff Metropolitan University, Cardiff, United Kingdom
* ablawrence@cardiffmet.ac.uk

With the broader aim of using a synthetic reality environment to improve and develop packaging designs for Welsh food Small-Medium Enterprises (SME), two studies were undertaken in a simulated environment to explore the geometry and realism of visual content of supermarket shelves, in relation to psychological variables that correlate with sense of presence. The first experiment compared two types of visual geometry: Linear perspective and 'Natural' perspective (using non-linear projection techniques) as well as the realism of the depicted supermarket scene (by comparing a Computer Aided Design (CAD) image versus a photograph). Results from the first experiment showed that the type of image geometry had more of an impact on the sense of presence than the realism of the depicted supermarket scene. A second study was then conducted to test whether a hybrid image of CAD components and a photograph could create a similar sense of presence compared with a photograph alone (because the use of a hybrid image can reduce costs). The results showed that there were no significant differences between the hybrid image and the photograph in terms of creating a sense of presence.

Keywords: Immersion, food packaging, design, user testing, presence, simulated environment

1 Introduction

Large food companies such as Coca Cola and Unilever regularly utilise user testing facilities and systems that allow for products to be tested before release. This iterative design process is hugely advantageous; however, the costs are prohibitive for Small-Medium Enterprises (SME), and the methods are not available to the public.

The wider aim of this research is to develop a cost effective, and customisable user testing space to validate and improve packaging design for Welsh food SMEs. Testing in context is ideal but logistically difficult; testing in a laboratory setting offers high levels of control, however lack environmental cues. Thus, the Perceptual Experience Lab (PEL), consisting of a 200° wrap-around screen, was developed to accommodate for immersion, whilst maintaining a high level of control of sensory cues and monitoring technologies. The following studies explore visual geometries and content realism to create the highest possible sense of immersion in a simulated environment.

The first part of this study looks at what visual geometry is best suited for projecting onto a 200° wrap-around screen. Research has found that peripheral vision has a big impact on spatial awareness and can increase the sense of presence (Strasburger, et al., 2011; Pepperell, 2015). Testing the geometry of the images will help determine whether linear perspective or natural perspective will create the most immersive content to use in future studies in PEL. The second part of this study is to determine whether Computer Aided Design (CAD) can be used as an alternative to real photographs as photographing a real space is logistically problematic in the long term. The purpose of PEL is to provide a flexible testing space that can achieve cost-effective and quick turnarounds for validation studies; using CAD shelves would allow for rapid set up and high levels of customisation.

1.1 Food Industry

The competition between packaged food products is growing ever more intense as they increase rapidly in choice. A review by Simmonds and Spence (2016) reveals that more than 70% of consumers make purchase decisions on daily necessities in store, 85% of goods are purchased without picking up an alternate option, and 90% are purchased after examining only the front packaging design of a product without holding it in their hands. Corporations that dominate the industry, have a distinct advantage in the food market as they have the capital for developing leading facilities that test branding and packaging design before a product is released (Wedel and Pieters, 2008; Tonkin, et al., 2011).

Incorporating iterative feedback into the packaging design process, may prove to be a challenge for SMEs as the cost of technology and testing space is a significant limitation. Thus, Tonkin et al. (2011) conceptualised The CUshop, a facility that functioned as an alternative to real supermarkets. Tonkin et al.'s study (2011) focused exclusively on the immediate visual cues of a shopping context (shelving) and suggested that further studies incorporate other environmental factors that can make the simulated shopping experience more realistic, and if possible, suggests higher fidelity projectors, but stresses the point of keeping the testing facility costs low.

1.2 Context in User-testing

The importance of keeping participants in a shopping context is emphasised by Young (2002) to attain the most relevant results in product testing. Research suggests that when a participant does not associate their surroundings with a shopping context, they will often disconnect themselves from a shopping mind-set, and instead assume a more aesthetically critical mentality, transforming the experiment into a 'beauty contest' where the most visually appealing design will rate higher; a behaviour that is inconsistent with purchase decisions made at the shelf in real life (Young, 2002).

If possible, user-testing conducted in-context is best as it yields the most true-to-life results, however a simulated environment is a good alternative as it accommodates for important testing considerations that traditional laboratory settings cannot achieve (Gordon, 2010). It is able to recreate social and physical variables (to some extent) and can induce mental states similar to that of the real context, with the advantage of confidentiality and ease of data recording, inherent to user-testing in traditional laboratories. Additionally, a simulated environment space is quick and easy to set up, providing flexibility for studies across a range of different fields, resulting in a comparatively more cost-effective alternative to testing in-context.

The capabilities of PEL as a low-cost simulated supermarket environment is developed by increasing the fidelity of projected images with the addition of exploring different visual geometries to further increase the sense of immersion while keeping costs low and provide high levels of customisation. The synthetic reality space can replicate external variables (to some extent) to simulate a real-life context in a laboratory setting; it is also customisable, it ensures confidentiality, and enables the easy set-up of an array of data recording devices.

1.3 Perceptual Experience Lab

A new synthetic reality space, PEL was developed by FOVOLAB© and the User Centred Design Research Group (UCD-R) at Cardiff Metropolitan University. The function of PEL is to serve as a low-cost, customisable, synthetic reality backdrop, providing context for product testing. A realistic context is crucial to this research as the most true-to-life results are yielded when product testing is conducted with participants in a shopping mind-set (Young, 2002).

The laboratory replicates real environments with controlled and monitored conditions. An idea initially conceived as the Augmented Virtual Environment (AVE) by Gordon (2010), the PEL space allows for customisable low-cost immersive synthetic environments. Expanding on Gordon (2010) and Tonkin's (2011) recommendations for further research, PEL has achieved higher image quality, and expanded on the field of view. High resolution images are back-projected by six 4K projectors, on to a custom built 5280px by 1980px, 200º wrap around screen.

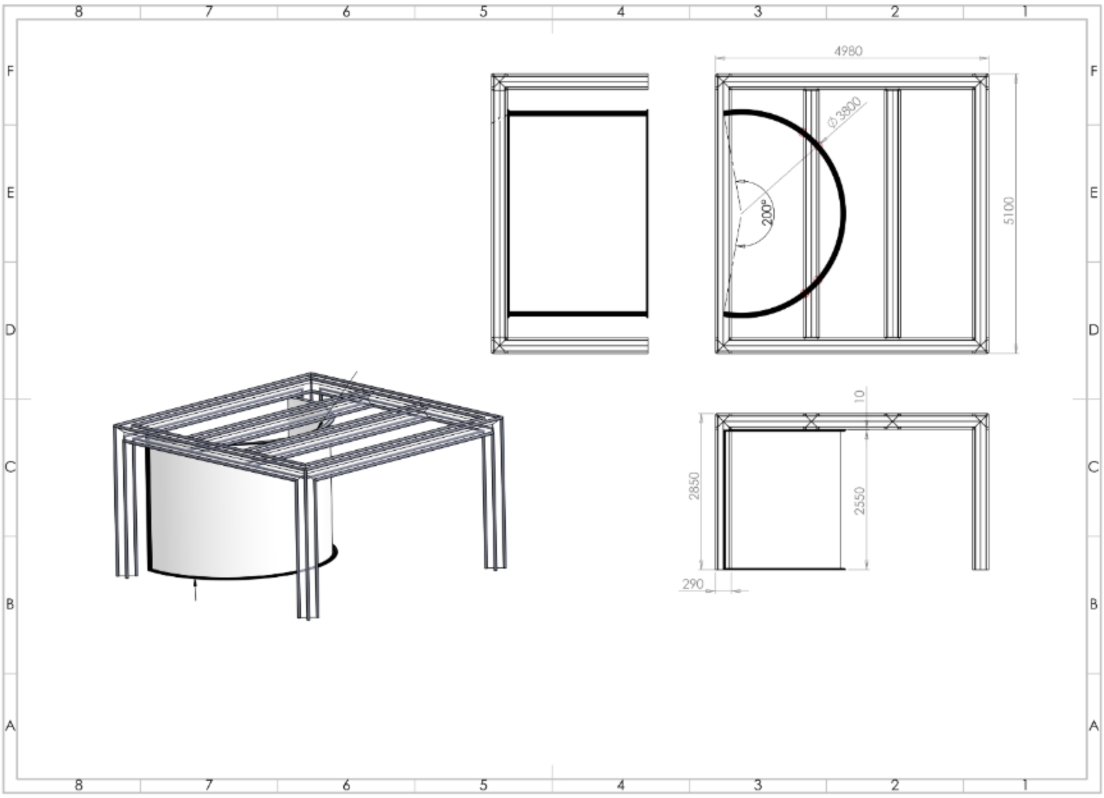


Figure 1. Perceptual Experience Laboratory Screen Dimensions

Figure 2. High resolution photograph of supermarket shelves projected on 200°-degree wrap-around screen

PEL offers a high level of customisation, flexibility, and a broad spectrum of data collection methods. Surround sound, light and temperature control, air flow, smell diffusion, and the capacity for physical props can be adjustment and manipulated to control the sense of immersion. State-of-the-art observation software, eye-trackers, microphones, and heart rate variability monitoring equipment allow detailed monitoring and recording of studies.

1.4 Linear vs Natural perspective

The process of vision is composed of both foveal and peripheral modes of seeing (Danahy, 2001). Foveal vision is a rapid, dynamic scanning and sampling of objects, whilst the peripheral vision works in tandem to judge where the body is in space. Research conducted by Watanabe and Matsuoka (1999) suggests that peripheral vision improves our ability to make depth judgements in the fovea and plays a significant role in our awareness of space. This is important because we want the participants to make true to life purchasing decisions.

The human binocular visual field is 180° horizontal and 130° vertical, however common methods of capturing what the eye perceives is usually cropped by the window format of linear perspective, consequently excluding much of the peripheral field, including our own bodies (Strasburger, et al., 2011; Pepperell, 2015). Artists have long been aware of linear perspective's limitations as it cannot effectively capture wide angles of view because objects in the periphery become increasingly stretched or distorted (Tyler, 2015).

The term "Natural Perspective" became popular amongst artists in the 19th century as an alternate method of depicting reality as it appears to the eye, rather than a mathematical equation (Herdman, 1853; Raynaud, 2016). Natural perspective accommodates for features of perception that linear perspective is unable to do, for example, the perceptible fading of objects as they recede from the viewer's frontal plane, or the distinct curvature of straight lines in the peripheral visual field (Macnair, 1957). Burleigh et al's (2018) research found that people prefer photographs of wide scenes in natural perspective as it has more curvature in the periphery and tends to enlarge areas of the scene under central fixation. Participants reported that they preferred natural perspective over linear perspective as they found that it has more spatial presence and is more comfortable to look at. Burleigh et al's research concluded that in comfortable viewing condition, natural perspective is more effective at depicting wide angle scenes than more common perspective alternatives.

Most image capturing devices are based on linear perspective, and generally capture only a single eye point of view. FOVOGRAPHY© overcomes these limitations by capturing the full field of vision, resulting in more images that appear to have much more breadth and depth than conventional images (Smith, et al., 2017). Fovography is a non-linear projection framework that reproduces the subjective appearance of what the eye sees as perceived via the human visual system. Burleigh, et al. (2017) have found that Fovogaphised images have shown higher ratings in psychological factors such as sense of presence, comfort, and ecological validity compared to standard visual projections. Furthermore, Fovograph images rated on par with a virtual reality system without glasses, headsets or specialist display hardware and rated as equally immersive on large format 180° cylindrical projection screen.

1.5 How to measure sense of presence?

Presence is generally defined as a participant's subjective sensation of "being there" in a scene depicted by a medium, additionally described as a "cognitive state" consistent with a sense of "being there" in an environment, a state that results from attending to and evaluating in coming sensory information (Barfield, et al., 1995).

The ITC-Sense of Presence Inventory (ITC-SOPI) is a questionnaire measure developed by previous research on determinants of presence and current self-report measures (Lessiter, Freeman, Davidoff, & Keogh, 2001). It uses a 5-point Likert scale (1=strongly disagree, 5 = strongly agree) for consistency and makes it easier for participants to complete the questionnaire and for responses to be scored. Questions are phrased carefully, simply, and unambiguously, and numbered. It focuses on users' experience of media, with no reference to objective system parameters.

2 Experiment 1: Geometry vs Realism

2.1 Aim

It is necessary that participants feel immersed in a shopping environment to obtain the most true-to-life purchasing decisions when user-testing. The aim of this experiment was to determine if image geometry (Linear vs Natural perspective) and content realism (Photograph vs Computer Aided Design (CAD)) have an impact on the sense of presence, and whether these two variables are dependent on one another.

2.2 Conditions

As found in a previous Environmental Validation experiment (Lawrence, 2019), the set up engaged the visual, olfactory, haptic and auditory senses.

Figure 3. Additional environmental stimuli (Visual, Auditory, Haptic, Olfactory)

To further augment the sense of presence, participants were given a filled shopping basket to hold, a specialist bread smell was sprayed around the screen, and a 24-point surround sound system created a full 360° soundscape (Darken et al., 1999) to serve as sensory cues to create a supermarket context.

Figure 4. Conditions from A-D; A – linear perspective photograph; B – Fovographised (natural perspective) photograph; C – linear perspective CAD model shelf; D – Fovographised (natural perspective) CAD generated scene.

Condition A is a linear perspective photograph of supermarket shelves taken at Tesco.

Condition B is the same image, “Fovographised”, and remapped into natural perspective. The Fovographised photo is more curved at the periphery and offers a wider field of view. Condition C is a CAD rendering of a supermarket shelf with the same cereal options as the photograph. Condition D is a “Fovographised” CAD scene, custom made to imitate the photograph in conditions A and B. It is important to note that although images for conditions A, B and D look distorted in Figure 4 above, when viewed while standing in front of the curved PEL screen the perceived distortion disappears and the aisle looks straight.

2.3 Methodology

1. 32 participants, varying in occupation, gender, and age, took part; the broad spectrum of demographics represents a diversified sample of supermarket frequenters. Participants and conditions were counterbalanced, so the cumulative increase of stimuli did not yield bias results.

Counterbalancing is a method of experiment design in which, when applied, the researcher can control order effects when using repeated measures (Field, 2013). Independent variables (usually two or more) occur equally in each test group and balance each other out in the results (Alferes, 2012). The 32 participants were split into 4 groups of 8, with each group experiencing a different order of conditions (ABCD, BCDA, CDAB, DABC).

2. Participants were taken to the test condition, asked to perform a search task in PEL and wait 30 seconds before being removed from the environment.

The search task given to participants to perform in each condition was to identify a brand of cereal in the projected image. The order of cereal brands was also counterbalanced against the order of conditions. The search task was a method of priming, and to further enhance the authenticity of the simulated shopping experience; the function was to maintain a sense of purpose and mitigate against the unfamiliarity of the PEL space.

Participants were asked to stand in each condition for 30 seconds to ensure consistency of time immersed in each simulated environment. 30 seconds proved long enough to complete the search tasks given in every condition test, but not so long that participants lost interest and/or become disconnected from the shopping context.

3. Each participant was asked to fill in a questionnaire form after each condition to capture their experience while it was fresh in their minds.

The questionnaire was informed by the Cross-Media Presence: ITC-Sense of Presence study (ITC-SOPI) (Lessiter, Freeman, Davidoff, & Keogh, 2001). It is an inventory of questions that measures the sense of presence with a focus on users’ experiences of media. There are three facets of media experience that are believed to be related to presence: Spatial presence, ecological validity, and negative effects. Questions relating to participants’ sense of immersion and believability were selected from this inventory for this experiment. Following the ITC-SOPI questionnaire guidelines, additional questions were added where deemed appropriate to get a better sense of how participants’ feelings of enjoyability, likability, and believability of the simulated space.

Table 1. This table lists all items used for the questionnaire in Experiment 1 and 2. The first, second, and third rows are items selected from the ITC-SOPI inventory; the fourth through sixth rows are customised questions.

Psychological Variables	Items used in Experiment 1 and 2
Spatial Presence	*"I felt I could interact with the displayed environment."* *"I felt I was visiting the places in the displayed environment."* *"I had a sense of being in the scenes displayed."* *"I felt that I could move objects (in the displayed environment.)"*
Ecological Validity/Naturalness	"The displayed environment seemed natural." "The content seemed believable to me." "I felt that the displayed environment was part of the real world."
Negative Effects	"I felt disoriented."
Enjoyability	"I enjoyed the experience."
Likeability	"I liked the image."
Believability	"The simulation is a realistic representation of a supermarket." "I felt I could interact with the displayed environment."

The Cardiff School of Art and Design's Research Ethics Committee gave ethics approval for the study. All participants gave their informed consent prior to their inclusion in the study.

2.4 Results

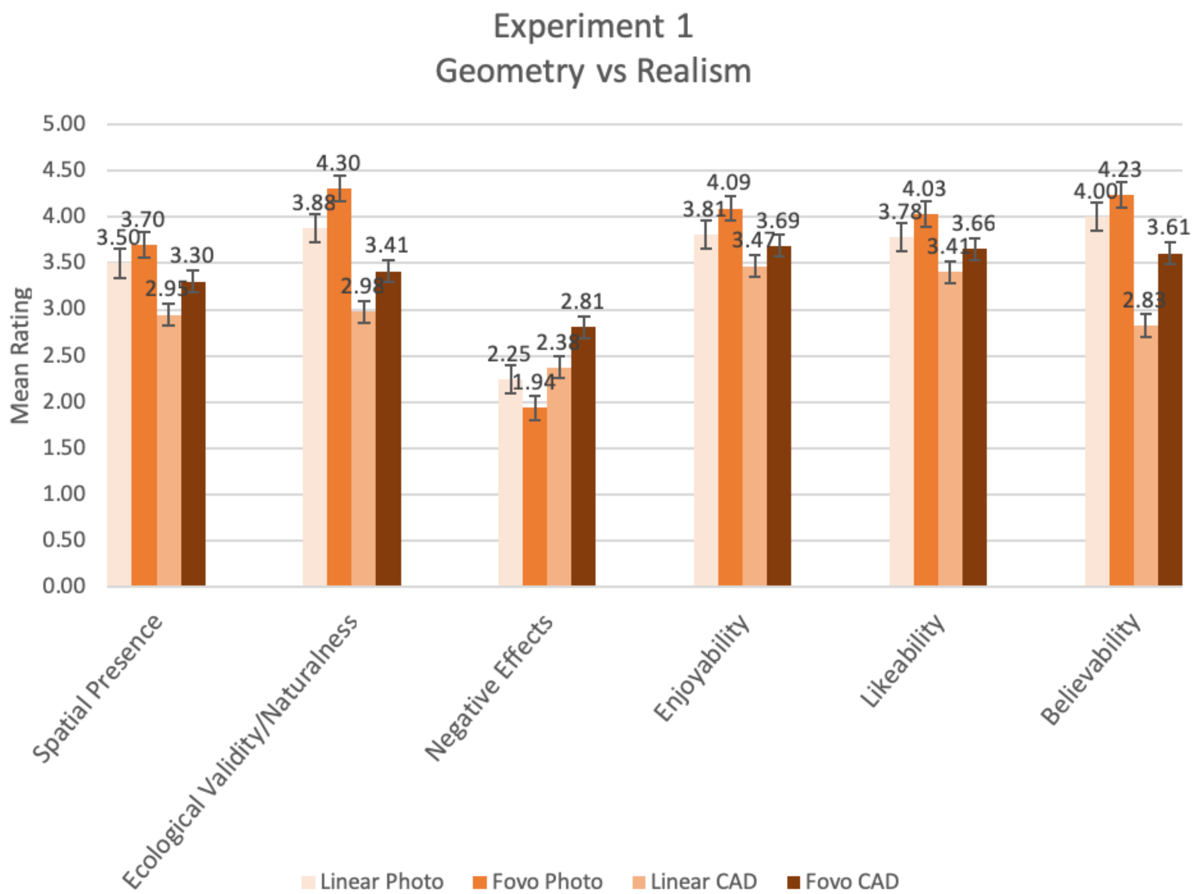


Figure 5 This graph reports the mean ratings (N= 32) of psychological variables on a 5-point Likert scale for each visual content: Linear Photo, Fovo Photo, Linear CAD, and Fovo Photo. Standard error is represented by the error bars attached to each column.

A repeated measures ANOVA was conducted for all the psychological variables. For the Spatial Presence variable, the Mauchly's Test indicated that the assumption of spherity had not been violated, $\chi^2(2) = 6.50$, $p = 0.26$. The pairwise comparison showed that there was a significant difference ($p < .05$) between the Spatial Presence rating of Fovo Photo (3.70) and Linear CAD (2.95). No other comparisons were significant (all $p > .05$).

For the Ecological Validity variable, with a Greenhouse-Geisser correction, the results showed that mean Ecological Validity differed significantly between images [$F(2.10, 65.10) = 18.74$, $p < 0.001$]. Post hoc tests, using the Bonferroni correction, revealed that there were significant differences ($p < .05$) between Linear Photo (3.88) and Fovo Photo (4.28), Linear Photo (3.88) and Linear CAD (2.98), Fovo Photo (4.28) and Fovo CAD (3.41), Linear CAD (2.98) and Fovo Photo (4.28). The highest average rating of Ecological Validity was Fovo Photo (4.28), and the low average rating of Ecological Validity was Linear CAD (2.98).

For the Negative Effects variable, the Mauchly's Test indicated that the assumption of spherity had not been violated, $\chi^2(2) = 10.56$, $p = 0.06$. The pairwise comparison showed that there was a significant difference ($p < .05$) between the Negative Effects rating of the Fovo Photo (1.94) and Fovo CAD (2.81). No other comparisons were significant (all $p > .05$).

For the Enjoyability variable, the Mauchly's Test indicated that the assumption of spherity had not been violated, $\chi^2(2) = 11.04$, $p = 0.05$. The pairwise comparison showed that there was a significant difference ($p < .05$) between the Enjoyability rating of the Fovo Photo (4.09) and Linear CAD (3.47). No other comparisons were significant (all $p > .05$).

For the Likabilty variable, the Mauchly's Test indicated that the assumption of spherity had not been violated, $\chi^2(2) = 6.25$, $p = 0.28$. The Post hoc test showed no significant interaction between the Likability rating of the four images.

For the Believability variable, with a Huynh-Feldt correction, the results showed that mean Believability differed significantly between images [$F(2.53, 78.43) = 17.89$, $p < 0.001$]. Post hoc tests using the Bonferroni correction revealed that there were significant differences ($p < .05$) between Linear Photo (4.00) and Linear CAD (2.83), Fovo Photo (4.23) and Linear CAD (2.83), Fovo Photo (4.23) and Fovo CAD (3.61), Fovo Photo (3.61) and Linear CAD (2.83). The highest average rating of Believability was Fovo Photo (4.23), and the low average rating of Believability was Linear CAD (2.83).

2.5 Discussion

The repeated measures ANOVA revealed that there was no significant interaction between geometry and realism. Meaning the Fovographised images were significantly impactful on the participant's sense of presence, irrespective of whether it was a photograph or CAD rendering.

The Fovo photo was consistently the highest rated in the psychological variables (except Negative effects, where it is rated the lowest), rating significantly higher than Linear CAD in all categories expect likeability. The Linear Photo ranked consistently in second place, however it did not rate significantly higher than the Fovo CAD in any category. The Fovo CAD ranked third with the Linear CAD rated the lowest throughout. This result reveals that geometry is a significant factor in affecting the participants' response with regard to sense of presence and that does not correlate with realism. However, realism is still important.

This is demonstrated by the mean believability ratings that showed that the Linear Photo was rated significantly higher than the Linear CAD, however not significantly higher than the Fovo CAD, meaning realism is important, but second to geometry.

The photograph used in this experiment was taken in Tesco, however, photographing permissions are difficult to acquire, and consent to photograph at the same store was later denied due to a rotation in store management. Moreover, external variables are hard to control in the real supermarket environment and may cause ethical concerns of unintentionally photographing real shoppers. Thus, the second part of this study studies whether a CAD-Photo hybrid can be used as an alternative to photographing real supermarket shelves for each new study. A hybrid will increase flexibility, allowing for quick turnovers of studies thus keep costs low for SMEs.

3 Experiment 2: Hybrid

To further investigate the possibilities and push the boundaries of conventional visual stimulus, a hybrid image between CAD shelving and the preferred Fovographised photograph was created. If successful, this hybrid scene will allow for high levels of customisation, and rapid content alteration for faster, more cost-effective testing; keeping costs low for Welsh SMEs.

3.1 Conditions

In this experiment, PEL was set up in the same way as the previous study. The visual (sight), auditory (sound), olfactory (smell), and haptic (touch) senses were added.

Figure 6 Condition A Fovographised© Photograph (Fovo photo); Condition B Fovographised© CAD-Photograph Hybrid (Hybrid)

Condition A is the same Fovo photo that resulted in the highest ratings in experiment 1.

Condition B is a hybrid of the Fovo photo and CAD rendered shelving.

3.2 Methodology

1. 16 participants from Cardiff Metropolitan University varying in occupation, gender, and age, took part; the broad spectrum of demographics represented a diversified sample of supermarket frequenters. Again, participants and conditions were counterbalanced, so the cumulative increase of stimuli did not yield bias results.

The 16 participants were split into two groups. Group 1 experienced the viewing order AB, whereas Group 2 experienced the viewing order BA.

2. Participants were taken to the test condition, asked to perform a visual search task on the PEL screen and wait 30 seconds before being removed from the environment.

As before, the search task given to participants to perform in each condition was to identify a brand of cereal in the projected image. The order of cereal brands was also counterbalanced against the order of conditions. Participants were asked to stand in each condition for 30 seconds to ensure consistency of time immersed in each simulated environment.

3. Each participant was asked to fill in the questionnaire form after each task and condition to capture their experience while it was fresh in their minds.

The Cardiff School of Art and Design's Research Ethics Committee gave ethics approval for the study. All participants gave their informed consent prior to their inclusion in the study.

3.3 Results

A paired sample t-test was conducted to compare dependent variable groups between condition A (Fovo photo) and condition B (Hybrid)

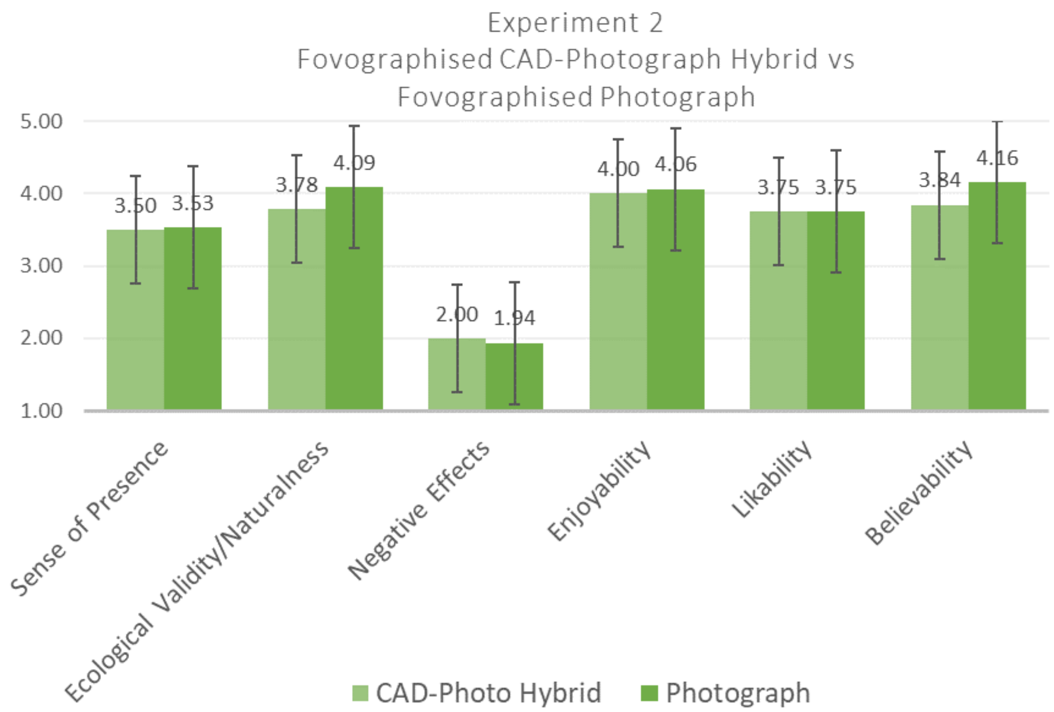


Figure 7. This graph reports the mean ratings (N= 16) of psychological variables on a 5-point Likert scale for each Fovo Photo and Hyrbid. Standard error is represented by the error bars attached to each column.

There was no significant difference between the ratings of the variables apart from the Believability variable: Sense of Presence between Fovo photo (M= 3.5, SD= 0.68) and Hybrid (M= 3.53, SD= 0.51) conditions; t(-0.26)= 15, p= 0.8; Ecological Validity between Fovo photo (M= 3.78, SD = 0.77) and Hybrid (M= 4.09, SD= 0.67) conditions; t(-1.72)= 15, p= 0.11; Negative Effects between Fovo photo (M= 2.0, SD= 0.89) and Hybrid (M= 1.94, SD= 0.68) conditions; t(0.44)= 15, p= 0.67; Enjoyability between for Fovo photo (M= 4, SD= 0.73) and Hybrid (M= 4.06, SD= 0.68) conditions; t(-0.57)= 15, p= 0.58; Likability between Fovo photo (M= 3.75, SD= 0.86) and Hybrid (M= 3.75, SD= 0.57) conditions; t(0.0)= 15, p= 1.0. There was a significant difference in ratings for Believability between Fovo photo (M= 3.84, SD= 0.72) and Hybrid (M= 4.16, SD= 0.65) conditions; t(-2.6)= 15, p= 0.02.

3.4 Discussion

The results from experiment 2 showed that although the hybrid rated slightly lower than the Fovo photo, there was no significant difference between Fovo Photo and hybrid images in any of the psychological variables except believability. This suggests that the sense of presence rating of the hybrid image is on par with the Fovo Photo, which rated the highest in experiment one.

4 Conclusion

Experiment one showed that regardless of the realism of the content, image geometry had more of an impact on participants' sense of presence, with participants preferring the Fovographised (natural perspective) version of content, which provided more depth and field of vision. However, realism was still an important factor, with the photograph being preferred over the CAD image, based on our psychological variables.

With geometry and realism both being important factors to consider, the use of a hybrid image is a way of retaining both factors in a cost effective and practical way. With results suggesting the hybrid is comparable to the Fovo Photo (the highest rated scene), it can be used as a versatile alternative that can be adapted for numerous studies. The hybrid offers high levels of customisation and flexibility, allowing for rapid experiment turnover times, which feeds into the broader aim of using PEL as a low-cost user-testing facility for SMEs.

5 Limitations

As only 32 participants were involved in the first study and 16 in the second, the results from this experiment cannot be used to represent the choices of the general population. Further larger scale studies are required to validate these results. This study focused exclusively on vertical shelving fixtures that featured flat surfaced packaged products. Manipulation of packaging designs on a flat surface is technically more straightforward than free form packaging or fixtures of different formats and features. Other products and fixtures may prove technically more difficult and require further investigation.

6 Future Implications

The overall aim of the research is to combine theoretical knowledge of marketing and design, with the practical implications of user testing, to investigate if packaging design can be improved through low-cost simulated environments and increase Welsh food SME sales in the supermarket. The next phase of this research is to employ the results of this study as a framework for creating future visual content as part of an iterative design process.

This experiment focuses on PEL solely as a user-testing space for food packaging, however the purpose of this space is to be flexible, and therefore has the has potential for a variety of uses in a wide range of fields.

7 References

Alferes, V. R. (2012). *Methods of randomization in experimental design* (Vol. 171). Sage Pulications.

Ampuero, O., & Vila, N. (2006). Consumer perceptions of product packaging. *Journal of Consumer Marketing, 23*(2), 100-112.

Barfield, W., Zeltzer, D., Sheridan, T. B., & Slater, M. (1995). *Presence and Performance within Virtual Environments.* Oxford: Oxford University Press.

Buchenau, M., & Suri, J. F. (2000). Experience Prototyping. *Proceedings of the 3rd conference on Designing interactive systems: processes, practices, methods, and techniques.* ACM.

Danahy, J. (2001). Technology for dynamic viewing and peripheral vision in landscape visualization. *Landscape and Urban Planning, 54*, 127-138.

Darken, R. P., Bernatovich, D., Lawson, J. P., & Peterson, B. (1999). Quantitative Measures of Presence in Virtual Environments: The Roles of Attention and Spatial Comprehension. *CyberPsychology & Behavior*, 337-347.

Field, A. (2013). *Discovering statistics using IBM SPSS statistics* (4th Edition ed.). Sage.

Gombrich, E. (1960). *Art and Illusion.* London: Phaidon Press.

Gordon, B. (2010). Emulation of a Real Life Environment via an Augmented Virtual Environment. Swansea: Swansea Metropolitan University.

Herdman, W. G. (1853). *A Treatise on the Curvilinear Perspective of Nature; and Its Applicability to Art.* London: John Weale & Co.

Kassab, E., Tun, J. K., Arora, S., King, D., Ahmed, K., Miskovic, D., . . . Kneebone, R. (2011). “Blowing up the barriers” in surgical training: exploring and validating the concept of distributed simulation. *Annals of surgery, 254*(6), 1059-1065.

Lawrence, A. (2019). Thought for Food: A research-led approach to improved Welsh food industry competitiveness. *The International Conference on Culinary Arts and Sciences.* Cardiff: IN PRESS.

Lessiter, J., Freeman, J., Davidoff, J. B., & Keogh, E. (2001, June 1). A Cross-Media Presence Questionnaire: The ITC-Sense of Presence Inventory. *Presence Teleoperatores and Virtual Environments, 10*(3), 282-297. Retrieved from http://research.gold.ac.uk/483/

Macnair, J. (1957). Spherical Perspective. *Journal of the Royal Society of Arts, 105*, 762–780.

Milton, H. (1991). *Packaging Design.* London: Bourne Press Ltd.

Murray, N., Ademoya, O. A., Chinea, G., & Muntean, G. M. (2017). A Tutorial for Olfaction-based Multisensorial Media Application Design and Evaluation . *ACM Computing Surveys, 50*(5).

OECD. (2014, May 15). *Competition issues in the Food Chain Industry.* Retrieved January 2, 2018, from OECD: http://www.oecd.org/daf/competition/competition-issues-in-food-chain.htm

Pepperell, R. (2015). Egocentric perspective: Depicting the body from its own point of view. *Leonardo, 48*(5), 424–429.

Raynaud, D. (2016). *Studies on Binocular Vision: Optics, Vision, and Perspective from the Thirteenth to Seventeenth.* New York: Springer.

Retail Think Tank. (2016, June 19). *The future of the grocery sector in the UK.* Retrieved January 2, 2018, from Retail Think Tank: http://www.retailthinktank.co.uk/whitepaper/the-future-of-the-grocery-sector-in-the-uk/

Rubin, J., Chisnell, D., & Spool, J. (1994). *Handbook of Usability Testing: How to Plan, Design, and Conduct Effective Tests* (2 ed.). New York: John Wiley Sons.

Simmonds, G., & Spence, C. (2016). Thinking inside the box: How seeing products on, or through, the packaging influences consumer perceptions and purchase behaviour. *Food Quality and Preference, 62*, 340-351.

Smith, C. H., Rasool, J., Lambert, N., Pepperell, R., Langford, T., & Veltman, K. (2017). Natural Media Workshop. *Electronic Visualisation and the Arts.* London: BCS Learning and Development Ltd.

Strasburger, H., Rentschler, I., & Jüttner, M. (2011). Peripheral vision and pattern recognition: A review. *Journal of Vision, 11*(13).

Tonkin, C., Ouzts, A., & Duchowski, A. (2011). Eye tracking within the packaging design workflow: Interaction with physical and virtual shelves. Research Gate.

Tyler, C. W. (2015). The Vault of Perception: Are Straight Lines Seen as Curved? *Art & Perception, 3*(1), 117-137.
Watanabe, H., & Matsuoka, K. (1999). Peripheral vision facilitates depth perception in the fovea . *ECVP'99 European Conference on Visual Perception.* Trieste: University of Trieste.
Welsh Government. (2015, June). *The Value of Welsh Food and Drink, Executive Report.* Retrieved November 2016, from https://businesswales.gov.wales/foodanddrink/about-us/welsh-food-and-drink-numbers-and-value-welshness
Young, S. (2002). Packaging design, consumer research, business stragety: The march toward accountability. *Design Management Journal , 10*(3), 10-14.

About the Authors:

Abbie Lawrence: With a background in Graphic Communication, Abbie is currently a PhD candidate at Cardiff School of Art and Design (CSAD), whose research is exploring whether product testing in a simulated environment can improve packaging designs and increase sales for Small-Medium Enterprises in Wales.

Professor Gareth Loudon: Active in academic and industrial research for over 25 years with several patents to his name and over 50 publications in total, Gareth's research interests focus on creativity and the innovation process, combining ideas from anthropology and psychology, engineering and design.

Professor Steve Gill: A product designer with 23 years of professional experience in industry and academia, Steve has designed, or product managed around 50 products to market and has published around 70 peer reviewed outputs.

Professor Robert Pepperell: The founder of FovoLab, Robert's current research combines methods from art and science to investigate the nature of visual experience and how it can be represented; to develop a new form of pictorial perspective based on the phenomenology of visual perception.

Dr Joe Baldwin: Joseph Baldwin is a Product Designer, Educator, and Research Scientist who works full time as a Research Officer within CSAD. The publication of both his Ph.D. research and further research as a Research Assistant helped support and promote the Fovography imaging method at CSAD.

High Heel Insole Design for Delaying Bunion Development

Lu, Hsiu-Ching *[ab]; Wu, Fong-Gong[a]; Chen, Chien-Hsu[a]

[a] Department of Industrial Design, National Cheng Kung University, Tainan City, Taiwan
[b] Department of Styling and Cosmetology, Tainan University of Technology, Tainan City, Taiwan
* t80058@gm.tut.edu.tw

THIS THESIS puts forward a discussion on the research of high podiatric pressure, recruiting 100 female workers who need to wear high heels. The background of the subjects is the hotel industry and department store workers. On average, they wear high heels for two days a week for 5 to 8 hours. By using contextual inquiry to better understand the needs and usage of users, as well as to analyze the pain points of the feet and unify the contents of three expert interviews to find the solution through the direction of bones and muscles with the concept of ergonomics. Find the location of the measurement through the direction of the bones and muscles as the basis for the assessment. Through the five young women with the same body condition, wearing the high-heeled shoes on the market, rubbing the footprints, and using the gravity distribution displayed by the footprints as an experimental observation and improved design, the results show that the design of the (experimental group/control group) insole can change the pressure state of the toe and ankle joints, which is limited for commercially available shoes. The shoe last has limited the space of the foot, and the increase of the insole requires consideration of the inner space of the shoe for design. This study proposes a relationship between bone structure and ergonomics. Through the support of the big toe ball and difference in heights, the distribution of foot pressure is effectively changed, and the comfort design is specifically proposed.

Keywords: sole pressure measurement; pressure distribution; biomechanics; gait analysis Introduction

1 Introduction

Fashion has brought to female workers the idea of the pursuit of clothing, but also the impact of cultural and social status. Most women work in high heels, and they will feel that wearing high heels will subconsciously remind them to have better posture, making their poise more elegant and more dignified. So, most modern women love high heels, and the development of high heels throughout the ages still captures the hearts of women (Domjani, Ujevi, & Wallner, 2016). With the support of scientific evidence, women wearing high heels increase in attractiveness, even more so towards men(Morris, White & Morrison, 2013; Guéguen,2014).High-heeled shoes are worn by many women, especially flight attendants, department store clerks, and hotel service personnel in order to enhance their professional image, because of long-term wear, high heels also bring great damage to their feet (APMA, 2014).Women who began wearing high heels at the age of 20-64 showed a 47% increase in cases of bunion development (Dufour, Casey, Golightly, & Hannan, 2014).Long-term wear of high-heeled shoes, whether standing or walking, experience uneven pressure on the knees and ankle joints, which causes the force of gravity to be concentrated on the forefoot. High heels have been proven to be one of the external factors that cause HV formation, it is pointed out that high-heeled shoes are more likely to increase the risk of bunions than flat-bottomed shoes (Coughlin & Jones, 2007). In addition, because the pointed tips of stilettos, the force is squeezed in the inner space of the upper shoes, and it is easy to form a bunion, hallux valgus or pinky valgus, neuroma, thick sputum and other disorders (Perera, Mason, & Stephens, 2011). The hallux joint of the foot will develop lesions due to the soft tissue sclerosis at different stages (Gefen, Megido-Ravid, Azariah, Itzchak, & Arcan, 2001; Klaesner, Hastings, Zou, Lewis, & Mueller, 2002). The use of insole and heel pads can aid in the relief of further damage. Suggestions regarding insoles: (a) Flat insoles made of soft material can reduce stress tensor (b) Flat insoles with tapered or cylindrical projections can reduce the maximum force, harder insole material allows the projections to be more supportive; (c) Customized insoles with tapered or cylindrical projections minimizes maximum stress applied and stress received (Luo, Houston, Garbarini, Beattie, & Thongpop, 2011).

1.1 Research Purpose and Process

Through papers regarding the study of high-heeled shoes, it can be divided into two parts to establish high-heeled design guidelines: (1) to understand the user's use through the vein observation, to confirm the use of high-heeled shoes through interviews and analysis; (2) biology based on the mechanics and musculoskeletal system kinetics proposed to use the action attributes of high heels to understand the active state of the human body to discover the basics of design, as shown in Figure 1.

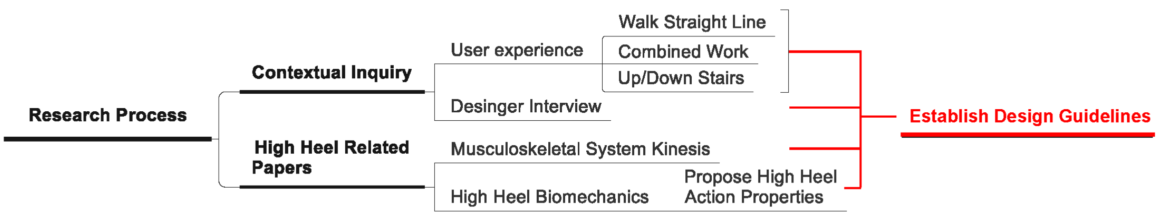


Figure 1. Research flow chart

1.2 Research purposes

- Through the design of high heel pads, relieve the situation of hallux valgus.
- Through observation of users, further understand current use of high heels.
- Learn about effects of hallux valgus on human anatomy through literature.
- Learn from experts to understand basis for high heel design, explore design rules for high heel insoles.

2 Literature review

The musculoskeletal system kinesiology and high heel biomechanics are the foundations of feet. Through the normal movement of the bones, the bone movement and function are understood. Based on the principle of high heel biomechanics, suggested design of the high heel can be found.

2.1 Musculoskeletal System Mobility

Figure 2 shows that in the exploded view of foot bones, the foot can be divided into three parts: the forefoot, the middle foot, and the hind foot. The main function of the forefoot and midfoot is to grasp the movement and balance body weight. Because the arch and the forefoot will balance via eversion and inversion, the main function of the hind foot is stability. Interface with the ankle joint has concave and convex curved surfaces, and these joint surfaces form a buckled wedge shape to resist sliding between each other (Buchanan & Davis, 2013).

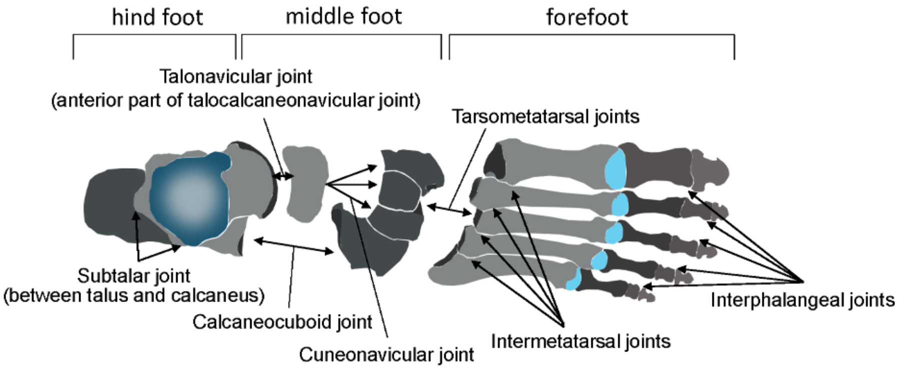


Figure 2. Joints of the foot

2.1.1 The direction of the ankle joint movement

Figure 3 shows the direction of the ankle joint movement. The ankle joint, the heel joint and the Achilles joint form the foot joint. Excessive dorsiflexion or plantar flexion can cause ankle injury. Fig (A) Dorsiflexion: the muscles of dorsiflexion are weak. They are the tibialis anterior muscle, the extensor hallucis longus, the long extensor digitorum and the third metatarsal muscle. Fig (B) Squatting: The muscles of the plantar flexion are strong and powerful, mainly assisting the gastrocnemius and soleus muscle, the posterior tibial muscle, the flexor hallucis longus, the long flexor digitorum and the long and short muscles of the tibia. When the plantar flexion is in the position of the loosest angle of the ankle joint, the plantar flexion will turn the talus between the inner and outer iliac crests to a narrower width, and the internal tension of the connecting tenon. The direction of movement of the plantar flexion is similar to the angle of the ankle joint when wearing high heels. The plantar flexion causes the distal ankle and the tibia to loosen the grip for the talus, so when the body weight comes down, the ankle joint is in an unstable position, usually deformed. It is easy for this angle to cause the inversion of the foot, which increases the potential of a sprained ankle (Watanabe, Fujii, Kitaoka, Kotajarvi, Luo, & An, 2012).

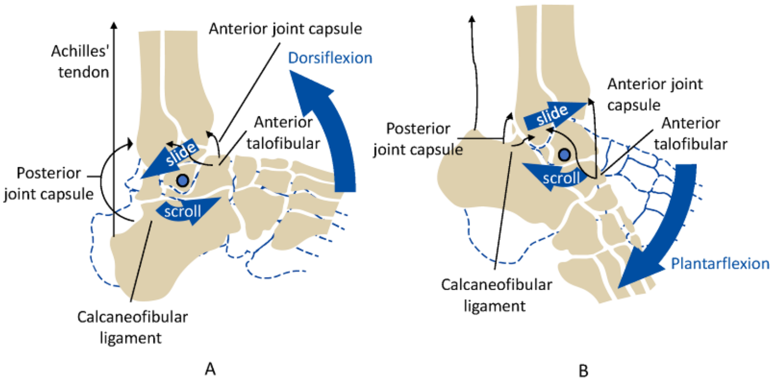


Figure 3. Ankle dorsiflexion and distortion

2.1.2 High-heeled Motion Mechanics

Pushing the action map through the foot gait displacement, as shown in Figure 4. Picture A: the state of normal walking, the way of weight displacement is 1 hind foot (downward joint): the heel first grounded, the foot will pre-rotate and lower the inner side, the height of the longitudinal arch is like the lever action principle of 2. The midfoot (transverse ankle joint): the outer leg plate balances the reaction force of the ground in a relatively inverted posture. The arch can achieve shock absorption and balance body weight. 3. Forefoot (toe): forced forward through the midfoot, this part pops up along the base of the big toe of the foot and pushes forward. Picture B: the state of abnormal walking, the position of the midfoot (transverse ankle) is directly passed by the 1 hind foot (the lower joint), and the walking will come like a gesture of the outer character, because the lack of 2. Midfoot (horizontal ankle joint) balance, the arch cannot absorb the weight of the body to reach balance, so 3. The forefoot (the toe) directly receives the weight of the body, causing the thumb joint too often have an abnormal torque, and the big toe will be elongated, forming hallux valgus (Lee & Wilkinson 2018).

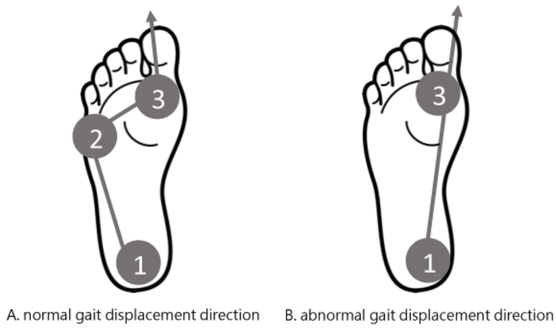


Figure 4. Foot gait displacement propulsion action diagram

There are three stages of action in the high-heeled gait activity, as shown in Figure 5. (A) Station force stage: the foot joints are stable and balanced, the footsteps are ready for external rotation, and the tibia is ready for external rotation. (B) Propulsion stage: Heel leaving the ground, center of gravity moves forward, sole of foot pushes, foot and humerus rotate outward; (C) Heel touches ground: heel first follows the lateral ground, foot and tibia are slightly inward, through the arch the force is generated, it has elasticity and shock level to stabilize the footsteps. In the early to middle stages of gait standing, the first ankle is gradually dorsiflexed by about 5 degrees (Cornwall & McPoil, 2014). This action occurs around the wedge bone, and when it sinks because of weight, at the same time, the ground pushes up the end of the first toe. This action is associated with a progressively lower medial zygomatic arch, which is a mechanism by which the foot helps absorb stress from the body (Glasoe, Yack, & Saltzman, 1999).

Figure 5. Three stages of high heel gait activity

2.1.3 Observation of Gait Movement Force

Feet are observed through a walking line, as shown in Figure 6: The dotted line shows the state of feet during normal walking, and the red arrow shows the direction of the big toe force. When walking, the soles will be subjected to equal stress along with the phalangeal joints.

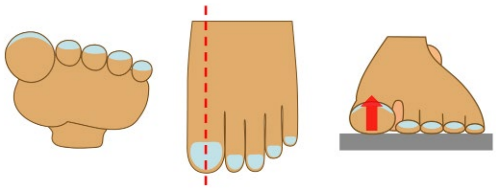


Figure 6. Normal walking foot diagram

Walking observation discovered that the force of the lesion begins to occur in the big toe joint. The dotted line in Figure 7 below shows the change in force. Gradually, the big toe joint will change due to the force factor.

Figure 7. Toe valgus while walking

2.2 High Heel Biomechanics

Figure 8 shows that lifting the heel forces, gravity onto the metatarsophalangeal joint, the force of the gastrocnemius contraction is relatively short from the ankle joint. Once the toe is standing, the weight of the body will fall behind the rotation axis of the metatarsophalangeal joint. This state is similar to wearing high-heeled shoes; the gastrocnemius muscle will always be in a state of contraction and cannot relax because of the balance between the heel and walking.

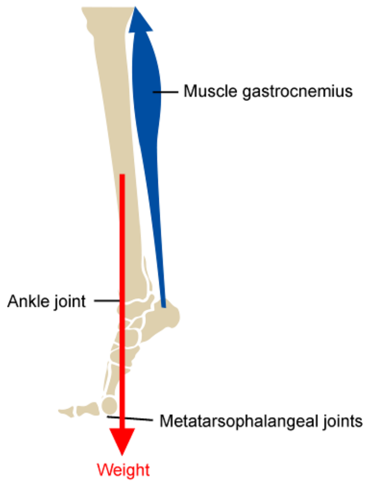


Figure 8. Mechanics of Lifting Heel

Figure 9 shows the state of wearing high heels. Because the heel is high, footsteps are formed by arching the toes for balance due to the gravity-down relationship. If the foot is divided into 4/1, the toe joint is stressed. The inner space is pointed, so the foot joints are limited by the inner space of the shoe for a long time. The long time in the high-heeled shoes causes the unevenness of the force to cause joint deformation, which forms a burden on the soles of the feet and even the ankles and knees are affected. (Donald, 1950/2013)

Figure 9. Wearing high heel toe bending

2.2.1 Wearing High Heels Outward and Inwards Exercise

Figure 10 shows the active state of the side of the foot in the high heels. By actual observation, the subject can see the toe by wearing a 10 cm transparent high heel for Toe observation (A). The joints are in the space of the high heels, and the state of the toes and the type of outward turning and inward turning can be seen in the figure. (B) Eversion: A muscle that passes through the lateral side of the foot axis, mainly the long and short tibia, and the third metatarsal and long extensor muscles. (C) Inversion: The muscles passing from the heel joint and the inner side of the joint axis of the joint have a function of varus. They are the anterior and posterior tibia, and the flexor digitorum, extensor muscle, and toe flexor. In order to balance the weight of the body, the toe joint will be stretched or bent to balance the grip (Tavara-Vidalón, Monge-Vera, Lafuente-Sotillos, Domínguez-Maldonado, & Munuera-Martínez, 2018).

Figure 10. Side of foot expanded and retracted

2.2.2 Formation of Hallux Valgus

Hallux valgus has many factors and can be better understood through anatomy. Figure 11 shows that the following figures (A) is a perspective view of the ligament of the first metatarsophalangeal joint and the bone complex. The second to fifth fingers are seen in the figure. The state of traction of each other, due to the strong muscles of the plantar flexion, the tension of the extensor tendon and the flexor hallucis longus makes the humerus slowly deviate, causing the valgus of the big toe (Kernozek, Elfessi, & Sterriker, 2003).

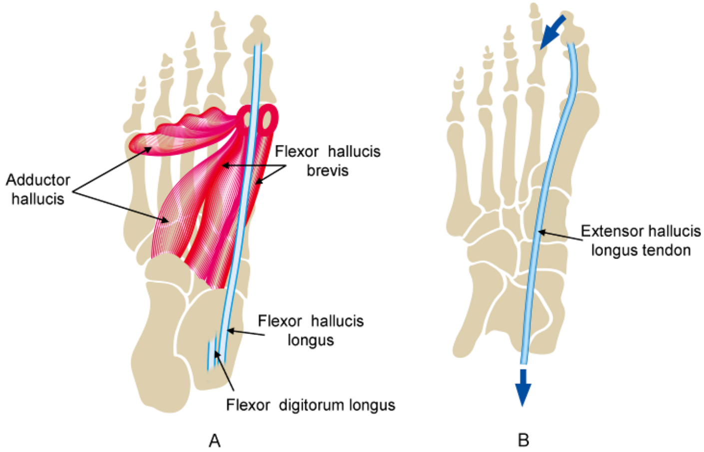


Figure 11. Foot anatomy

Figure 12 shows that compression of the space inside the shoe and joint lesions accelerate the symptoms of hallux valgus. There is a fluid-filled sac in the toe, the sac, which cushions the pressure on the bones near the big toe joint (Kernozek et al., 2003). When the joint becomes larger due to a bunion, the sac may also swell and cause pain, forming bursitis. It may exacerbate the pain of the bunion and may damage the smooth tissue (cartilage) covering the joint, which may lead to arthritis, and some of the more severe cases may also have a phenomenon in which the first knuckle overlaps the second phalanx.

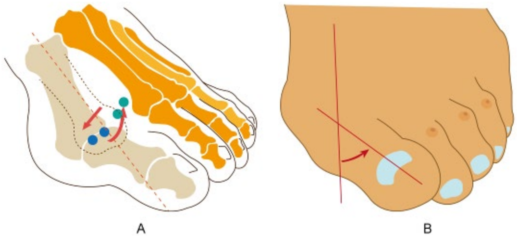


Figure 12. Formation of Hallux Valgus

Figure 13 shows that the ball of the big toe flipped outward through the bone chart. When the weight of the foot is applied to the talus, we can see the direction of the arrow in the pressure distribution. The force of the joint of the foot is transmitted from the joint to the scap. In the case of the first to third metatarsal, it is squeezed due to the restriction of the inner space of the shoe. There are three processes in the foot lesion: 1. normal condition, 2. thick stroke of the foot, 3. foot bunion condition causing the foot plate to become larger, because the foot plate becomes larger, and the inner space of the shoe changes (Hardaker, Margello, & Goldner, 1985). In this case, the speed of the foot lesion is accelerated.


Figure 13. Pressure on the foot

3 Methods

3.1 Contextual inquiry

Contextual inquiry provides a user-oriented approach in which researchers collect user data from the field and use it to assist in defining product characteristics and developing procedural methods to meet the needs of development teams and organizations (Beyer & Holtzblatt, 1997) .The key to this method is to use interviews to allow users to ask questions on a series of pre-set questions in real-life situations, observing department store sales staff and to obtain close-to-true information through questioning and observing user interaction with the system, and form suggestions on the issue based on these interactions.

3.1.1 Objects of Research

Data was collected from 100 users, with an average age of 23 to 35 years old. The experience of wearing high heels was more than five years. The background of the subjects was hotel industry and department store workers. On average, they wore high heels for two days a week for 5 to 8 hours. The subject is in good health.

3.1.2 User Experience and Procedures

Execution method: Each subject has an execution time of 15 minutes, and the task is divided into: standing for 10 minutes. The process observes the tester's usage status and questionnaire records, understanding the uncomfortable point of pain and analysis generated by the user when wearing the heels, and the most natural observation method records the uncomfortable part of the foot. After the experiment, subjects were repeatedly asked about a point of pain from the experiment. The position allows the user to confirm the location of the pain by saying out loud and thinking and drawing, as shown in Table 1.

Table 1 Fixed standing observation

Task List	Chart	Analysis
Standing stationary		1. Due to the weight of the body, feet are always slipping forward, and the first phalangeal joint and the fifth phalangeal joint are squeezed by the space inside the shoe, causing pain. 2. The lower joint is the main bone that stabilizes the body weight when standing, and the foot is balanced by the toe joint when standing.

Through Usability Testing, this focuses on users and their tasks, finding accurate evidence and improving interface usability. (Gould & Lewis, 1983)

For user observations and interviews, we can summarize the use of high-heeled shoes to discover their usage preferences and habits, as shown in Table 2

Summary:

Through the users' observations and visits, we can know the condition of the shoes worn by their feet. It was discovered that at first, purchases were often motivated by the outer appearance and style of the shoes. Secondly, it would depend on the level of comfort. It is not until podiatric problems begin to occur, that the user pays attention to the choice of inner shoe design or function; users will choose the appropriate high-heeled shoes for special occasions to accommodate professional performance; the insole interviews found that the commercially available insole often compresses the inner space of the shoe, resulting in the shoe feeling as though it was shrinking in size. After all, the insoles are not integrally formed, so the insoles that were added later mostly did not match the space inside the shoe.

Table 2 User interviews

Question 1: How do you choose a pair of high heels?	• Usually whichever is my favorite based on comfort and appearance, after trying them on. • The appearance is very important, first impressions take first priority, and then I consider comfort. • I buy functional shoes that can solve my feet problems.
Question 2: How do your feet feel when you are standing stationary?	• Because the toes are pressed against the shoe, so I will keep alternating the center of my weight. • My calves felt sore during the experiment. • More people felt soreness in the big toe joints and pinky joints. • Feeling numb in the middle of the foot.
Question 3: When do you wear high heels?	• Because I work in a department store, the company requires me to wear high heels at work. • Because of the nature of some commemorative events, I will wear high heels. • When participating in special or formal events, I will choose to wear heels during these occasions.
Question 4: Have you used insoles sold on the market?	• Yes, I felt very comfortable when I first use it, but then it became useless after a while. • I have used a silicone insole before, but it kept moving while I walked, so I found it to be uncomfortable. • When my feet are uncomfortable, I will take my shoes in to be adjusted to become more comfortable. • I felt that the shoes became smaller after I added the insole. • I felt that there was something extra in my shoes, so I didn't like it.

3.2 Expert interview

Table 3 What to pay attention to while designing high heels

Mr. Tu	Currently available shoes, because the center of gravity is wrong, it is easy for the feet to overturn when walking, so you can increase the space of the big toe, so that the foot can achieve natural gait activity in the inner rotation.
Mr. Cheng	Many customers wear high-heeled shoes that are not suitable for walking, thus causing deformation and swelling of the feet. Taiwanese people have large feet and are used to wearing shoes that are half a size to a whole size larger. Therefore, shoes that do not fit the feet properly often cause foot injuries.
Mr. Hung	What determines a pair of heels to be good or bad really depends on whether the midsole matches the position of the heel. It balances the stability and evenness of the entire shoe. At present, women who wear high-heeled shoes often want to make changes or additions to inner portion of the shoes, so they may be more comfortable to wear. For the inner and outer waist area (the foot is not the same, the height of the upper is not just at the ankle). The inner waist is 4 mm wider than the outer waist. The higher the heels are (the Achilles / heel is easy to rub), the height of the back (the highest point of the instep / the height of the back of the line).

The insole design interview was conducted through three shoe-making experts, as shown in Table 3 and Table 4. The interview process was conducted through semi-structured interviews. The interview questions were for the design of high-heeled shoes, and for the design of the insole. What are the suggestions? The experience of shoes, combined with the content of the literature, lead to the most effective design improvement for high heels. Mr. Tu of Tu Huo Long Shoes, Co., Ltd. has developed a project technology and has 15 years of experience. He has produced special shoes for Olympic athletes, golf shoes, soccer shoes, etc. Handmade shoe craftsman, Mr. Cheng of CYC Handmade Shoes, specializes in manual shoemaker, tailoring shoes for customers and very equipped in design and development of skinny shoes. He is also factory director and has many other titles under his belt. Creating a leather boots studio, Mr. Hong has been making shoes for 20 years, specializing in the production of soles, and the opening of brand division, plus the experience of being factory director.

Table 4 What advice is there for the insole design?

Mr. Tu	Allows the inner space of the shoe to cover the feet, like footprints on the beach, which can cover the weight of the body.
Mr. Cheng	Because the foot is collapsed or the high arch is caused by the arch of the foot, the weight of the shoe is offset. If it fits a universal insole, it will need to be between this and a package that allows the customer to make finer adjustments.
Mr. Hung	The best condition of the foot is to fix the bone in its original position, minimize the displacement of the bone, and help the support of the foot.

Summary:
From the interview of three senior designers, we can better understand the places to pay attention to regarding the design of high-heeled shoes, and provide suggestions for the design of insoles in the future: users can start to use insoles to relieve the discomfort of the feet, and can feel the difference in a short time. It is still not practical for the products to be self-adhesive for a long time. There will be problems with degumming. Taiwanese people have larger feet and will wear shoes that are half a size or a full size larger, which will cause injuries to the feet.

3.3 Experimental Methods and Steps

All five subjects were invited were female with an average age of 25 years, a foot length of 24 cm, an average weight of 55 kg, and an average height of 165 cm, without foot disease. Using the method of foot rubbing, the users print the model map of the foot to find out the position of the inner space of the shoe subjected to pressure and using the thickness of the insole to change the inner space of the shoe. When measuring, the knees of the subject were straight and at shoulder width, and the eyes looked straight ahead to avoid posture affecting test results, as shown in Figure 14.

Figure 14. Footprints in high heels

3.3.1 Footprint and Positioning

Footprints show a heavier color, indicating a heavier load of pressure. Collecting the foot types of the five female subjects tested, we can find the difference in the forefoot status, and the weighted pressure also varies due to the length of the metatarsophalangeal joint. In Figure 15, the footprints in the high heels show error of the force around the big toe joints, the place where there is no ink in the picture below is the metatarsophalangeal joint arch and the midfoot arch. We look forward to improving the valgus of the big toe joint and will try to increase the resistance at the metatarsophalangeal joint.

Figure 15. Footprints in high heels

3.3.2 Materials and Principles

Using 3mm elastic latex to design the raise support, changing the space inside the shoe through concave and convex shapes, supported by document (Luo et al., 2011). That provides two suggestions for the insole: first, with tapered or cylindrical protrusions the flat insole can be used to reduce the maximum force, while the harder insole material can make the protrusion more supportive. Second, through the custom cone or cylindrical protrusion, the maximum stress and force can be minimized, as shown in Figure 16. The difference between the pre-measurement and the post-measurement of the feet was determined by discussing the measurement points of the big toe joint and the metatarsophalangeal joint with the experts (Fig. 17) (Cong, Cheung, Leung, & Zhang, 2011). The Interlink Electronics FSR 400 Series is a single-zone force sensing resistor for measurement comparison. The FSR 400 series is a single-zone force sensing resistor with a sensing pressure range of 0.1 to 102 Newtons (maximum 10kg). Unpressurized output resistance: >10M Ω, sensing area: 5.08mm, thickness range: 0.2 to 1.25 mm, Force Repeatability 3: ± 2% (Single part), Operating temperature: -30 ~ 70 ° C (FSR 400 Data Sheet, 2010).

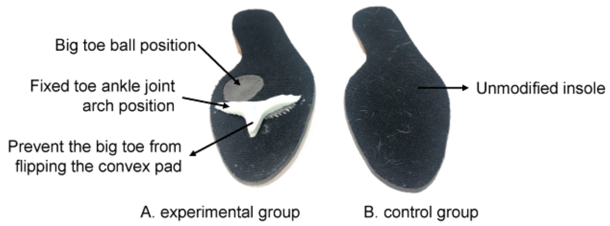


Figure 16. Insole test comparison chart

The measurement point distribution is shown in Figure 17，①measurement of the big toe joint ② ③ measuring front and back of big toe ball ④ ⑤ measuring intercondylar joint ⑥ measures the fourth metatarsophalangeal joint。After measurements are completed, the insole is drawn at coordinates of 0.5 cm each, and the absolute position of 1 to 6 is marked in a coordinated manner and is calculated by the stacking calculation method.

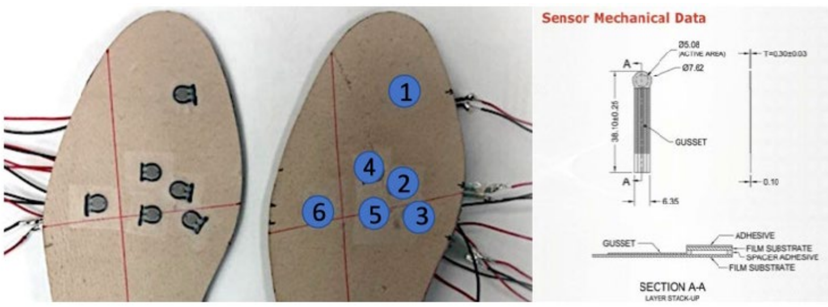


Figure 17. Measuring distribution point and sense resistor

Take the value of the bending point of the curve from the Typical Force Curve, obtaining the trend line via exponentiation; the known resistance value can be obtained by this trend line to further calculate the corresponding estimated force value, as seen in Figure 18.

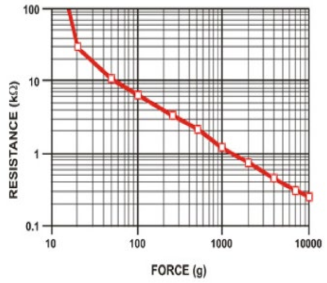


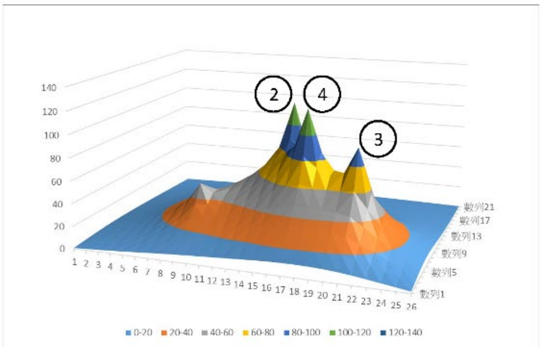
Figure 18. Typical Force Curve

4 Results

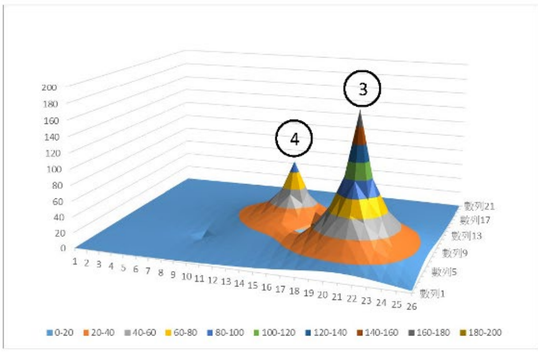
Through this study, it can be known that the design of the insole can change the position and direction of the force through the concave and convex shape of the insole. The following is a three-dimensional surface diagram of the experimental force. It can be observed that the subject experiences a great change after using the improved insole.

Subject No. 1: position 1 big toe joint estimated force value is 0.02 g, position 2 big toe ball (front) estimated force value of 0.02 g shows a significant reduction in big toe force, position 3 the measurement of the big toe ball (post) is 180.01g, which absorbs most of the podiatric pressure and allows the feet to be assisted while standing, as shown in Table 4.

Table 4 Three-dimensional surface diagram of number 1 experimental force



Controlled Group

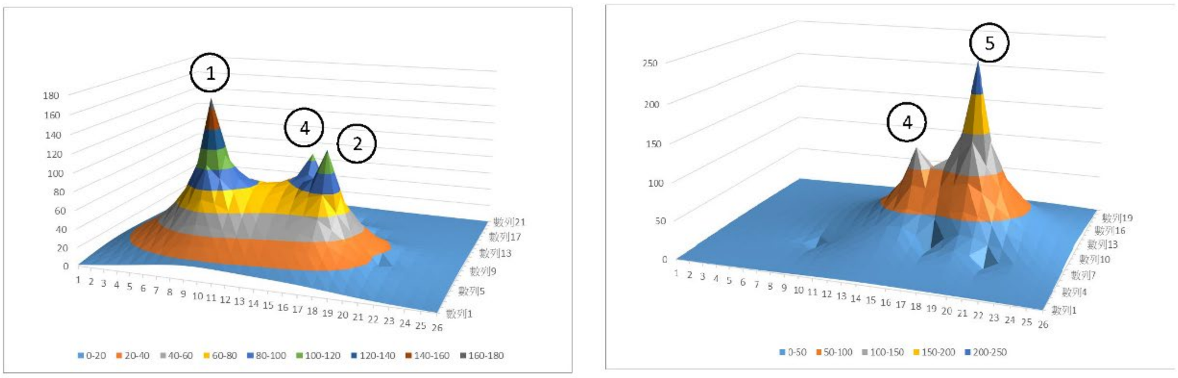


Experimental Group

No. 1		Position 1	Position 2	Position 3	Position 4	Position 5	Position 6
Controlled Group	Resistance	0.01KΩ	5.6 KΩ	6.7 KΩ	5.7 KΩ	4.6 MΩ	1.2 MΩ
	Estimated stress value	51.53	121.55	95.15	118.65	0.01	0.08
Experimental Group	Resistance	3.07 MΩ	3.2 MΩ	4.20K Ω	6.8KΩ	94.30 KΩ	5.7 MΩ
	Estimated stress value	0.02	0.02	180.01	93.25	2.58	0.01

Subject No. 2, it can be observed from the control group: position 1 big toe joints are more stressed, the estimated force value is: 172.1g, through the experimental group, the insole completely transfers pressure, greatly reducing the force on the big toe joint. Results can be found in position 1, position 2, and position 3 in the Table 5.

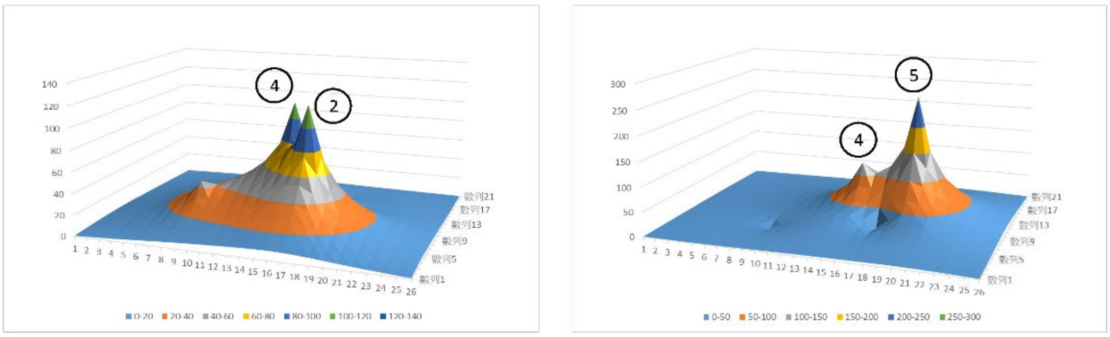
Table 5 Three-dimensional surface diagram of number 2 experimental force



No. 2		Controlled Group Position 1	Position 2	Position 3	Experimental Group Position 4	Position 5	Position 6
Controlled Group	Resistance	4.34KΩ	5.55 KΩ	31.39 KΩ	6.15 KΩ	3.57 MΩ	13.78 MΩ
	Estimated stress value	172.1g	123.2g	11.56g	107g	0.018g	0.003g
Experimental Group	Resistance	0.3 MΩ	0.33 MΩ	134.9K Ω	5.42KΩ	3.38KΩ	0.7 MΩ
	Estimated stress value	0.02	0.02	180.01	93.25	2.58	0.01

Subject No. 3: For the big toe muscle ball, the estimated value of position 1 in the control group is 45.33g, and the estimated value of position2 is 120.59g. Compared with the experimental group, the force is larger, and it is easier to form a reticular valgus. Converting the force to position 4 and position 5 reduces the stress on the big toe joint, as shown in Table 6.

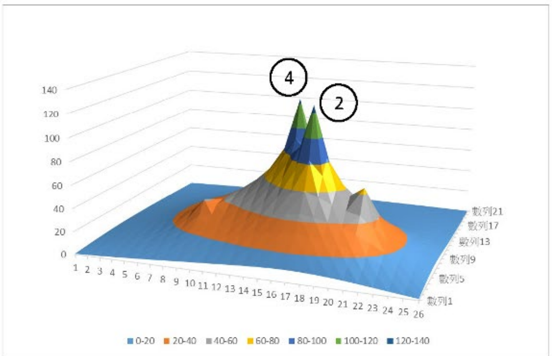
Table 6 Three-dimensional surface diagram of number 3 experimental force



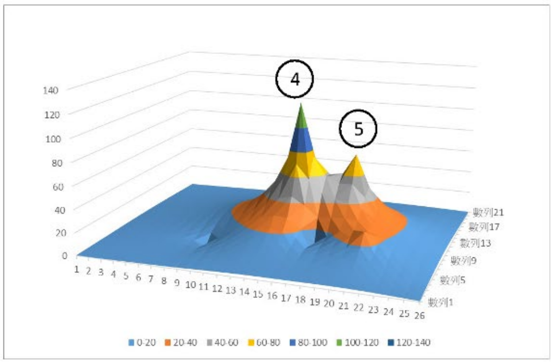
No. 3		Controlled Group Position 1	Position 2	Position 3	Experimental Group Position 4	Position 5	Position 6
Controlled Group	Resistance	11.54KΩ	5.63KΩ	17.5KΩ	5.84KΩ	7.53 MΩ	3.92MΩ
	Estimated stress value	45.33g	120.59g	25.66g	114.78g	0.01g	0.02g
Experimental Group	Resistance	7.0 MΩ	7.8MΩ	12.66K Ω	5.55KΩ	3.22KΩ	6.2MΩ
	Estimated stress value	0.01g	0.01g	39.94g	123.20g	258.98g	0.01g

Subject No. 4: Due to the second decimal place, the estimated force value: 0.00g value; in the control group, position 5 estimated force value: 0.01 g and position 6 estimated force value: 0.00g and the experimental group position 1 estimated force value: 0.01g, position 2 estimated force value: 0.00g, from the change in value, the displacement of the force position can be observed, as shown in Table 7.

Table 7 Three-dimensional surface diagram of number 4 experimental force



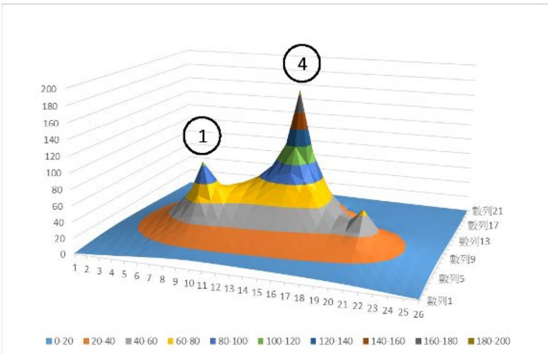
Controlled Group



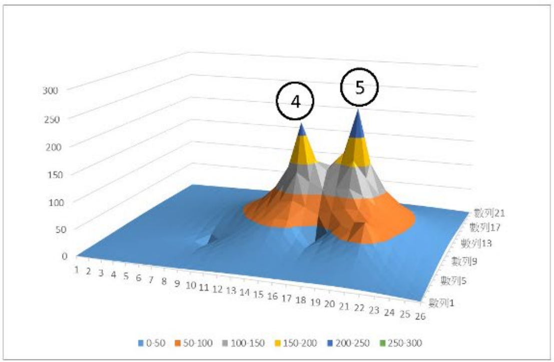
Experimental Group

No. 4		Position 1	Position 2	Position 3	Position 4	Position 5	Position 6
Controlled Group	Resistance	12.41KΩ	5.43KΩ	8.92KΩ	5.52KΩ	8.618MΩ	3.92MΩ
	Estimated stress value	41.03g	126.77g	64.40g	124.08g	0.01g	0.00g
Experimental Group	Resistance	7.88MΩ	14.582MΩ	16.07K Ω	5.61KΩ	7.80KΩ	7.88MΩ
	Estimated stress value	0.01g	0.00g	28.83g	121.25g	77.43g	0.01g

Table 8 Three-dimensional surface diagram of number 5 experimental force



Controlled Group



Experimental Group

No. 5		Position 1	Position 2	Position 3	Position 4	Position 5	Position 6
Controlled Group	Resistance	6.24KΩ	8.32KΩ	8.79KΩ	4.09KΩ	3.68MΩ	4.36MΩ
	Estimated stress value	104.86g	70.84g	65.69g	186.65g	0.02g	0.01g
Experimental Group	Resistance	0.67MΩ	25.9MΩ	7.62K Ω	3.58KΩ	3.30KΩ	8.78MΩ
	Estimated stress value	0.18g	0.001g	79.83g	223.9g	251g	0.005g

Subject No. 5: The estimated force value of position 1 of the control group is 104.86g, the estimated force value of position 2 is 70.84g, and the estimated force value of position 3 is

65.69g. The force is completely in the big toe joint and the big toe muscle. The position of the ball is the typical condition of hallux valgus; the data of the experimental group shows that the estimated force value of position 1 after improvement is 0.18g, the estimated force value of position 2 is 0.001g, and the estimated force value of position 3 is: the force distribution of 79.83g effectively improving the stress of the big toe joint and the big toe muscle ball, as shown in Table 8.

Through SPSS and Paired Sample t test, we can find the significance of treatment group and control group at the six positions via P-VALUE. The P-VALUE is 0.03 at the position1, while the value is 0.00 at the position2. There are significances at the two positions, but none is at the others, which is because of the transfer of stress value. Paired Sample t test of project is shown in Table 9.

Table 9 Paired Sample t test of project

Project	Controlled Group		Experimental Group		T test	P-VALUE
	Mean	Std deviation	Mean	Std deviation	(> 1.96)	(< 0.05)
Position1	82.97	56.10	0.04	0.07	3.30	0.03*
Position2	112.58	23.45	0.01	0.09	10.73	0.00*
Position3	52.49	33.65	101.72	73.93	1.38	0.23
Position4	130.22	32.15	130.96	53.91	0.06	0.94
Position5	0.014	0.00	118.51	128.30	2.06	2.06
Position6	0.02	0.03	0.010	0.00	0.85	0.44

5 Conclusions

By using the method of experimental groups and the control groups, the differences in wearing high heels were thoroughly compared. Position display for gravity is divided into forefoot and midfoot to find the position of maximum force. Forefoot: The first toe ankle joint is the most stressed of the second, due to the pushing of the space inside the high heels. The flexion of the metatarsophalangeal joint and the flexion of the interphalangeal joint can easily cause claw toe lesions or hallux valgus. The results of this study show that increasing the arch of the metatarsophalangeal joint can prevent the foot from sliding forward, and the force that is originally concentrated on the big toe and the first metacarpophalangeal joint is transferred to the position of the interphalangeal joint to stall the formation of hallux valgus.

Understanding the formation factors of hallux valgus through biomechanics and anatomy and establishing a state of exercising with high heels. In order to balance the weight of the body, the toe joint will be stretched or bent to balance the grip. Due to the limited space inside the heel, the toe joint is squeezed, which causes a problem for the feet. Through contextual inquiry, user's use of high-heeled shoes and pain points analysis was observed to understand the user's podiatric problems, collecting the experience of podiatric problems via natural observation, confirming the pain position and forming a chart.

Understanding the designer's considerations during shoemaking, through expert interviews, exploring the design of the insole for preventing hallux valgus, and conducting design experiments. From the values predicted by the estimated force values, the difference between the pressures was shown and the feasibility of our ideas confirmed.

6 References

American Podiatric Medical Association, (2014). Report of the APMA Task Force on Public Opinion Research on Foot Health and Care Findings from a Survey of 1000 US Adults. Retrieved from https://www.apma.org/files/APMA2014TodaysPodiatristSurveyAllFindings.pdf

Buchanan, K. R. & Davis, I. (2013). The Relationship between Forefoot, Midfoot, and Rearfoot Static Alignment in Pain-Free Individuals. Journal of Orthopaedic & Sports Physical Therapy. https://doi.org/10.2519/jospt.2005.35.9.559

Beyer, H., & Holtzblatt, K. (1997). Contextual Design: Defining Customer-Centred Systems. In Morgan Kaufmann Publishers Inc. https://doi.org/10.1145/291224.291229

Coughlin, M. J., & Jones, C. P. (2007). Hallux Valgus: Demographics, Etiology, and Radiographic Assessment. Foot & Ankle International. https://doi.org/10.3113/fai.2007.0759

Cornwall, M. W., & McPoil, T. G. (2014). Motion of the Calcaneus, Navicular, and First Metatarsal during the Stance Phase of Walking. Journal of the American Podiatric Medical Association. https://doi.org/10.7547/87507315-92-2-67

Cong, Y., Tak-Man Cheung, J., Leung, A. K. L., & hang, M. (2011). Effect of heel height on in-shoe localized triaxial stresses. Journal of Biomechanics. https://doi.org/10.1016/j.jbiomech.2011.05.036

Domjani, J; Ujevi, D; Wallner, B. (2016, October). Increasing women's attractiveness: high heels, pains and evolution - A GMM Based Study. Paper presented at the 8th International Textile, Clothing & Design Conference-Magic World of Textiles, Croatia.

Dufour, A. B., Casey, V. A., Golightly, Y. M., & Hannan, M. T. (2014). Characteristics associated with hallux valgus in a population-based foot study of older adults. Arthritis Care and Research. https://doi.org/10.1002/acr.22391

Donald, A. N. (2013) Kinesiology of the Musculoskeletal System Foundations for Rehabilitation. (Hsiuchuan, H; Yujiun, H; Chunghsien, T; Chihwei , C; Hsinying, W; Chihhsiang, Y, & Chiawen H.,trans.).Taiwan ROC. (Original work published 1950).

FSR 400 Data Sheet. (2010, October). *Interlink Electronics.* Retrieved from https://cdn.sparkfun.com/datasheets/Sensors/ForceFlex/2010-10-26-DataSheet-FSR400-Layout2.pdf

Gefen, A., Megido-Ravid, M., Azariah, M., Itzchak, Y., & Arcan, M. (2001). Integration of plantar soft tissue stiffness measurements in routine MRI of the diabetic foot. Clinical Biomechanics. https://doi.org/10.1016/S0268-0033(01)00074-2

Guéguen, N. (2014). High Heels Increase Women’s Attractiveness. Archives of Sexual Behavior. https://doi.org/10.1007/s10508-014-0422-z

Glasoe, W. M., Yack, H. J., & altzman, C. L. (1999). Anatomy and biomechanics of the first ray. Physical Therapy.

Gould, J. D., & Lewis, C. (1983). Designing for usability---key principles and what designers think. Proceedings of the SIGCHI Conference on Human Factors in Computing Systems - CHI ’83. https://doi.org/10.1145/800045.801579

Hardaker Jr, W. T., Margello, S., & Goldner, J. L. (1985). Foot and ankle injuries in theatrical dancers. *Foot & ankle*, *6*(2), 59-69.

Klaesner, J. W., Hastings, M. K., Zou, D., Lewis, C., & Mueller, M. J. (2002). Plantar tissue stiffness in patients with diabetes mellitus and peripheral neuropathy. Archives of Physical Medicine and Rehabilitation. https://doi.org/10.1053/apmr.2002.35661

Kernozek, T. W., Elfessi, A., & Sterriker, S. (2003). Clinical and biomechanical risk factors of patients diagnosed with hallux valgus. Journal of the American Podiatric Medical Association, 93(2), 97-103.

Luo, G., Houston, V. L., Garbarini, M. A., Beattie, A. C., & Thongpop, C. (2011). Finite element analysis of heel pad with insoles. Journal of Biomechanics. https://doi.org/10.1016/j.jbiomech.2011.02.083

Lee, S., & Wilkinson, M. (Eds.). (2018). *Foot Function, Exercise Related Pain and the Influence of Footwear.* Retrieved from https://static1.squarespace.com/static/5acb4d675b409b3ac7b385fb/t/5af21d876d2a73fe26cf2aeb/1525816745969/Foot-Function-EBook-UK-Saxby-Wilkinson.pdf

Morris, P. H., White, J., Morrison, E. R., & Fisher, K. (2013). High heels as supernormal stimuli: How wearing high heels affects judgements of female attractiveness. Evolution and Human Behavior. https://doi.org/10.1016/j.evolhumbehav.2012.11.006

Perera, A. M., Mason, L., & Stephens, M. M. (2011). The pathogenesis of hallux valgus. Journal of Bone and Joint Surgery - Series A. https://doi.org/10.2106/JBJS.H.01630

Tavara-Vidalón, S., Monge-Vera, M., Lafuente-Sotillos, G., Domínguez-Maldonado, G., & Munuera-Martínez, P. (2018). Static range of motion of the first metatarsal in the sagittal and frontal planes. *Journal of clinical medicine*, *7*(11), 456.
Watanabe, K., Fujii, T., Kitaoka, H. B., Kotajarvi, B. R., Luo, Z. P., & An, K. N. (2012). Analysis of ankle-hindfoot stability in patients with ankle instability and normals. International Orthopaedics. https://doi.org/10.1007/s00264-011-1376-6

About the Authors:

Lu, Hsiu-Ching: Research Interests, Ergonomic Design, Industrial Design, Creative Styling for Wedding.

Wu, Fong-Gong: Research Interests, Design Philosophy and Ethics, Ergonomic Design, Industrial Design, Simulation in Ergonomic Design.

Chen, Chien-Hsu: Research Interests, Augmented Reality Application, Ergonomics & Interaction Design, Human Computer Interaction, Virtual Reality Application.

Acknowledgement: The authors would like to acknowledge Mr. Tu Hay-Tung (Twu Huolong Precision Lasts Co., LTD) and Mr. Cheng Chin-Yang (CYC Handmade Shoes) for their contribution to this study, who gave us the golden opportunity to do this wonderful project on the topic High Heel Insole Design for Delaying Bunion Development. They also helped us in doing a lot of research and we came to realize many new things, so we are thankful to them.

Imagining a Digital Future: how could we design for enchantment within the special education curriculum?

Keay-Bright, Wendy*[a]; Eslambolchilar, Parisa[b]

[a] Cardiff Metropolitan University, Cardiff, Wales, UK
[b] Cardiff University, Cardiff, Wales, UK
* wkbright@cardiffmet.ac.uk

The implementation of the new “Successful Futures” curriculum in the UK, means that learners between the ages of 3 to 16 will be challenged to use digital media to develop their life skills, personal confidence, work skills, career planning, health and well-being (Donaldson, 2015). Teaching staff, responsible for delivering this multi-faceted programme for learners with profound disabilities, have reported that the perceived benefits of technology are misaligned to individual needs and capabilities. This is particularly evident when combined with a developmental approach that favours the achievement of milestones rather than discovery-led, task free, interaction (Simmons, 2019). The work reported here aims to directly address these gaps. We describe a series of *Digital Imagining* workshops, which set out to encourage creative and co-productive relationships between teaching professionals, academic artists, makers and computer scientists. During the activities we experimented with digital fabrication tools as a means to envision contingent, imaginative interactions between learners with Profound and Multiple Learning Disabilities (PMLD), other people and their environment. In collectively critiquing the ideas developed during the workshops participants recognized the benefit of simple contingent, cause and effect actions for drawing attention to the material properties of objects. Almost seamlessly, these sensory explorations became the trigger for more complex ideas for integrating the demands of the digital curriculum into more natural daily scenarios. The shared process of ideation and tinkering was reported to be vital in generating a shift toward inclusion as a creative, imaginative and expressive counterpoint to the pervasive emphasis on utility and function.

Keywords: digital curriculum; technologies; disability; enchantment; design

1 Introduction

In the Autumn of 2019, the new “Successful Futures” curriculum will be implemented for learners between the ages of 3 to 16 in Wales, UK. The Successful Futures curriculum focuses on life skills, personal confidence, basic skills, work skills, career planning and health and well-being (Donaldson, 2015). The design of the curriculum has taken into account feedback from teaching professionals who wanted more power to make decisions on delivery and assessment, and children themselves, who felt that the existing provision for technology, software and digital skills was out-of-date. The data gathered from nine months of consultation, revealed that children wanted “lessons to be fun, interesting and not something that there just to pass assessments or get qualifications” (Donaldson, 2015, p3).

The Enchanting Technologies project has emerged from prior research and consultation events in which teachers of children with Profound and Multiple Learning Disabilities, (PMLD) – some of whom had participated in the Successful Futures research - reported that, while the ambition of the curriculum opened opportunities for discovery-led digital learning, existing technologies were not fit for purpose. The barriers to using technologies in areas such as personal confidence and health and well-being, were reported to be cost and lack of flexibility to accommodate the diversity of learner abilities. For the more profoundly disabled children the perceived benefits of technology were misaligned to individual needs and capabilities, and the interaction lacked opportunities for personal agency through play, exploration and discovery.

In order to address this issue, we proposed to use Digital Imagining as a way of combining the real-world experience of teachers with our own interests in technology as academics, artists, makers and computer scientists. The goal of Digital Imagining was to propose a common language for creativity and entrepreneurship, in which the materials function as "*instruments of the imagination, able to enchant by movement, speed instantaneous communication and above all by bestowing upon us what cannot be fully grasped yet*" (Marenko, 2017, p. 30). The method focused on building a positive, exploratory relationship with the teachers, firstly, by using familiar paper tools as a means to describe the day-to-day ebb and flow of school activity, and, secondly, using digital materials to trigger ideas for imagining playful activities within a school environment. Further work needs to be undertaken to establish the impact of this approach on learners. However, using digital imagining to leverage the input of teachers, enabled us to collaborate on proposing a range of narratives that placed enchantment at the heart of the learner experience. With regard to the Successful Futures curriculum, this project has potential to reduce the barriers of inflexibility and cost, and to make the digital learning more meaningful and fun for learners with PMLD.

2 Background

2.1 Profound and Multiple Learning Disability

The term PMLD is used when a person has more than one disability, with the most significant being a learning disability. These people are among the most vulnerable in society, with poorer general health and more specific health needs - such as problems with hearing and eyesight, mental health and behavioural difficulties, epilepsy, thyroid disorders, heart disorders and dental problems - than the general population (NHS, 2018).

The World Health Organisation International Classification of Functioning, Disability and Health, (Children and Youth Version), addresses the need for integrated activities that enable individuals to have a high amount of personal autonomy over their lives (WHO, ICF-CY, 2007). Within this document emphasis is placed on the importance of relationships between the person with a disability, other people, and the environment, which is recognised to be an evolutionary and interactive process and subdivided into (a) Body Functions and Structures, (b) Activities and Participation, (c) Environmental Factors, and (d) Personal Factors. Recommendations include providing assistance with the development of awareness of time and place, self and others, objects and space. Other recommendations, relevant to our aim of co-designing open-ended contingent interactions, include encouraging the ability to adapt to, and accept, new experiences, through positive, energetic activities that enhance curiosity, imagination, inquisition and emotional expression.

2.2 Designing Interaction

With the above recommendations in mind, Enchanting Technologies is building on research that addresses the importance of contingency on the development of the imagination, and expressive communication. In terms of interaction design, this means shifting the emphasis away from task or intended outcome, toward more experiential, open-ended and emergent possibilities.

2.2.1 Contingent interaction

In the context of child development, the term contingent interaction is used to describe the phase when children begin to take the actions of others into consideration and to display reciprocal actions in response to other people. Within the social sciences, this process is referred to as intersubjectivity, whereby successful social interaction is contingent on the development of shared understanding of the mental states of others, otherwise known as theory of mind (Baron-Cohen,1999). Many disabilities and developmental disorders are characterised by more or less profound disturbances of intersubjectivity (Fuchs, 2015; Zlatev et al., 2008), which are reported to limit opportunities for contingent interaction (Cress et al, 2013). Emerging from anthropology (Csordas, 2008), psychotherapy, (Gieser, 2008) and linguistics, (Noland, 2010), the idea that intersubjectivity is dependent on theory of mind is being challenged and embodied and intersubjective research is coming together to shape the way in which human cognition is understood (Schmicking & Gallagher, 2009).

2.2.3 Embodied learning

Embodied learning is of particular interest to interaction designers (Harrison & Sengers, 2011) where notions of contingent interaction have moved beyond interface semiotics toward full body interaction and felt experience. In other words, naturally and bodily felt human-material interactions and kinaesthetic creativity (i.e. designing, creating and exploring future solutions through movement) constitute rich resources to inform design (Svanæs, 2013; Levisohn & Schiphorst, 2011).

Malinverni and Schaper (2018) suggest that contingent enhancement should be considered as a quality in embodiment interaction design i.e. digital augmentation should be contingent to the feature of the embodied experience. They propose “the quality of contingent enhancement as the degree to which digital technologies can make some aspects of the embodied experience richer and more interesting” (Malinverni & Schaper, 2018, p. 8).

2.3 Relevant Research and Development in Interaction Design

Research into task free, contingent, human-material interactions in relation to profound disability is relatively sparse as the design of technology has traditionally focussed on assistive devices that help communication and the acquisition of information (Achmadi et al, 2012; Campigotto et al., 2013; Flores et al., 2012). Instructional technologies such as social stories, which use multimedia (for example, digital video composition) are favoured as a means to help children with learning difficulties understand social cues and potential responses in different situations (Porayska-Pomsta et al., 2018; Spencer et al., 2008).

Whilst there have been several examples of game platforms and movement sensing technologies being used successfully with to support playful, experiential interaction for children with learning difficulties (Kontogeorgakopoulos et al., 2014; Keay-Bright, 2011), a problem with the technology is the difficulty in adapting software for individual abilities. Although many platforms offer developer kits, the level of programming experience required for customisation or making original applications, is beyond the scope of most teaching professionals (Márquez Segura et al., 2016; Simon, 2009; Tanenbaum, 2015). Similarly, virtual reality and augmented reality (Billinghurst et al. 2015; Gillies, 2016), are generally overly complex to customise for non-experts interested in experimentation, sustaining longer-term experiences and expanding learning opportunities.

From the point of view of Enchanting Technologies, we are interested in body movement as the core of interactive experience. Shusterman describes how our bodily movements, sensations, and somatic training, are central to being and thinking in the world, which have led to the development of the somaesthetics theory (Shusterman, 2008). These ideas are expanded upon from a practice perspective through the work of Hanna, who defines somatics as the field which studies the body – the soma - as perceived from within (Hanna, 1988). Whereas Descartes states: "*To think* is not merely "to be" passively; it is *to move",* Hanna's view is "I am self-aware, therefore I act" (Hanna, 1991, p. 33). This first-person perspective respects bodily awareness as central to human agency, which contrasts with the third person perspective of the sciences, for example psychology, which sees bodily acts as behaviour, responding to the universal laws of cause and effect (Hanna, 1991, p. 31). Responsive, interactive artworks that bring movement into consciousness, have been tested in different contexts by Hansen and Keay-Bright (2017). These studies have revealed unprecedented levels of unscripted experimentation and creative flow from children on the autism spectrum and adults with PMLD (Keay-Bright, 2018), when their body movements are made visible. Höök et al. (2018) argue that "*novel ways of engaging with our soma cannot be 'put into us'—we cannot be moved into shape. The concept of self-agency in somatics practice is key. Self-agency is the result of the reflective practice of self-observation coupled with intention*" (p.6). Notable somaesthetics works are discussed briefly below.

BrightHearts is an interactive artwork and biofeedback application for smart handheld devices and used as a tool for reducing pain and anxiety amongst children undergoing medical procedures (Khut et al., 2011) In *BrightHearts*, the user's heart rate is coupled with the diameter and the colour of a collection of overlapping concentric circles visually presented on the handheld. The more relaxed the child is, the less bright and warm colours appear at the interface i.e. the child can explore ways to decrease his or her average heart rate through a combination of muscle relaxation, slow breathing and relaxing memories in the application space. The relaxed child is rewarded by gentle chimes, and new layers of colourful circular imagery.

Höök et al. (2016) provide two example prototypes developed through their workshops with design exemplars: the *soma carpet* and *breathing light*. With *soma carpet* the mat is designed such that heat stimuli directs user's attention to different part of the body parts while the user follows audio recorded instructions. For example, when the instructor says, "How does your body contact the floor right now under right heel?", the mat heats up under user's right heel. The mat is aimed at increasing the body awareness. The authors report that while engaging in these somatic exercises, the user sometimes feels pain, aches and bodily memories surfacing during the exercise (Höök et al., 2018). To reduce user's vulnerability, the carefully designed thermal mat provides enclosure and softness. In *breathing light*, the aim is to create a room for reflection (Höök et al., 2016) The prototype has a fabric-based enclosure, where the user can crawl underneath and shut out the external world. Inside the enclosure, a breathing sensor measures the user's breathing pattern and controls a lamp inside the module. A lamp creates an ambient light that will dim in cadence with the breathing. *Soma carpet* and *breathing light* can complement each other when used together.

With overwhelming evidence to support the role that gesture and bodily action play in the process of thinking (Ishii, 2012; Kirsh, 2013; Osgood-Campbell, 2015) and the recognition that cognitive, social, emotional and physical development are co-dependent processes influenced by bodily sensations (Ishii, 2012), we are focusing our initial explorations on body sensing technologies as triggers for imagining and relating to contexts that can include others.

2.4 Maker Movement in Education (or Maker Education)

Maker education is a term that applied to a wide variety of activities such as household DIY, computer programming, and sewing where hands and mind are engaged. Maker education supports academic learning and the development of a mindset that values playfulness and experimentation, growth and iteration, and collaboration and community (Halverson & Sheridan, 2014).

Maker education attempts to solve a particular problem initiated by one or a community of users, to create a physical or digital artefact, and share that product with others. In maker education the process of making is often more important than the product.

The rise of affordable digital maker tools, including microcontroller platforms such as Arduino, rapid-prototyping tools such as 3D printers, and online community of makers such as Github, Hack Clubs, Kickstarter have in recent years empowered people even without university degrees or formal education to use such tools and or participate in making digital products (Niezen et al. 2016). Therefore, maker education has enhanced diversity, inclusivity and equity, which many observers view as much needed in a movement that has tended to focus on the interests and experiences of middle-class white males (Vossoughi et al. 2016).

Finally, key to an effective maker education that works for all in the education system is facilitating “playfulness”, encouraging "resourcefulness”, ability of students and or teachers to draw not just on their own internal skills and experiences, but the assets of other people and their communities known as “participatory design” (Sheridan & Konopasky, 2016).

3 Methods

“...*methodology should not be a fixed track to a fixed destination but a conversation about everything that could be made to happen*.” Jones, 1991, p.32)

In the 1970s, long before computers became personal and ubiquitous, Welsh designer, John Chris Jones, addressed the need for design methods that attune to the changing landscape of human relationships with technology. Motivated by the functional and aesthetic failure of design to adapt to local physical and social environments, he advocated that rather than consider methods as things, they should instead focus on relationships, or “ways of enabling things to get into better relationships with each other” (Jones, 1992, p.6).

The overarching aim of Enchanting Technologies is to enable teaching professionals from the special educational sector and children with disabilities to take an active role in exploring the creative interplay between the design process and the digital artefacts that emerge. We are calling this method Digital Imaging, which constitutes a series of workshops using digital fabrication to open up conversations and trigger the imagination. Our partners in Digital Imagining include teachers working with pupils with a diagnosis of autism and PMLD as well as health experts providing specialist, residential provision for autistic students in further education (post 16); other professionals in our group include representatives from Occupational Therapy, IT specialists and management. These partners elected to join the project on the basis of prior experience of collaborating with the research team. Their detailed understanding of children and the changing landscape of the digital curriculum provided the grounding for the project. Their determination to improve the lived experience of learners brought additional motivation that could not be approximated by designers taking on the role of users.

Whilst the need to address the challenge of the new curriculum provides the motivation for Enchanting Technologies, the overarching goal of Digital Imagining is to facilitate a relationship that taps into the real-life experience of everyone concerned. In this respect, the research team and the teaching professionals are co-dependent. Rather than attempt to implement a method whereby designs become concrete through iteration and testing, our interest is in exploring the role that technologies could play in imagining and unlocking untapped creativity. Such relationship building, whilst understood to be core to the user-centred design, rarely achieves a genuine balance of ownership within project hierarchies.

We were inspired by the workshops done by Mogensen and Trigg (1992) and Frauenberger et al. (2016), where designers and practitioners are seen as active cooperating subjects investigating current practice. Mogensen and Trigg (1992) formulate a joint enterprise linking three perspectives (depicted as three vertices in a triangle): research (analysis), design, and practice. They see "the activity primarily as involving reflection on practice, either one's own or another's" (p.3). Their response to this challenge is that simultaneous changes in all three can be triggered through the use of concrete artefacts in workshops between developers and users. Following Mogensen (1992), Hartmann (2009) and Preece et al., (2015) we see an artefact as not only triggering discussions of future technologies and practices represented, or suggested, by the artefact, but also as triggering penetrating discussions of current practice.

The term *artefact* here is used to denote two different kinds of objects and prototypes. On the one hand, the physical nature of an artefact implies *persistence,* something concrete lasting over time. At the same time, the term artefact suggests deliberate and purposeful creation by human hands. In our workshops, both aspects were crucial: "*the persistent nature of the artefacts' forms, and the appropriate, appropriable, and provocative nature of their contents*" (Mogensen & Trigg, 1992, p.3).

3.1 Digital Imagining Workshops

The Digital Imagining workshops factored in the need to discover enchantment within the day-to-day routines and experiences of pupils with profound disabilities, and to identify the barriers to inclusion (e.g. pragmatics of co-design and ethics). In Workshop One we used visuals such as videos, storyboards, drawing and sketching to gain insight into the day-to-day routines and experiences of pupils with profound disabilities, and to identify the barriers to inclusion (e.g. pragmatics of co-design and ethics). In workshop one, *movement,* we included teachers, policy representatives and experts from movement theory and education, therapy and performance.

In Workshop Two, *Enchantment,* we used a tinkering approach (Hendriks-Jansen, 1996), in which everyone was invited to explore existing and off-the-shelf coding and material that had the potential to be easily modified. This workshop focused on requirement gathering, using digital maker tools to reimagine existing situations and model new possibilities, prioritising ideation over functional detail. The workshops are described in more detail below.

3.1.1 Workshop One

Eight professionals from five special education schools and a further education college participated in the first Digital Imagining workshop with five members of the research team, who were also practicing artists and designers. The workshop was convened at a special school where we focused on building a relationship through the identification of complementary skills and interests. We began the workshop with a collective activity that was designed to quickly capture the level of motivation, expertise and creativity of all participants. To give everyone an opportunity to comment, each participant was given a set of coloured Post-It® notes, bright pink for the special education partners and blue for the research team. Everyone was invited to contribute 10 keywords about their work using a separate note for each word. Next, the activity was repeated with everyone noting 10 challenges they experienced in supporting digital engagement. All the Post-It® notes were collected and assembled onto large sheets of A1 flip chart paper and made into Post-It® artworks, the idea being that even something as ordinary as a Post-It® could be enchanting. The colours revealed the source of the idea but maintained anonymity (Figure 1).

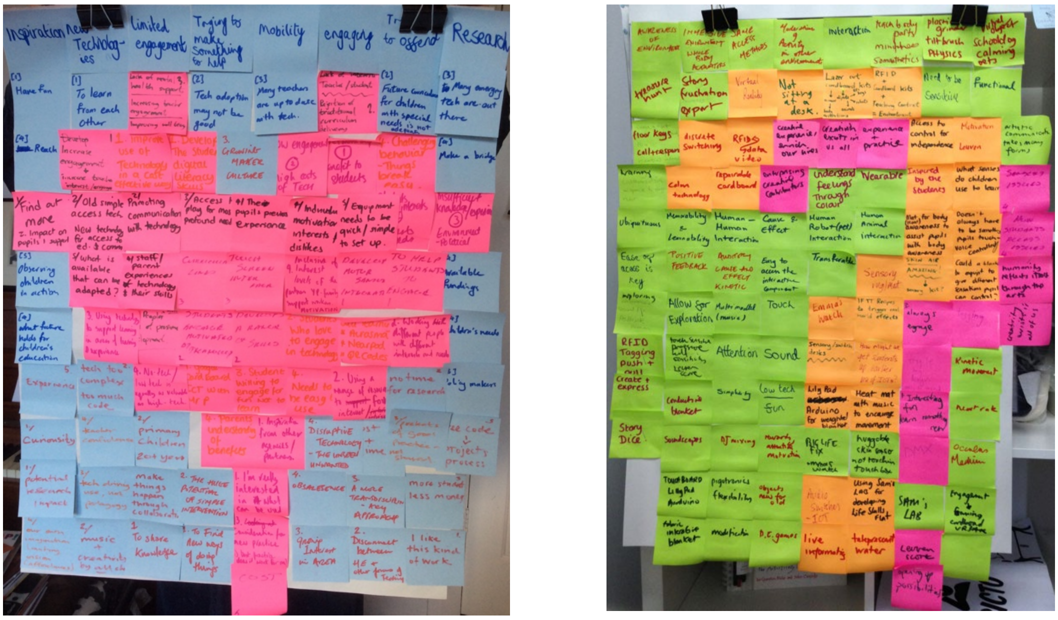


Figure 1. Workshop One, collecting participant viewpoints and ideas

The notes revealed that teaching professionals were motivated by the need to increase pupil engagement and to improve the effectiveness of technology use, particularly supporting sensory integration across a range of needs. Barriers to engagement included the diversity of needs, lack of training resources for teachers, lack of flexibility, benefits of technology misunderstood or misaligned to the needs of profoundly disabled children. The perception of low-tech technologies was that it was not as useful as high-tech, with not enough access to playful technologies or play activities in general for children with PMLD.

For the research team the motivating factors were noted to be the importance of collaboration, learning from each other, generating meaningful, impactful research, sharing knowledge, discovering and maximising on the curiosity of learners and having fun. It was noted that materials could be useful for discovering new ways to connect and make a difference to others. However, there was a notable divide between higher education research and the needs of people in the real-world, and suggestions that technological determinism can make innovation overly complex.

The next exercise involved the teaching professionals sharing examples of current technologies, classroom activities, and experiences that they, or their pupils, found interesting. They described a rich array of products, such as the LilyPad Arduino board, RFID tags, robots, interactive floor mats, Electroplankton (2009), plastic recycling ("Precious Plastic.", 2016), story dice, conductive blankets and virtual reality headsets. With an emphasis on body sensing technologies, the researchers demonstrated devices that emphasised 'making', such as Arduino, Raspberry Pi, conductive paint, and augmented reality markers, plus ideas from the maker movement ("FabCre8 Maker Lab.", n.d.) and IFTTT ("If This Then That (IFTTT)", n.d.), somaesthetics (Höök et al., 2016), kinaesthetic awareness (Hansen et al., 2017) and play (Lewis, 2017).

In order to encourage responses to these demonstrations, we re-used the Post-It® technique and invited 10 comments from each person on interactions that had inspired them (Figure 1).

The final activity was conducted in mixed academic/professional groups. Each group was invited to use paper-props to create a short story in which technology could enchant learners, and to present their ideas as a storyboard or paper-prototype one-minute pitch. These simple paper-based interactions enabled teams to express ideas fluently and intuitively. With an emphasis on digital materials rather than task, the discussions focused on opportunities for discovery-led learning, for example, through the sense of pressure or touch, with technologies that afford haptic feedback employed to encourage greater attention on the possibility of interaction. Feedback and contingency were noted to be key to engagement, with the timeliness of response adapted to suit different processing abilities. Adding causality to visual or audio outputs was suggested as a means to capture attention, leading to further ideas of how contingent interaction could be encouraged on the basis of the emergent creativity and self-expression of pupils. These ideas were further played out in the short stories, which ranged from virtual school pets to treasure hunts, using RFID tagging or connected objects.

Following the workshop, we began the process of organising all the notes into ideas for digital props that could trigger casual, contingent interaction. We chose the themes of Soma, Optic and Sonic (SOS) to concentrate on simple bodily sensations. The technologies selected for this purpose deliberately made the materiality visible, for example, pressure sensitive resistors, proximity sensors, ultrasonic sensors, vibration motors, accelerometers, gyrometers, heat/motion/vibration actuators and an open source AR marker application. With ideas for bodily interaction based on these technologies, we set about making simple prototypes in readiness for the second Digital Imagining workshop.

3.1.2 Workshop Two

The second workshop was conducted in our University fabrication lab with the same team of professionals, plus two additional special education participants. The core findings from the first workshop were revisited followed by demonstrations of the SOS prototypes (Figure 2). Rather than draw attention to the functionality of the technologies, we sought to expose the rawness of the materials and to invite conversations on how they could afford opportunities for causality.

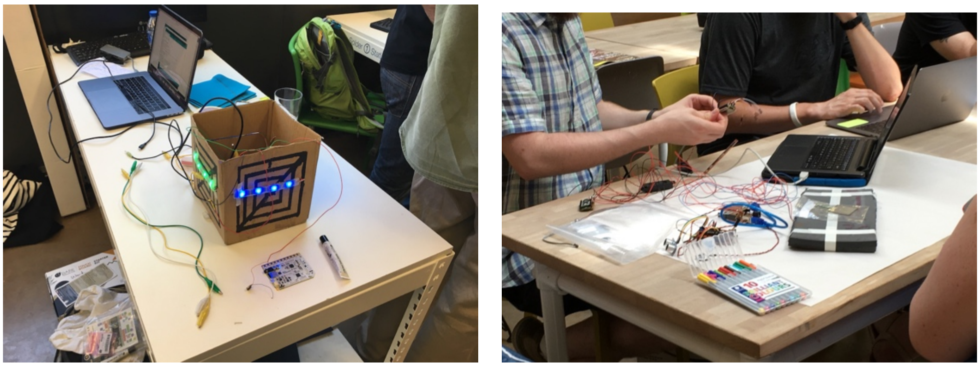


Figure 2. Tinkering with materials to produce optical and sonic effects

During the next stage of the workshop we encouraged tinkering with the prototypes, and each of the participants naturally clustered toward the prototypes that interested them. Each cluster was assigned a technical expert and academic partner, and together they experimented with the prototypes, writing or drawing ideas for real life scenarios, which seemed to flow naturally within the conversation stream. At the end of the day, all the ideas were pinned to the wall and presented to the whole group.

Scenarios ranged from a treasure hunt navigation system using RFID tags to generate individualised props, to pressure and movement sensitive hand-held puppets that could be connected to other devices. Opportunities for embedding sensors into favourite textures and objects were suggested as means of facilitating experimentation with sonic and optic effects to encourage social interaction with staff and peers. At the end of the session, the partners unanimously agreed that in order to better understand the potential of any of the technologies, it would be vital to be able to rapidly test interactions, and to establish a responsive ‘maker’ network prototyping.

4 Discussion

Anthropologist Alfred Gell’s description of technological capacity as a medium of production (career skills, life skills, basic skills), of reproduction (social communication) and of enchantment, (creativity, health and wellbeing) (1992) affords an opportunity to explore how better to connect humans and technology within the new curriculum. Digital Imagining workshops enabled the direct involvement of teaching professionals in designing with materials - from paper to technical components. The impact of this method has been to give confidence to creative exchanges as the building blocks of a more dynamic and magical relationship between people, contexts and environments. Below we describe the three main discussion points that need to be factored into future developments.

4.1 Digital Imagining as a process

“The enchantment of technology is the power that technical processes have of casting a spell over us so that we see the real world in an enchanted form”, (Gell, 1998*,* p. 44).

Our workshops encouraged collaboration on imagining enchanting and creative applications for low cost technologies. The academic partners commented that through digital imagining, the design process was more discovery-led and playful. Teachers stated that the workshops revealed that technologies for children with PMLD do not need to be complex to respond to the diversity of needs and need not require exhaustive training sessions. Furthermore, knowing how to adapt and customise devices can extend use in response to the child’s needs and or the context of use.

Workshops can be employed as analytical lenses during research with teachers and children with PMLD in co-production design cycles. In particular, we consider that enchantment and causality features make them particularly suitable for understanding interactions beyond usability, task-completion and effectiveness in learning.

4.2 Contingent interaction and enchantment

When the teaching professionals developed scenarios through materials, we noted that they naturally converged on ideas around enchantment. Even though they employed different somatic and aesthetic strategies to accommodate the diversity of learner ability (e.g. body massage, warm bath and swimming), there was a shared understanding that digital tactics could make such experiences more intriguing. Ideas such as slowing down movements with colour changes or discovering environmental clues; disrupting the habitual movement to help grasp and articulate on a story; directing attention to specific areas of the body with sound or heat and putting sustained attention to body parts or cues in the space, all implied an intrinsic connection between the body, technology and enchantment.

4.3 Scaffolding creativity

Finally, the digital imagining workshops served as useful meetings for building confidence in teaching professionals through the articulation of shared values. On a latter point, as Levisohn and Schiphorst (2011) point out, often the traditional interaction design pedagogy tends to neglect training users or conversations about experiential qualities such as enchantment, contingency and embodiment. Hence, we need tools and approaches to help teachers to think about embodiment and for researchers to draw on the nuances and differences of individual experience.

The goal of the first workshop was discover a mutual vocabulary for creativity. The non-digital props opened up possibilities for conversations, without imposing a structure, allowing us to maintain a degree of flexibility in moving forward. The scenarios and stories created by teachers in the workshops, demonstrated a willingness and commitment to explore enchantment and contingency, and to set a direction, rather than a solution, for future digital engagement.

Inspired by these scenarios our simple Soma, Optic, Sonic prototypes, became the basis for experimenting with inter-subjectively constructed meanings for both academics and teaching professionals. The teachers realised that creating enchanted objects with off-the-shelf digital tools could be fun, rapid and easy to test in the classroom with children.

Both parties experienced the tangibility of design as a process of connecting with tacit aesthetic sensibilities such as movement, to the degree that discussions emerged for how this designing could become a classroom-based practice that could render different results depending on individual and context. Rather than describe how the digital environment could improve access, conversations shifted toward how each interaction could lead to discovering possibilities for the next.

5 Conclusions and Future Work

The design of technologies, for most people, remains a mystery. We are surrounded by devices and interactive objects that are made, typically from a rationalised, operational process. The mass production and ubiquity of personal computers has diminished our relationship with technology as a source of enchantment. Moreover, ubiquitous devices and their programming still remain a complex process and require extensive training in programming and computer science.

Through the first Digital Imagining workshop, we created a design space, in which we used simple paper-based materials to create a picture of the learning context. This was followed by further ideation, that added some digital magic, by coding ideas into simple bodily inputs and outputs (how to design for the body and with the body to explore the body).

In the second workshop, we used demos of aesthetics design, such as bodily inputs and outputs (how to design for the body and with the body to explore the body) to further probe context, motivation and the triggering of imaginative ideas, to maintain a dialogue for designing with teachers. We used fabrication tools to make the digital tangible, offering hands-on experience of materials, such as easy to program and off-the-shelf microprocessors, sensors and actuators. In order to make digital imagining more palpable, we used a collaborative tinkering approach to trigger ideas for real-life scenarios. We also modified existing and off-the-shelf software using modular programming technique, which is common for microprocessors suitable for maker culture (e.g. Arduino, Touch Board, Teensy and Raspberry Pi). We are intending to use this technique further in our next workshop as a means to separate the functionality of a program into independent, interchangeable modules, such that each contains everything necessary to execute only one aspect of the desired functionality (Gosling et al., 2005). This allows novice developers to reuse code whenever and wherever they need, to perform the same or similar task in a different context.

Planned future work on this project will enable us to develop technologies directly with learners with PMLD. Feedback from teachers stressed the importance of Enchanting Technologies as a community of practice for sharing prototypes and stories, without which designing with children would not be feasible. Collectively, we see this as a window of opportunity to discover the enchantment of technology by attuning to the competences of children with profound disabilities.

6 References

Achmadi, D., Kagohara, D. M., van der Meer, L., O'Reilly, M. F., Lancioni, G. E., Sutherland, D., & Sigafoos, J. (2012). Teaching advanced operation of an iPod-based speech-generating device to two students with autism spectrum disorders. *Research in Autism Spectrum Disorders*, 6(4), 1258-1264.

Arduino Lily Pad. Retrieved January 2019 from https://www.arduino.cc/en/Main/ArduinoBoardLilyPad/

Augmented Reality markers. (2018). Retrieved January 2019 from https://pypi.org/project/ar-markers/

Baron-Cohen, S. (1999). *The evolution of a theory of mind*. na.

Billinghurst, M., Clark, A., & Lee, G. (2015). A survey of augmented reality. *Foundations and Trends® in Human–Computer Interaction*, *8*(2-3), 73-272.

Campigotto, R., McEwen, R., & Epp, C. D. (2013). Especially social: Exploring the use of an iOS application in special needs classrooms. *Computers & Education*, *60*(1), 74-86.
Cress, C. J., Grabast, J., & Burgers Jerke, K. (2013). Contingent interactions between parents and young children with severe expressive communication impairments. *Communication Disorders Quarterly*, *34*(2), 81-96.
Csordas, T. J. (2008). Intersubjectivity and intercorporeality. *Subjectivity*, 22 (1), 110-121.
Donaldson, G. (2015). Successful futures: independent review of curriculum and assessment arrangements in Wales: February 2015.Retrieved January 2019 from https://gov.wales/docs/dcells/publications/150225-successful-futures-en.pdf
Electroplankton. (2009). Retrieved January 2019 from http://nintendo.wikia.com/wiki/Electroplankton
FabCre8 Maker Lab. (n.d.) Retrieved January 2019 from https://fabcre8.wordpress.com/the-projects/
Fabrication Lab Cardiff. (n.d.) Retrieved January 2019 from https://www.fablabcardiff.com/
Flores, M., Musgrove, K., Renner, S., Hinton, V., Strozier, S., Franklin, S., & Hil, D. (2012). A comparison of communication using the Apple iPad and a picture-based system. *Augmentative and Alternative Communication*, *28*(2), 74-84.
Frauenberger, C., Good, J., & Pares, N. (2016, May). Autism and technology: beyond assistance & intervention. In *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems* (pp. 3373-3378). ACM. DOI: https://doi.org/10.1145/2851581.2856494
Fuchs, T. (2015). Pathologies of intersubjectivity in autism and schizophrenia. *Journal of Consciousness Studies*, *22*(1-2), 191-214.
Gell, A. (1992). The technology of enchantment and the enchantment of technology. *Anthropology, art and aesthetics*, 40-63.
Gell, A. (1988). Technology and magic. *Anthropology Today*, *4*(2), 6-9.
Gieser, T. (2008). Embodiment, emotion and empathy: A phenomenological approach to apprenticeship learning. *Anthropological theory*, *8*(3), 299-318.
Gillies, M. (2016, July). What is Movement Interaction in Virtual Reality for?. In *Proceedings of the 3rd International Symposium on Movement and Computing* (p. 31). ACM.
DOI: https://doi.org/10.1145/2948910.2948951
Gosling, J., Joy, B., Steele, G., & Bracha. G. (2005). *The Java Language Specification,* Third Edition, ISBN 0-321-24678-0.
Halverson, E. R. & Sheridan, K. M. (2014). The Maker Movement in Education, in *the Harvard Educational Review*, 84(4), 495-504.
Hanna, T. (1988a). *Somatics: Reawakening the mind's control of movement, flexibility, and health*. Reading, MA: Addison-Wesley.
Hanna, T. (1991). What is somatics? *Journal of Behavioral Optometry*. Volume 2.
Hansen, L, Keay-Bright, W. (2017) Conceptualising Kinesthesia: Making Movement Palpable. 12th EAD Conference, Sapienza University of Rome 12-14 April 2017
Harrison, S., Sengers, P., & Tatar, D. (2011). Making epistemological trouble: Third-paradigm HCI as successor science. *Interacting with Computers*, *23*(5), 385-392.
Hartmann, B. (2009). *Gaining design insight through interaction prototyping tools* (pp. 19-22). Stanford University.
Hendriks-Jansen, H. (1996). *Catching ourselves in the act: Situated activity, interactive emergence, evolution, and human thought*. MIT Press.
Höök, K., Caramiaux, B., Erkut, C., Forlizzi, J., Hajinejad, N., & et al. (2018). Embracing First-Person Perspectives in Soma-Based Design. *Informatics*. Vol. 5. No. 1. Multidisciplinary Digital Publishing Institute.
Höök, K., Jonsson, M. P., Ståhl, A., & Mercurio, J. (2016, May). Somaesthetic appreciation design. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems* (pp. 3131-3142). ACM. DOI: https://doi.org/10.1145/2858036.2858583
If This Then That (IFTTT). (n.d.) Retrieved January 2019 from https://ifttt.com/
Ishii, M. (2012). Acting with things: Self-poiesis, actuality, and contingency in the formation of divine worlds. *HAU: Journal of Ethnographic Theory*, *2*(2), 371-388. DOI: https://doi.org/10.14318/hau2.2.019 Keane, W. (2005).
Jones, C. (1991). Designing designing. Phaidon Press Ltd; Revised edition
Jones, J. C. (1992). *Design methods: with additional texts*. Van Nostrand Reinhold.
Keay-Bright, W. (2011) Designing Interaction Though Sound and Movement with Children on the Autistic Spectrum, Proceedings title: Arts and Technology, Second International Conference, ArtsIT 2011, Lecture Notes of the Institute for Computer Sciences, Social Informatics and

Telecommunications Engineering (LNICST); Springer USB Proceedings ISBN: 978-1-936968-38-1
Keay-Bright, W. (2018) Somability: Explorations with digital meda, movement and space within adult disability services, AMPS proceedings services. ISSN 2398-9467
Link: http://architecturemps.com/proceedings/
Khut, G. P., Morrow, A., & Watanabe, M. Y. (2011, November). The BrightHearts project: a new approach to the management of procedure-related paediatric anxiety. In *OzCHI Workshop Program: Canberra, Australia*.
Kirsh, D. (2013). Embodied cognition and the magical future of interaction design. *ACM Transactions on Computer-Human Interaction (TOCHI)*, *20*(1), 3.
Levisohn, A., & Schiphorst, T. (2011). Embodied engagement: Supporting movement awareness in ubiquitous computing systems. *Ubiquitous Learning: An International Journal*, *3*, 97-111.
Lewis, J.G. (2017). Reactickles 3. Retrieved January 2019 from https://joelgethinlewis.com/category/projects/reactickles-3/
Malinverni, L., & Schaper, M. M. (2018). An Experience-Centered Framework for Designing Non-Task-Oriented Embodied Interaction Environments. *Multimodal Technologies and Interaction*, *2*(2), 22.
Márquez Segura, E., & et al. (2016). Embodied sketching. *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*. ACM (2016). DOI: https://doi.org/10.1145/2858036.2858486
Mogensen, P. (1992). Towards a Prototyping Approach in Systems Development. *Scandinavian J. Inf. Systems*, *4*(1), 5.
Mogensen, P., & Trigg, R. (1992). Artefacts as triggers for participatory design. In *Proceedings of the 1992 Participatory Design Conference* (pp. 55-62).
Marenko, B. (2017). Filled with Wonder. The enchanting android from cams to algorithms. In L. Atzmon & P. Boradkar (Eds.), *Encountering Things Design and Theories of Things* (pp.19-32). Bloomsbury Academic.
NHS. (2018). Learning Disabilities. Retrieved January 2019. http://www.nhs.uk/livewell/childrenwithalearningdisability/pages/whatislearningdisability.aspx
Niezen, G., Eslambolchilar, P. & Thimbleby, H. (2016). Open Source Hardware for Medical Devices. In *BMJ Innov*ation, Published Online First: [2016;0:1–6.] doi:10.1136/bmjinnov-2015-000080
Noland, C. (2010). *Agency and embodiment*. Harvard University Press, 2010.
Osgood-Campbell, E. (2015). Investigating the educational implications of embodied cognition: A model interdisciplinary inquiry in mind, brain, and education curricula. *Mind, Brain, and Education*, *9*(1), 3-9.
Precious Plastic. (2016). Retrieved January 2019 from https://preciousplastic.com/
Porayska-Pomsta, K., Alcorn, A. M., Avramides, K., Beale, S., Bernardini, S., Foster, M. E., Keay-Bright, W & Kossyvaki, L. (2018). Blending human and artificial intelligence to support autistic children's social communication skills. *ACM Transactions on Computer-Human Interaction (TOCHI)*, *25*(6), 35.
Preece, J., Rogers, Y., & Sharp, H. (2015). *Interaction design: beyond human-computer interaction*. John Wiley & Sons.
Schmicking, D., & Gallagher, S. (Eds.). (2009). *Handbook of phenomenology and cognitive science*. Springer Science & Business Media.
Sheridan, K. M. & Konopasky, A. (2016). Designing for resourcefulness in a community-based maker space. In K. Peppler, E. R. Halverson, & Y. B. Kafai (Eds.), *Makeology: Makerspaces as learning environments* (Vol. 1, pp. 30–46). New York, NY: Routledge.
Márquez Segura, E., Turmo Vidal, L., Rostami, A., & Waern, A. (2016, May). Embodied sketching. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems* (pp. 6014-6027). ACM.
Shusterman, R. (2008). *Body consciousness: A philosophy of mindfulness and somaesthetics*. Cambridge University Press.
Simmons, B. (2019). From living to lived and being-with: exploring the interaction styles of children and staff towards a child with profound and multiple learning disabilities. *International Journal of Inclusive Education*, 1-14.
Simon, B. (2009). Wii are out of control: Bodies, game screens and the production of gestural excess. *Game Screens and the Production of Gestural Excess (March 5, 2009)*. http://dx.doi.org/10.2139/ssrn.1354043

Spencer, V. G., Simpson, C. G., & Lynch, S. A. (2008). Using social stories to increase positive behaviors for children with autism spectrum disorders. *Intervention in School and Clinic*, *44*(1), 58-61.
Svanæs, D. (2013). Interaction design for and with the lived body: Some implications of Merleau-Ponty's phenomenology. *ACM Transactions on Computer-Human Interaction (TOCHI)*, *20*(1), 8.
Tanenbaum, J., & Tanenbaum, K. (2015). Envisioning the Future of Wearable Play: Conceptual Models for Props and Costumes as Gme Controllers. In *FDG*.
Touch Board. (n.d.). Retrieved January 2019 from https://www.bareconductive.com/shop/touch-board/
Vossoughi, S., Hooper, P. & Escudé, M. (2016), Making through the Lens of Culture and Power: Toward Transformative Visions for Educational Equity**,** In *Harvard Educational Review*, 86(2), 206-232.
World Health Organisation (WHO). (2007) Interactional Classification of Functioning, Disability and Health. Retrieved January 2019: http://apps.who.int/iris/bitstream/handle/10665/43737/9789241547321_eng.pdf;jsessionid=809D97E6BF0521325A6BE6A0C01A8D9E?sequence=1
Zlatev, J., Racine, T. P., Sinha, C., & Itkonen, E. (2008). What makes us human. *The shared mind: Perspectives on intersubjectivity*, *12*(1), 1-14.

About the Authors:

Professor Wendy Keay-Bright is Director of the Centre for Applied Research in Inclusive Arts and Design (CARIAD) at Cardiff Metropolitan University. In the last 2 decades Wendy has led a range of digital arts and design projects with hard to reach audiences, funded through NESTA, National Film Board of Canada, Rayne Foundation, Technology Strategy Board, ESRC, Arts Council of Wales and the Raspberry Pi Foundation.

Dr Parisa Eslambolchilar is an Associate Professor in Human-Computer Interaction (HCI) at School of Computer Science and Informatics at Cardiff University. Her research interests include ubiquitous computing and designing interactive systems to support self-reflection, self-monitoring, feedback (audio, haptic, visual and soma).

Acknowledgement: We thank all the teaching professional, who participated in our workshops and schools gratefully acknowledge the funding support from FabCre8, Cardiff Metropolitan University.

Integrating Cooperative Design and Innovative Technology to Create Assistive Products for Older Adults

Yang, Danying*[a]; Moody, Louise[a]; Cobley, Andy[b]

[a] Centre for Arts, Memory and Communities, Coventry University, Coventry, UK
[b] The Functional Materials Research Group, Coventry University, Coventry, UK
* danying.yang@coventry.ac.uk

With a focus on increasing quality of life and independence for older adults, the MATUROLIFE project aims to utilise smart textiles in the development of desirable assistive products (specifically footwear, clothing and furniture). The project integrates designers, with researchers and technologists from a range of disciplines in a multidisciplinary team to facilitate design-driven innovation. This paper will outline the approach taken to building empathy and understanding with the wants, needs and requirements of the older adult population in Europe and thus bring a human-centric focus to the MATUROLIFE project. Collaboration with end-users and stakeholders as well as between partners during the co-creation process is central to the ongoing research and development approach.

Keywords: assistive technology; smart textiles; co-design; co-creation; independence; multidisciplinary design

1 Introduction

The '**M**et**a**llisation of **T**extiles to make **Ur**ban living for **Ol**der people more **I**ndependent and **F**ashionable' (MATUROLIFE) project is a unique multidisciplinary project funded by the European Commission involving 20 partners from 9 countries. It integrates material science together with creative and artistic design to produce innovative products that aim to revolutionise assistive technology (AT) for older adults.

Urban areas are seeing an increasing population of older adults and existing approaches to care for them are becoming unsustainable, creating a European-wide societal challenge (Wait & Harding, 2006). As a result, there is an increasing need for products that assist people in maintaining their health, well-being and independence. The World Health Organization (WHO) highlights assistive technology as an umbrella term covering the products, systems and services that maintain or improve an individual's functioning and independence, thereby promoting their health and well-being (WHO, 2018). However, such technologies are developed without in-depth consideration of the design, and can be unsightly and stigmatise the user (Yusif, Soar, & Hafeez-Baig, 2016). Typically, the user is not part of the end-to-end design process, and as a result, the outcome does not provide a meaningful, valuable service, thus resulting in high abandonment rates. In contrast, MATUROLIFE was initiated to provide an opportunity to increase quality of life through assistive products that are enhanced with smart technology and appeal to the end-user – thus bringing scientific innovation together with design (Moody, York, Ozkan, & Cobley, 2019).

2 Design Approach and Development Process

The MATUROLIFE project has involved three approaches to embed the needs of older adults in the innovation process. A qualitative research strategy utilising interviews was first adopted to gather participants convergent and divergent views, interests and propositions (Ritchie, Lewis, Nicholls, & Ormston, 2014). A co-design approach has then been employed to ensure the AT solutions are not only designed for older adults, but also most importantly with them. Ongoing development from concepts through to functioning prototypes has then been achieved through a multidisciplinary approach. This has guided the integration process as we bring together the creative design work with technical development activities, as well as the utilisation of innovative metalized textiles. A design management approach has been adopted to address the resulting complexity and facilitate collaboration between different partners, countries and disciplines through development process.

2.1 Design research

The early design research explored the health and independence needs of European older adults. A literature and product review were used to narrow the project focus and gain an understanding of existing knowledge in relation to the needs, wants and preferences and factors affecting independence. Semi-structured interviews were then undertaken with 37 older adults from France, Italy, Poland, Spain, Turkey, and United Kingdom. The questions explored real life experiences and views, building insights into attitudes, behaviours and preferences. The interviews explored what participants felt most threatened their independence, where they most needed support, as well as their current use of products and technology (Callari, Moody, Magee, & Yang, 2019). The findings led to the generation of tools for use by the design team including personas, a list of requirements, experience highlights and some guiding design principles for the project.

2.2 Co-design

As an exploratory process of "joint inquiry and imagination" where "problem and solution co-evolve" (Steen, 2013), co-design allows a design team to combine knowledge and insights from end users and professionals (Trischler, Pervan, Kelly, & Scott, 2018). The approach involves designers and people not trained in design work working together in the design and development process (E. B.-N. Sanders & Stappers, 2008; Venkat & Ozcan, 2018). Here co-design was used to bring together and integrate views and ideas from participants and project partners with varying expertise through a series of workshops (an exemplar workshop is shown in Figure 1).

Figure 1. Co-creation workshop

Ten co-creation workshops were conducted in nine countries (Spain, Italy, Belgium, UK, France, Slovenia, Poland, Turkey and Germany) as illustrated in Figure 2. In total, 94 older adults were involved. During the workshops, the participants worked alongside designers, manufacturers and researchers from the project consortium to create new ideas responding to the insights and functional requirements from the design. The process enabled the development of design concepts to address their needs and prioirties and fit with their life experience.

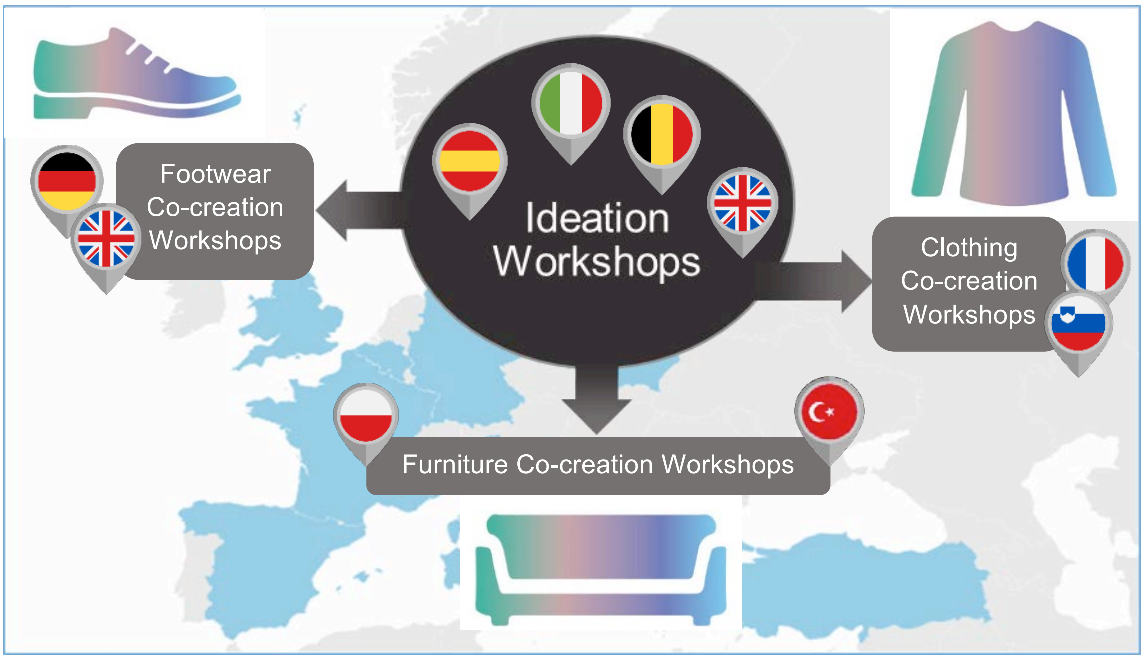


Figure 2. 10 Co-Creation Workshops in 9 Countries

In designing the co-creation workshops it was understood that people contribute at different levels depending on their level of expertise, creativity and also based on their character (Venkat & Ozcan, 2018). In order to make it easier for participants to contribute and express themselves, various design tools and conversation canvasses were created to provide a framework for participant creativity and encourage collaborative exploration and dialogue (B. E. Sanders, Brandt, & Binder, 2010). With workshops taking place in nine countries in nine different languages, these tools were also valuable in ensuring ease and consistency in the facilitation of the workshops, as well as in capturing the workshop content and translation and analysis of the workshop outputs. A number of tools were utilized including product idea canvases, journey mapping, concept critiques and prioritisation activities (Blomkvist & Segelstro¨m, 2015).

As shown in Figure 2, the first phase of ideation workshops in four countries (Spain, Italy, Belgium and UK) were facilitated to scope initial requirements and develop a design brief. The design team then translated the design brief into a series of early product concepts. These were focused on product areas that embedded selectively metallised textiles in their design to allow utilisation of the emerging smart textiles. Assistive footwear, clothing and furniture concepts were considered. These were then further developed and iterated during the following six focused workshops, with the aim then being to prioritise the functionalities and styles that users wanted to see incorporated into the final products. Examples of the output generated in the workshops are shown below - footwear design in Figure 3a and 3b, clothing design in Figure 4a and 4b, and furniture design in Figure 5a and 5b. Concepts were presented in ‘sketch’ form to communicate work in progress and encourage comment and intervention from participants (Raijmakers, Thompson, & Garde-Perik, 2012).

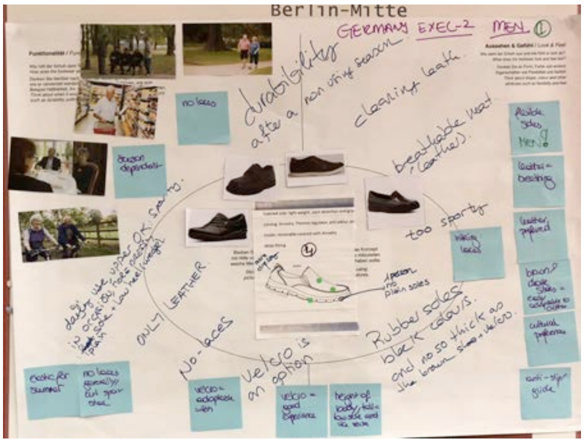


Figure 3a. Participants critique and evaluation of the smart footwear concepts generated by designers

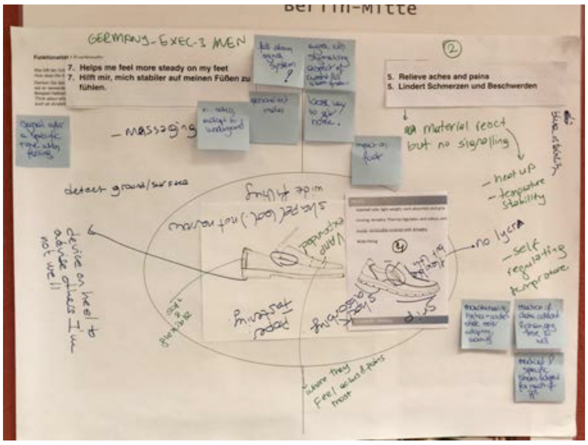


Figure 3b. Group modifications in Germany in collaboration with the designer

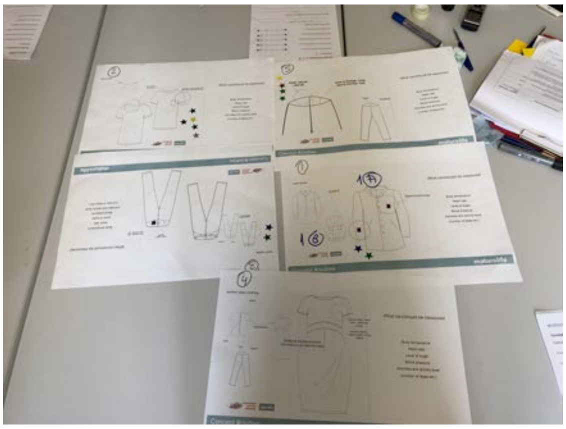


Figure 4a. Clothing design development of Men’s T-shirts, trousers and long jacket in France

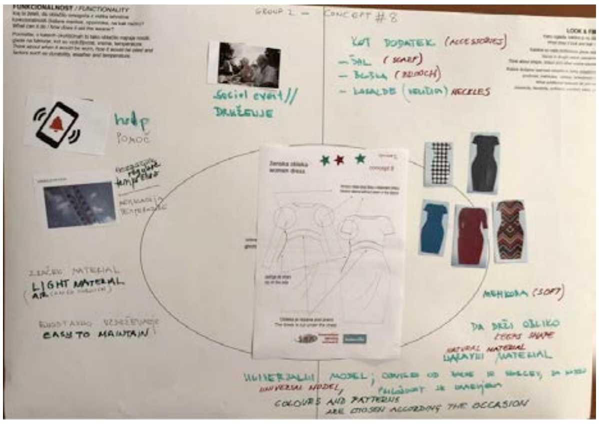


Figure 4b. Design development of a smart dress concept in Slovenian workshop

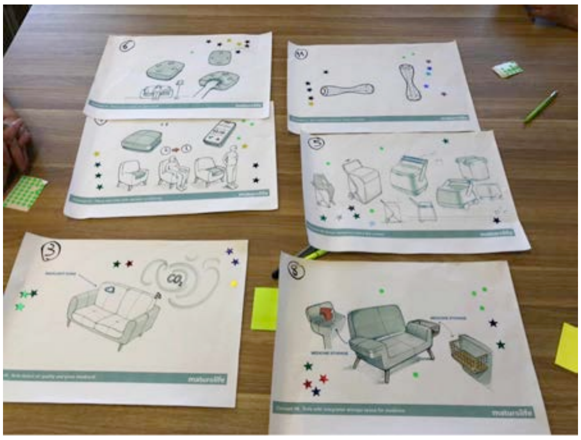


Figure 5a. Participants voted on their preferred six concepts using stars

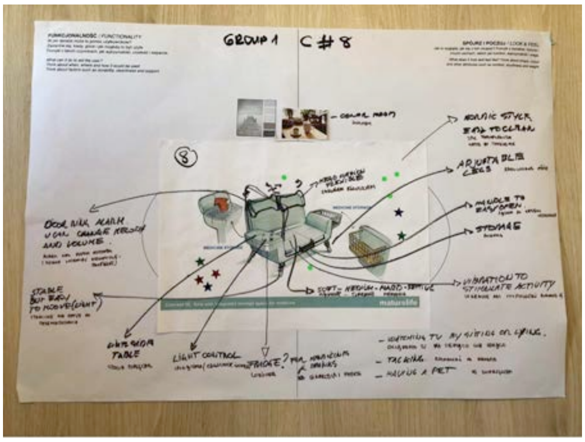


Figure 5b. Design development of a smart sofa concept at the co-creation workshop in Poland

2.3 Multidisciplinary design approach

Following the co-creation workshops, the design partners who had taken part further developed the generated ideas for footwear, clothing and furniture. They refined the designs embedding the style preferences discussed and exploring further the technology that might be embedded to enable the proposed assistive functions. The design and development activities for each of the three prototypes was then facilitated and reviewed through a series of meetings and workshops. These workshops enabled an in-depth focus on the products and creation of a working culture and language around the product narrative.

During the multidisciplinary team workshops three sub-teams were formed to support the ongoing development activity and enable the production of functional prototypes. These were focused on the design of footwear, clothing and furniture, and included expertise from across the consortium representing design, materials, manufacturing, electronics, data and connectivity. The interaction between the teams and the interrelation of activities are illustrated in Figure 6. The teams were led at this stage by partners representing a specific area of design expertise i.e. footwear manufacturers, clothing designers, and furniture design.

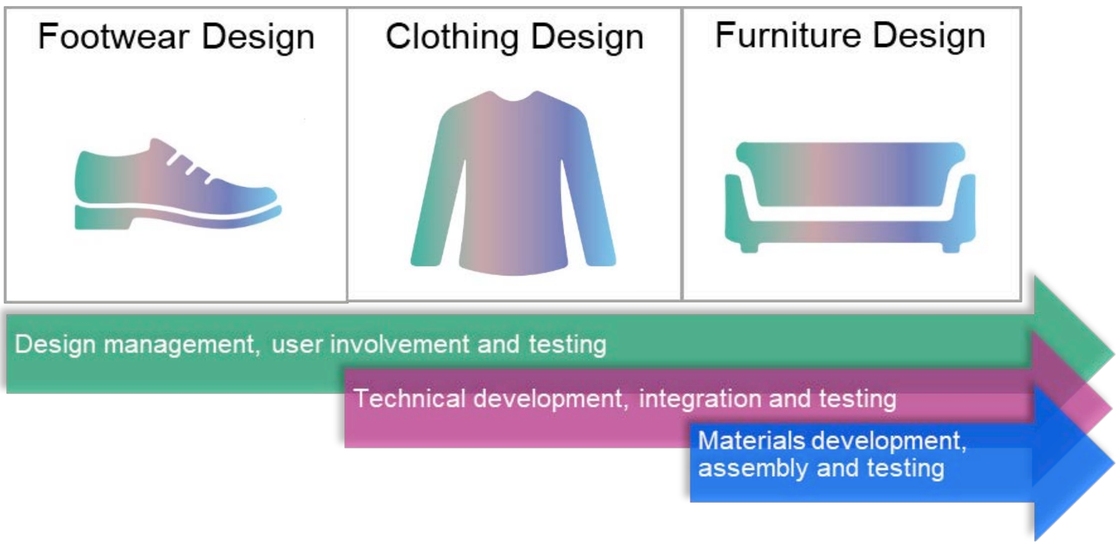


Figure 6. Multidisciplinary Teams with Concept Development Activities

During the session, the developing designs were reviewed against a set of criteria including the extent to which the concepts incorporated a metallised textile, mapped to identify user needs, technical feasibility, manufacturing difficulty and commercial viability. Iterative development by the teams occurred between each workshop. A significant element of the process was collaborative development of service design maps and detailed user journeys to map interactions with the proposed products. This was an important activity to align partners and develop a shared understanding of the project scope and directions.

2.4 MATUROLIFE Concept Prototypes

Ongoing development of the prototypes continues through multidisciplinary team working. The emerging prototypes address the following needs:

1. Assistive footwear to improve balance and reduce falls
2. Assistive clothing to help regulate temperature and encourage hydration
3. Assistive furniture to support safety at home and enable improved sleep and mobility

From traditional data collection to creative co-creation, low resolution and workshop-based concepts are being developed alongside use of 2D-illustration, 3D modelling and rapid-prototyping to help participants' ideas come to life with initial functionality and aesthetics, interaction design and control systems.

The electronic design and sensing technology, including the development and integration of big data platform will be further developed in the functional prototypes, whilst the overall aesthetics will continue to be developed through iterative design and testing activities. Local user groups have been established to ensure user feedback is embedded throughout the development phase to maximise user acceptance and usability.

3 Conclusion

This paper has outlined the focus and development approach employed in the MATUROLIFE project. Our focus is on assistive technology and smart materials, and how these can be harnessed for a better quality of life and independence for older adults. The concepts that emerged through the co-creation activity demonstrated a desire for attractive products discretely embedding assistive functionality and vital signs monitoring for a sense of safety, security and independence in older age.

A multidisciplinary design approach is crucial to successfully integrate the elements of the emerging prototypes and to fully utilise the skills and methodology from a wide range of disciplinary experts. The approach is bringing together electronics, sensors, informatics, material science and care into a collaborative effort with artistic designers to produce smart and assistive footwear, clothing and furniture.

How we deliver the envisaged assistive products to meet user expectations without compromise of design aesthetics or technological ability is a key challenge. Sustained multidisciplinary work and iterative user involvement, as well as partner collaboration is key to achieving optimal solutions.

The project is now 18 months into the 3-year timeframe. The remaining months will involve prototype production, integration of smart textiles and a thorough testing and validation schedule. Continuing the user-focused development approach, iterative testing will ensure the involvement of older adults with the aim of producing assistive technology that is functional, meets the needs and requirements of the end user whilst being aesthetically pleasing, desirable and fashionable.

4 References

Blomkvist, J., & Segelstro¨m, F. (2015). Benefits of External Representations in Service Design: A Distributed Cognition Perspective. *The Design Journal, 17*(3), 331-346. doi:10.2752/175630614X13982745782849

Callari, T. C., Moody, L., Magee, P., & Yang, D. (2019). ‘Smart – not only intelligent!’ Co-creating priorities and design direction for ‘smart’ footwear to support independent ageing. *International Journal of Fashion Design, Technology and Education*. doi:10.1080/17543266.2019.1628310

Moody, L., York, N., Ozkan, G., & Cobley, A. (2019). *Bringing Assistive Technology Innovation and Material Science Together Through Design*. In Vol. 145. Y.-W. C. Z. J. H. C. Jain (Ed.), *Innovation in Medicine and Healthcare Systems, and Multimedia*. Retrieved from doi:10.1007/978-981-13-8566-7_30

Raijmakers, B., Thompson, M., & Garde-Perik, E. v. d. (2012). *New goals for design, new roles for designers?* Paper presented at the Cumulus conference, Helsinki.

Ritchie, J., Lewis, J., Nicholls, C. M., & Ormston, R. (2014). *Qualitative research practice : a guide for social science students and researchers*. London: SAGE Publications.

Sanders, B. E., Brandt, E., & Binder, T. (2010). *A Framework for Organizing the Tools and Techniques of Participatory Design*. Paper presented at the 11th Biennial Participatory Design Conference, Sydney, Australia.

Sanders, E. B.-N., & Stappers, P. J. (2008). Co-creation and the new landscapes of design. *International Journal of CoCreation in Design and the Arts, 4*(1), 5-18. doi:10.1080/15710880701875068

Steen, M. (2013). Co-Design as a Process of Joint Inquiry and Imagination. *Design Issues, 29*(2), 16-28. doi:10.1162/DESI_a_00207

Trischler, J., Pervan, S. J., Kelly, S. J., & Scott, D. R. (2018). The Value of Codesign: The Effect of Customer Involvement in Service Design Teams. *Journal of Service Research, 21*(1), 75-100. doi:10.1177/1094670517714060

Venkat, R., & Ozcan, K. (2018). What is Co-Creation? An Interactional Creation Framework and its Implications for Value Creation. *Journal of Business Research, 84*, 193-205. doi:10.1016/j.jbusres.2017.11.027

Wait, S., & Harding, E. (2006). *The State of Ageing and Health in Europe*. Retrieved from https://ilcuk.org.uk/wp-content/uploads/2018/10/StateOfAgeingAndHealthInEurope.pdf

Yusif, S., Soar, J., & Hafeez-Baig, A. (2016). Older people, assistive technologies, and the barriers to adoption: A systematic review. *International Journal of Medical Informatics, 94*, 112-116. doi:10.1016/j.ijmedinf.2016.07.004

About the Authors:

Danying Yang: Research Fellow in design in the Centre for Arts, Memory and Communities at Coventry University. Her research interests lie in the areas of Smart Fashion and Wearable Technology through innovative textile and material research to promote a variety of products with multidisciplinary collaboration.

Louise Moody: Professor of Health Design and Human Factors in the Centre for Arts, Memory and Communities at Coventry University.
Her research is focused on the development of products, interventions and services to benefit health and wellbeing.

Andy Cobley: Professor of Electrochemical Deposition and leader of the Functional Materials Research Group at Coventry University. An electrochemist by training his research group has a wide range of interests

with a focus on innovative and enabling technologies to add functionality and value to materials.

Acknowledgement: This publication is based on work performed in MATUROLIFE (Metallisation of Textiles to make Urban Living for Older People more Independent and Fashionable), which has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 760789. The authors wish to sincerely thank the participating older adults who gave their time for the interviews and the co-creation activity. Any dissemination reflects the authors' view only and the European Commission is not responsible for any use that may be made of the information it contains. The views and opinions expressed in this paper are those of the authors and are not intended to represent the position or opinions of the MATUROLIFE consortium or any of the individual partner organisations.

Living Better with Water: Identifying Design Considerations for Products aimed at Motivating Regular Water Intake

Yıldız, Mert*[a]; Hepdoğan, Deniz[b]; Coşkun, Aykut[a]

[a] Koç University, Arçelik Research Center for Creative Industries, İstanbul, Turkey
[b] Koç University, İstanbul, Turkey
* mertyildiz18@ku.edu.tr

Water is one of the key nutritional sources for the human body. Its absence causes psychological and physical health problems such as anxiety, headaches and urine problems. Design researchers have previously addressed this problem (i.e. dehydration) through developing interactive products, which track daily water intake and give feedback to the users. However, to the best of our knowledge, no study specified the design considerations for designing products aimed at supporting regular water intake. Addressing this gap, we first designed a smart water bottle concept that reminds and motivates drinking water by using its own surface as an ambient display. By using this concept as a reference, we conducted semi-structured interviews with 10 prospective users and 6 health experts. As a result, we identified 5 design considerations that can inspire researchers and practitioners who are aiming to design products that support regular water intake. These considerations are 1) designing for tailored water intake, 2) connecting water intake with other activities, 3) using different feedback modalities, 4) tracking multiple sources of water intake, and 5) designing for hydration as a social activity.

Keywords: *Water Intake; Design for Behavioural Change; Design Considerations; Smart Water Bottle*

1 Introduction

Water is an essential nutritional source for the human body (Jéquier & Constant, 2010; Kleiner, 1999). Insufficient water intake causes both physical and physiological harms to the human body by triggering headaches, fatigues and stress as well as urine and infection problems (Blake, 2011). All bodily organs such as kidney, liver, heart and brain depend on healthy hydration to function properly (Edmonds, Harte & Gardner, 2018). Without consuming enough water, people are at high risk of getting heart attacks, faints and loss of concentration (Sawka, Cheuvront & Carter, 2005).

Recent studies showed that even though people are aware of this fact, they might ignore drinking enough water. For example, a study conducted in the U.S. discovered that more than 30 percent of the adults and almost 50 percent of the children are inadequately hydrated (Cheng, Ravi, Plegue, Sonneville & Davis, 2016; Kenney, Long, Cradock &

Gortmaker, 2015). Another study from the UK indicated that more than 30 percent of adults are also inadequately hydrated (Gibson, Gunn & Maughan, 2012).

This problem has recently gained interest from academy (Chiu, Chang, Chang, Chu, Chen, Hsiao, & Ko, 2009; Ko, Hung & Chu, 2007; Neves, Costa, Oliveira, Jardim, Gouveia, & Karapanos, 2016; Lessel, Altmeyer, Kerber, Barz, Leidinger, & Krüger, 2016) and from industry[1], indicating a trend in designing products aimed at motivating regular water intake (see the following section for a detailed discussion of previous work). However, to the best of our knowledge, there has been no study providing guidance to designers for designing such products. In this paper, following a research through design methodology (Zimmerman, Forlizzi & Everson, 2007; Frayling, 1994), we aimed to create design knowledge that can inspire the design of products and systems for supporting users' healthy hydration behaviour.

We first designed a novel smart water bottle concept. Then we conducted a user study with 10 potential users to learn about their reactions towards this concept. Based on this user study, we revised our initial concept and devised a use case scenario tailored to an office setting. By using this scenario as a reference, we conducted expert interviews with three sports medicine physicians and three dietitians in order to attain a better understanding of people's water intake behaviours and identify techniques for supporting healthy hydration habits. Finally, we synthesized the results of each phase into five design considerations that should be taken into account while designing products aimed at encouraging regular water intake.

In the remainder of this paper, we first present the smart water bottle concept and explain how it differs from previous examples. Then, we share the results of the user study and discuss users' reactions towards this concept as well as their expectations of similar products. Later, we present the results with experts. We elaborate on the factors influencing healthy hydration, techniques that can be used to motivate healthy hydration, barriers for acquiring healthy hydration habits and user groups which are likely to use products for supporting regular water intake. Finally, we discuss design considerations and identify potential directions for further research.

2 Smart bottle concept

There are several studies that focus on supporting regular water intake through design. For example, *Playful Bottle* is a mobile system that reminds drinking water through computer-automated reminders and computer-mediated social reminders. It collects water intake data with a smart phone camera and supports water intake via gamification by turning this behaviour into a challenge i.e. users earn notification credits by drinking water and spend these credits to remind other users on drinking water (Chiu et al., 2009). *Hydropromt* is another concept that collects water intake data through a weight sensor and provides historical information by sending regular notifications to the user's computer screen (Neves et al., 2016). *Mug-Tree* is a concept consists of a mug, which uses a tilt sensor to collect water intake data and gives this data through a visual of a tree with a separate LED display (Ko et al., 2007). Using a similar approach, *Watercoaster* is a system that calculates water

[1] HydrateSpark (https://hidratespark.com), EightCups (https://www.8cups.me/en/), H2Opal (https://www.h2opal.com)

intake with a table top device and weight sensor (Lessel et al., 2016). It aims to motivate beverage intake via a mobile phone application that is connected to the device. In this phone application, the user selects an avatar from undersea creatures and whenever s/he consumes the beverage, the wellbeing of the avatar increases. In the end, user needs to take care of the avatar selected from the theme: undersea creatures.

It appears that these concepts commonly measure water intake via various sensors, and they all give feedback about this intake with screen-based displays such as smart phone screens and traditional LEDs. Diverging from these concepts, we would like to design a product that gives feedback without using a screen-based display since users are already exposed to such displays in daily life. Thus, we designed a smart water bottle concept which uses its own surface as an ambient display to remind drinking water (Figure 1). When designing this concept, we inspired from four design principles proposed by Jafarinaimi, Forlizzi, Hurst and Zimmerman (2005). These are abstract (showing the feedback in abstract form rather than raw sensor data), non-intrusive (showing data in an unobtrusive way), presentable in public (illustrated data should be suitable for the public environment), aesthetic (showing the feedback in an aesthetic way so the interest is sustained over time).

Figure 1: Ambient smart water bottle concept

The concept uses a built-in liquid level sensor to measure water intake with no additional device (see Figure 2, image in the right). We applied thermochromic paint on the surface of the bottle and hid a tree image under the thermochromic paint. As the user drinks water, the tree visual becomes visible slowly due to the paint’s material characteristics. The bottle has two states (Figure 2, three images on the left): idle and feedback. When there is no interaction, the bottle remains in the idle state and looks like an ordinary water bottle without the tree image. When the user drinks water, tree branches become visible. If the user drinks enough water, flowers on the tree branches, are also become visible to indicate sufficient water intake.

Figure 2: States of the bottle and technical details

3 Initial User Study

We conducted semi-structured interviews with 10 healthy individuals to understand their reactions and expectations of this concept. We recruited participants through sending e-mails from [anonymous] university repository and authors' social media accounts. All the participants were living in a metropolitan city, located in Southeast Europe. Their ages varied between 26-46 (*M=32, SD=5.58*). Interviews started with general questions, continued with questions related to the concept and participants' general expectations of smart bottles (Table 1).

Table 1: Questions about water intake for our initial concept

-	Questions about lifestyle and healthy living: participants' routines, their well-being and nutrition intakes etc.
-	Questions about water intake: the amount of water they drink, awareness towards their water intake, means of water intake i.e. water bottle, glass cups, mugs etc., determining the necessity of reminding water intake
-	Questions about expectations from a smart bottle: necessary features of a smart water bottle, integration of these bottle to their daily lives, expected benefits of this kind of a bottle
-	Questions about our water bottle concept (after showing the video): necessary features, the usability of the bottle, improvement points, general expectations from this concept

To explain how the concept works, we prepared a video where an office employee drinks water from the smart water bottle and the tree visual starts to appear smoothly (Figure 3). Each interview took approximately 25 minutes. We voice-recorded the interviews, transcribed them into text and then analysed the results with qualitative coding by using interview questions as analysis scheme (Miles, & Huberman, 1994).

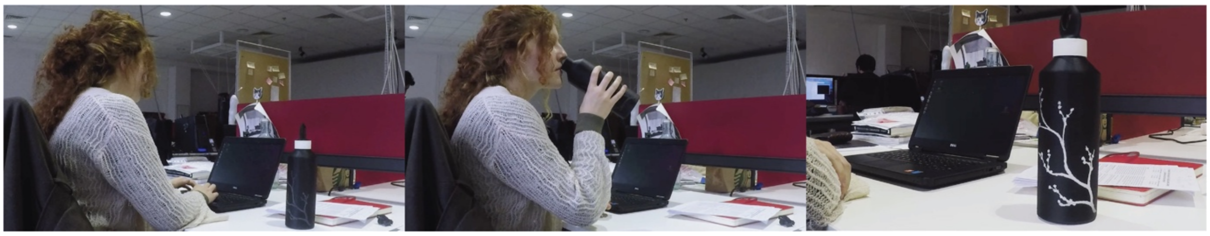


Figure 3: Snapshots of the video sketch demonstrating the interaction and how our concept works.

4 Users reactions towards the concept and their expectations

Overall, participants liked the concept as it gives feedback with an appealing visual. Five of them, who works in offices, suggested that applying this concept to the office environment would be beneficial because they said that there is a tendency to forget drinking enough water while working. They also shared their concerns related to the tree image and its wear-off effect. They said that it might be useful to change the tree image with different visuals to maintain the surprise effect in the long term. Besides these general comments, participants mentioned four characteristics that a smart bottle should have in order to motivate them to drink water regularly.

4.1 Expectation 1: Receiving notifications as reminders

The concept gives unobtrusive feedback only when the user drinks water. The design rationale behind this was giving feedback without creating a distraction for the user. Although the participants appreciated this type of feedback, they mentioned that a smart water bottle should also remind drinking water periodically since they may forget how much they already drank or need to drink more. They predicted that providing notifications would be helpful to motivate drinking water. They suggested that this could be achieved via a smart phone application with a simple and easy to use interface without overloading themselves with too many settings.

4.2 Expectation 2: Accessing precise and detailed information

Participants mentioned that the amount of sufficient water intake may differ according to individual characteristics. They expected that a water bottle should calculate this amount by using personal attributes like basal metabolism, height, weight and so on. They wished to receive personalized information regarding to these attributes. Furthermore, although they appreciated the abstract feedback, they wished to receive more precise information regarding their water intake. They said that having more feedback stages (e.g. the tree gradually becomes more visible from root to bottom) may be helpful to know how much they drank, and how much more they need to drink.

4.3 Expectation 3: Personalizing the feedback

Participants considered the water bottle as a highly personal product. Thus, they wanted to have the option to replace the tree image with a more personal visual representing their own personal characteristics such as lifestyle, age, sex, and identity. Personalization was also desired for changing the frequency of water intake reminders, as receiving lots of notifications may be annoying in some situations (i.e. while working or relaxing).

4.4 Expectation 4: Gamifying the water intake habit

Participants found the revealing tree image surprising and half of them stated that this leads to a playful interaction for drinking water. They further told that this playful interaction can be supported by gamification. They suggested a gamified environment that involves levelling-up and competing with friends throughout an online community would provide additional motivation for regular water intake.

5 Concept revision and scenario description

We revised the initial water bottle concept based on these expectations. We added a companion smart phone application to the water bottle. The rationale behind this revision was fulfilling user expectations without changing the abstractness and unobtrusiveness of the feedback given on the bottle surface. The mobile application notifies the users when they do not interact with the bottle for a long time *(expectation 1*) and provides more precise and detailed information such as the amount of water intake numerically or comparison between two days (*expectation 2*). It has also a page in which the users can see their ratings among friends (*expectation 4*). Furthermore, this app gives the users the option to select the appropriate feedback visual for their personal preferences (*expectation 3*). We also envisioned that the number of available feedback visuals depends on users' goal achievement to create a playful experience (*expectation 4).* We visualized these revisions through a scenario tailored to office employees (Figure 4).

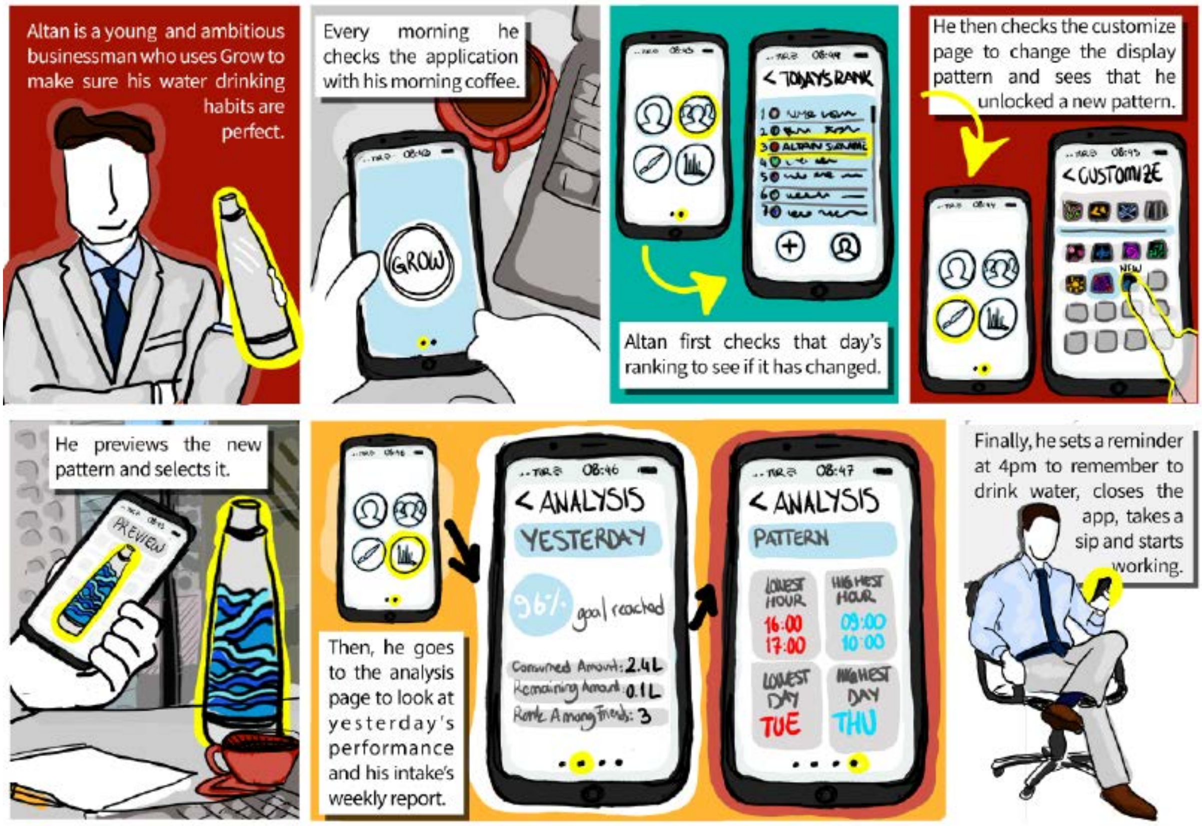


Figure 4: Envisioned usage scenario for an office environment

6 Expert Interviews

We conducted interviews with 6 health experts with the aim of acquiring a deeper understanding of people's water intake behaviours and identify possible techniques for supporting healthy hydration habits. Three experts were dieticians (E1, E2, E3), and others were sport medicine physicians (E4, E5, E6). Respectively, the dieticians had 23, 2, and 1.5 years of experience; and the sport medicine physicians had 17, 21 and 23 years of experience. We contacted all the experts via our personal accounts and received their consents prior to interviews. During the interviews, we showed the scenario (Figure 4) to the experts in order to trigger discussion as well as to help them understand the concept clearly. Interview questions were structured under the following categories (Table 2).

Table 2: Interview question structures for health experts.

- Questions about sufficient water intake amount for a healthy individual
- Questions about factors that influence water intake amount
- Questions about potential user groups for the concept and the differences between these groups
- Questions related to barriers for healthy hydration habits and techniques that can be used to motivate these habits
- Questions about experts' opinions about the smart water bottle concept and envisioned use case scenario

Expert interviews took approximately 45 minutes. We followed the same data analysis method as in initial user study. We voice recorded the interviews, transcribed them into text and then analysed results with qualitative coding method by using interview questions as analysis scheme. In the remainder of this section, we will share the findings from the expert interviews categorized in four main topics: healthy hydration, potential target groups, techniques to motivate regular water intake and potential barriers towards drinking water.

6.1 Healthy Hydration

Expert interviews revealed two important insights pertaining to healthy hydration. The first is that water intake should be balanced with water loss, as both the lack of water and excess of water harms the body. E6 pointed out that required daily water intake for an individual is calculated based on this balance. For example, on a day-off, an athlete should drink less water than his/her training days as his/her water loss would be lower. Another expert (E4) said that when the balance is not achieved, the body faces with deficiencies like kidney problem. E4 further pointed out that the diabetics should be careful of how much they drink as over drinking may vitally harm them. E6 stressed that a person's sodium level may drop dangerously due to drinking too much water which is also known as water intoxication. This expert added that over drinking can lead to dizziness which affect physical and cognitive performance.

The second insight is that although a generalized required water intake amount for healthy hydration can be given, this amount is distinct for everyone. This is because various environmental and personal factors influence an individual's healthy hydration baseline level, i.e. the minimum water intake amount required for healthy hydration. Climate and weather are two environmental factors influencing the baseline (E1 & E5). For example, while people have less water loss in humid and cold weather, and they have higher water loss in hot and dry weather (E5).

Personal factors influencing the baseline is more diverse. These include the level of physical activity, health condition, weight, age, sex, weight and hormonal changes. All the experts agreed that the level of physical activity is a strong indicator of the baseline. The more an individual has an active lifestyle the more s/he should drink water. In addition to that, almost all of the experts (*N = 5*) stated that a person's health condition alters the baseline level. For example, E3 stated that one needs to drink more water if s/he has an acute illness; and E2 noted that one's baseline level is also influenced by whether s/he has any chronic disease or not. The next personal factors are age and sex. E2 stated that the individualized baseline level changes throughout a person's life. E3 mentioned that generally women require less water intake (2,5 litres a day) than men (3.5 litres a day). The following personal factor is weight. E1 and E3 agreed that adults should take 30-35 ml of water daily per kg. The last factor is hormonal changes. E2 told that hormonal changes within a woman influence the baseline level of the individual, e.g. being pregnant or nurturing a new born requires an increased level of water intake.

6.2 Potential Target Groups for products aimed at supporting regular water intake

With the interviews, we identified several target user groups that might want to use a smart bottle that tracks and reminds daily water intake. Firstly, E4 agreed that office employees can be a potential group, as we envisioned in the scenario (Figure 3). Additionally, experts argued that elderly and nurturing woman can be two potential user groups. E5 stated that the decrease in the ability to sense the thirst and memory decline makes the elderly a vulnerable population for healthy water intake. Furthermore, drinking water becomes more crucial for the pregnant women as the body temperature increases during the pregnancy. The fourth user group is sports people. As the experts pointed out, sports people, especially athletes, sweat more and lose more water on average than their peers. Therefore, people who exercises regularly needs to drink more water than their peers who have a sedentary lifestyle. The next group is children. While E4 emphasized the importance of childhood years for making drinking water a habit, E1 stated that this is not an easy task because children's inadequate hydration is usually due to their preference for other beverages (e.g. fruit juice, coke) for compensating their need of water. The last user group was people with chronic diseases: people with diabetes (E1, E4, E5) kidney and neurological disease patient (E2), and people with hormonal disorders (E5).

6.3 Techniques to Motivate Regular Water Intake Behaviour

The water is essential for human life; yet, it is not easy for everyone to drink it. Therefore, the experts implement various techniques to motivate regular water intake of their patients.

6.3.1 Increasing the visibility of the water

E4 emphasized the importance of turning drinking water into a habit as this is an efficient way to prevent dehydration. Healthy water intake habit can be achieved through consuming water before our senses detect dehydration. E4 suggested that, in order to attain this habit, a person should have a source of water nearby regardless of the environment, in the home, while traveling, during work etc. In such places, a personalized water bottle can be used to make water visible and accessible. This will trigger the person to drink water without necessarily feeling the thirst, to help establishing a regular water intake habit.

6.3.2 Using alternative sources for water

Sometimes, individuals might lean towards using alternative sources of hydration instead of drinking plain water. In order to create a healthy water intake habit suitable for the individual, E6 pointed out that professionals should know about the lifestyles of their patients. This knowledge will provide insight about the possible alternative sources of water that the patient may tend to consume. For example, there are people who drink 20 glasses of tea on a daily basis. Also, E2 pointed out that for the patients who do not like to drink water, foods with high amount water are being advised to eat to them, such as lettuce, dill, arugula, parsley and yoghurt. On the other hand, E3 stated that people who consume too much caffeine should increase their plain water intake accordingly because caffeinated beverages cause to water loss in human body. Therefore, people might be dehydrating themselves when they intend to do the reverse. It is important to note that both the experts 6 and 2 stated that people should still drink plain water in a given amount, around 1.5 litres per day.

6.3.3 Connecting an activity with water intake behaviour

All the experts stated that associating water intake with an activity can be useful for groups of people, and they use this association technique with their patients to motivate them. Almost all of the experts (*N=5*) have declared that they advise their patients to drink water before and after each of their meals to associate drinking water with eating. Also, E4 stated that the amount of water drunk before and after the meal is not important, having a glass of water nearby and taking a sip is enough to create the motivation to drink water. Experts also suggested connecting hydration with sleeping. Three of them pointed out that they asked their patients to drink water before they go to sleep and right after they wake up. In fact, E5 noted that patients are reminded to drink water right after they wake up, even before washing their faces. Another activity that was used by most of the experts (*N=5*) is exercising. They all advised their patients to drink water before and after exercising.

6.3.4 Facilitation through social support

Another technique in motivating regular water intake was using social support. From a personal experience, E4 stated that she encouraged her daughter to drink water regularly. Initially, E4 was giving a glass of water to her at every meal. Even when giving a milk, E4 put a glass of water next to it regardless of how much the daughter drank it. After a while, the daughter started to ask for a glass of water if there was not any. As a result, she made this a habit, and now she drinks water more sufficiently than her peers. Another technique to motivate regular water intake used is assigning someone else to monitor the water intake of the individual. For example, E4 pointed out that the inclusion of coaches to track water intake may lead to better results for athletes. Similarly, she mentioned that parents and teachers may involve in the tracking process of the children’s water intake because it can lead to an increased level of water intake due to the influential power of parents and teachers on children.

Also, E4 emphasized the importance of obtaining awareness of healthy water intake during childhood. As the person gets older, it becomes harder to induce a habit onto that person; therefore, childhood is a critical period. In fact, when the children who obtained this habit get older, they will be much less likely to face with dehydration problems.

6.4 Potential Barriers Toward Drinking Water

Increase in the water intake could also lead to an increase in the need of going to the bathroom. As E5 stated, this may reduce individuals’ motivation for drinking water in the right amount. The expert expressed that elderly people, specifically who have urinary and prostate problems, have very low motivation to drink water as they tend to avoid going to the bathroom. Similarly, E4 stated that people may be hesitant to go to the bathroom in public spaces like fitness centres, shopping malls etc. Also, the parents may be hesitant to take their children to the bathroom in public places, which in turn lower the hydration level of their children. All these avoidances turn into potential barriers toward drinking water as they lead people to prevent drinking enough amount of water.

E2 stated that there are people who do not like the taste of water; hence not drinking it. In order to overcome this barrier, infused waters are used. Additionally, nutrients containing a high amount of water are also given to this kind of patients to substitute the drinking water.

7 Design considerations

Based on two interviews with prospective users and health experts, we identified five points that are important to consider when designing products and systems that aim to support regular water intake.

7.1 Designing for tailored water intake

Hydration behaviour is a highly personal (Grandjean, 2004, Valtin, 2002) since an individual's hydration requirement is based on personal (weight, age, sex) and environmental factors (climate). Thus, when designing for regular water intake, it is essential to consider the diversity in these factors and to provide tailored feedback. This could be achieved by integrating a smart water bottle into a bigger system in which various devices like mobile phones, smart watches, water fountains and so on, communicating with each other to exchange personal and contextual data. Furthermore, since a tailored tracking of water intake involves responding to changes in personal and environmental factors, it is important to design dynamic visual feedback that can adapt to these changes. For example, in the case of the water bottle concept presented in this paper, when the user has a more active day compared to previous days, the colour of the visual tree can change from white to red to indicate that the user needs more water than previous days.

7.2 Connecting water intake with other activities

As health experts especially mentioned about habits, it is more beneficial to connect water intake behaviour with already existing activities rather than trying to create a new healthy hydration habit from scratch (Lally, Jaarsveld, Potts & Wardle, 2010). However, since the water intake should be a repetitive action (small portions but frequent intake), selecting the appropriate activity is a critical task. Expert interviews revealed that daily routines and activities such as eating and sleeping might be a good point to start creating these connections. It might be an interesting dimension to connect drinking water with daily activities of the user. For example, the water bottle may be connected to the smart wearable devices. The system can understand daily routines and it can remind drinking water from such routines of the user like waking up at a certain time, regular meal times or going to the sports centre etc. Furthermore, the system can understand (from GPS data) if the user is going to the sports centre and suggests drinking water in appropriate time. Also, it might be interesting to observe which daily activities are suitable for connecting with water intake action.

7.3 Using different feedback modalities

User interviews revealed that although participants appreciated unobtrusive feedback given by the smart bottle concept, they still would like to see more precise data about their water intake. However, users' expectation of precision should be approached critically. This is because quantification of one's behaviour is only one component of tracking; the goal is to reflect upon this data, obtain meaningful insights, and make positive changes (Choe, Lee, Lee, Pratt, & Kientz, 2014).Thus, it is essential to combine different feedback modalities, e.g. combining abstractness with concreteness and ambiguity with precision. One way to achieve this is developing a mobile phone application that gives precise and concrete feedback (e.g.

you drank 127 ml of water), as envisioned in the scenario (Figure 4), but keeping the abstract and ambiguous feedback given on the bottle surface (e.g. revealing some parts of an abstract visual). In such a scenario, while the app provides detailed quantitative feedback about one's behaviour at the early stages of habit formation, when intake behaviour turns into a habitual behaviour, users may be satisfied with a glance at the abstract feedback on the bottle surface.

7.4 Tracking multiple sources of water intake

There are multiple sources of water intake such as coffee, juice, and people may drink water from sources other than water bottles such as disposable water bottles and water fountains. This seems to be a major limitation for products relying on collecting water intake data via a water bottle. Thus, instead of depending on a single product, future products and systems can communicate in an IoT environment to collect multiple water intake data. These systems can be supported by emerging machine learning and artificial intelligence technologies (Chun, Sanders, Adaimi, Streeper, Conroy & Thomaz, 2019) to understand water intake and develop solutions in accordance to users' water intake sources. For example there are emerging studies that focus on tracking water intake with wearable technologies such as measuring hydration level from the wrist (Yao, Myers, Malhotra, Lin & Bozkurt, 2017). For that, the smart water bottle can connect with these technologies to remind water intake in necessary times.

7.5 Designing for hydration as a social activity

Last but not least, as experts stated, regular water intake also has a social aspect. Focusing on social support becomes important when designing systems to motivate healthy hydration. For that, even though drinking water may seem as a personal activity, sharing water intake data in an ambient and ambiguous way in public settings can trigger collective behaviour change for communities It has been mentioned that each individual affects the group dynamics and %25 of group members can change the behaviours of others (Centola, Becker, Brackbill & Baronchelli, 2018). In that sense, one path can be designing a system by combining water bottles with a water fountain. For example, in an office environment, water fountains are often used on regularly basis. This water fountain may get connected with smart water bottles of employees and the visual (white tree image) can appear also on the surface of the water fountain. This can provide the continuity of the feedback for the individuals as well as it can make water intake a social activity with visualizing other employees water intake data too. So, the water fountain can both collect individual water intake data and share it in an ambiguous medium in an office environment.

8 Conclusion

In this paper, we presented a novel smart water bottle concept along with two interview studies conducted with prospective users and health experts. Developing on both, we provided five design considerations to guide design researchers and practitioners who are willing to work on designing products or systems for supporting healthy hydration. In that sense, we contribute to the existing literature by, designing a novel water bottle and delivering design considerations for researchers. However, one should note some limitations to our work. For example, the sample size for the initial user study was small, and it mainly represents individuals working in office settings. In the future, we aim to conduct user studies with other target groups such as elderly people and nurturing mothers to understand their needs, barriers, existing practices and their reactions towards the water bottle concept.

Another limitation is that we derived design considerations from interviews with users and experts. In other words, although we provided several examples of how these considerations can be applied, we have not full validated them through new designs. In the future, we intend to explore the validity of these considerations with real-life applications such as a water fountain system. We aim to design a water fountain system according to these considerations mentioned and connecting it with our smart water bottle concept may provide deeper understanding of behaviour change for healthy hydration habits.

9 References

Blake, H. (2011). Healthy hydration in the workplace. *Health Psychology Update*, *20*(2), 22.

Centola, D., Becker, J., Brackbill, D., & Baronchelli, A. (2018). Experimental evidence for tipping points in social convention. *Science*, *360*(6393), 1116-1119.

Chang, T., Ravi, N., Plegue, M. A., Sonneville, K. R., & Davis, M. M. (2016). Inadequate hydration, BMI, and obesity among US adults: NHANES 2009–2012. *The Annals of Family Medicine*, *14*(4), 320-324.

Chiu, M. C., Chang, S. P., Chang, Y. C., Chu, H. H., Chen, C. C. H., Hsiao, F. H., & Ko, J. C. (2009, September). Playful bottle: a mobile social persuasion system to motivate healthy water intake. In *Proceedings of the 11th international conference on Ubiquitous computing* (pp. 185-194). ACM.

Choe, E. K., Lee, N. B., Lee, B., Pratt, W., & Kientz, J. A. (2014, April). Understanding quantified-selfers' practices in collecting and exploring personal data. In In M.Jones, & P. Palanque (Eds.), *CHI 2014. Proceedings of 32th conference on human factors in computing systems* (pp. 1143-1152). ACM.

Chun, K. S., Sanders, A. B., Adaimi, R., Streeper, N., Conroy, D. E., & Thomaz, E. (2019, March). Towards a generalizable method for detecting fluid intake with wrist-mounted sensors and adaptive segmentation. In *Proceedings of the 24th International Conference on Intelligent User Interfaces (pp. 80-85).* ACM.

Edmonds, C. J., Harte, N., & Gardner, M. (2018). How does drinking water affect attention and memory? The effect of mouth rinsing and mouth drying on children's performance. *Physiology & behavior*.

Frayling, C. (1994). Research in art and design (Royal College of Art Research Papers, vol 1, no 1, 1993/4).

Gibson, S., Gunn, P., & Maughan, R. J. (2012). Hydration, water intake and beverage consumption habits among adults. *Nutrition Bulletin*, *37*(3), 182-192.

Grandjean, A. (2004). Water requirements, impinging factors and recommended intakes. *ILSI North America, Hydration: Fluids for Life.*

Jafarinaimi, N., Forlizzi, J., Hurst, A., & Zimmerman, J. (2005, April). Breakaway: an ambient display designed to change human behavior. In *CHI'05 extended abstracts on Human factors in computing systems* (pp. 1945-1948). ACM.

Jéquier, E., & Constant, F. (2010). Water as an essential nutrient: the physiological basis of hydration. *European journal of clinical nutrition*, *64*(2), 115.

Kenney, E. L., Long, M. W., Cradock, A. L., & Gortmaker, S. L. (2015). Prevalence of inadequate hydration among US children and disparities by gender and race/ethnicity: National Health and Nutrition Examination Survey, 2009–2012. *American journal of public health*, *105*(8), e113-e118.

Kleiner, S. M. (1999). Water: an essential but overlooked nutrient. *Journal of the American Dietetic Association*, *99*(2), 200-206.

Ko, J. C., Hung, Y. P., & Chu, H. H. (2007). Mug-Tree: A Playful Mug to encourage healthy habit of drinking fluid regularly. *the Late Breaking Results (LBR) session of Proc. UBICOMP.*

Lally, P., Van Jaarsveld, C. H., Potts, H. W., & Wardle, J. (2010). How are habits formed: Modelling habit formation in the real world. *European journal of social psychology*, *40*(6), 998-1009.

Lessel, P., Altmeyer, M., Kerber, F., Barz, M., Leidinger, C., & Krüger, A. (2016, May). WaterCoaster: A Device to Encourage People in a Playful Fashion to Reach Their Daily Water Intake Level. In *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems* (pp. 1813-1820). ACM.

Miles, M. B., Huberman, A. M., (1994). *Qualitative data analysis: An expanded sourcebook*. sage.

Neves, D., Costa, D., Oliveira, M., Jardim, R., Gouveia, R., & Karapanos, E. (2016). Motivating Healthy Water Intake through Prompting, Historical Information, and Implicit Feedback. *arXiv preprint arXiv:1603.01367*.
Sawka, M. N., Cheuvront, S. N., & Carter III, R. (2005). Human water needs. *Nutrition reviews*, *63*, S30-S39.
Valtin, H., & (With the Technical Assistance of Sheila A. Gorman). (2002). "Drink at least eight glasses of water a day." Really? Is there scientific evidence for "8× 8"?. *American Journal of Physiology-Regulatory, Integrative and Comparative Physiology,* 283(5), R993-R1004.
Yao, S., Myers, A., Malhotra, A., Lin, F., Bozkurt, A., Muth, J. F., & Zhu, Y. (2017). A wearable hydration sensor with conformal nanowire electrodes. *Advanced healthcare materials*, *6*(6), 1601159.
Zimmerman, J. (2005). Video Sketches: Exploring pervasive computing interaction designs. *IEEE pervasive computing*, *4*(4), 91-94.
Zimmerman, J., Forlizzi, J., & Evenson, S. (2007, April). Research through design as a method for interaction design research in HCI. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 493-502). ACM.

About the Authors:

Mert Yıldız: is a PhD student at Koç University Design, Technology and Society program, a teaching and research assistant. He received his B.Sc. from METU department of Industrial Design. His research focuses on healthy hydration at office environment, as well as time and temporality in wellbeing area.

Deniz Hepdoğan: is an undergraduate Psychology student at Koç University where she also completes Design Track Program. She is a member of the Interaction Design Research Group at Koç University Design Lab and aims to specialize in designing for mental wellbeing.

Aykut Coşkun: is an Assistant Professor of Design at Koç University, a design researcher at KUAR. He received his B.Sc. M.Sc. and Ph.D. from METU department of Industrial Design. He attended CMU Human-Computer Interaction Institute in 2015 as a Fulbright Visiting Researcher. His research focuses on design for behavioural change, design for sustainability, and design for wellbeing.

Acknowledgement: We thank all the health experts and participants for their contributions and valuable opinions.

Opportunities to improve the user experience of package delivery services in Northern Finland through AI (Siri)

Suoheimo, Mari*[a]; Raudanjoki, Özge[a], Beaulé, Caoimhe Isha [a], Laitinen-Tolonen, Aulikki[b]

[a] University of Lapland, Rovaniemi, Finland
[b] Lapland University of Applied Sciences, Rovaniemi, Finland
* msuoheim@ulapland.fi

This short paper studies how package delivery could be assisted by AI. Three customer journeys were performed to understand the pain points and the opportunities related. The mapped journeys reveal how Siri is currently limited and still not able to do interaction with humans as humans interact with each other. It is able to do just simple commands and struggles with more complex issues as making the transactions or interacting with an online website. The study confirms Bellagarda's (2013) statements on how AI could assist in three domains as interlinking the user's personal information, integration of the virtual assistant (Siri) with across domains and be capable of doing transactions. Siri has great potential in improving package delivery service as through linking the online calendar of the client with the service; it could take the role of a secretary. The participants were all located at the northern part of Finland.

Keywords: User Experience; Service Design; Customer Journey; Siri & Artificial Intelligence; Delivery Services; Remoteness

1. Introduction

Like most countries around the globe, most sectors in Finland are increasingly becoming digitized. Nonetheless, the country struggles to deliver mail and packages to remote areas like Lapland (Aimo-Koivisto, 2019; Hietala, 2019; Hiltunen 2019). These areas could perhaps benefit from digitized services and take advantage of the rapidly changing service systems. The influence of e-markets has, for example, created challenges in securing mail delivery and printed newspapers (Posti Proposed Solutions, 2019). To address these changes, postal and media industries are progressively switching to digital means. Moreover, the gradual migration of rural populations to larger bigger urban centers cities decreases the offering of the delivery services in the Northern regions area (Ahola, 2016; Pölkki & Saarinen, 2017). Beyond the complexities relating to remoteness, delivery services in these areas are regularly affected by extreme winter conditions, like ice and snow collecting on trucks (Rontti et al., 2018). All in all, these issues can create negative user experiences within delivery services in Northern Finland, especially when one relies on the effectiveness of the service to receive important mail. The need to address these issues, especially from the perspective of mobility and logistics, has been highlighted by recent funding calls in Finland[1]. Could Artificial Intelligence (AI) personal assistants play a role in improving delivery service experiences for all Finnish inhabitants? According to Bellagarda, artificial intelligence and personal assistants such as Siri can be integrated into online services, but progress is needed in these three areas:

> [a] a deep integration within the operating system, so as to leverage user-level information such as contact, calendar, email, and other personal data; [b] an integration of assistant capabilities across domains, to enable potential coreference resolution and leverage any other temporary context state; and [c] a broad integration with a variety of web services, to offer an appealing palette of utility and support successful transactions in the selected domains. (Bellagarda, 2013, p. 2031

This short study seeks to identify opportunities to improve the experience of Lapland delivery service users through AI personal assistants and shed light on what Bellagarda (2013) mentions regarding the needs of development in these fronts. The research is of exploratory nature and seeks to identify current limits, and potential areas to further be explored within design research, but also for companies and actors within the delivery service systems. The main questions guiding this paper are:

- What are the problems and opportunities relating to the experience of package delivery services in Northern Finland?
- How can Siri currently be used to improve a delivery service experience in Northern Finland, and what are its limits?

The objectives of this paper will be to identify opportunities for AI regarding the improvement of delivery services in Finland, in order to deserve all its citizens (i.e. outside the most densely populated areas). The data was collected through auto-ethnographic customer journeys, documenting delivery experiences by the researchers in Rovaniemi and Oulu (Finland). Hence, the data collection was conducted by mapping the current experience of using Siri in this particular context. Furthermore, it seeks to discuss the general potential benefits of using AI in package delivery service design.

2. Methodology

The epistemology of the research is pragmatic, as it starts from ‘action’ and how knowledge is created through action (Kilpinen, 2008). As mentioned by Kilpinen (2008), the action comes through the journeys that the subjects perform in relation to the “world”, in this case, of package service delivery. It is also exploratory as it starts from a problem perspective and wants to discover something new and interesting (Swedberg, 2018). Swedberg (2018) advances that, when the topic is not new and study aims to create more knowledge on a known field. The assumption is that there is potential for AI to assist package delivery services and can help to create a seamless service in customer experience. This study seeks to also verify or clarify what is the knowledge in relation to AI as online assistant. The study uses qualitative analysis by mapping three user’s service experience through auto-ethnographic customer journey mapping.

[1] For example, Business Finland’s *Smart Mobility* sector and EAKR regarding regional development, and particularly within the Lapland and Eastern Finland areas.

Auto-Ethnography "builds on personal experience" and it tells stories in the social contexts (Reed-Danahay, 2017, p. 146). According to Adams and his colleagues "autoethnographers also describe moments of everyday experience that cannot be captured through more traditional research methods" (Adams et al., 2017, p. 4). Autoethnography is a method that humanizes research (Adams et al., 2017). In this particular case, the form of autoethnography (or self-ethnography/ documentation) is used as defined within basic service design tools. These take the form of field notes, recordings and photographs. In contrast to "real" academic autoethnographic research (where a researcher would immerse oneself into an organization for multiple months), service designers regularly use a smaller version of this to immerse themselves in real life situations to better understand them (Stickdorn, 2018). In this research three authors of this paper are the autoethnographers and the research was done as an assignment of a doctoral service design course.

Moreover, Solis (2015) indicates that journey maps bring customers' needs into focus in order to serve them better through technological and strategic solutions. User's experiences are affected by the service encounters (touchpoints), which work for the users (magic moments) and parts needing to be developed (pain points), that together form the complex user journey where people, information, products and spaces are identified (Vakulenko et al., 2019; Design Council, 2015). The customer journey map consists several touchpoints where only some are under firm's control (Trischler et al., 2018). Forming the experience "pre-core" and "post-core" encounters are as significant as the core service encounter (Vakulenko et al., 2019, p 2.). Experience maps help to focus on the emotional part of customer journey by indicating what are the highs and the lows during their engagement, and including time, place, devices that they are attached to service and channel (Solis, 2015, p. 145).

3. Data of Mapping Three Customer Journeys

In total, there were three customer journeys mapping the user-experience of ordering a package; the users filled out a questionnaire in order to better understand the sample of this study. The questionnaire summarized their profiles and provided preliminary information regarding the users' previous experiences with Siri. According to the preliminary questionnaire results, their previous experiences and competencies of using digital devices were relatively similar. The ages of participants varied between 28 and 35. The results revealed each participant used different iOS devices. Siri was selected since all the three autoethnographers were already using it and had iOS and MacOS operating system based mobile phones or computers. None of the users were native English speaker, but they preferred to use Siri in English. According to the results of the questionnaire, most of the participants find Siri practical and easy to use for basic tasks. On the other hand, the participants also stated that some of the features are still limited and it demands too much effort.

The packages in question were ordered from both local and international suppliers. First, the three users were asked to note all steps, events, in the user journey from the moment they ordered their package, up to the moment they received it, as well as their emotional state and thoughts in each section. Secondly, the users were asked to explore how Siri could assist in the process of delivering online shopping during the phase of package delivery, and identify its current limits. The data set comprised digital texts, screenshots, and notes the process of delivering online shopping during the phase of package delivery. All these details were added to individual costumer journey excel files, which were then used for investigation and to identify the general observations and results of this study.

The users were asked to try to use Siri during the whole process of checking out on an online store until picking up the packet if it was possible. The Table 1 shows more in detail what areas the users were asked to document. The users could adapt it according to their journey. The study does not concentrate on the voice-based interaction or Siri as an input method as such but more how Siri can enable the shopping experience to work better during the whole process of a customer journey.

Table 1 Customer journey template.

	1. Check Out	2. Giving Address	3. Selecting the way to send the packet	4.Payment	5. Commu-nication of the payment	6. Commu-nication of the tracking	7. Commu-nication of the arrival	8. Picking up
Date:								
Weather every single day:								
Specify the device used:								
PRINT SCREEN OF THE MOMENT								
WHAT DID YOU ASK SIRI?								
HOW DID IT HAPPEN? (SIRI)								
SIRI Was Siri implemented yet? How? Did it work?								
I FEEL What the service experience made me feel at each stage?								
I SHOULD FEEL What it should have been?								
PAINPOINTS What were the painpoints encountered?								
SOLUTIONS & OPPORTUNITIES								

Source: Authors.

Figure 1 & 2. Users were asked to try using Siri in all possible steps. Receiving the package. Source: Authors.

3.1 Observations of the Customer Journeys

In order to compare the differences between the experiences of users, all stages of the process were examined by combining them into a single visual map to better observe the overall experiences (see figure 3 & 4). In this map, the users first examined their general delivery experiences and emotional journey.

According to the research data, during this stage of the process, all users had an overall positive experience. Then, the users investigated the same process in terms of the advantages and disadvantages of using Siri in the package delivery process. In addition, the questionnaire data shows that the participants' previous experiences and expectations in using Siri were similar to each other. However, U1 and U3's feelings of using Siri in complicated issues was frustrating. On the other hand, U2 indicated that although Siri was unable to perform some of the complex tasks, not all of them. In this sense, U2 had time to perform tasks with Siri more intensively by using alternative methods during the same process and as a result of this U2 had a slightly better experience.

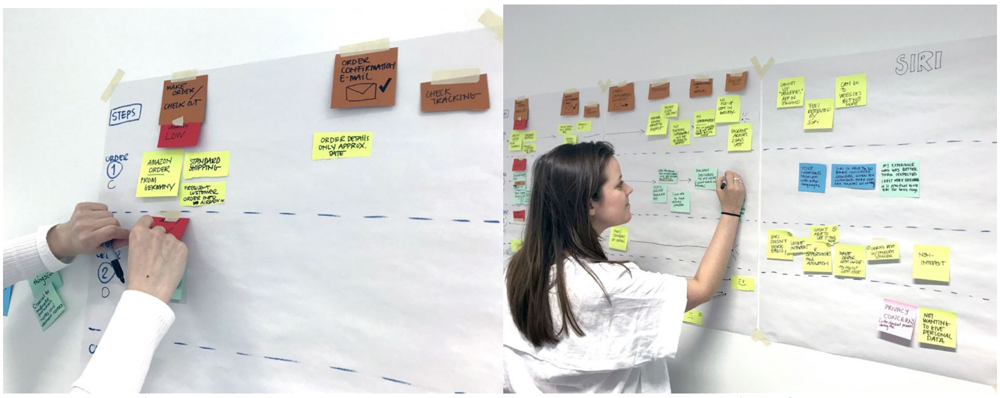


Figure 3 & 4. Mapping the observations documented by user 1,2 & 3. Source: Authors.

According to the analysis of the three customer journeys, all the participants had a relatively good experience in receiving the packages. During this process, User1 (U1) indicated that the package did not arrive on estimated arrival time and information regarding the delay was not accessible. In contrast to U1, User2 (U2) had a slightly different experience during the same process. In this case, the package was delivered far earlier than estimated delivery time, however, online information regarding the estimated arrival time of the package was contradictory with the actual time. User3 (U3) and U2 received a locker code as an electronic phone message and handled the package from the located pickup point with the locker code sent by Posti national delivery service as SMS (short message service).

All users experienced tracking through various email communications as well as through online tracking webpages. One user had a 'medium' urgent package to receive, while the other two had non-urgent packages. The three journeys also mapped the local weather each day. Although the weather in Northern Finland can definitely impact the efficiency and speed of deliveries, the weather conditions were not considered as a conclusive element in this study. U1 had suspected severe snow storm could have impacted the delivery of the shipping but was not able to confirm this claim. Users were assigned different tasks in each step of the research process, which included: ordering a product, making payment and adding shipping details. While performing the initial tasks, two of the users became discouraged or uninterested to explore other ways of using Siri after the first attempts were unsuccessful.

In addition, security issues emerged during computer use to enable Siri to use an autofill function in payments. Although the U3 authorized Siri to autofill addresses and personal information Siri was unable to proceed with the task. U3 also took over the Siri during the payment phase as she knew that it would be unable to cover this task. Actually, none of the users were able to use Siri during the payment part of the delivery. In the customer journey, U1 mentioned being disappointed to not have been able to use the deliveries application which is developed for service systems in the U.S.A.

On the other hand, throughout the research process, users observed that Siri was not able to recognize non-English words at the first attempt. For example, when U3 asked Siri was to open a store called *Matsmart,* Siri responded: “It does not look like you have an app named my dad smart”. The language barrier complicates the user situation. However, U2 indicated that when spelling out foreign domain addresses or coding the direct links letter-by-letter, including the punctuation marks, Siri led to successful results. Moreover, during this process, U2 noticed that pronunciation modus, commanding velocity and command sequence have also a critical effect in interacting with Siri. This user also indicated that the usage of external apparatus such as headphones has a positive effect in terms of word recognition accuracy.

4. Discussion and Conclusion

The research presented in this paper prefaces the need for using an artificial digital assistant (Siri) in delivery services. To reach this goal, the authors explored how package delivery could be assisted by AI. This paper summarized the author’s customer journey experiences. The authors explored the use of Siri in package delivery and evaluated the deficiencies and benefits of using an artificial digital assistant during the delivery process. The data analyzed from three participants showed that although there are significant limitations of using Siri in package delivery, Siri can perform basic commands and assist users in certain tasks, but struggles with more complicated ones as with payments.

Siri could assist users in performing introductory tasks and could be used as an intermediary tool in performing some of the more complex tasks during the package delivery process. Siri reveals great potential in improving user experience and the current deficiencies can be overcome in the near future. For instance, it could take the role of a personal secretary and combine the delivery time with the user’s online calendar, or inform the user on the progress of the shipment. According to the data collected, Siri is still pretty far from interacting with the users as humans interact with humans what Saad and his colleagues have proposed (2017).

The results of the analysis of three customer journeys follow the assumption that the artificial intelligence could have potential in creating a seamless service in customer experience in package delivery for following four categories: (1) making an order, (2) paying the order (3) tracking, (4) picking it up. This answers to the assumption made previously in the paper. The Siri has potential, but today is unable to deliver totally seamless service in the four areas.

These answers verify the points that Bellargarda (2013) has pointed out: Siri ought to be enabled to use customer’s personal information, integrate across domains and support transactions

This short paper is unable to identify the relation of the local weather to the package delivery due to the small data amount. Nonetheless, it could be an interesting topic to explore further, and see how AI advancement could potentially improve the general experience of package delivery for Northern and remote areas in Finland, specifically during the winter season. The service could be more accurate and transparent regarding the delivery and how the weather influences in it. Sensor technologies and machine learning could be an aid in this as there are plenty of weather sensor and open data available. This data could be brought to the services. As the delivery was made to remote area of Finland, the delivery service could be more transparent in the terms when packets delay, what is the reason of the delay. As an example, weather is a common cause in the northern region especially in winter time that could affect the delivery service? There are already a lot of weather sensors on the roads or in the air that could be connected to the service through artificial intelligence and machine learning to improve the current services to be more transparent.

The study seems to support the idea that Siri can be an effective tool in delivery services, but further research is needed in order to draw more precise conclusions. Although users investigated significant limitations of using Siri at different stages of the research, they could be improved in the near future. Further research would be needed to explore how new technological development could positively impact delivery service experience. This requires more cross domains collaboration among the different stakeholders in order to explore the opportunities offered by these emerging technologies regarding life in Northern and remote regions.

5. References

Ahola, O. (2016, September 18). Suomessa on käynnissä uusi ”suuri muutto” – tästä syystä kaupunkeihin kaivataan vauraita [There is a new “big move” in Finland - that's why the city needs wealthy people]. *Aamulehti*. Retrieved April 18, 2019, from https://www.aamulehti.fi/kotimaa/suomessa-on-kaynnissa-uusi-suuri-muutto-tasta-syysta-kaupunkeihin-kaivataan-vauraita-23923017

Aimo-Koivisto, A. (2019, January 23). Posti esittää valtiontukea paperilehtien jakeluun maaseudulla – perusteena "moniarvoisen tiedonvälityksen turvaaminen" haja-asutusalueilla [Post presents state aid for the distribution of paper leaflets in rural areas - as a basis for "safeguarding communication pluralism" in sparsely populated areas]. *Talous*. Retrieved April 18, 2019, from https://www.ess.fi/uutiset/talous/art2514266

Bellegarda, J. R. (2016). Large–Scale Personal Assistant Technology Deployment: The Siri Experience. *9th ISCA Speech Synthesis Workshop,*2029-2033. doi:10.21437/ssw.2016

Hietala, A. (2019, January 8). "Ei ollut tasapuolista" – Posti lopettaa kuitattavien lähetysten kotiinkuljetuksen maksutta myös haja-asutusalueilla, Näätämöstä matkaa lähipostiin 150 kilometriä ["There was no equality" - Posti will stop delivering receivables for home delivery free of charge also in sparsely populated areas, closest Posti is 150 kilometers from Näätämö]. *Lapin Kansa*. Retrieved April 18, 2019, from https://www.lapinkansa.fi/lappi/ei-ollut-tasapuolista-posti-lopettaa-kuitattavien-lahetysten-kotiinkuljetuksen-maksutta-myos-haja-asutusalueilla-naatamosta-matkaa-lahipostiin-150-kilometria-200647673/

Hiltunen, V. (2019, January 12). Harvaan asutun maaseudun verkosto vaatii Postia perumaan päätöksensä – "Pakettien satojen kilometrien noutomatka on kohtuuton" [A sparsely populated rural network demands Posti to overturn its decision - "The hundreds of kilometers of the package picking is unreasonable"]. *Lapin Kansa*. Retrieved April 18, 2019, from https://www.lapinkansa.fi/lappi/harvaan-asutun-maaseudun-verkosto-vaatii-postia-perumaan-paatoksensa-pakettien-satojen-kilometrien-noutomatka-on-kohtuuton-200665428/

Kilpinen, E. (2008, June). Pragmatism as a Philosophy of Action. In *First Nordic Pragmatism Conference, Helsinki, Finland*.

Posti’s proposed solutions for decision makers to secure delivery in the 2020s: Fixed-term State aid for printed newspapers in rural areas, the renewal of postal regulation should be continued. (n.d.). Retrieved April 18, 2019, from https://www.posti.fi/private-news/english/current/2019/20190123_Postis_proposed_solutions.html

Pölkki, M., & Saarinen, J. (2017, December 30). Kuolevien kylien maa – HS:n erikoisartikkeli kertoo tuhannen kadonneen kylän tarinan ja sen, miksi poikamies Arto Voutilaisella on oma pisteensä kartalla. *Helsingin Sanomat* [The Land of Dying Villages - The Special Feature of HS says the story of a thousand lost villages and why the bachelor Arto Voutilainen has his own point on the map]. Retrieved April 18, 2019, from https://dynamic.hs.fi/2017/katoavatkylat/a

Reed-Danahay, D. (2017). Bourdieu and critical autoethnography: Implications for research, writing, and teaching. *International Journal of Multicultural Education*, *19*(1), 144-154.

Rontti, S., Ahola, S., Miettinen, S., & Ahola, S. (2018). *Arctic Truck Platooning Challenge: Investigating Arctic Challenges of Road Transport* (pp. 1-16, Rep.). Rovaniemi, Lapland: University of Lapland.

Saad, U., Afzal, U., El-Issawi, A., & Eid, M. (2017). A model to measure QoE for virtual personal assistant. *Multimedia Tools and Applications, 76*(10), 12517-12537. doi:http://dx.doi.org.ezproxy.ulapland.fi/10.1007/s11042-016-3650-5

Solis, B. (2015). *X: The experience when business meets design*. John Wiley & Sons.

Stickdorn, M., Hormess, M. E., Lawrence, A., & Schneider, J. (2018). *This Is Service Design Doing: Applying Service Design Thinking in the Real World*. " O'Reilly Media, Inc.".

Swedberg, R. (2018). On the Uses of Exploratory Research and Exploratory. In J. Gerring, C. Elman, J. Mahoney (Ed.), *Producing Knowledge. (Forthcoming).*

Trischler, J., Zehrer, A., & Westman, J. (2018). A designerly way of analyzing the customer experience. *Journal of Services Marketing*, *32*(7), 805-819.

Vakulenko, Y., Shams, P., Hellström, D., & Hjort, K. (2019). Service innovation in e-commerce last mile delivery: Mapping the e-customer journey. *Journal of Business Research.* doi:10.1016/j.jbusres.2019.01.016

About the Authors:

Mari Suoheimo: is a Ph.D. candidate at the Culture-based service design Doctoral program. She has been facilitating the service design process in the European Union (ESR) funded Voitto-project and currently the Cross-Border Mobility in the Barents region.

Özge Raudanjoki: is a doctoral candidate in Culture-based service design program at the University of Lapland and continues to pursue her studies in new media design and production program at Aalto University. Her research focuses on unconventional forms of interaction through digital media tools.

Caoimhe Isha Beaulé: is a multidisciplinary designer and researcher from Montréal (CA), pursuing doctoral studies in Culture-based service design at the University of Lapland, Finland. Her current research revolves around exploring the role design in individual and community development in Northern regions and winter cities.

Aulikki Laitinen-Tolonen: received her M.Sc. (International Relations) degree from University of Tampere and MBA (International Business) from Aalto University (previous Helsinki School of Economics and Business Administration). She is currently working as Senior Lecturer in Lapland University of Applied Sciences

Acknowledgement: This research was supported by the Co-Stars Service Design Research Group, University of Lapland, Rovaniemi, Finland. Mari Suoheimo would like to show gratitude to the Lapland Regional Fund of the Finnish Cultural Foundation for their one-year grant for her Ph.D. research.

Portraying with Letters: An Interactive Installation

Martins, Tiago*; Rebelo, Sérgio*; Bicker, João; Machado, Penousal
CISUC, Department of Informatics Engineering, University of Coimbra, Coimbra, Portugal
* tiagofm@dei.uc.pt, * srebelo@dei.uc.pt

As people became acquainted with typographic forms, letters soon began to be explored as visual shapes of their own accord. In this work, we explore the potential of typographic shapes in the development of an interactive installation that will be part of a museum's permanent exhibition about Portuguese literature. This installation employs generative design techniques to automatically create custom typographic images that combine facial portraits of the users and texts selected by them. Each portrait is made of letters strategically placed to better depict the input image. The final output image consists of a typographic portrait accompanied by a text selected by the user. In this paper, we present the computational approach behind the installation and assess it according to the museum's requirements.

Keywords: computer vision, interactive installation, generative design, graphic design, portrait, typography

1 Introduction

Letters have a key role in our society enabling the transmission and storage of knowledge. Similarly to symbols and figures, primitive letters were already used at prehistoric age such as a visual add-on to spoken language (Meggs & Purvis, 2012). The invention of movable types in western society (around the mid-fifteenth century) triggered one of the foremost shifts in human development (McLuhan, 1994; Spiekermann, 2008). Until then, to produce a book, one had to write the letters. Hereafter, this process could be mechanised and repeated anywhere and everywhere (Lupton, 2014; Meggs & Purvis, 2012). When people became more acquainted with typography, letterforms started to no longer be exclusively viewed as phonetic symbols. Consequently, many artists and designers began exploring how to assemble typographic shapes as a primary resource to create images, either by implanting new meanings in texts through the visual layout or by replicating an image.

In this paper, we explore a generative design approach for the automatic creation of typographic compositions that combine facial portraits, made exclusively of letterforms, and texts. This work is aligned with a commercial design project introduced to us by Fundação Cupertino Miranda (Portugal). They required an interactive installation to integrate a permanent exhibition dedicated to Portuguese literature, which will be installed in a continuous helical tower of ten floors located at the centre of Vila Nova de Famalicão, in Portugal. The main purpose of this installation is to allow visitors to create custom typographic compositions and this way promote a more interactive experience and a closer relationship between the exhibition and its visitors.

We present an interactive installation that works like a photo booth machine, but it only uses black typographic elements to render each photo. The interaction process is simple. First, the visitor enters a dedicated space to take a photograph of his/her face. Second, the facial photo is rendered using letterforms, thus creating a typographic portrait. Then, the visitor customises the typographic composition by selecting and adding to it one of the texts featured in the exhibition. In the end, the final composition is made available to the visitor through a dedicated section on the museum web page.

We developed a generative design process for the automatic creation of the typographic compositions. This generative process generates portraits by assembling letterforms so that their whole arrangement depicts the input facial image. The placement of the letters considers the visual features of the input image. Each letter is strategically positioned, rotated, and scaled in order to maximise the ability of the resulting portrait to recreate the input image. This generative design process also composes, in a dynamic way, each output portrait with a piece of text selected by the user.

We assess the presented installation, and the typographic compositions it creates, according to four goals identified by the museum as crucial: (i) the installation should be able to generate portraits, using only letterforms, that depict the facial features of the users, so they recognise themselves in the portraits; (ii) the user should be able to select the text that will appear with his/her portrait in the final composition; (iii) the final composition of the portrait with a text should please the user; and (iv) the interaction of each user with the installation should be fast, more exactly, not much more than one minute.

The remainder of this paper is organised as follows. Section 2 summarises related work on the automatic creation of portraits using typographic elements. Section 3 explains the behaviour of the presented interactive installation. Section 4 describes user testing on a prototype of the installation and provides the analysis of the obtained results. Finally, section 5 presents our conclusions and directions for future work.

2 Background

Over the years, several works explored the arrangement of typographic elements in order to produce layouts where the letters are assembled as an image. Poets and writers have explored this to insert expressiveness into their works. The first well-known examples date back to ancient times when some Greek poets composed his/her texts as visual shapes (Higgins, 1987). Until modern times, some authors sporadically designed similar composition (Higgins, 1987; Meggs & Purvis, 2012).

However, it is with Futurism and Concrete Poetry movements that these kinds of compositions became known. Futurist artists explored a novel disruptive layout — coined as *Parole in Libertá* — where emotional texts were designed as dynamic and non-linear compositions (Meggs & Purvis, 2012). On the other hand, concrete poets explored non-standard layouts to insert meaning in their texts (Polkinhorn, 1993). The portrait was well-explored thematic, either in its conceptual form (e.g. Fernando Aguiar's *Auto-Retrato em Forma de Soneto* (Aguiar, 1993:548)), or in its visual shape (e.g. Duarte's *Sin Título* (Gutierrez, 1993:418)). Also, modernist visual artists explored the letters' visual shape. They ignore the letter phonetic functions and handled with letterforms as visual artefacts per se. It is notable the work of cubist artists, such as Pablo Picasso, George Braque, and Fernand Léger, that used typographic elements and words as pictorial elements in their artworks

(Marcus, 1972). Similar approaches can also be seen in artworks of other artists such as Kurt Schwitters, John Heartfield, George Grosz, Iliá Jdaniévitch or El Lissítzky (Meggs & Purvis, 2012).

Although with a low status compared to the other artistic practices, Typewriter Art is one foundational reference in our research. In these artworks, letterforms were mostly used as a visual resource to design an image (Poynor, 2014; Riddell, 1975). The portrait was one widely explored subject. It is emblematic, for instance, the typed portrait of *"Queen Elizabeth"* (1953) from Dennis W. A Collins (Riddell, 1975:71). Perhaps without realising it, typewriter artists produced artworks employing algorithmic approaches. At the time, this presented a forward-looking approach, enabling everyone to reproduce an image as often as he/she would like. With the democratisation of personal computer, these approaches were transposed to digital media leading to the emergence of movements such as Radio Teletype Art or ASCII Art.

Using coding approaches, graphic designers can explore new visual and conceptual possibilities, creating systems that allow crafting one process that generates multiple outcomes, instead of crafting a singular outcome (Reas, McWilliams, & LUST, 2010). Nevertheless, in the typographic portraits' generation, these approaches are not widely explored. Most of the designers employ calligraphic or typographic processes to create typographic portraits. However, they are time-consuming processes, inapplicable for our work due to the goals defined by the museum.

Nevertheless, there are some interesting examples of computationally generated typographic portraits that should be referenced. The earliest experiences were associated with ASCII Art and appeared during the advent of the computation. *Digital Mona Lisa* (Philip Peterson, 1965) and *Studies in Perception I* (Kenneth Knowlton, 1966) are some of the first experiments in typographic portraying (Dietrich, 1986; Mezei, 1967).

More recently, in 2007, the artist Gui Borchert (Borchert, 2007) created a series of portraits with typography. The creation process of each portrait was twofold. Firstly, Borchert generated an initial mapping with a program developed with Noel Billig. Then, based on this automatic mapping, Borchert manually crafted the final design. Based in typographic portraits of Borchert, in 2008, the programmer Jeff Clark (Clark, 2008) decided to try to do something similar in a completely automatic fashion. To do so, he adapted a word-filling algorithm, that he previously developed, to automatically fill shapes with words. The resulting algorithm reconstructs the input image using words in varied colours and sizes. With this algorithm, he built, for instance, the image *Obama Word Portrait* with repetitions of the text fragments "HOPE", "CHANGE" and "YES WE CAN".

In 2016, the artist Sergio Albiac (Albiac, 2016) used a code approach to generate typographic portraits from collages of typographic textures. Users were asked to take a picture and describe themselves to the software. Their voice was automatically transcribed into text, which was after transformed and complemented with related literary and philosophical passages. The resulting texts were used to create typographic rectangular textures that were used as collages to construct the resulting portraits.

The software engineer Jonathan Feinberg, who has created the famous word-cloud layout system "Wordle", demonstrated in 2010 (Feinberg, 2010) the use of a randomised greedy algorithm to fill an input image with a set of words. In short, the algorithm places words of different sizes over the dark parts of the image in a way that minimises the space between the words. The output is a compact composition of words that well represents the original image.

Unlike the automatic design of typographic portraits, the development of template-based compositions is a well-explored field. Usually, someone develops a framework, and after the user performs the necessary adjustments to generate outputs as desired. Due to the recent trend of developing a more participative practice in Graphic Design, these kinds of compositions became even more popular (Armstrong & Stojmirovic, 2011). The installation *Productive Posters* (2008), developed by Project Projects Studio in collaboration with Kounkuey Design Initiative, enabled anyone to design posters, applying this approach. The poster's content was defined by the user (via filling blank spaces). Afterwards, he/she defined the visual style of the elements, employing pre-defined operation modules over the poster's elements (Armstrong & Stojmirovic, 2011). The installation *Poster Machine* (2013), designed by Luiz Ludwig, generated poster designs in a similar fashion. In the installation, the user could generate poster designs through the manipulation of a series of knobs and switches (Ludwing, 2013; Pelsoh, Kin, Dlugash, & Zotter, 2014).

Computer Vision techniques are sporadically used on some works with the aim of collect user/environmental data to generate designs. *Text Rain* installation, developed by Camille Utterback and Romy Achituv (Utterback & Achituv, 1999), displayed texts that respond to users' motion. The installation displays the user mirrored in a large projection screen while letters are falling. The user's body works as an obstacle whenever the letters are falling. The text displayed in the installation was a poem chosen by authors. On the other hand, *Camera Postura* installation (LUST, 2014), developed by LUST for Netherland Film Festival, used the user's gestures to generate poster designs. It achieved this by searching for scenes where a gesture similar to the user was performed in the frames of most popular movies at the festival. The matching scenes were, then, used as background in poster designs. The posters were generated by adding information about the chosen movie, e.g. title, credits, nominations, awards, etc.

3 Approach

In this work, we present an interactive installation that allows users to create compositions with their own portraits made of letters and texts by their favourite authors featured in the exhibition. The main hardware components of the installation include a computer, a camera, and a touchscreen. The camera and the touchscreen are connected to the computer and positioned in order to face the user. The camera is placed on the top of the screen.

The interaction with the installation is described as follows: (i) the user observes his/her face on the screen, in a mirror-like style, and presses a button to take a picture, when the image framing pleases him/her; (ii) a countdown of three seconds to the image capturing begins; (iii) after capturing the image, the system generates the portrait, and presents it to the user; (iv) if the portrait pleases the user, he/she selects the option to continue, otherwise, the user has the option to take a new picture and therefore going back the beginning; (v) the user selects his/her preferred text, from a preset list of Portuguese writers, that will go along with the portrait, whenever the user selects a text, the composition of the portrait with the text is updated and displayed; (vi) the user finishes the composition, and the system saves it to a database and presents a QR code for the URL of his/her portrait at the museum web page;

(vii) the user may scan the QR code at the moment or find afterwards his/her portrait in the museum web page, more precisely in a section that is dedicated to this interactive installation and that compiles all portraits it generated. Figure 1 compiles screenshots of the different interaction steps. In the following paragraphs, we detail the mechanisms behind each step.

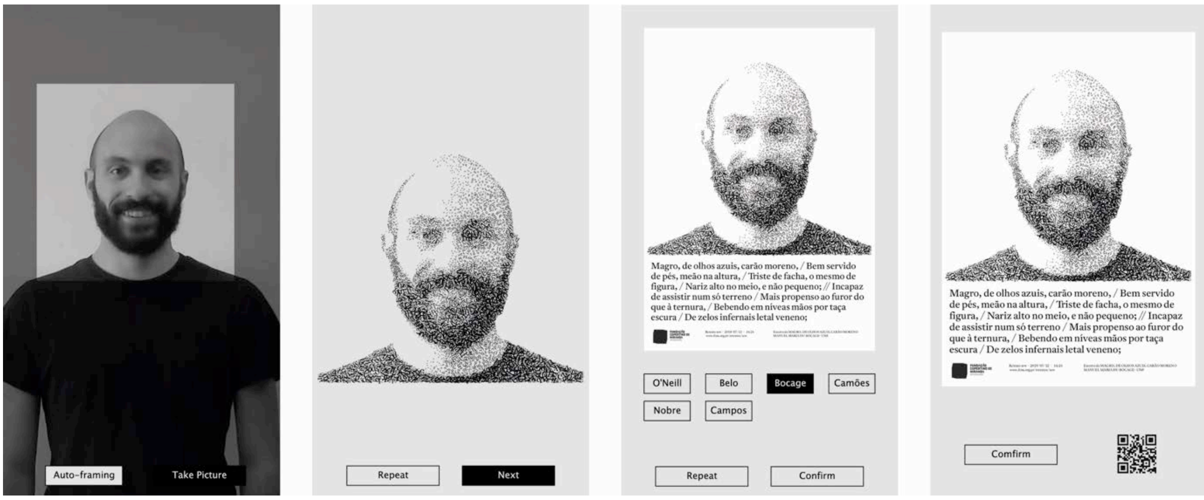


Figure 1. Screenshots of the different interaction stages. From left to right: (i) the user observes his/her face on the screen; (ii) the system presents the portrait to the user; (iii) the user selects his/her preferred text from a preset list of Portuguese writers featured in the exhibition; and (iv) the final composition is presented to the user, along with a QR code for the URL of that composition at the museum web page. A demo video of the installation can be seen at www.cdv.dei.uc.pt/portraying-with-letters.

At the beginning of the interaction, when the image of the user is being captured, we use a computational face detector to locate automatically faces in the image and, according to this, calculate the region of interest. This region includes the area of the face plus a preset margin around it (see Figure 2). This region will be rendered in the typographic portrait, while the remainder of the image will be ignored. This allows us to automatically frame the portrait to a region of interest (the faces of the users) and this way provide focus and detail to the resulting portrait where is essential. We implemented this feature to handle a different number of faces. When multiple faces are detected (group portraits), the region will consist of a smaller rectangle that encloses all detected faces. When users are seeing their image, in a mirror-like style, the region that will be rendered is calculated and shown on the screen in real time. This way, users know when a face is being detected or not, and which region of the face will be rendered in the portrait. Users have the option to turn off this feature, which is useful when users are not pleased with the region that is being calculated automatically.

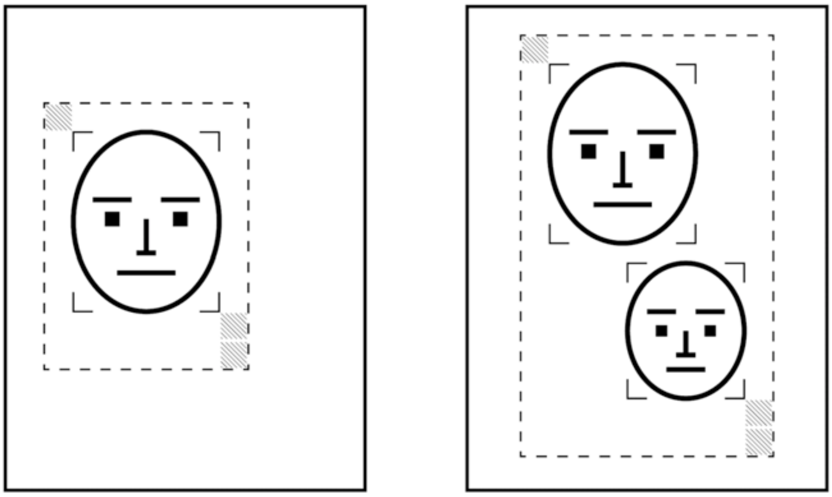


Figure 2. Calculation of the region of interest (dashed boxes) for two example scenarios according to automatically detected faces in the captured image. Each region of interest encloses the detected face(s), plus a preset margin (shaded squares).

For the portraits' generation, we have explored different approaches. This allowed us to attain results with different levels of granularity and precision, as well as different balances between the recognisability of the input image and the readability of textual content used to render the image (Rebelo, Martins, Bicker, & Machado, 2018). Together with the museum, we analysed the advances and disadvantages of each approach and selected one to continue the installation development. In this paper, we focus on the approach that will be implemented at the museum, including the user interaction with the installation and the resulting outputs.

Each portrait consists of a composition of letters that are placed over the dark regions of the input image. By varying the size and density of the letters, we are able to render different shades of grey. The process that creates a portrait from an input image comprises the following steps: (i) convert the input image to greyscale; (ii) normalise each pixel brightness according to a minimum and a maximum threshold; (iii) perform a quadtree decomposition of the image (Samet, 1984); (iv) calculate for each rectangle of the quadtree structure the average brightness of the pixels located inside it; and (v) place letters inside each quadtree rectangle according to its brightness. Figure 3 shows the image processing process before the placement of the letters, which is detailed in the following paragraph.

The positioning of letters over the quadtree rectangles is implemented so that each quadtree rectangle is rendered with a composition of letters with a more or less visual weight depending on its brightness. This way, a dark rectangle is rendered with more visual weight than a bright one.

Different levels of visual weight are attained by adjusting the following aspects: (a) number of font sizes that can be used — darker rectangles are filled with letters that can have different sizes, while brighter rectangles are filled with small letters; (b) minimum area of each letter that must be covering non-white pixels of the processed input image — greater minimum area in lighter rectangles; (c) maximum number of consecutive failed attempts to place letters while complying with aspect b — more attempts in darker rectangles; and (d) the space around each letter — lighter rectangles are filled with letters that have more space around them.

Figure 3. Processing of the input image. From left to right: image converted to greyscale; image normalised according to preset minimum and maximum thresholds; and quadtree decomposition with quads filled with the average brightness of the corresponding regions in the normalised image.

For each quadtree rectangle with brightness below a preset threshold, we calculate the aspects mentioned above and initiate the placement of letters. For each font size (aspect a), from the larger to the smaller, random letters are placed inside the rectangle at random positions with random angles until the maximum number of consecutive failed attempts (aspect b) is reached. The placement of each letter is considered successful if it covers a certain minimum, or more, area of non-white pixels of the input image (aspect c). When a letter is placed, it is drawn on the output portrait canvas in black, and on the input image in white with an outline with a thickness set to provide a certain margin (aspect d).

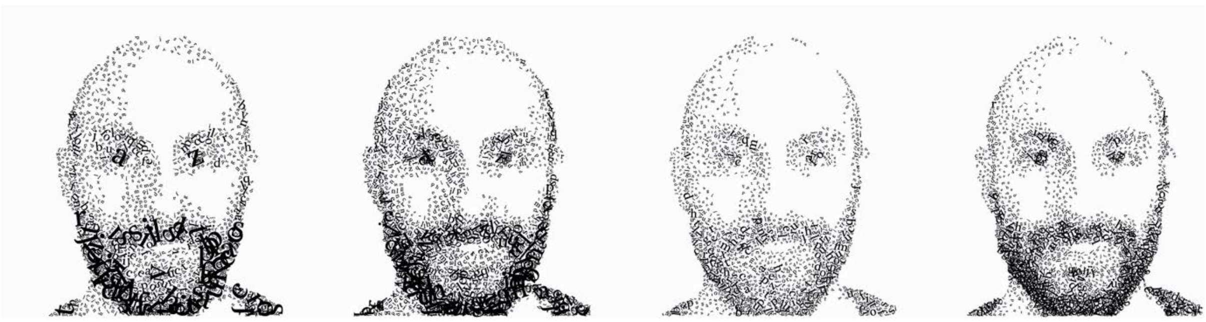


Figure 4. Portraits generated from the same input image using different configurations. The two portraits on the left have different levels of detail. The two portraits on the right have different levels of contrast.

The process that generates the portraits can be configured to attain different results. For instance, the darkness and brightness sensibility of the rendering process can be controlled by adjusting the minimum and maximum thresholds of the normalisation of the input image. This is useful to calibrate the system according to external conditions, such as the light at the installation space. Regarding the characteristics of the portraits, different levels of detail can be attained, for example, by changing the range of font sizes that can be used (larger ranges of font sizes tends to create more detail) or by adjusting thresholds of the quadtree decomposition (more quadtree rectangles tend to create more detail). The adjustment of these parameters also influences the ability of the system to reproduce smooth gradients. The contrast of the portraits can be adjusted by setting the amount of overlap between the letters (more overlay creates darker regions) and the space around them (more space creates lighter regions). Figure 4 shows a set of portraits generated from the same input image using different configurations. The two portraits on the left have different levels of detail and the two portraits on the right have different levels of contrast. Based on preliminary tests, we consider the configuration that generated the rightmost portrait in Figure 4 works better in most images. Therefore, the tests described in this paper use this configuration.

The final outputs created using the installation are compositions made of two main components: (i) the portrait of the user; and (ii) a piece of text selected by the user. Also, they present complementary technical information. The components are placed on outputs through a template-based layout. The portrait is placed on the output's upper section and fulfils most of the available space. The text is placed following. In the end, technical information is placed in the output's bottom section. Figure 6 display some typical outputs.

The texts available in the installation are selected by the exhibition's staff and may change over time. Accordingly, these texts are inputted dynamically in installation, through the placement of text files in a specific folder on file. The texts should be provided with section cutting marks, i.e. special characters that identify the text's sections. These marks are used to compose the text automatically on the output.

When the user chooses one text, it is presented immediately in output. This is achieved by a method that permits the automatic composition of a text in a rectangular area of varied dimensions. This method is described as follows. First, it subdivides the text according to the section cutting marks. Next, it composes, line by line, the text according to default font size and baseline height. If the section does not fit in the remaining space, the system, incrementally, downsizes the font size (and, consequently, the baseline height) until the section fits. It tries to compose the next section until the text is composed at minimum possible font size or it not possible to place the next section in the remaining space. When this occurs, the system keeps the last best arrangement achieved. Line and paragraph breaks are replaced by special characters in order to uniform the texts. By default, the system uses the slash ('/') to identify a line break and the double slash ('//') to identify the paragraphs. Similarly to portraits' generation method, text composition method can be configured to attain different results.

Also, the outputs present some technical information about the installation, their generation, and the museum. These pieces of information always have the same position, arrangement, and visual style. They consist of: (i) the portrait code and the permalink for the web repository where the image can be downloaded; (ii) the date and hour where the image is generated; (iii) the text title, author and date; (iv) the logotype of Fundação Cupertino Miranda.

Each output is automatically stored, after its generation, in a database linked to the museum web page. The user can obtain the output scanning the QR code displayed at the end of his/her interaction. Furthermore, the user can find the output, later, accessing to museum web page and looking for it in a special section. Herein, the outputs are organised by date to aid users in finding a specific one. After locating it, users can download a digital version or order a print-on-demand copy. Since the outputs are exported as vector graphics, they can be applicated in different kinds of media.

4 Testing

We tested the presented installation with users in order to assess to what extent it accomplishes the goals identified by the museum as crucial (see Section 1). We have set up a functional prototype of the installation at our laboratory and invited people who were passing through to test it (see Figure 5). This way, we tested the prototype with 44 users. Most of the users were students and professors of the bachelor and master's degree in design and multimedia.

Figure 5. The prototype being tested by users.

Each test began with a brief introduction to explain to the user the purpose of the installation. Then, we asked the user to experiment with it in order to generate his/her own typographic portrait. Also, we informed the user that he/she could create different portraits until he/she appreciates the output.

In each test, we measured (M1) the number of portraits generated and (M2) the time the user took until a satisfying output was attained. In the end, we asked three questions to the user: (Q1) "How much do you recognise yourself in the portrait?"; (Q2) "How much do you appreciate the final composition?"; and (Q3) "Would you like to make any comment on the installation or on the generated output?". We asked the user to answer Q1 and Q2 with an integer number between 1 and 5. The numerical results obtained from the 44 tests are listed in Table 1. We calculated the average and the median of the results for M1, M2, Q1 and Q2. We set side by side the average and the median in order to analyse the tendency of the results and how skewed the data is.

Table 1. Results of the 44 users who tested the interactive installation.

Variable	Average	Median
Portraits created (M1)	1.3	1
Interaction time (M2)	1m 16s	1m 2s
Recognition (Q1)	4.4	4
Satisfaction (Q2)	4.6	5

Analysing the visual results, one could say the portraits generated are able to (i) depict distinct facial expressions and (ii) render high contrast features and continuous transitions from darker to lighter areas present in the input images. Some typical outputs created by different users are shown in Figure 6. One can access all outputs created during the tests session (in raster and vector format) at www.cdv.dei.uc.pt/portraying-with-letters.

Comments made by some users when they were asked question Q3 were valuable to identify aspects that can be improved. Most comments were related to the step when the user selects one text by a Portuguese writer. For instance, users mentioned that (i) the selected text should somehow influence the portrait; (ii) the variety of texts is too small, and suggested that this could be solved by providing more writers or selecting a random part of one text of the selected writer; and (iii) the writer selected by default should be random rather than the first one.

In more general terms and based on the observation of the users during the tests, we can say that all users had no major issues in using the installation to generate portraits. In other words, they were able to operate the installation without any external help. We consider therefore the installation interface is able to guide the user through the steps required to obtain an output. Another general comment goes to the enthusiasm observed on most users, who enjoyed the experience of creating, seeing, and recognising their own portraits made of letters.

Figure 6. Typical outputs generated by different users. More results can be visualised at www.cdv.dei.uc.pt/portraying-with-letters.

These tests also allowed us to assess some technical parts of the installation, namely the performance of the mechanism that automatically detects and crops the face(s) of the user(s) when the camera is capturing them. Despite the diversity of faces the installation was tested with, the face detection mechanism performed well, detecting all faces during most of the time.

As mentioned above the outputs are also exported as vector graphics. This way, the visitor can buy a print version of the output in the museum store. Also, this allows the use of outputs (or part of them) in various kind of media, with varied sizes and formats, always ensuring high quality in the resulting prints. To validate this scenario, we designed some visual applications wherein the output, in whole or in part, is the main visual element. Some results are displayed in Figure 7.

Figure 7. Some print designs created using outputs. Postcards created from the outputs (left) and staff identification badges where the photograph is replaced with a typographic portrait (right).

5 Conclusions and Future Work

We have presented an interactive installation to integrate a permanent exhibition dedicated to Portuguese literature. This installation creates custom typographic images that combine facial portraits of the users and texts featured in the exhibition. We employ a generative design process to generate each portrait by strategically placing letterforms in order to depict the input image.

We conducted user testing sessions to evaluate to what extent the installation accomplishes the museum requirements. We tested a functional prototype of the installation with 44 users. In each test, we studied the user interaction and appreciate the quality of the outputs from the users' point of view. The tests unveil that most of the users recognised themselves in the portraits and highly appreciated the outputs. The average time of user interaction was 1 minute and 16 seconds, which is a value that complies with the requirements of the museum.

Future work will focus on: (i) improvement of the installation according to users' feedback obtained from the testing sessions; (ii) performing further tests on the installation when it will be working at the museum with the ideal hardware and lighting conditions; and (iii) testing the installation in the creation of portraits of multiple persons.

6 References

Aguiar, F. (1993). Portuguese Visual Poetry. *Visible Language*, *27*(4), 444–466.
Albiac, S. (2016). I am. Retrieved April 20, 2018, from www.sergioalbiac.com/wall/i-am.html
Armstrong, H., & Stojmirovic, Z. (2011). *Participate: Designing with user-generated content*. New York

City, NY: Princeton Architectural Press.
Borchert, G. (2007). Typographic Portraits. Retrieved April 20, 2018, from www.cargocollective.com/mynameisnotkeith/Typographical-Portraits
Clark, J. (2008). Obama Word Portrait. Retrieved April 20, 2018, from www.neoformix.com/2008/WordPictures.html
Dietrich, F. (1986). Visual Intelligence: The First Decade of Computer Art (1965-1975). *Leonardo*, *19*(2), 159–169.
Feinberg, J. (2010). Wordle. In J. Steele & N. Iliinsky (Eds.), *Beautiful Visualization: Looking at Data through the Eyes of Experts* (pp. 37–58). Newton, MA: O'Reilly Media.
Gutierrez, P. J. (1993). Cuban Visual Poetry. *Visible Language*, *27*(4), 410–421.
Higgins, D. (1987). *Pattern Poetry: Guide to an Unknown Literature*. Albany, NY: SUNY Press.
Ludwing, L. (2013). The Poster Machine. Retrieved February 28, 2019, from www.luizludwig.com/seventeen.html
Lupton, E. (2014). *Thinking with Type: A Critical Guide for Designers, Writers, Editors, and Students* (2nd ed.). New York City, NY: Princeton Architectural Press.
LUST. (2014). Camera Postura. Retrieved March 30, 2019, from www.lust.nl/#projects-5939
Marcus, S. (1972). The Typographic Element in Cubism, 1911-1915: Its Formal and Semantic Implications. *Visible Language*, *6*(4), 321--340.
McLuhan, M. (1994). *Understanding Media: The Extensions of Man*. (L. H. Lapham, Ed.). Cambridge, MA: MIT press.
Meggs, P. B., & Purvis, A. W. (2012). *Meegs' History of Graphic Design* (5th ed.). Hoboken, NJ: John Wiley & Sons, Inc
Mezei, L. (1967). Computers and the Visual Arts. *Computers and the Humanities*, *2*(1), 41–42.
OPENRNDR. (2018). Detecting and Matching Poses from Film Fragments. Retrieved March 30, 2019, from www.medium.com/openrndr/detecting-and-matching-poses-from-film-fragments-80c4a8a218b6
Pelsoh, B., Kin, J., Dlugash, N., & Zotter, C. (2014). Animation and Code. In E. Lupton (Ed.), *Type on Screen: A Critical Guide for Designers, Writers, Developers and Students*. New York City, NY: Princeton Architectural Press.
Polkinhorn, H. (1993). Visual Poetry: An Introduction. *Visible Language*, *26*(4), 390–393.
Poynor, R. (2014). Rediscovering the Lost Art of the Typewriter. Retrieved April 20, 2018, from www.designobserver.com/feature/rediscovering-the-lost-art-of-the-typewriter/38478
Reas, C., McWilliams, C., & LUST. (2010). *Form and Code: In Design, Art and Architecture, A Guide to Computational Aesthetics*. New York City, NY: Princeton Architectural Press.
Rebelo, S., Martins, T., Bicker, J., & Machado, P. (2018). Typography as Image: Experiments on Typographic Portraits. In *Proceedings of the Ninth Typography Meeting (9ET)*. Instituto Politécnico de Tomar.
Riddell, A. (1975). *Typewriter art*. London, UK: London Magazine Editions.
Samet, H. (1984). The Quadtree and Related Hierarchical Data Structures. *ACM Computing Surveys (CSUR)*, *16*(2), 187–260.
Spiekermann, E. (2008). Typography. In M. Erlhoff & T. Marshall (Eds.), *Design Dictionary: Perspectives on Design Terminology* (pp. 409–416). Basel, CH: Birkhäuser Basel.
Utterback, C., & Achituv, R. (1999). Text rain. *SIGGRAPH Electronic Art and Animation Catalog*, *78*, 388.

About the Authors:

Tiago Martins: Researcher at the Computational Design and Visualization Lab. (CISUC) working at the convergence of evolutionary computation, artificial intelligence, and design. His work focuses on the development of computational generative systems for the creation of visual outputs.

Sérgio Rebelo: Researcher at Computational Design and Visualization Lab. (CISUC). His research concerns the exploration of novel approach towards a sustainable inclusion of artificial intelligence techniques in Graphic Design

scenario. Currently, his work focuses on automatic layout generation and generative typography.

João Bicker: Graphic designer, educator, design writer and curator who lives and works in Coimbra, Portugal. He is professor at the Multimedia and Design courses of the University of Coimbra. He has a PhD in Contemporary Art.

Penousal Machado: Associate Professor at the University of Coimbra and scientific director of the Computational Design and Visualization Lab. His research interests include Computational Creativity, Artificial Intelligence, and Information Visualization. His work was featured in the Leonardo journal, Wired, and MoMA.

Acknowledgement: The second author is funded by Fundação para a Ciência e Tecnologia (FCT), Portugal, under the grant SFRH/BD/132728/2017. The authors would also like to express their gratitude to Fundação Cupertino de Miranda for presenting us the design challenge that originated this research as well as to the users who tested with great enthusiasm the presented interactive installation.

Prospective design: A future-led mixed-methodology to mitigate unintended consequences

Galdon, Fernando*; Hall, Ashley; Wang, Stephen J.

Royal College of Art, London, UK
* fernando.galdon@network.rca.ac.uk

In this paper, the authors propose prospective design as a future-led mixed-methodology to address unintended consequences. It combines systems analysis with extrapolations and constructivist perspectives to reconcile confronted models of design future(s). In the results presented, the authors suggest a need to include ethical frameworks in design to involve students in ethical issues to address the main task of design in the digital and exponential technological age within which we are living including; preparedness, readiness, and appropriateness.

Keywords: design futures; preparedness ; readiness; appropriateness; anticipation

1. Introduction

1.1. Anticipation and design

As are moving from the industrial to the digital age, the acceleration of innovation is transforming reality and affecting the development of society and the nature of design practice. In this context, recent strategies in the social sphere call for anticipatory strategies. For instance, Guston introduced the idea of anticipatory governance defining it as:

> "…a broad-based capacity extended throughout society that can act on a variety of inputs to manage emerging knowledge-based technologies while such management is still possible." (Guston, 2014, pp. 218).

In a report presented by the Institute for the Future on 'anticipatory governance' (Future, 2009), the authors aim for processes that involve the simulation of possible futures to address anticipation as a strategy for good government.

Historically anticipating and designing the future has always been a human characteristic. In antiquity (1000BC - 1400AC), prophecies and alternative presents were introduced by priests and Greek and Roman philosophers such as Plato (The Republic) or Cicero. In the Renaissance (1400 - 1800), planetary explorations via utopias of other places were structured around mathematical and philosophical endeavours by the likes of Da Vinci or Thomas More. With the scientific revolution (1600 - 1700), observations became the main method to lucubrate biological and scientific-based futures with the likes of Bacon or Newton. In the Enlightenment (1700 -1900), theories of progress via theoretical and metaphysical insights became the main approach to construct the future. Finally, with the theories of Einstein and the integration of time directionality a clear notion of the future became settled. It led the transformational industrial era (1900 - 2000) where Knowledge-based futures were built via scientific, social and critical approaches. In 1927 Richard Buckminster Fuller called for an 'industrially realisable design science' (Fuller, 1992) through his 'Eight strategies for a comprehensive anticipatory design science'. However this failed to fully materialise as a new field. Now with the advent of the digital age, accelerating technology complexity, black box technologies and wicked problems new prospective approaches are required to deal with the exponential nature of our emerging new era.

1.2. Framing design

One of the first design science theorist, John Chris Jones, postulated in the 1970s in his seminal book, Design method, that design was different from the arts, sciences, and mathematics. In response to the question "Is designing an art, a science or a form of mathematics?" Jones responded:

> 'The main point of difference is that of timing. Both artists and scientists operate on the physical world as it exists in the present (whether it is real or symbolic), while mathematicians operate on abstract relationships that are independent of historical time. Designers, on the other hand, are forever bound to treat as real that which exists only in an imagined future and have to specify ways in which the foreseen thing can be made to exist.' (Jones, 1992. pp. 10)

From this perspective, we would position design as a prospective thinking activity in the context of abductive reasoning (making decisions without having all the information) (Douven, 2011). In this area, research by Dorst (Dorst, 2010) or more recently Cramer-Petersen et al. (Cramer-Petersen, 2018) have concluded that design combines deductive and abductive reasoning, however, in both cases, abductive reasoning plays a fundamental role as initiator of the design activity. Furthermore, as the digital paradigm, with its exponential development (Kurzweil, 2005) and network uncertainty becomes more prevalent in design, practice will need to focus more in the preventive/anticipatory aspects of design (preparedness, readiness and, appropriateness). In this context, the deductive becomes limited by access and the abductive reasoning aspects becomes more dominant, prevalent and necessary.

This intrinsic prospective approach of design, based on abductive reasoning, planning, solution-based problem solving, problem shaping, synthesis, preparedness, readiness and appropriateness in the built environment determines a different model of knowing. In this scenario, the designer is dealing with wicked problems by accessing areas yet-to-be or not-fully-formed (Rittel & Webber, 1973; Buchanan, 1992; Conklin, 2006) . Consequently, its output is based on potentialities, not certainties. As Glanville proposed, 'knowledge for' future action and possibilities rather than 'knowledge of' past actions and events (Glanville, 2005). In this context, as the life of the intervention is extended into the future, time to assess the impact of the design is extended during its lifetime and forever bounded to its environment by exchange. Validation, therefore, is always a posteriori, and the proposed output becomes the main element to be assessed. This intrinsically means that knowledge in design is probabilistic in nature. Design implies a posteriori development based on exchange which demands to go beyond existing time with a very clear function in mind; to transform.

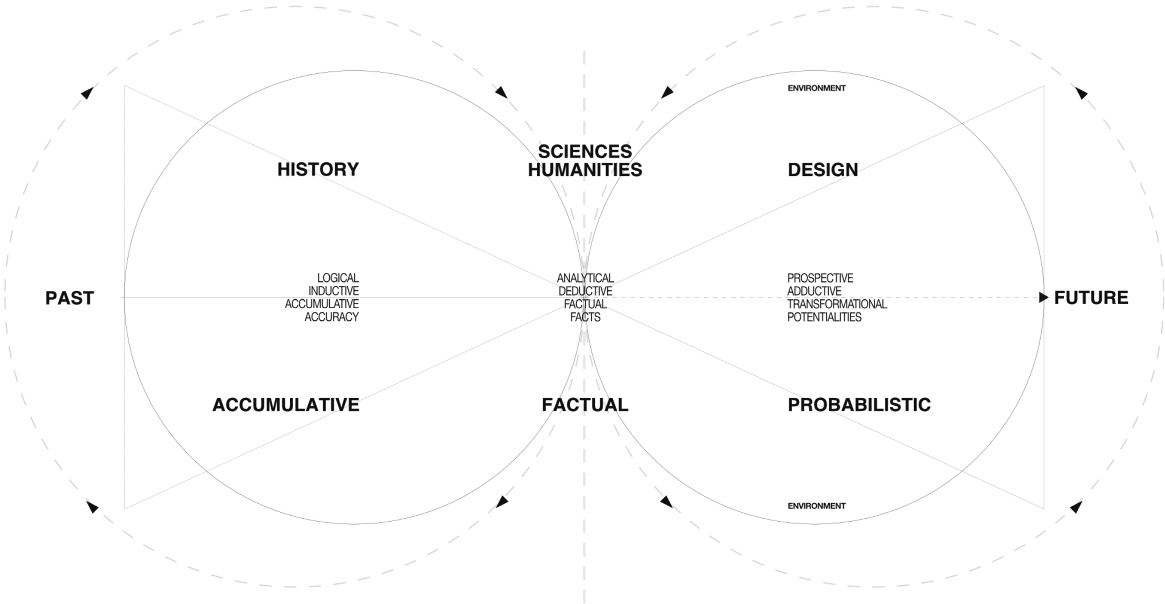


Figure 1. Timeframe model. Source: Fernando Galdon.

Within this scenario, an investigative overview of twentieth century approaches to future studies structured prospective design practises around two main approaches; the scientific-positivistic based on the method of extrapolation (1900-1950), and a sociological-pluralistic perspective based on constructivism (1950-2010).

1.3. Designing the future

1.3.1. Scientific Empirical

Methods based on Newtonian physics. This approach is based on the systematic practice of repeating laboratory experiments and controlling variables to establish proof of our hypothesis. Main methods: extrapolations of historical data, utilisation of analytical models and the systematic use of experts as forecasters of opinion. This approach uses techniques based on Mathematics, Modelling, Simulation and, Gaming.

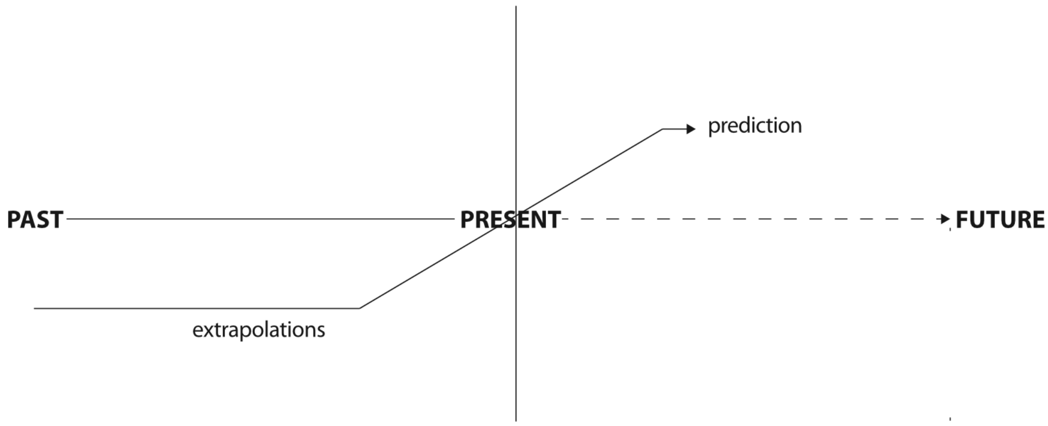


Figure 2. Positivistic model based on extrapolation. Source: Fernando Galdon.

1.3.2. Pluralistic Human-Centred

Methods based on sociology. This approach is based on the social and critical practice of mapping a wealth of possibles futures. Main methods: contextual data analysis, interpretative analytical methods and the systematic use of participatory methods. This approach uses techniques based on Cones, Mind maps, Future wheels and, Flow-scapes.

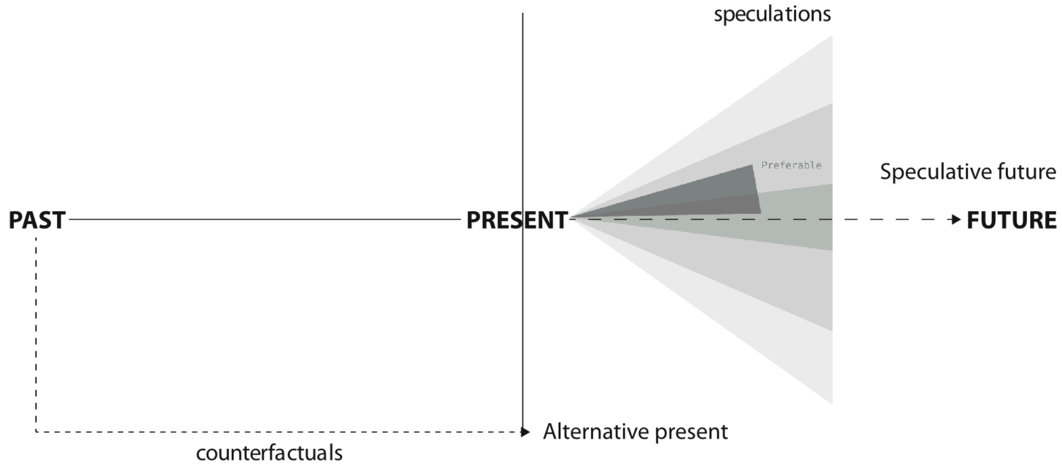


Figure 3. Pluralistic model based on constructivism. Source: Bezold, C. and Hancock, T. (1994), Voros, J. (2003), and Auger, J. (2012)

1.3.3. Critical analysis

Although these perspectives have been widely used, they present limitations. The scientific/positivistic approach is perceived as objective and values-neutral, however, it is also perceived as presenting narrowness in focus (only one possible future) and lack of contextual awareness. On the other hand, the pluralistic approach is perceived as inclusive and impartial, however, it is also perceived as presenting a loose focus (too many possible futures) and is too dependent of contextual awareness (Gidley, 2017).

In terms of the widest used methodology of speculative design, one of the fundamental advantages is that it removes a range of constraints normally used in product design. It limits the validity of its outcome to plausibility and the uncanny (Auger, 2012). However, it creates a lateral problem; the difficulty of controlling the speculation. As a result, many of the proposed outputs end in what future studies expert Jennifer Gidley names ‘Pop futurism’ (superficial and media-friendly outputs) (Gidley, 2017).

In this paper, the authors consider both limitations and propose a mixed-methodology aimed at enhancing the positive side of each confronted approach and present an integrative model aimed to reconcile different perspective to improve the main task of design in the digital and exponential technological age we are living in via; preparedness, readiness and, appropriateness.

2. Method

The methodological approach we have used includes literature reviews and research through design to develop a proposed model. Academic conferences were used to validate the model. Finally, workshops and co-design activities were implemented to evaluate key elements of the proposed model.

Literature reviews focused on future studies, design futures and on models of design research. Research through design was implemented in the sense of using the design process as a critical and reflective tool to investigate limits and opportunities in the design discipline to develop potential methods and techniques. In the process, it uses system analysis to underpin a potential case study on virtual assistants to develop the intended framework. In this context, academic conferences were targeted to validate different aspects of the proposed case. Finally, as design is not a linear process and depends on emergent elements, iterative evaluations were conducted via two co-design workshops on the relationship between design and futures at the Royal College of Art to test the core aspects of the proposed framework.

3. Discussion

3.1 Anticipatory design model development

3.1.1 Trajectories

First, building from the literature review, the leading author used timelines as graphical projective tools to gain a contextual understanding of the technology at hand and project a possible trajectory based on relational patterns. The main author approached its design mainly by dividing the space into two equal parts by drawing the timeframe in the middle. This action immediately created two spaces which were used as comparative or relational spaces for prospective inquiry and analysis aiming to spatialise abductive thinking. In total, two timelines were implemented. First, the author implemented a contextual analysis of the system to generate a hypothesis. Then, a second timeline was implemented to underpin a case study to address the initial hypothesis.

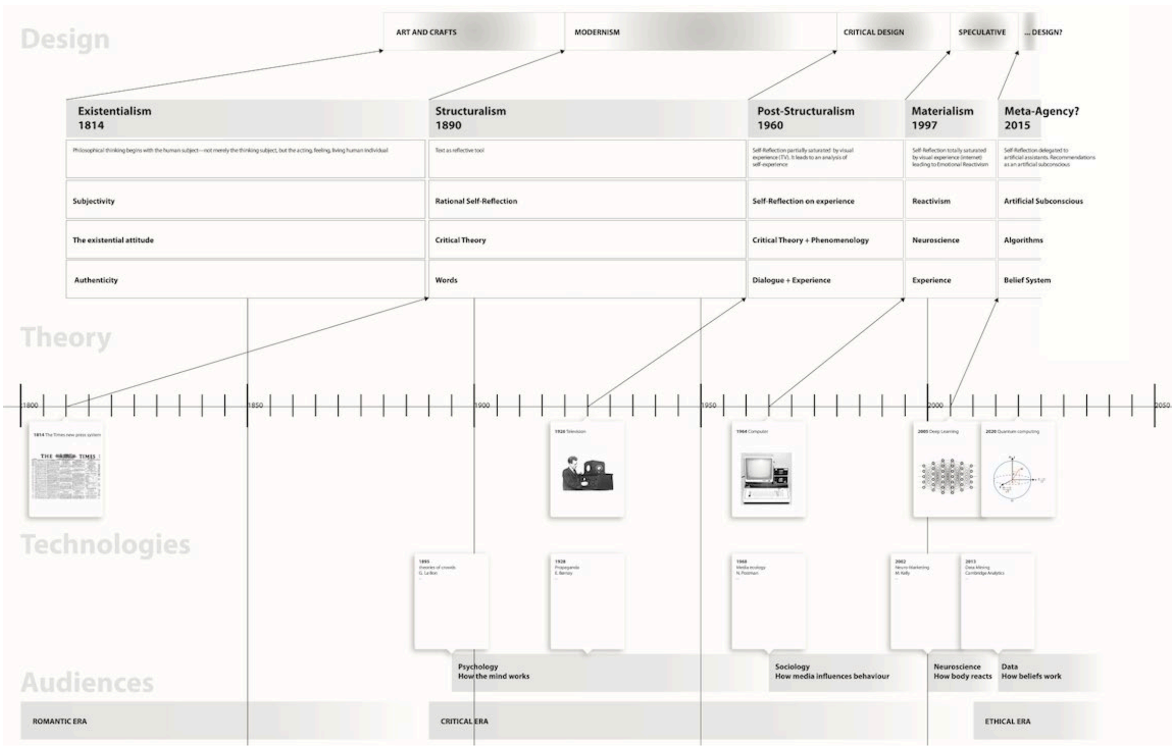


Figure 4. Understanding relational patterns among technology, theory and practise for prospective analysis. Source: Fernando Galdon.

The first timeline focused on the relationships between technology, theory and practice. It underlined a range of impactful elements based on the potential impact of AI; the emergence of meta-agency, the emergence of an artificial subconscious, the relevance of algorithms and the impact of belief systems. These elements led to building a hypothesis around Virtual Assistants, and the potential need for a new kind of design to address all these elements.

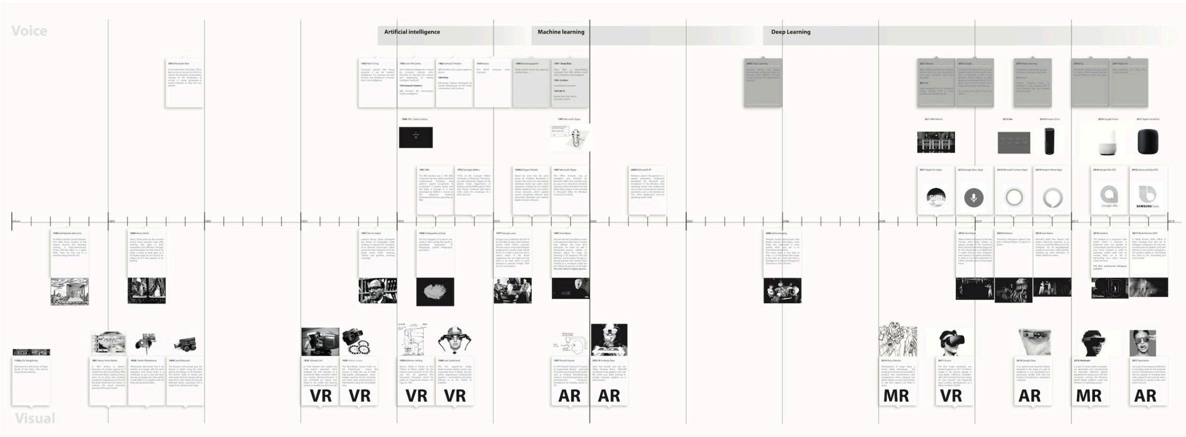


Figure 5. System-based relational analysis in virtual assistants. Source: Fernando Galdon.

Once a case study was underpinned, a second timeline was implemented to understand the context of Virtual Assistants. This systems-based relational analysis presented the key technology of Natural Language Processing (NLP) and its embodying potentialities (robots and holograms) as the main elements to address.

3.1.2. Probabilistic extrapolations

As we are projecting the interaction into the future, questions of evidence regarding the prospective development and impact of emerging technology raised. In this context, due to the limited access of emerging technologies by researchers, three elements were used to underpin probabilistic extrapolations;

- Demos: Demos are introduced by tech companies to illustrate the potentialities of new technologies. They can be used by researchers to understand the potential development of emerging technologies. In this case, the author selected a demo called Duplex introduced by Google. The extraordinary levels of fluidity, coherence, and autonomy presented a case to understand the evolutive nature of Virtual Assistants form queries to conversations and from reactive to proactive interactions.

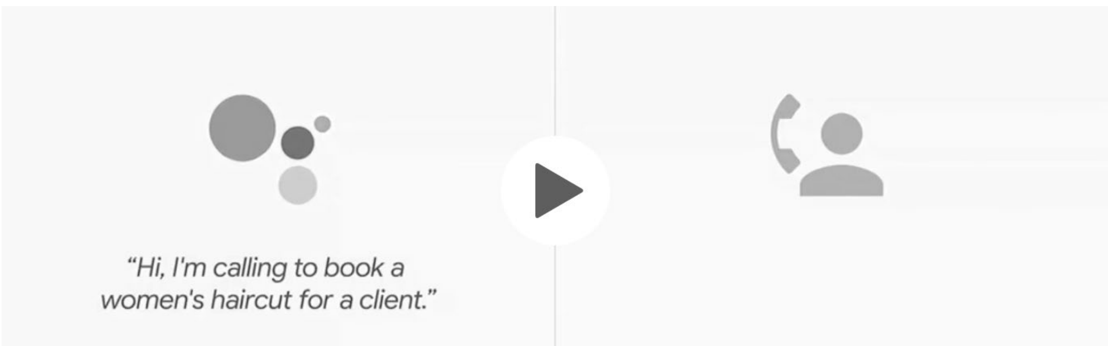


Figure 6. Duplex demo by Google. Source: Google.

- Prototypes; Prototypes also present a case on potential technological developments. As an example, the author conducted research into state of the art technology and underlined a prototype capable of predicting depression. This prototype raised ethical questions and illustrates how technology may impact our lives in a positive or negative manner. (Eichstaedt, *et al.*, 2018)

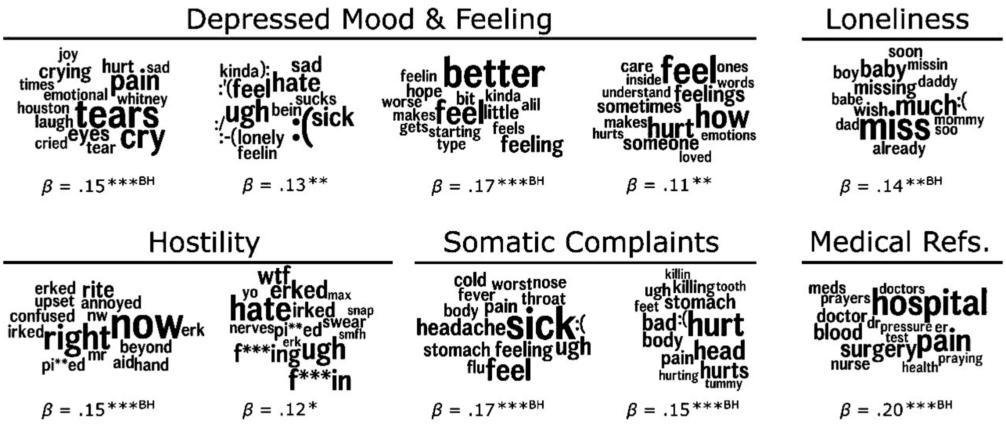


Figure 7. Depression prediction algorithm. Source: (Eichstaedt, et al. 2018)

- Patents; Patents also illustrate the potential development of a given technology. As an example, the author conducted research into patent applications to underpin potential developments in the context of Virtual Assistants. A clear case was a patent filed by Amazon capable of diagnosing a cough and providing treatment. This patent aims to transform Alexa into a doctor and raises many ethical questions regarding its implementation (Jin, 2018).

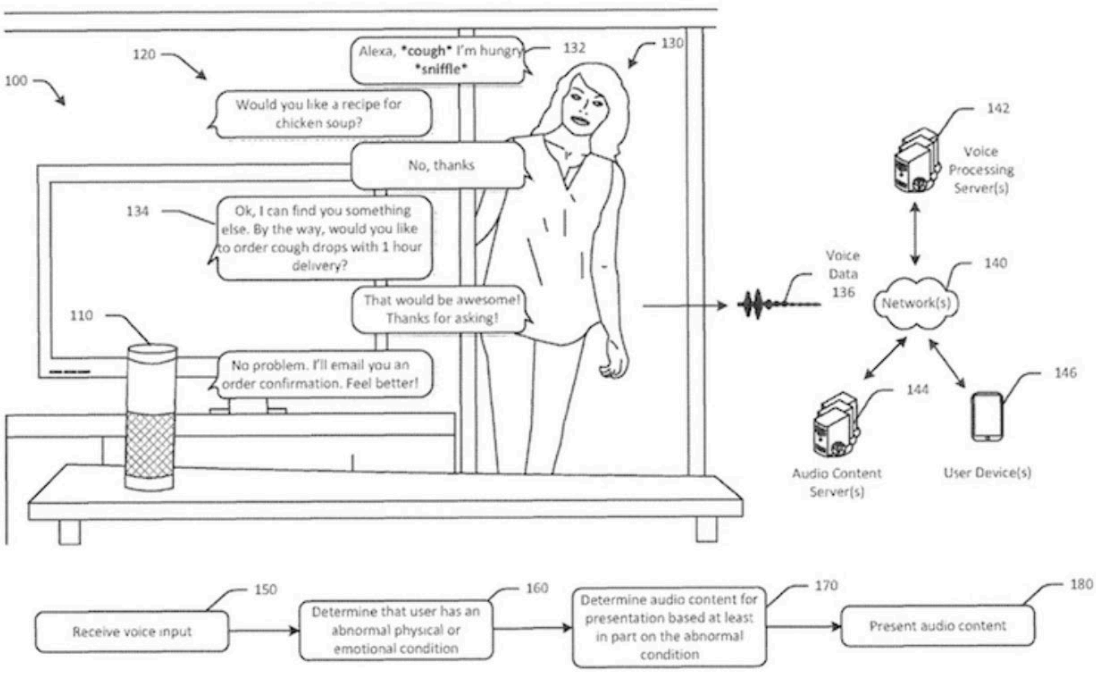


Figure 8. Cough prediction algorithm patent. Source: Amazon (Jin, 2018)

These examples illustrate how designers can use these elements - demos, prototypes and, patents - to anticipate potential positives and/or negative interactions.

3.1.3. Asymmetries
In order to understand the positive and negative potential dynamics of the system asymmetries needed to be understood and identified. They uncovered potential areas of conflict, exploitation and injustice which may have a tremendous impact on society and businesses. As an example, building from a case study on Facebook and Cambridge Analytica, data asymmetry became a major element to address. Therefore positioning this process as key for the successful development of the project.

3.1.4. Consequences
This area aims to integrate ethical analysis into the development of new products and services. Ethics focuses on how a person should behave. It is a philosophy applicable to daily life or existence. It integrates two areas in order to determine rules or codes of conduct; philosophy, the art as asking questions, and morality, what is good or bad. Its main objective is to determine the right thing to do. Its ontology is based on creating social constructs for the adequate functioning of society. It's epistemology to decode these constructs while its output aims to set standards of behaviour for daily life. Once the area was defined, a literature review on normative ethical frameworks was conducted. From this process, a debate emerged on which framework to use; Socrates's virtue, Jeremy Bentham's Consequentialism, Emmanuel Kant's Deontology or John Dewey's Pragmatism.

Virtue refers to being. In this paradigm, morality emerges from the identity of the individual rather than their actions or consequences. Socrates approach refers to an end to be sought. It asserts that the right action will be that chosen by a suitably 'virtuous' agent. Practical reason results in action or decision.

Consequentialism states that the consequences of somebody actions are the ultimate basis for any kind of judgment regarding that action. This perspective is non-descriptive, in the sense that the value of the action is determined by its consequences rather than its intentionality. It focuses on the outcome of conduct.

In deontology, the rightness or wrongness of actions does not depend on their consequences but on whether they fulfil our duty or not. These actions are conditioned by a set of rules, may they be natural, religious or social.

Pragmatism aims for social reform as a strategy to address morality. Actions and consequences are possible because the context or system allows for them. Aimed at social innovation, in this perspective we should prioritise social reform over concerns with consequences, individual virtue or duty.

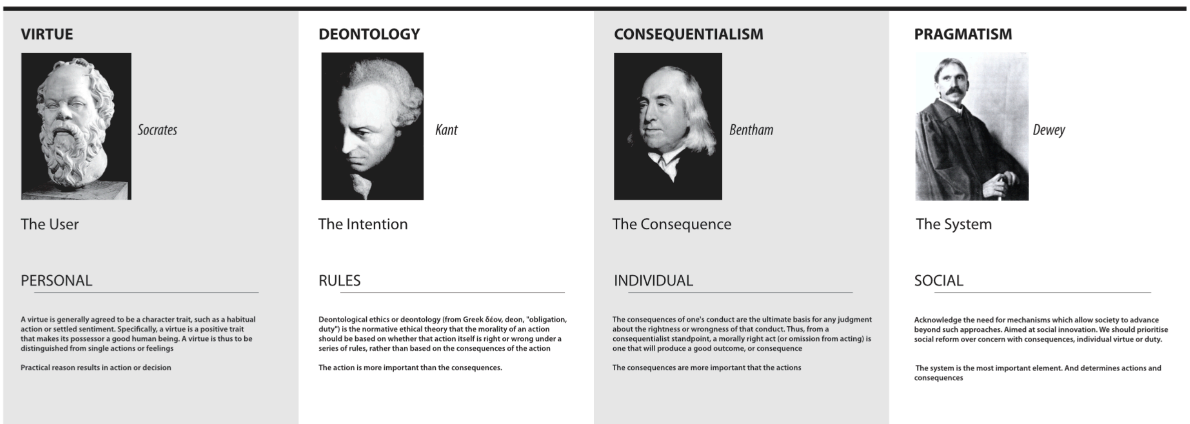


Figure 9. Normative ethics main frameworks. Source: Fernando Galdon

The fundamental problem with Dewey's perspective is that in order to change the system, we need an alternative or global consensus. As illustrated by Professor Harari, AI is a global problem such as climate change or nuclear war which entails global consensus (Harari, 2019). Insofar as we have not reached this consensus it is not an adequate framework to address the design of a system.

In Socrates virtue, the fundamental problem is the limited capability of humans to assess what is happening. The acceleration and volume of information delivered by social interactions and algorithmic updates is fragmenting reflection and cognition by disconnecting the pre-frontal cortex by saturation; our attention span has been reduced from 12" to 8" in four years by multitasking (National Center for Biotechnology Information, 2016) (Kahneman, 2011) and after 21 minutes comparing information our pre-frontal cortex shuts down (Mullins, 2013) and only information with a big emotional impact is retained (Buchanan, 2007). These processes are transforming society from reflective to reactive. The digital era is bringing Emotional Reactivism as its main paradigm. It is questioning the idea of truth and reality and repositioning the decision centre from reason to emotional experience. Thus invalidating the model proposed by Socrates based on reason.

In this scenario, two main candidates remain. On one side, Jeremy Bethan's consequentialism. On the other, Emmanuel Kant's deontology. The former situates the ethical intervention on the consequence, whereas, the latest, on the intentionality. In terms of deontology, fundamental problems are interpretability and interruptibility. The system does not know what is doing, therefore, it cannot stop. According to researchers from the most advanced AI company in the world DeepMind, this is currently impossible (Ortega, 2018). Insofar as we are not capable of designing them, it is not a suitable strategy. Consequently, the only paradigm remaining is Consequentialism. In this framework the fundamental elements are the consequences of an action, therefore, the system will be judged by the consequences of its actions.

In this scenario, a design framework-toolkit presented by Mark Michael to address unintended consequences was integrated into the design process (Michael, 2019). However, it proved limited as contexts and actions emerged from the literature as fundamental variables to address (Bradshaw, 2013). These elements became integrated via the design of a multi-focus system analysis process capable of integrating different perspectives.

3.1.5. Counter-fictions

Counter-fiction is an experimental emerging area in design practice. So far, only two publications were found during this research that explore its possibilities; A monographic journal issue (Multitudes, 2012), and a book (Belliot, 2018). This approach aims to address the relations of domination. Its main approach, rather than being imposed or forced, is based on the co-production of control systems aimed to decrease repression and enhance individual freedom and responsibility. In this paradigm:

> 'Freedom is nothing other than the correlative of the implementation of security devices. A form of power announced as "near future" or immediate present, which makes obsolete old forms of resistance still indexed on disciplines and forces us to invent "new weapons'' (Foucault on Claisse, 2012, pp.108)

Control is the main element to account for. It is understood as a mode of relationships between individuals. In this relational perspective, power is a dynamic and reciprocal force addressed through asymmetric relations in which the controlled one sees his actions, cognitions and possible effects reduced, although not totally determined by the controller. Power can be seen as a relation or as an influence, and differs from the point of view of the spectrum of possibilities actually controlled by individuals. This approach places trust as a fundamental variable to build and maintain the relationship.

In this context, the use of counter-fictional strategies emerged for the author as a strategy to address the dynamics of the system, but also as an experimental method to ground speculations. Its intervention can be placed a priori, meanwhile or a posteriori.

Building from a literature review, the author underpinned levels of automation (LoA) as a tool to address trust in automated systems. Gradient-based models of approximation have been used extensively in the field to address trust in automated systems. This approach has been consistent in the automation literature since its introduction by Sheridan and Verplanck (1978). Levels of automation (LoA) is acknowledged by Kaber (2018) as a fundamental design characteristic that determines the ability of operators to provide effective oversight and interaction with systems autonomy. In this context, a preliminary level of automation was built. However, contexts and actions emerged as capital variables to address two fundamental questions; if something goes wrong, how can we repair trust in the system? and, Who should be accountable for the reparation?

In this scenario reparation raised as an element to address. This acknowledgment led to the articulation of two complementary scales; levels of reparation and levels of accountability. These two scales became a posteriori design intervention. At the same time, by unifying these scales with the automation scale and the variables of contexts and actions, and the integration of the variables around access; a calculator was build to generate a trust rating by which to understand the risk of a particular action. This design became an a priori design intervention. Finally, by combining a priori and a posteriori interventions an algorithm could be designed to allow the system to self-calibrate. This intervention becomes a meanwhile design intervention.

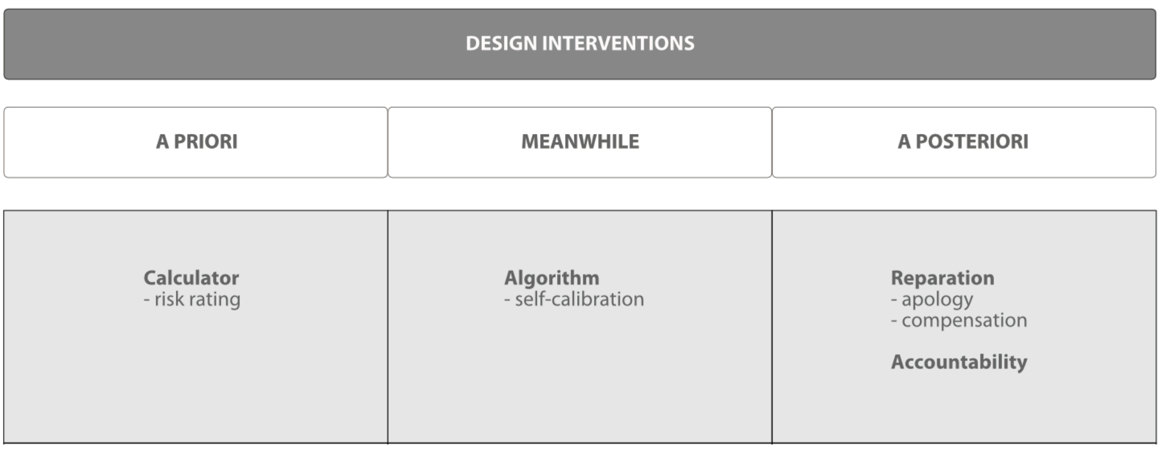


Figure 10. Design interventions. Source: Fernando Galdon.

3.1.6. Final model - Behavioural
Relational methods based on ethics. This approach is based on the systematic practice of relational system analysis to predict and model behaviour. Main methods: historical data analysis, relational frameworks and the systematic use of ethical methods. This approach uses techniques based on Trajectories , Probabilistic extrapolations, Asymmetries, Consequences, and Counter-fictions

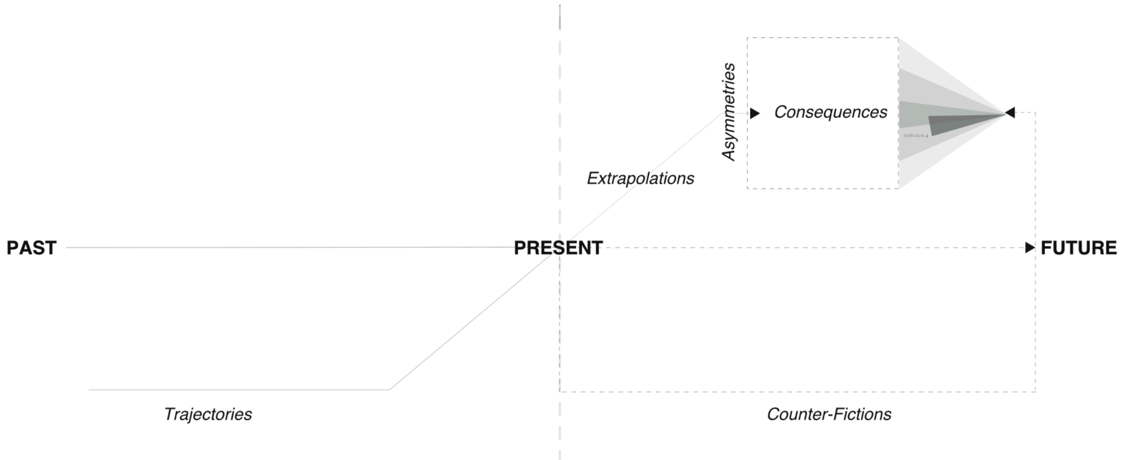


Figure 11. Anticipatory model based on systems analysis. Source: Fernando Galdon.

1 TRAJECTORIES	**Define trajectories** Timelines - *Designing literature review & comparative studies*
2 PROB. EXTRAPOLATIONS	**Analyse prospective technologies** Demos / Patents / Prototypes - *Desk research*
3 ASSYMETRIES	**Define asymmetries in the relationship system/user** Data / Inferences / Dependencies - *Surveys*
4 CONSEQUENCES	**Systematically analyse consequences and impact** Unintended Consequences / Actions / Contexts - *Workshops*
5 COUNTER-FICTIONS	**Design interventions to revert asymmetries** Control / Repression / Power - *Co-Design*
6 DESIGN INTERVENTIONS	**Place intervention in time** A Priori / Meanwhile / A posteriori - *Design*

Figure 12. Anticipatory design methods description and interventions. Source: Fernando Galdon.

3.2 Model test
3.2.1 Academia
The framework proposed has been tested through a range of academic publications.
The levels of automation, reparation, and accountability were tested via a survey and five papers were produced. The foundational paper of levels of automation will be presented and published in the proceedings of INAIT'19 at the University of Cambridge (Galdon, 2019a). The levels of reparation and accountability will be presented and published in the proceed-

ings of IHIET'19 at University of Côte d'Azhur (Galdon, 2019b), (Galdon, 2019c). The calculator has been presented and published in the proceedings of MIT A+B Applied Engineering conference at the Massachusetts Institute of Technology in May 2019 via an applied case on user engagement optimisation to enhance energy consumption and management (Galdon, 2019d). In this conference, the author was also invited to present an additional poster illustrating the research through design process (Galdon, 2019e). Finally, a collaborative project is being discussed to develop a proof-of-concept for the self-calibrating algorithm.

3.2.2 Co-design workshops

Workshops have been used to further test key aspects of the framework proposed. The first Workshop invited 20 participants from the School of Design at the RCA to test on the first hand, differences amongst group and individual work, and on the other hand, the simplified systematic analysis of unintended consequences presented by Mark Michael (Michael, 2019). The participants were distributed in four groups of five members.

Giving a potential technological development, the framework presented by Michael demanded participants to analyse four elements; anticipated desired, anticipated undesired, unanticipated desired and unanticipated undesired potential outputs. As a result, the anticipated quadrants were better developed with 61 proposals, whereas the unanticipated aspects of product development presented 54 proposals in overall from the participants. Unanticipated undesired outcomes presented a very clear challenge for participants. They were referential to known issues. Answers were logical, rational and expected. There was a lack of originality and incapability to go 'beyond'. The main author had to instigate debate by introducing some examples. However, instead of opening the scope of outputs, these examples become replicated by variation or integration. Occasionally, some participants proposed interesting ideas, but the group dynamics demanded consensus and prevented them going 'beyond' what they already knew, thus limiting abductive thinking and jeopardising anticipatory strategies. In anticipatory contexts is fundamental to go 'beyond'. Only if you can imagine contentious developments, you can develop strategies to mitigate prospective consequences.

The second hour in the first workshop aimed to redo the same task from an individual perspective. A booklet for individual development was distributed among participants. The engagement was articulated around the idea that they could re-appropriate the method by integrating their own individual research into the process. Half an hour into the task and half of the participants left the workshop. It seems that they need constant engagement, and when requested to conduct individual work and reflect within themselves, they tended to disengage and abandon the task. The other half engaged as expected, with 20% of participants engaging vigorously, to the extent of asking whether they could carry the task at their homes after the workshop. Yet, outcomes were building from the previous task. Again, a lack of 'going beyond' of what is already known or proposed was present.

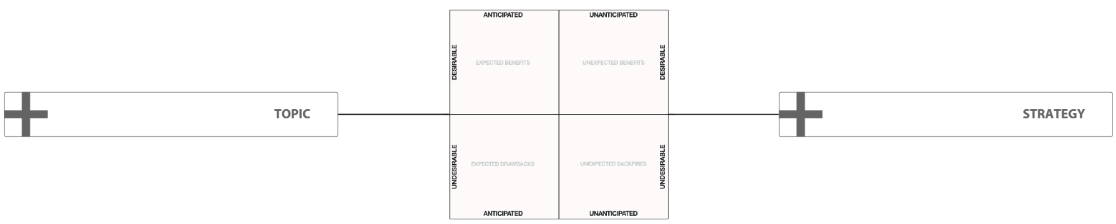


Figure 13. Consequential analysis. Source: Fernando Galdon from Mark Michael.

The second workshop invited 10 participants from the School of Design and Architecture at the RCA to test and improve a multi-layered approach to systematically analyse consequences by addressing contexts and actions to propose mitigating strategies. Participants were distributed in two groups. The workshop was structured completely to operate as a group task to maintain engagement. All the participants completed the 2 hours workshop and they engaged consistently through all the stages.

The second workshop aimed to further investigate anticipatory analytical skills. As a result, the author introduced a range of variations. First, students mapped the current state of the art. (what a virtual assistant can do today). Then, in order to address originality and lack of 'going beyond', it introduced a What if …? approach to allow participants to break the logical and rational thinking and project possible or potential developments of the technology. This task was successful and unexpected outcomes emerged, allowing participants to go 'beyond' what already exists. This approach included positive and negative outcomes. As an example, outputs presented food-related issues as highly relevant in the context of energy consumption and management for future developments of Virtual Assistants in this area. This was highly unexpected and when presenting this particular outcome at MIT and Ideo it was received with surprise, yet, making total sense of the future impact of the smart fridge.

In terms of outputs, the workshop aimed to understand if speculative insight could be grounded by applying a systematic analysis between the insight and the design activity. The system analysis consisted of a three-level analytical process of the system at hand. First, they were requested to conduct the consequences quadrant used in Workshop 1, however differently, each group mapped the anticipated desired and undesired, and by confronting both groups the unanticipated emerged for each group. This element presented participants with their own limitations and enhanced self-criticality. Then, they mapped the prospective outcomes in terms of impact in contexts and impact of actions. This analytical step allowed them to understand contexts and actions impact on users. Finally, participants were requested to complete a design activity consisting of developing preventive strategies to the potentially negative interactions they had mapped. They were requested to use counter-fictional principles to transform the dystopic into real-world strategies that could be applied. The results were successful and presented strategies aiming to ground speculation into potential real-case interventions.

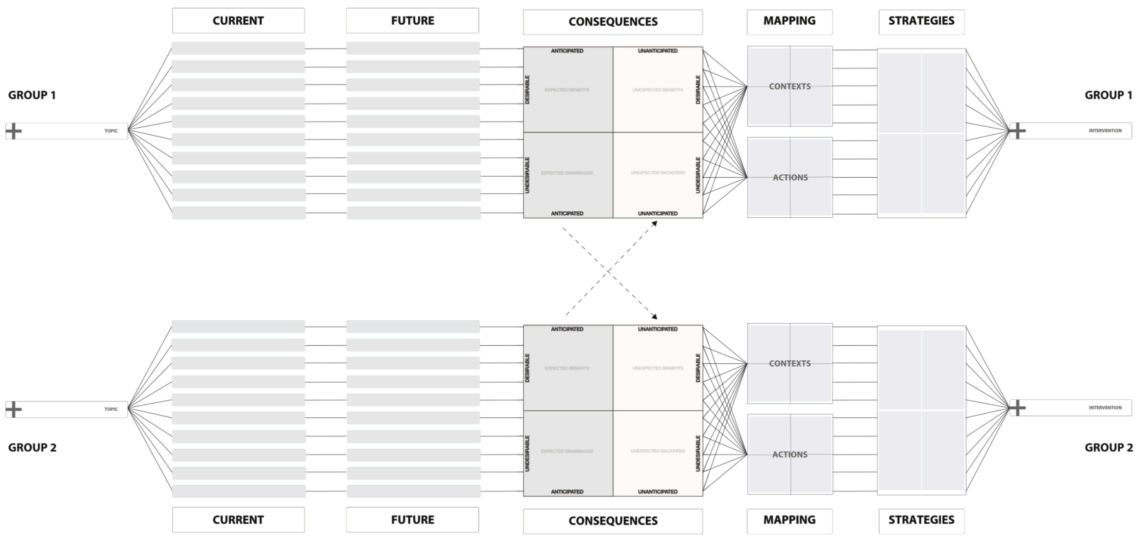


Figure 14. Multi-focus Consequential analysis for Anticipatory Design. Source: Fernando Galdon.

4. Conclusion

In this paper, the authors propose prospective design as a method to address unintended consequences. It combines systems analysis with extrapolations and constructivist perspectives to reconcile confronted models of design future(s).

In the results presented, the authors suggest a need to include ethical frameworks in design to involve students in ethical issues. To go beyond the positive impact of technology and design strategies to address and/or mitigate unintended consequences, as they are fundamental for the adequate development of society.

In developmental terms, results suggest that working in groups generates engagement, however, one of the fundamental problem of group tasks was that decisions were based on consensus when approaching the task from a rational and logical perspective, and some interesting ideas to address the potential impact of technological systems became superseded by the dynamics of the group. It recommends the integration of What if …? metaphysical affordances to break logical and rational analysis and enhance more distributed results. Furthermore, it is suggested the integration of a three-level consequential analysis including consequences, contexts, and actions to ground and focus the analysis. Finally, by implementing counter-fictional principles, results become real-world interventions aimed to address the main task of design in the digital and exponential technological age we are living; preparedness, readiness, and appropriateness to the build environment.

In the process, it challenges and evolves current notions in design research based on technological progress revolving around product development to a model based on ethical responsibility which places equal value on the process of design and the impact of the system in society. In this context, abductive thinking becomes the main design mindset in driving the transition from current to potential states leading to the mediation of anticipated and non-anticipated consequences. The anticipatory design framework introduces a process to deal with the increasing complexity of wicked problems, black box technologies and AI/ML technology acceleration, enhancing social values and ethical principles in the process.

This paper presents preliminary insights. Academic conferences and publications have been used to test the design outputs emerging from the process proposed and tailored workshops have tested key specific aspects of the methodology. Further research is being planned to test the full extension of the methodology proposed in educational and professional settings.

5. References

Auger, J. (2012). Why Robot? Speculative design, the domestication of technology and the considered future. PhD thesis. Royal College of Art.

Belliot, E. (2018). Counter-Fictional Design. Critique d'art[En ligne], Toutes les notes de lecture en ligne, mis en ligne le 04 novembre 2016, consulté le 01 novembre 2018. URL : http://journals.openedition.org/critiquedart/19220

Bezold, C. and Hancock, T. (1994). An Overview of the Health Futures Field. WHO Consultation, July 19-23

Bradshaw, J. M., Hoffman, R. R., Woods, D. D., & Johnson, M. (2013). The seven deadly myths of autonomous systems. IEEE Intelligent Systems, 28(3), 54–61.

Buchanan, R., (1992) Wicked Problems in Design Thinking, Design Issues, Vol. 8, No. 2, (Spring), pp. 5-21.

Buchanan, T. W. (2007). Retrieval of emotional memories. Psychological Bulletin, Vol 133(5), 761-779.

Claisse, F. (2012). Contr(ôl)e-fiction : de l'Empire à l'Interzone. Multitudes, 48(1), 106-117. doi:10.3917/mult.048.0106. https://doi.org/10.3917/mult.048.0106.
Conklin, J., (2006) "Dialogue mapping." Building Shared Understanding of Wicked Problems. West Sussex, England: John Wiley & Sons.
Cramer-Petersen, C. L., Christensen, B. T., & Ahmed-Kristensen, S. (2019). Empirically Analysing Design Reasoning Patterns: Abductive-deductive Reasoning Patterns Dominate Design Idea Generation. Design Studies, 60, 39-70. DOI: 10.1016/j.destud.2018.10.001
Dorst, K. (2010). The nature of design thinking. DTRS8 Interpreting Design Thinking: Design Thinking Research Symposium Proceedings, 2010, pp. 131 - 139
Douven, I. (2011). "Abduction", The Stanford Encyclopedia of Philosophy (Spring 2011 Edition), Edward N. Zalta ed., plato.stanford.edu/archives/spr2011/entries/abduction
Eichstaedt, J. C., Smith, R. J., Merchant, R. M., Ungar, L. H., Crutchley, P., Preoţiuc-Pietro, D., Asch, D. A., Schwartz, H. D. (2018). Facebook language predicts depression in medical records. Proceedings of the National Academy of Sciences Oct 2018, 115 (44) 11203-11208; DOI: 10.1073/pnas.1802331115
Foucault, M. (2004). Sécurité, Territoire, Population. Cours au Collège de France (1977-1978), Paris, Seuil, coll. « Hautes Études », p. 50. On Claisse, F. (2012). Contr(ôl)e-fiction : de l'Empire à l'Interzone. Multitudes, 48(1), 106-117. doi:10.3917/mult.048.0106. https://doi.org/10.3917/mult.048.0106.
Future, I. (2009). Anticipatory governance. Retrieved: 25 March 2019. Available from: http://www.iftf.org/ uploads/media/SR-1272_anticip_govern-1.pdf
Galdon, F., & Wang, S. J. (2019a). Designing trust in highly automated virtual assistants: A taxonomy of levels of autonomy. International Conference on Industry 4.0 and Artificial Intelligence Technologies. Cambridge, UK. ISBN: 978-1-912532-07-0
Galdon, F., & Wang, S. J. (2019b). From apology to compensation; A multi-level taxonomy of trust reparation for highly automated virtual assistants. Proceedings of the 1st International Conference on Human Interaction and Emerging Technologies (IHIET 2019) conference August 22-24, 2019, Nice, France.
Galdon, F., & Wang, S. J. (2019c). Addressing accountability in highly autonomous virtual assistants. Proceedings of the 1st International Conference on Human Interaction and Emerging Technologies (IHIET 2019) conference August 22-24, 2019, Nice, France.
Galdon, F., & Wang, S. J. (2019d). Optimising user engagement in highly automated virtual assistants to improve energy management and consumption. Proceedings of the 2019 Applied Energy Symposium AEAB Conference Proceedings, MIT. 22-24 May 2019.
Galdon, F., & Wang, S. J. (2019e). Future development of AI Virtual Assistants (VAs) in Energy management and consumption. Proceedings of the 2019 Applied Energy Symposium AEAB Conference Proceedings, MIT. 22-24 May 2019
Gidley, J. M. (2017). The future; A very short introduction. Oxford University Press. DOI: 10.1093/actrade/9780198735281.001.0001
Glanville, R. (2005). The Unthinkable Doctorate: Brussels, Design Prepositions. Cybernetics Research. American Society of Cybernetics, UK and Australia
Guston, D. H. (2014). Understanding 'anticipatory governance.' Social Studies of Science, 44(2), 218–242. https://doi.org/10.1177/0306312713508669
Harari, Y. N. (2019). Professor Yuval Noah Harari In conversation with Lord Hague of Richmond. RUSI, 13th November 2018. Available from: https://www.ynharari.com/wp-content/uploads/2018/12/20181113-RUSI-Harari_Discussion_TRANSCRIPT.pdf
Jin, H., Wang, S. (2018). Voice-based determination of physical and emotional characteristics of users. http://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO2&Sect2=HITOFF&u=%2Fnetahtml%2FPTO%2Fsearch-adv.htm&r=1&p=1&f=G&l=50&d=PTXT&S1=10,096,319&OS=10,096,319&RS=10,096,319
Jones, J. C. (1992). Design methods. New York: Van Nostrand Reinhold.
Kaber, D. B. (2018). Issues in Human–Automation Interaction Modeling: Presumptive Aspects of Frameworks of Types and Levels of Automation. Journal of Cognitive Engineering and Decision Making, 12(1), 7–24. doi:10.1177/1555343417737203
Kahneman, D. (2011). Thinking, fast and slow. New York: Farrar, Straus and Giroux.
Kurzweil, R. (2005). The Singularity is Near. New York: Viking Books. ISBN 978-0-670-03384-3.

Michael, M. (2019). An introduction to unintended consequences. Accessed; 16 March 2019. https://www.markmichael.io/insights/mapping-mitigating-unintended-consequences/

Mullins, P. a. (2013, November 22). Ground-Breaking project to brain-scan shoppers. Retrieved from Bangor University: https://www.bangor.ac.uk/news/university/ground-breaking-project-to- brain-scan-shoppers-16874

Multitudes (2012). Political Counter-Fictions – Fukushima: Voices of Rebels. No 48, 2012/1. Publisher : Assoc. Multitudes. ISBN : 9782916940779.

National Center for Biotechnology Information, U. N. (2016, July 2). attention span statistics. Retrieved from Statisticbrain: http://www.statisticbrain.com/attention-span-statistics/

Ortega, B. P. A. (2018). Building safe artificial intelligence : specification , robustness , and assurance Specification : design the purpose of the system. Medium. Retrieved from https://medium.com/@deepmindsafetyresearch/building-safe-artificial-intelligence-52f5f75058f

Rittel, H.W.J. & Webber, 1973. Dilemmas in a General Theory of Planning, M.M. Policy Sci 4: 155.

Sheridan, T. B., & Verplank, W. L. (1978). Human and Computer Control of Undersea Teleoperators: Fort Belvoir, VA: Defense Technical Information Center. https://doi.org/10.21236/ADA057655

Voros, J. (2003). A Generic Foresight Process Framework. Foresight, 5(3), pp.10-21

About the Authors:

Fernando Galdon: A Ph.D. candidate, Fernando is pursuing a doctoral programme in Global Innovation Design at the Royal college of Art, where He is investigating trust design at the intersection of Artificial Intelligence and society.

Ashley Hall: Ashley is Professor of Design Innovation at the Royal College of Art where he leads postgraduate research for the design school and the MRes in Healthcare Design. Ashley researches innovation methods, experimental design, design for safety, design pedagogy, globalisation design and cultural transfer.

Stephen Jia Wang: Head of Programme for the Global Innovation Design and Innovation Design Engineering programmes. Stephen explores challenges through international and/or interdisciplinary collaborative experimental design projects from the development of biomedical systems and devices, urban energy conservation systems, intelligent navigation systems, to the interactive exhibition media solutions.

IASDR 2019

International Association of Societies of
Design Research Conference 2019
DESIGN REVOLUTIONS

Manchester School of Art
Manchester Metropolitan University
02-05 September 2019

Research on Japanese Typefaces and Typeface Customisation System Designed for Readers with Developmental Dyslexia

Zhu, Xinru*[a]; Kageura, Kyo[ab]

[a] Graduate School of Education, The University of Tokyo, Tokyo, Japan
[b] Interdisciplinary Initiative in Information Studies, The University of Tokyo, Tokyo, Japan
* shushinjo@p.u-tokyo.ac.jp

This research aims to create Japanese typefaces and a Japanese typeface customisation system for readers with developmental dyslexia. In previous research, we have defined the requirements for Japanese typefaces for readers with dyslexia and created a set of new Japanese typefaces, *LiS Font*. This paper reports the evaluation experiment conducted regarding the readability and legibility of *LiS Font*. The results indicate that typefaces have impacts on both objective and subjective measures of readability, and readers with dyslexia consider *LiS Font* more readable compared to existing Japanese typefaces. In addition, the results imply the necessity of meeting the needs of readers with different symptoms of dyslexia. Hence this paper also reports our progress with developing a Japanese typeface customisation system for readers with dyslexia by introducing an initial prototype.

Keywords: typeface; customisation; Japanese characters; developmental dyslexia; readability; legibility

1 Introduction

This paper introduces our research which aims to develop a set of new Japanese typefaces specially designed for readers with developmental dyslexia and a Japanese typeface customisation system for readers with developmental dyslexia.

1.1 Background

Developmental dyslexia, or dyslexia, is “a specific learning disability that is neurobiological in origin. It is characterised by difficulties with accurate and/or fluent word recognition and by poor spelling and decoding abilities” (International Dyslexia Association, 2002). Evidence shows that 5–17% of the population in English-speaking countries (Reid, Fawcett, Manis & Siegel, 2008) and 8% of the population in Japan (Japan Dyslexia Research Association, 2018) have developmental dyslexia. It is essential to provide readers with developmental dyslexia with an assistive environment.

There is a wide range of assistive tools for readers with dyslexia (Smythe, 2010) and in this research, we focus on typefaces as a visual assistive tool for the readers.

Several Latin typefaces that are specially designed for readers with dyslexia have been created over the years and some research shows that readers with dyslexia are able to read with fewer errors or are more comfortable reading in these typefaces compared to standard typefaces (Hillier, 2006; Marinus et al., 2016; Zikl et al., 2015). With regard to Japanese language, recent studies indicate that typefaces have effects on reading performance of readers with dyslexia in Japanese (Okumura et al., 2018; Tani, Goto, Uno, Uchiyama & Yamanaka, 2016). These results imply that Japanese typefaces designed for readers with dyslexia would be effective.

1.2 Problems

However, Japanese typefaces for readers with dyslexia had not been created so far due to the following problems.

1. The characteristics of typefaces designed for readers with dyslexia (both in Latin and Japanese) were not systematically clarified,
2. Japanese typefaces contain a large number of complicated characters which makes creating new typefaces expensive,
3. To create a typeface that fits every reader with dyslexia is not easy.

1.3 Research Objectives

In our research, we aim to solve the first problem by (i) clarifying the characteristics of Latin typefaces designed for readers with dyslexia and mapping them to Japanese typefaces to define the requirements for Japanese typefaces designed for readers with dyslexia, to solve the second problem by (ii) creating a Japanese typeface for readers with dyslexia by programmatically manipulating glyphs of open source typefaces, and to solve the third problem by (iii) creating a Japanese typeface customisation system that enables readers with dyslexia to adjust typefaces within a certain range to fit their symptoms. This research, thus, consists of the following three phases:

- Phase 1: Defining the requirements for Japanese typefaces designed for readers with dyslexia by mapping the characteristics of the Latin typefaces designed for readers with dyslexia,
- Phase 2: Creating a set of Japanese typefaces based on the requirements defined in Phase 1 and evaluating the typeface,
- Phase 3: Developing a Japanese typefaces customisation system for readers with dyslexia.

This paper reports the results of the evaluation experiment of Phase 2 and our progress with Phase 3.

2 LiS Font: New Japanese Typefaces Designed for Readers with Dyslexia

LiS Font, as shown in Figure 1, is a new set of Japanese typefaces designed for readers with dyslexia that we have created in this research. *LiS Font walnut* and *LiS Font cashew* are two variations of *LiS Font* and each of them contains 2776 characters including Japanese kana characters and Jōyō kanji (common-use Chinese) characters.

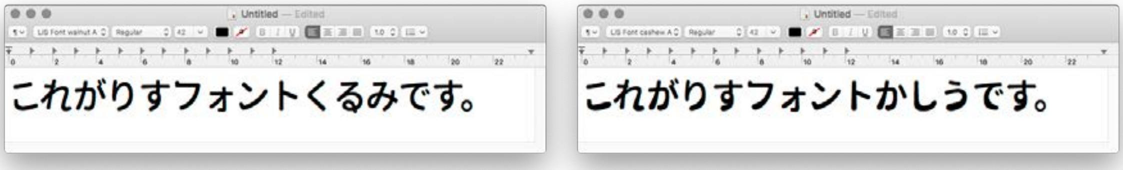


Figure 1. LiS Font walnut (left) and LiS Font cashew (right).

Figure 2. Standard Japanese typefaces, sans serif style (left) and serif style (right).

In this section we will report the definition of the requirements for Japanese typefaces for readers with dyslexia and the creation of *LiS Fon*t in brief and report the results of the evaluation regarding the efficacy of *LiS Font* in detail.

2.1 Requirements for Japanese Typefaces for Readers with Dyslexia

As is mentioned in Section 1.2 and 1.3, we extracted visual characteristics of the existing Latin typefaces designed for readers with dyslexia by comparing their elements quantitatively and qualitatively to those of standard typefaces (Zhu, 2016). As a result, we obtained 9 characteristics of Latin typefaces designed for readers with dyslexia.

On the basis of the characteristics extracted, we defined the requirements for Japanese typefaces designed for readers with dyslexia by mapping those characteristics to typographic elements in Japanese (Yamada & Zhu, 2018). It is reasonable to assume that the characteristics of the Latin typefaces designed for dyslexia can be mapped to Japanese typefaces because research shows that character recognition process is similar across the languages and writing systems (Dehaene, 2009) and moreover, similar visual symptoms of dyslexia such as letter reversals, distortion, blurring, and superimposition are reported in both Japanese and English (Stein, 2008; Stein & Walsh, 1997). As a result, we defined 9 requirements for Japanese typefaces designed for readers with dyslexia as below.

1. Larger characters,
2. Maru gothic (rounded sans serif),
3. Bolder strokes,
4. Larger height/width ratio,
5. Contrast in strokes,
6. Larger space between characters,
7. Easy-to-distinguish kana characters with similar shapes,
8. Easy-to-identify kanji characters,
9. Frames added to kanji characters to illustrate radicals.

2.2 Creation

In order to create Japanese typefaces that fulfil the requirements defined above, We combined programmatic methods of manipulating glyphs of an existing typeface, or the base font, with manual adjustments.

We selected Source Han Sans JP as the base font for the reason that it is an open source project of CID-keyed OpenType fonts and its character collection is large enough for Japanese typefaces. Tools adopted during the process include RoboFont, Glyphs, and Adobe Font Development Kit for OpenType (AFDKO).

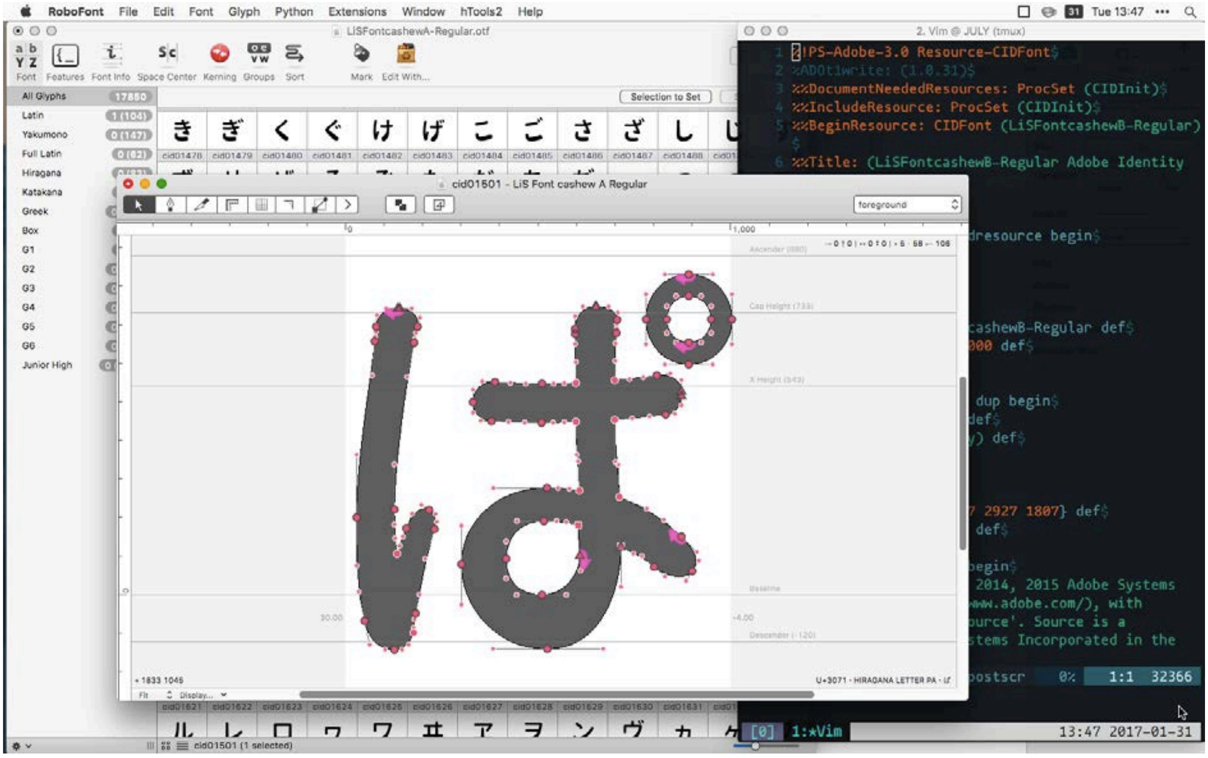


Figure 3. Creation process of LiS Font.

The results of this process are *LiS Font walnut* and *LiS Font cashew*. *LiS Font walnut* fulfils the requirements 1--4, 6, 7, and 9 while *LiS Font cashew* fulfils the requirements 1--7, and 9.

2.3 Evaluation

We conducted an evaluation experiment on readability and legibility of *LiS Font.* Twenty participants with dyslexia (DX group) and 20 participants without dyslexia (TP group) participated in the experiment. Table 1 shows age of the participants.

Table 1 Age of the participants

Group	N	Age			
		mean	*SD*	*min*	*max*
DX	20	19.05	11.35	10	53
TP	20	27.80	12.78	8	47

2.3.1 Procedures

The experiment consists of rapid reading tasks for objective measures and interviews for subjective measures. In rapid reading tasks, we asked the participants to read aloud 2 kinds of materials (short random characters and random kana characters) typeset in 4 different typefaces (*LiS Font walnut*, *LiS Font cashew*, Hiragino Maru Gothic, and Hiragino Mincho, in which Hiragino Maru Gothic and Hiragino Mincho are commonly used Japanese typefaces that bundled with macOS.), and recorded the duration of reading, number of errors, and number of corrections. In interviews, we asked the participants about the most and worst readable typeface in their point of view and recorded the answers. Figure 4 shows the typefaces used in the experiment.

Figure 4. Typefaces used in the experiment.

2.3.2 Results

2.3.2.1 Objective measures

Figure 5, Figure 6, and Figure 7 show the results of objective measures of the participants reading text.

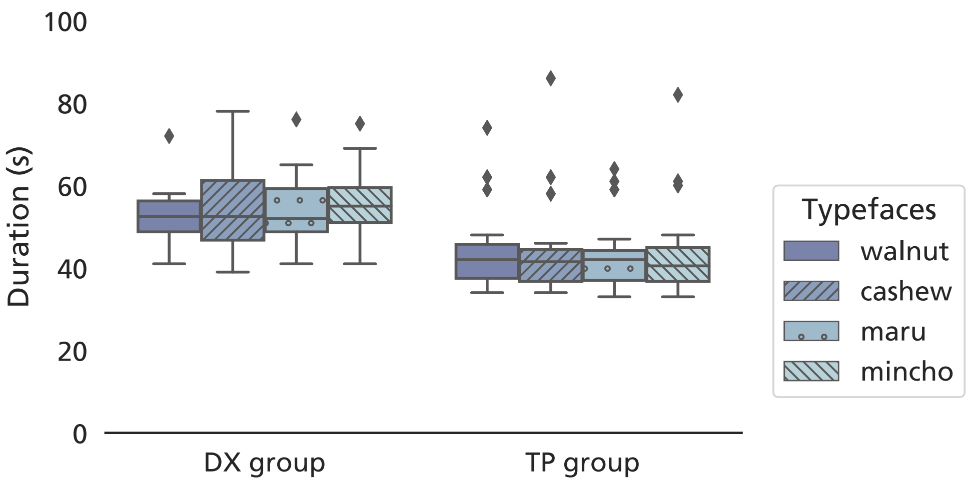


Figure 5. Duration of reading text.

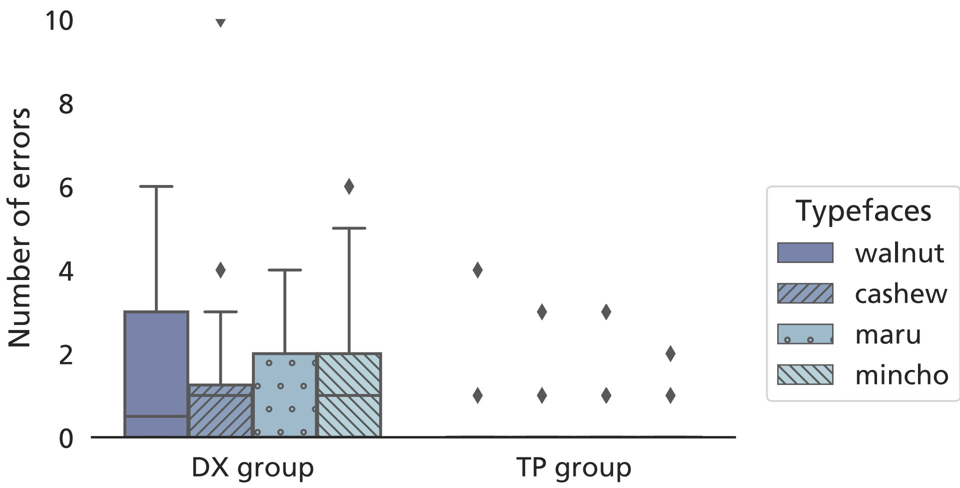


Figure 6. Number of errors of reading text.

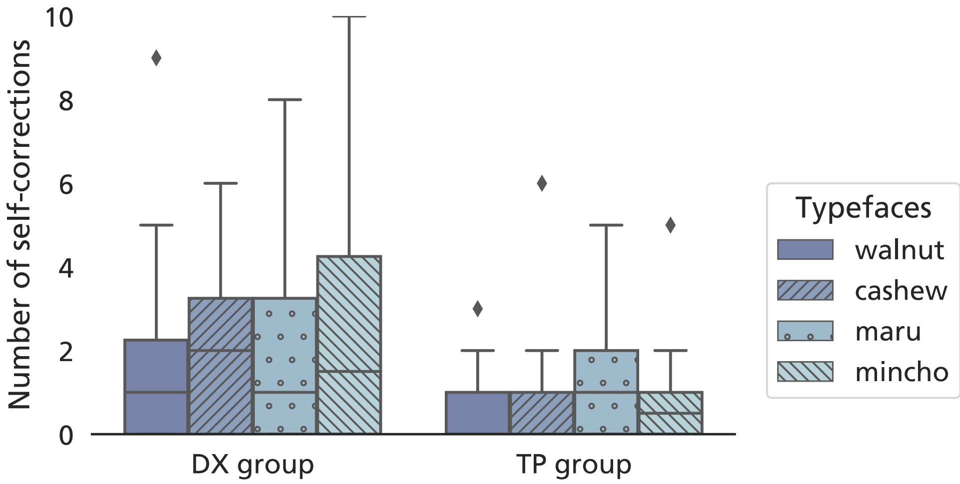


Figure 7. Number of self-corrections of reading text.

Figure 8, Figure 9, and Figure 10 show the results of objective measures of the participants reading random characters.

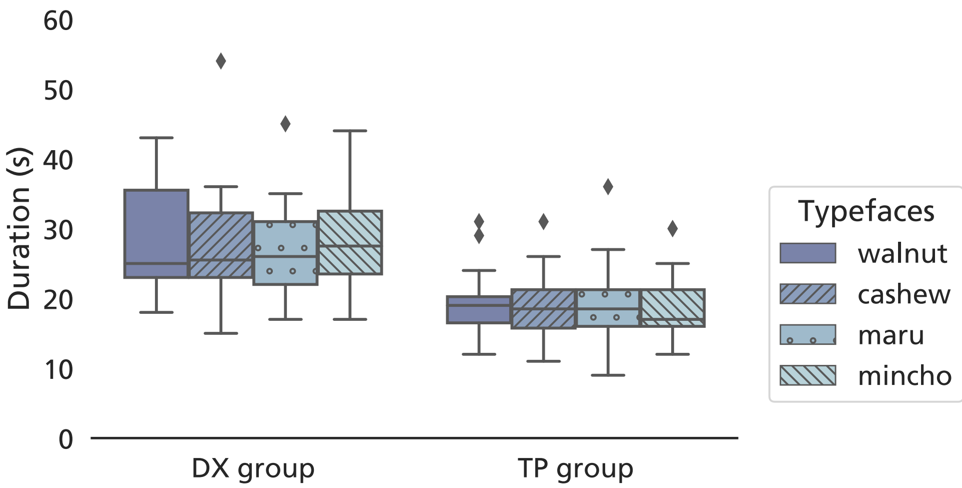


Figure 8. Duration of reading random characters.

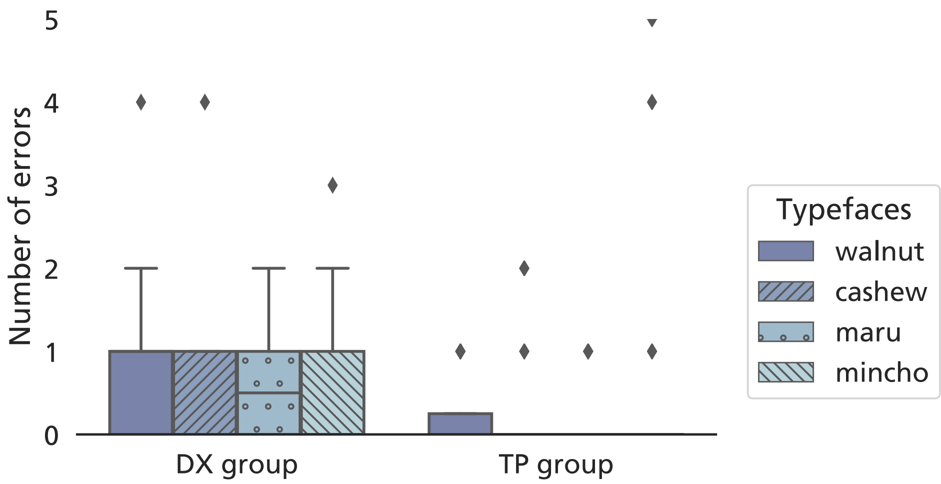


Figure 9. Number of errors of reading random characters.

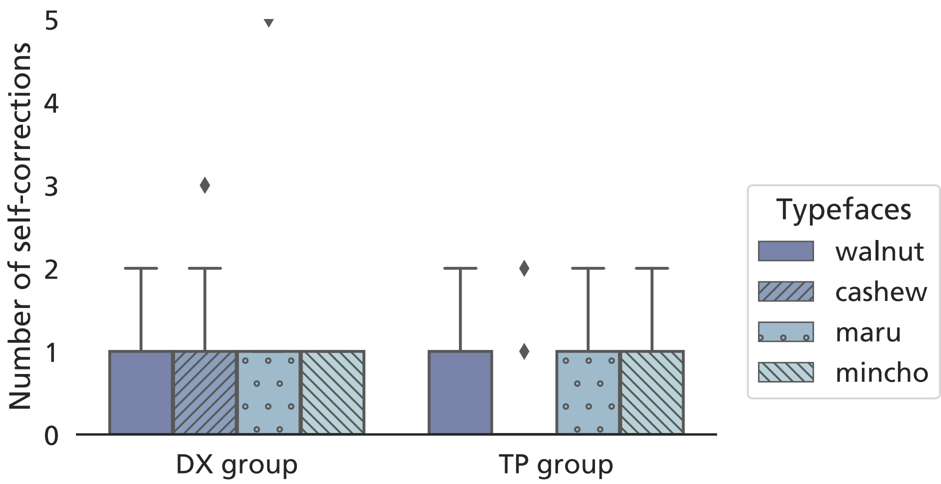


Figure 10. Number of self-corrections of reading random characters.

We conducted Friedman test on the results. As Table 2 shows, although no significant differences were detected between 4 typefaces in all the measures, small to medium effect sizes (η^2) were observed for all the measures except for the duration of reading random characters.

Table 2 Results of Friedman test

Material	Measure	Group	$\chi^2(3)$	η^2	p
Text	Duration	DX	2.862	0.048 *	0.413
		TP	1.737	0.029 *	0.629
	Number of errors	DX	2.395	0.040 *	0.495
		TP	1.286	0.021 *	0.733
	Number of self-corrections	DX	0.886	0.015 *	0.829
		TP	6.094	0.102 **	0.107
Random characters	Duration	DX	0.452	0.008	0.929
		TP	0.223	0.004	0.974
	Number of errors	DX	5.764	0.096 **	0.124
		TP	1.357	0.023 *	0.716
	Number of self-corrections	DX	1.268	0.021 *	0.737
		TP	6.780	0.113 **	0.079

In Friedman test, the effect size can be calculated by the formula $\eta^2 = \frac{\chi^2}{N(p-1)}$, in which N is the total sample size and $p-1$ is the degree of freedom (Morse, 1999). Interpretations of the effect size are shown in Table 3. Since effect sizes "provide an objective measure of the importance of an effect" (Field, 2009) regardless of sample sizes, it is safe to conclude that typefaces do have impacts on objective measures of readability and legibility in readers with and without dyslexia.

Table 3 Interpretations of the effect size

Interpretation	η^2	Cramer's V
Small	0.01	0.10
Medium	0.09	0.30
Large	0.25	0.50

Source: Mizumoto & Takeuchi (2008)

We will conduct further analysis of multiple comparisons in future research.

2.3.2.2 Subjective measures

Table 4 and Figure 11 show the result of subjective readability recorded from the interviews. Figure 12 shows this result in proportion of all the answers.

Table 4 Subjective readability

Material	Typeface	DX group		TP group	
		Readable	Not readable	Readable	Not readable
Text	walnut	7	1	1	1
	cashew	5	8	3	14
	maru	6	0	9	2
	mincho	2	11	7	3
Random characters	walnut	5	1	3	3
	cashew	7	8	3	10
	maru	5	2	9	1
	mincho	3	9	5	6

Figure 11. Subjective readability.

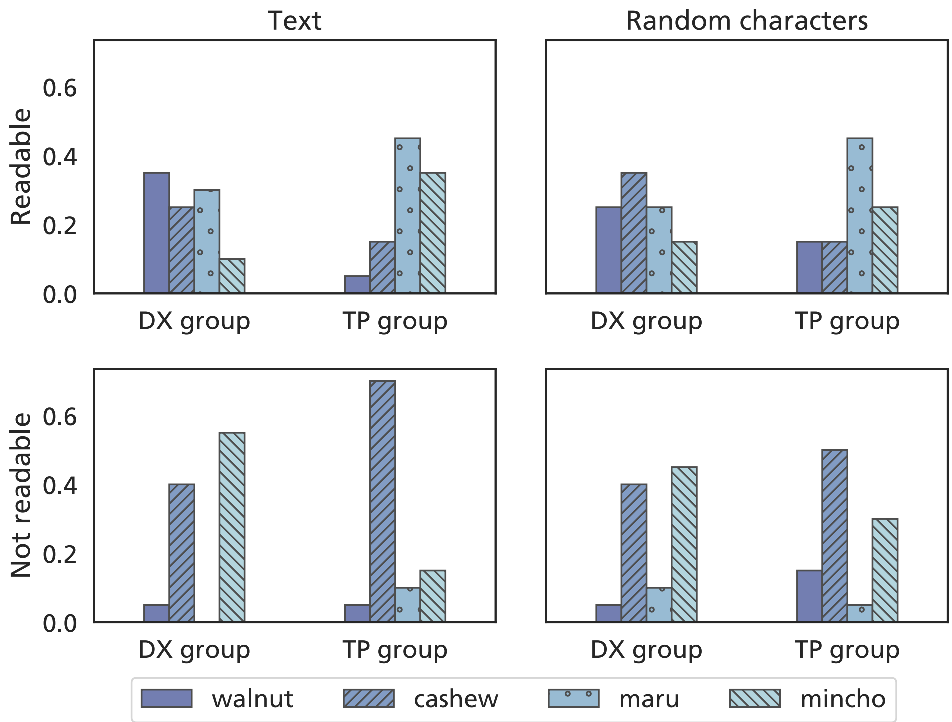


Figure 12. Subjective readability in proportion of all the answers.

The result of subjective readability indicates that readers in DX group tend to consider *LiS* Font more readable in both text and random characters compared to standard typefaces and readers in *TP* group consider the opposite.

We conducted χ^2 test on the result of subjective readability for each group in each material. The results are shown in Table 5. From the table, we can see that typefaces have large or medium effect sizes (Cramer's V) in the reading of text and random characters in both groups. This indicates that the effects of typefaces are easier to observe in subjective measures than objective measures.

The results also indicate that readers in DX group consider *LiS Font walnut* more readable in both text and random characters and readers in TP group consider *Hiragino Maru Gothic* more readable in both text and random characters. As for *LiS Font cashew*, while most readers in TP group found it less readable, the answers were divided into two for readers in DX group. It is possible that this result was caused by the difference in symptoms of dyslexia and we will investigate into this in future research.

Table 5 Results of χ^2 test

Material	Typeface	DX group			TP group		
		Residuals		Cramer's V	Residuals		Cramer's V
		Readable	Not readable		Readable	Not readable	
Text	walnut	2.372 *	-2.372 *	0.660 ***	0.000	0.000	0.574 ***
	cashew	-1.013	1.013		-3.518 **	3.518 **	
	maru	2.657 **	-2.657 **		2.479 *	-2.479 *	
	mincho	-3.038 **	3.038 **		1.461	-1.461	
Random characters	walnut	1.771 +	-1.771 +	0.419 **	0.000	0.000	0.506 ***
	cashew	-0.327	0.327		-2.363	2.363	
	maru	1.248	-1.248		2.921 **	-2.921 **	
	mincho	-2.070 *	2.070 *		-0.354	0.354	

In summary, the following conclusions are drawn from the evaluation experiment for now.

- Typefaces affect both objective and subjective measures of readability and legibility,
- Impacts of typefaces on subjective readability are easier to observe,
- Readers with dyslexia consider *LiS Font walnut* more readable in both text and random characters,
- Readers without dyslexia consider Hiragino Maru Gothic more readable in both text and random characters,
- Symptoms of dyslexia may affect subjective readability of readers with dyslexia.

These conclusions indicate the efficacy of *LiS Font* and the validity of the requirements for Japanese typefaces designed for readers with dyslexia. In the meantime, the results show that readers with different symptoms of dyslexia may perceive varying characteristics of typefaces as readable and/or legible, thus implying the necessity of a typeface customisation system in order to meet the needs of readers with different symptoms of dyslexia.

We will report our progress regarding the customisation system in the next section.

3 A Japanese Typeface Customisation System for Readers with Dyslexia

The aim of our research in this phase is to develop a Japanese typeface customisation system that enables readers with dyslexia to adjust the elements of typefaces within a certain range to fit their own symptoms.

At the moment we are at an early stage of this phase and are conducting a review on related studies and projects. Also we have made an initial prototype of this system, which will be developed as a cross-platform web application, with Python.

3.1 Related Work

The history of programmatic type design goes back to the fifteenth century (Knuth, 1999), and the practice flourished after the invention and spread of computers as Amado (2013) pointed out in his work of the timeline of font formats and production software.

We reviewed all the parametric systems for designing typefaces and 4 software for font production that can be extended by scripting (FontLab Studio, FontForge, Glyphs, and RoboFont) listed in Amado (2013) along with more recent projects (RoundingUFO, Metaflop, Metapolator, Project Faces, Variable Fonts, and FontLab IV) and projects regarding Japanese typefaces (Tanaka (1992), Yamamoto (2003), Kamichi (2007)). Table 6 shows a list of projects we reviewed.

Table 6 Related work

Year	Work	Developers	Approaches
1967	ITSYLF	Mergler and Vargo	Outline and skeleton (Mergler & Vargo, 1968)
1975	CSD	Coigneaux	Outline and skeleton (Ruggles, 1983)
1979	METAFONT	Knuth	Skeleton (Knuth, 1986)
1991	Multiple Master	Adobe Inc.	Outline (Adobe, 2004)
1992	Font Chameleon	Ares Corp.	Outline
1992	Tanaka (1992)	Tanaka	Skeleton and parts (Tanaka, 1992)
1993	InfiniFont	McQueen and Beausoleil (ElseWare Corp.)	Outline (McQueen & Beausoleil, 1993)
1993	FontLab Studio	SoftUnion and Pyrus (now Fontlab Ltd.)	Outline
1994	TrueType GX	Apple Inc.	Outline (Rickner, 2016)
1996	Metatype	Vakulenko	Skeleton (Vakulenko, 2003)
1996	RoboFog	Petr van Blokland, van Rossum, and Erik van Blokland	Outline
1997	LiveType	Shammir and Rappoport	Outline (Shamir & Rappoport, 2006)
1998	DaType	Schneider	Outline and skeleton (Schneider, 1998)
2001	CPFPage	Hu and Hersch	Outline and skeleton (Hu & Hersch, 2001)
2001	FontForge	Williams	Outline
2002	Meek FM	Meek Design	Outline
2003	Elementar	Ferreira	Parts
2003	Font Remix Tools	Ahrens (Just Another Foundry)	Outline
2003	RoboFab	Erik van Blokland and van Rossum	Outline
2003	Yamamoto (2003)	Yamamoto	Skeleton (Yamamoto, 2003)
2006	Kalliculator	Berlaen (TypeMyType)	Skeleton (Berlaen, 2006)
2006	GlyphWiki	Kamichi	Skeleton and parts (Kamichi, 2007)
2007	Font Constructor	Berlaen (TypeMyType)	Parts
2007	Superpolator	Erik van Blokland (LettError)	Outline
2008	UFOstretch	Berlaen (TypeMyType)	Outline
2009	LetterModeller	Blokland (Dutch Type Library)	Skeleton (Blokland, 2016)
2009	Prepolator	Leming (Type Supply)	Outline
2009	RoundingUFO	Berlaen (TypeMyType)	Outline
2009	Glyphs	Seifert	Outline and skeleton

2011	RoboFont	Berlaen (TypeMyType)	Outline and skeleton
2011	Prototypo	Mathey and Babé (Prototypo)	Skeleton and outline
2012	Metaflop	Reigel and Müller (Metaflop)	Skeleton
2013	Metapolator	Egli and Crossland (Metapolator)	Skeleton
2015	Project Faces	Adobe Inc.	Skeleton and outline
2016	Variable Fonts	Adobe Inc., Apple Inc., Google LLC, and Microsoft Corp.	Outline
2017	FontLab VI	Fonrlab Ltd.	Outline and skeleton

From the review, it is revealed that each system adopts one or two approaches among three approaches, namely, manipulating outlines, manipulating skeletons, and assembling the parts, to designing glyphs. The review also shows that recent projects tend to adopt skeleton-based approaches, that theoretically originated from Noordzij (2005) and technically originated from Knuth (1986), and in regard to projects of Japanese typefaces, all of them adopt skeleton-based approaches.

Therefore the skeleton-based approaches will be the major candidate for developing the Japanese typeface customisation system for readers with dyslexia in our research.

3.2 Prototype

An initial prototype adopting skeleton-based approaches has been written with Python in DrawBot (van Rossum, van Blokland & Berlaen, 2019), as shown in Figure 13. The skeleton data of Japanese characters are from KanjiVG project (Apel & Quint, 2004), an open source project that describes skeleton of Japanese characters in vectorial data. We adopted a simple conversion algorithm of Beziér curves to give outlines to the skeletons.

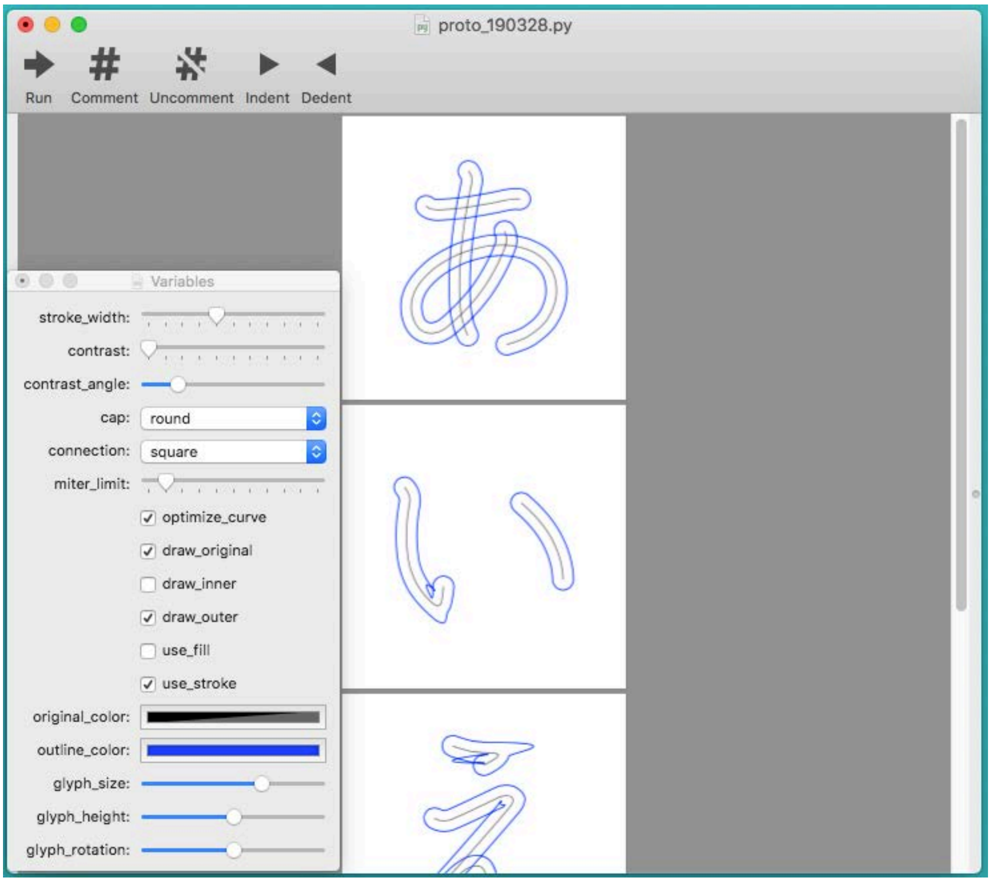


Figure 13. An initial prototype.

There is much to be done to develop the typeface customisation that truly helps readers with dyslexia.

4 Future Work

We intend to continue developing the typeface customisation system in future research, especially focusing on implementation of better conversion from skeletons to outlines. In the meantime, we will look into algorithms of manipulating glyph outlines in a typeface while keeping the characteristics of the typeface consistent, such as Campbell & Kautz (2014).

As for the requirements of Japanese typefaces for readers with dyslexia, besides continuing on evaluating their validity with empirical experiments and machine learning approaches, we will improve these requirements based on opinions from professional type designers.

Since the method of our research has good compatibility with other languages of East Asia and any languages with syllabaries or/and logographic writing systems, we have the intention to extend our research to those languages in future research.

References

Adobe. (2004). Multiple Master Fonts General Information. Retrieved from https://www.adobe.com/support/techdocs/328600.html

Amado, P. (2013). Font Formats Timeline. Retrieved April 22, 2019, from https://typeforge.wordpress.com/category/documents/history/

Apel, U. & Quint, J. (2004). Building a Graphetic Dictionary for Japanese Kanji—Character Look Up Based on Bruch Strokes or Stroke Groups, and the Display of Kanji as Path Data. In *Proceedings of the COLING 2004 Workshop on Multilingual Resources* (pp. 36–39).

Berlaen, F. (2006). *Kalliculator* (Master's thesis, Royal Academy of Art The Hague).

Blokland, F. E. (2016). *On the Origin of Patterning in Movable Latin Type* (Doctoral dissertation, Leiden University).

Campbell, N. D. F. & Kautz, J. (2014). Learning a Manifold of Fonts. *ACM Transactions on Graphics*, *33*(4), 1–11. doi:10.1145/2601097.2601212

Dehaene, S. (2009). *Reading in the Brain*. New York, USA: Penguin Books.

Field, A. (2009). *Discovering Statistics Using SPSS*. London: SAGE Publications.

Hillier, R. A. (2006). *A Typeface for the Adult Dyslexic Reader* (Doctoral dissertation, Anglia Ruskin University).

Hu, C. & Hersch, R. D. (2001). Parameterizable Fonts Based on Shape Components. *IEEE Computer Graphics and Applications*, *21*(3), 70–85.

International Dyslexia Association. (2002). *Definition of Dyslexia*. Retrieved April 2, 2018, from https://dyslexiaida.org/definition-of-dyslexia/

Japan Dyslexia Research Association. (2018). *Definition of Dyslexia [in Japanese]*. Retrieved April 22, 2019, from http://square.umin.ac.jp/dyslexia/factsheet.html

Kamichi, K. (2007). GlyphWiki: Construction of Wiki System for Kanji Glyph Management [in Japanese]. In *Proceedings of Jinmoncom 2007* (pp. 237–244).

Knuth, D. E. (1986). *The METAFONTbook*. Reading: Addison-Wesley.

Knuth, D. E. (1999). *Digital Typography*. CSLI Publications.

Marinus, E., Mostard, M., Segers, E., Schubert, T. M., Madelaine, A. & Wheldall, K. (2016). A Special Font for People with Dyslexia: Does it Work and, if so, why? *Dyslexia*, *22*(3), 233–244.

McQueen, C. D. & Beausoleil, R. G. (1993). Infinifont: A Parametric Font Generation System. *Electronic Publishing*, *6*(3), 117–132.

Mergler, H. W. & Vargo, P. M. (1968). One Approach to Computer Assisted Letter Design. *The Journal of Typographic Research*, *2*(4), 299–322.

Mizumoto, A. & Takeuchi, O. (2008). Basics and Considerations for Reporting Effect Sizes in Research Papers. *Study in English Language Teaching*, *31*, 57–66.

Morse, D. T. (1999). Minsize2: a Computer Program for Determining Effect Size and Minimum Sample Size for Statistical Significance for Univariate, Multivariate, and Nonparametric Tests. *Educational and Psychological Measurement*, *59*(3), 518–531.

Noordzij, G. (2005). *The stroke: theory of writing*. London, UK: Hyphen Press.
Okumura, T., Miura, T., Nakanishi, M., Tominaga, E., Wakamiya, E. & Tamai, H. (2018). Subjective Impression of Readability with UD Digital Font: A Pilot Study with Elementary School Children Who Have Reading and Writing Difficulty [in Japanese]. *Japanese Journal of Optometry and Ophthalmic Science*, *21*(2), 21–24.
Reid, G., Fawcett, A. J., Manis, F. & Siegel, L. S. (Eds.). (2008). *The SAGE Handbook of Dyslexia*. London: SAGE Publications.
Rickner, T. (2016). *Part 1: From TrueType GX to Variable Fonts*. Retrieved from http://www.monotype.com/blog/articles/part-1-from-truetype-gx-to-variable-fonts/
Ruggles, L. (1983). *Letterform Design Systems*. Stanford University.
Schneider, U. (1998). DaType: A Stroke-Based Typeface Design System. *Computers and Graphics*, *22*(4), 515–526.
Shamir, A. & Rappoport, A. (2006). Feature-Based Design of Fonts Using Constraints. *Lecture Notes in Computer Science*, *1375*, 93–108.
Smythe, I. (2010). *Dyslexia in the Digital Age: Making IT Work*. London: Continuum International Publishing Group.
Stein, J. (2008). The Neurobiological Basis of Dyslexia. In G. Reid, A. J. Fawcett, F. Manis & L. S. Siegel (Eds.), *The SAGE Handbook of Dyslexia* (pp. 53–76). London: SAGE Publications.
Stein, J. & Walsh, V. (1997). To See but Not to Read: The Magnocellular Theory of Dyslexia. *Trends in Neurosciences*, *20*(4), 147–152.
Tanaka, T. (1992). *Making Kanji Skeleton Fonts through Compositing Parts [in Japanese]* (Doctoral dissertation, The University of Tokyo).
Tani, N., Goto, T., Uno, A., Uchiyama, T. & Yamanaka, T. (2016). The Effects of Font Type on Reading Aloud in Japanese-Speaking Children with Developmental Dyslexia [in Japanese]. *The Japan Journal of Logopedics and Phoniatrics*, *57*(2), 238–245.
Vakulenko, S. (2003). The Metatype Project: Creating TrueType Fonts Based on METAFONT. *TUGboat*, *24*(3), 569–574.
van Rossum, J., van Blokland, E. & Berlaen, F. (2019). *DrawBot*. Retrieved April 22, 2019, from http://www.drawbot.com/
Yamada, S. & Zhu, X. (2018). A Research on Readable Japanese Typography for Dyslexic Children and Students: Creating Japanese Typefaces for Dyslexic Readers. *Bulletin of Center for Advanced School Education and Evidence-Based Research*, *3*, 50–70
Yamamoto, K. R. (2003). *Development of Kana Typeface Generated Using Stroke Data for Print Media [in Japanese]* (Master thesis, Keio University).
Zhu, X. (2016). Characteristics of Latin Typefaces for Dyslexic Readers [in Japanese]. In *Information Processing Society of Japan SIG CE Technical Reports* (Vol. 2016-CE-135, *4*, pp. 1–4).
Zikl, P., Bartošová, I. K., Víšková, K. J., Havlíčková, K., Kučírková, A., Navrátilová, J. & Zetková, B. (2015). The Possibilities of ICT Use for Compensation of Difficulties with Reading in Pupils with Dyslexia. *Procedia - Social and Behavioral Sciencesaa*, *176*, 915–922.

About the Authors:

Xinru Zhu: Xinru Zhu is a PhD student of the University of Tokyo, whose work on typefaces for readers with dyslexia has been awarded by the Information Processing Society of Japan, and is interested in investigating the role of visual design, especially typography and type, in communication.

Kyo Kageura: Kyo Kageura, PhD, is Professor of Library and Information Science Course at the Graduate School of Education and the Graduate School of Interdisciplinary Information Studies, the University of Tokyo. He has published extensively in the fields of information studies, terminology, computational linguistics and translation studies.

Acknowledgement: This research is supported by JSPS KAKENHI Grant Number 19J11843.

IASDR 2019
International Association of Societies of
Design Research Conference 2019
DESIGN REVOLUTIONS

Manchester School of Art
Manchester Metropolitan University
02-05 September 2019

RethinkAI™: Designing the Human and AI relationship in the Future of Work

Lalioti, Vali

Royal College of Art, School of Design, London, UK
vali.lalioti@rca.ac.uk

The innovation landscape is drastically changing due to the adoption of Artificial Intelligence (AI), as whole industries are incorporating AI into smart products and automated processes. Designing AI for industry 4.0 requires revolutionary thinking. It requires the emergence of new design paradigms that build designers' ability to navigate the ethical and socioeconomic issues that AI brings in the future of work. This research develops RethinkAI™ a new participatory design method to address this gap. The paper focuses specifically on how to design the relationship of humans and AIs working together.

RethinkAI™ builds an interactive, social way for designers and transdisciplinary teams to explore this relationship. It creates insights on how human and AI strengths can be designed together in a co-evolving relationship in the future of work. RethinkAI™ was designed, tested and refined through a series of three workshops. The method was evaluated in a final workshop with 24 multinational industry professionals, involved in the decisions of integrating AI into their products and processes. The paper analyses the results from its application. It explores how this participatory method can be a valuable and rich medium to stimulate new thinking into the current design paradigms of humans and AI systems interaction. The analysis indicates that the use of human strengths and participatory method can help develop designers' agency in surfacing and mitigating social and ethical issues when designing AI into products and services. The paper concludes with a reflection on current insights and direction of further research.

Keywords: new design paradigms; artificial intelligence; future of work; design innovation design; participatory methods; transdisciplinary design research

1 Introduction

Designing Artificial Intelligence (AI) for industry 4.0 requires revolutionary thinking, if it is to give back human agency and ability to navigate ethical and socioeconomic issues in the future of work (Huxley, 1957) (Bostrom, 2014). AI is bringing major changes in the nature of work as a result of rapid advances in machine learning and cognitive technologies. It brings strengths that create efficiencies and help solve problems at scale, enhancing cognitive and physical capabilities of humans in the future of work (McKinsey Global Institute, 2017).

Though the benefits are clear, there are a multitude of socioeconomic implications and ethical issues in AI design which are rapidly developing the complexity and characteristics of a “wicked problem” (Emmerson & Young, 2017).

These range, from concerns over job losses (Deloitte Review, 2017), the well-being of gig economy workers and dehumanisation of the augmented worker (Bhatnagar et al., 2018) to ethical issues rising from AI autonomy (Stewart, 2018) and dystopian futures from singularity (Medeiros, 2017). Dystopian narratives about AI are compelling and the calls to regulate and create policies that safe guard societal values are justified. This happened throughout human history, as our technologies evolved and changed how we work. During the first industrial revolution, for example, regulation for child labour was put forward through 1833's Factory Act.

1.1 Research Rational and Motivation

The goal of this research is to inform the design of work with Artificial Intelligence (AI) and to navigate forwards, beyond the polarized views and negative publicity of dystopian futures or the current positively over-hyped AI scenarios.

This paper focuses specifically on how to design the relationship of humans and AIs working together. It brings new ways on how to help designers explore this relationship, how to surface human and AI strengths and preferences on how these are combined when working together with AI. The ultimate aim is to stimulate new thinking into the current design paradigms of humans and AI systems interaction, to inform the design of human work with AI in a coevolving relationship.

As with the IoT and the need for new product development processes (Lee, Cooper, & Hands, 2018) there is a need to shift our design paradigm when designing AI in the future of work. As AI evolves, becoming more autonomous, our human-centred design paradigms also need to evolve and extend interaction and user experience design into designing the relationship with AI. This is why this paper's design research into methods and tools to explore and design the relationship between human and AI agents at work is significant.

1.2 Research Questions and Methods

The key research questions therefore addressed in this paper and contributing towards this broader vision are:

How can a design research exploration of the relationship of human and AI at work inform the design of work with AI?

Q1: What are the current issues in the relationship between the human and AI at work?

Q2: How can we research human and AI strengths coming together at work?

Q3: How can this research exploration surface human preference in AI design?

Q4: How can this research exploration inform the design of work with AI?

The research methodology brings together research in design through literature review and use of participatory research methods in workshops with business professionals (Sanders, 2006) (Sanders, 2008). Action research is used in an iterative approach, to plan, action, observe and reflect on the research (Eikeland, 2001), for each of the questions above, with each participatory workshop informed the design of the next workshop, as shown in Figure 1.

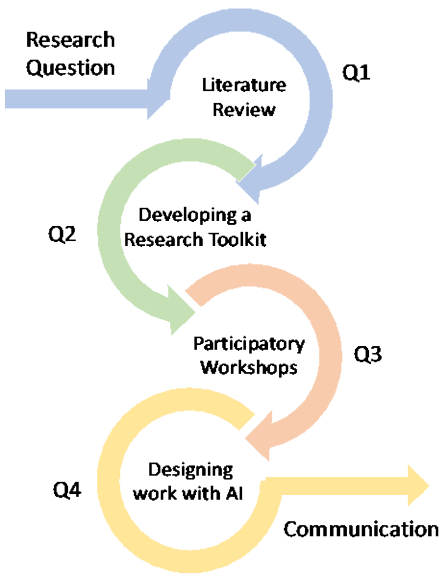


Figure 1. The Research Methodology combines research in design with research through participatory design practice, within an Action Research framework, to explore the four sub-questions, Q1, Q2, Q3 and Q4.

The participatory research kit, was developed as a glossary of human and AI strengths and designed as a game with 50 cards. It provides an interactive, social way to create insights in communication between designers and business professionals. The research frames the design of work with AI in a coevolutionary relationship of human and AI strengths working together. The participatory research approach was developed through a series of workshops with business professionals, including business coaches, MBA students and business managers from across different functions and diverse industries. The toolkit was evaluated and improved through an iterative design process. It was informed by extensive literature review on the wide range of challenges and ethical issues around AI and the future of work.

The participatory research approach is validated in a workshop with 24 Chief Finance Officers (CFOs) from a global steel corporation. CFOs are chosen because they are leading important decisions on how AI is integrated into work due to the economic drivers for AI use. It has been found that it enables the designer in communication with business decision makers, to build understanding of human strengths and challenges in our relationship with AI at work. It empowers participants to co-design AI in their work as a coevolving relationship between humans and AI. It stimulates a dialogue between designers and business professionals on how to design AI into human work.

The literature review is described in section 2 and the iterative design process and workshops are detailed in section 3 of this paper. Section 4 concludes with the future research directions.

2 AI and the future of Work

What are the current issues in the relationship between the human and AI at work?

From a technological perspective, AI is a computer program that learns by itself. There are, however, real issues with how AI learns. A key one is, that human biases are being passed on to AI algorithms, through the data sets that are used to train AIs. Google's image search engine categorising black faces as a gorilla is the most often cited example (Simonite, 2018).

Another key issue, is that of transparency of how AI algorithms are reaching their predictions and decisions, often referred to as the issue of "explainability". This is significant in view also of AI becoming autonomous. The first fatal accidents involving autonomous cars (Stewart, 2018) have surfaced new fears around AI autonomy and the recent Cambridge Analytica scandal has brought out questions on the drivers behind AI use (Tett, 2018). These concerns are also echoed by the broader AI community. For example, Mustafa Suleyman, co-founder and Head of Applied AI at DeepMind, Google's AI company, argues for "up-ending the processes by which technology is developed and deployed, and proposes new ways to ensure it contributes to greater economic and social justice around the world" (Suleyman, 2017).

Journalists posing as gig economy workers are gathering first hand experiences in companies such as Uber and Deliveroo of work conditions and ethical dilemmas (Bloodworth, 2018), raising awareness of the impact on human well-being (Rapacki, 2018). Smart devices, like Amazon's wristband (Olivia Solon, 2018) that facilitate workflows, connecting AI with the human worker, also spark concerns on the de-humanization and control of the worker. These inform the debate and raise questions on the kind of work relationship between human and AI we want to create (Bostrom, 2014)(Harari, 2018).

While regulations and policies for AI are drawn up, there is also a pressing need to build ownership and the agency of the decision makers in business, to understand and negotiate the ethics and challenges when integrating AI into human work. This also requires an evolution in our design paradigms. Matt Jones, principal designer for Google AI is advocating for a human-centred approach that designs our relationship with AI, beyond the industry's current design paradigms which stem from human-computer interaction methods and user experience toolkits (Koch, 2017) (Amico, 2017), advocating a collaborative relationship with AI (Jones, 2018) (Google, 2019).

Japan, for example, sees AI as the solution to its socioeconomic challenges resulting from its aging demographic. As Japan's prime minister said, "Japan has no fear of AI. Machines will snatch away jobs? Such worries are not known to Japan. Japan aims to be the very first to prove that growth is possible through innovation, even when a population declines" (Kharpal, 2017). Popular culture also with comic heroes like astro-boy (Schodt, 2007) has reinforced the "AI as a friend" relationship in Japan.

The strengths that AI brings are welcomed in Japan, as a solution to its ageing population which impacts its workforce. Japan has low levels of foreign workforce hence AI and its robotic materialisations are considered a solution and not a problem. The UK is seen job losses from robotic automation which are hitting the headlines and the well-being of human workers, thus AI strengths are perceived as replacing human strengths and agency. This results in also differences in the way AI strengths are designed into work and its acceptance in the society (Ito, 2018). The next section describes the participatory methods and iterative approach used in the research toolkit design.

3 Human-AI relationship in the future of Work

To explore this relationship, a card-based toolkit and a participatory method was developed. A participatory approach was chosen as it can open up a dialogue between designers and business professionals on how to design work with AI. This is in the form of four workshops with business professionals, involving them as co-creators in the design research process.

The participatory research artefacts, were designed as thinking tools, to help designers and participants research how human and AI strengths can come together at work. These were developed as a glossary of strengths, through the first workshop with business coaches (section 3.1). The participatory research approach was tested through the second workshop with MBA students (section 3.2) and refined in the third workshop with 20 business managers from across functions and industries (section 3.3). The final workshop evaluated the method and explored how it can be used to inform the design of work with AI in a business case workshop with a group of 24 executives from a global steel industry corporation (section 3.4).

3.1 Designing a participatory research toolkit

How can we research the relationship of human and AI strengths coming together at work?

If we are to design the work relationship between human and AI, as a coevolving, collaborative relationship, a good place to start is research into how humans work together. There is a plethora of organisational research tools, to explore and improve the dynamics of how humans work together. One category of these, focuses on individuals' strengths and how these might be brought together more effectively when working in teams. Some of the most researched and well proven ones, used by global corporations and NGOs are Myers-Briggs MBTI® (Myers-Briggs & Myers, 1980) (Jung, 1971) and Belbin® (Belbin, 2010).

Through this research in related organisational tools, an initial glossary of positive traits or strengths was developed. These were translated into a glossary of strengths and designed as a kit of coloured cards, with one word on each card, describing a human strength at work. Alternatives and complementarity of this glossary of words, was tested through a one-hour workshop with six business coaches, accredited to work with MBTI® and Belbin® typologies.

Figure 2. Developing a glossary of human strengths, designed as a set of 50 cards.

For this workshop, an initial set of coloured cards were complimented by blank cards, which the participated business coaches used to add words or change existing ones. For example, "bossy" which is used in (Shapiro, 2010), was changed to "assertive" and words such as "detailed" or "rigorous" became part of the glossary, as shown on the left and right images of Figure 2. The initial colours were blue, green, red and brown. The brown colour was changed to yellow and orange hues, because brown was perceived as dull to represent people's strengths, in comparison to the other colours (see central image in Figure 2). This resulted a kit of 50 coloured cards used as a form of participatory artefacts and a thinking tool throughout the research practice.

3.2 Testing the Design Research Kit

These participatory artefacts, were further tested in an hour-long workshop with a group of four, part-time MBA students at Westminster Business School. This group was chosen, as they are working managers and students at the same time and in the point of considering their future careers and work beyond the MBA.

After a short introduction on the future of work and how this might change because of AI, participants were invited to choose from the set of 50 cards the strengths that best describe them. The choice was restricted to 5 cards, as the intention is for participants to narrow down their selection to their most valued strengths. Participants were then asked to look at their cards and think which of these strengths AI could also have in the future. Participants dropped these strengths from their hands to a black board, as shown on lower right image in Figure 3. The black board was chosen because, according to the literature review, AI remains a black box, in terms of our understanding of how it reaches predictions and decisions.

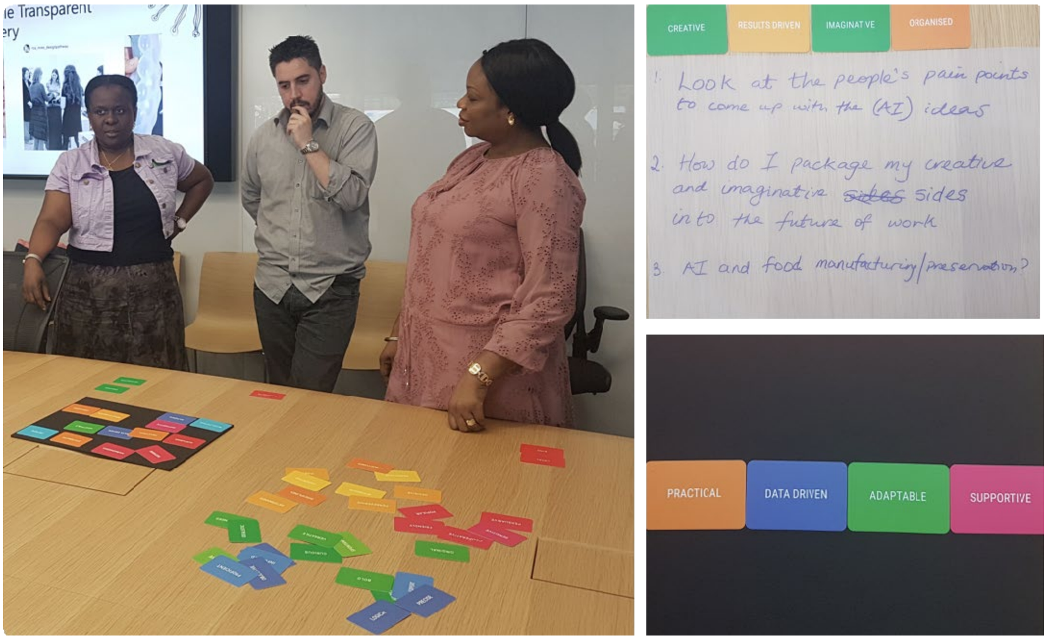
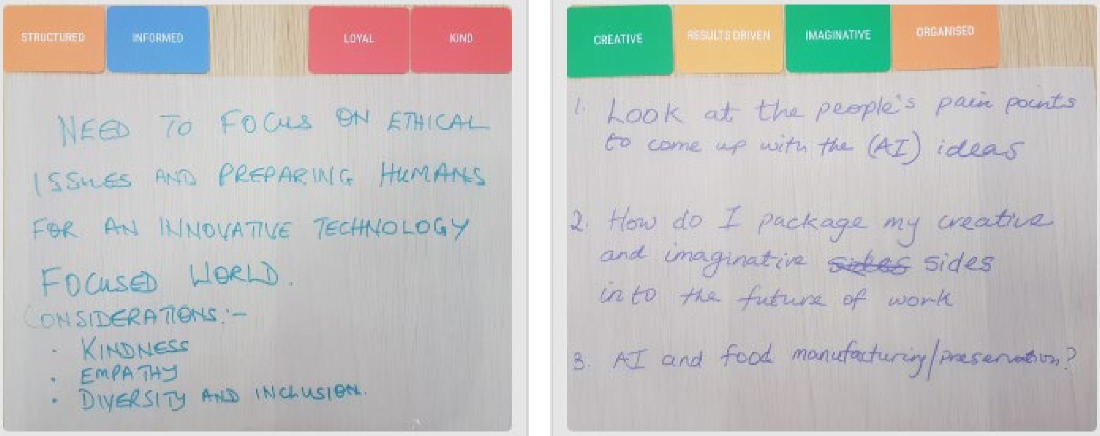


Figure 3. Participants reflect on AI strengths (left and bottom right) and their career options (upper right).

Participants discussed what it means for them and their own strengths and how they might develop these in the future. At the end participants were given time to write down how they might grow their strengths in their future careers working with AI, as shown in Figure 4. One participant, for example, decided to focus on their “kindness” and “empathy” to build their HR career on “diversity and inclusion”, while another chose to “package their creative and imaginative strengths” in their career in innovation in “food manufacturing and preservation.”

Key findings are: a) it enabled participants to surface their own strengths and which of these are most important to them, b) removing cards from their own strengths reinforced the negative, fear element about AI, c) participants needed a warm up step to familiarise themselves with the words on the cards, as presented all 50 of them was a lot of information to absorb as a first step and d) the reflective and group discussion time allowed rich insights into how participants view their future work with AI.



"I will focus on my kindness and empathy strengths to build my career in Human Resources on diversity and inclusion."

"I will package my creative and imaginative strengths in my career in innovation in food manufacturing and preservation."

Figure 4. *Participants' reflections on their strengths and how they can best use these in the future of work with AI.*

3.3 Refining the design research approach

How can this research exploration surface human preference in AI design?

The glossary and participatory research methods were further refined in a third workshop of one and a half hours long, with 20 business managers attending an Agile Management Conference. Based on the key findings from the previous workshop, a warm up game was introduced to familiarise participants with the words on the cards. Participants are split into groups of 5 to 6 people, each dealt with 5 cards. Participants first exchange cards with others in their group, to end up with five cards that best represent their strengths. The remaining cards are spread on the table with the words visible to all. Participants can drop a card from their hands and pick up one from the table, ending up with five cards that represent their most valued strengths.

Participants then choose from their own and the remaining cards on the table, the strengths that they would like AI to have, to work better together with them. These are placed on a black board, as before. Therefore, participants design the AI as "a board of strengths". They are given time to reflect and negotiate their own preferences and those of others in their groups into a final design. Groups present their AI designs, with time to reflect and debate their designs with other groups (see Figure 5).

AI designs across groups were different, shown in Figure 6. For example, one team designed AI as "Loyal, "Friendly, Supportive", because as the group articulated they would like to see, "AI as supportive to the user, so technology is a friendly access to services offered. AI is playing a supportive role." Another group designed their AI as "Analytical, Objective, Structured". They articulated that they prefer their AI to support them on analytical tasks and structuring their work, rather than as a friend: "we like to design AI to be friendly and supportive, but as a human if you have a machine that is supportive and empathetic, and you have a friend, where would you go? I would say, we would always go for the human."

Key findings are: a) framing this research as designing the AI they would like to work with, creates positive dynamics and energetic conversations, b) the warm up game helps participants familiarise with the glossary of strengths c) the group conversations and reflections allow participants to surface and debate their preferences and biases towards AI, building up rich insights for designers and d) empowers participants to become designers of their own AI, defining it through a set of strengths and according to what they would like AI to do for them in the future of work.

Figure 5. Participants design AI using the RethinkAI™ glossary of strengths and participatory research method.

"Supportive AI is good but if you have the choice of a machine and a friend, where would you go? I would say, we would always go for the human."

"AI is supportive to the user, so technology is a friendly access to services offered. AI is playing a supportive role."

Figure 6. Reflecting on human strengths in the future of work

3.4 Validating with industry - Designing work with AI

How can this research exploration inform the design of work with AI?

The fourth workshop was a half-day workshop with 24 Chief Finance Officers (CFOs) from a global engineering corporation. The participants were CFOs of national divisions within the multinational. CFOs are chosen because they are leading important business decisions on how AI is integrated into work, due to the economic drivers for AI use in business. The aim of the fourth workshop was to evaluate the research approach in a business case and test how a participatory approach can create ownership and agency to surface and negotiate the impact of human-AI issues resulting from these decisions. It further explored, how business professionals in communication with designers can use this research approach to design their work with AI, as a coevolving relationship.

The workshop started with capturing words that the CFOs associate with AI. These were used to benchmark and compare with change of attitudes towards AI at the end of the workshop. The initial words were centred around the technical and economic benefits of introducing AI and ethical issues, such as privacy, bias and job losses. These were in line with the literature review and the emphasis of organisations in using AI to maximise efficiency and automate processes to reduce costs.

The workshop proceeded by framing the introduction of AI together with the impact on humans and workflows, as a co-evolving relationship. The octopus was used as the metaphor for designing work with AI. The octopus's nervous system is distributed, with octopus tentacles so packed with neurons that it is as if there are "thinking" independently and with their bodies (Montgomery, 2015) (Godfrey-Smith, 2017). This distributed, embodied intelligence resembles more closely the way that AIs are integrated into our workflows and business systems, connecting with other AIs and learning from humans and large data sets distributed across businesses. This reframed the design of work with AI, as designing the human and AI strengths working together in a distributed and coevolving relationship (see Figure 7).

Participants first designed their AI as a black board of strengths, as in previous workshops, and then redesigned one of their finance functions to work with AI. AI integration in organisations is currently dealt with as a technical system integration. Conversations about the impact on human strengths, human workflows and jobs are typically addressed separately and as part of business transformation processes and Human Resources. Putting the human and AI on the same design framework, allowed the CFOs to go beyond the economics and efficiencies of AI integration. They debated what this AI integration means for the current teams and their own CFO roles.

They then designed three phases of the human-AI working relationship, based on the capabilities of the AI system in each phase: a) initial, b) learning and c) autonomous. The first phase is the introduction of AI, the second is the learning through humans and data and finally the phase of AI as more autonomous and able to make decisions. Participants used the cards to design the human and AI strengths in each phase and how these would work and evolve together as AI strengths change through these phases.

Figure 7.The Octopus metaphor in designing a collaborative and co-evolving relationship

They further debated ethical issues and reflected on job losses and skill changes, as well as a process for negotiating AI autonomous decision making and human control. Finally, they used the cards to reflect on what skills would be required which the teams currently lack and developed an initial plan to reskill and redeploy people in jobs. Due to commercial confidentiality the full details of the function and the solution cannot be disclosed.

Findings: a) the use of the research kit created again a dynamic, positive energy and produced rich insights for designing work with AI, further validating the contribution of this participative research approach b) it stimulated a dialogue about job changes and reskilling c) it helped participants debate ethical issues and to develop human agency in designing work with AI in communication with designers e) the HR Director who also attended the workshop suggested that the kit can also be used as a team building tool.

4 Discussion and further research

Recent studies on the impact of AI in the UK, estimate that AI will automate 7m jobs over the next 20 years, but also create 7.2m. AI revolution will work best when it complements human skills, and future jobs will rely on humans utilising unique strengths such as creativity and empathy (PwC, 2018). RethinkAI™ puts the human in the centre of designing work with AI. It aims to build ownership and human agency in designing our relationship with AI at work and to stimulate new thinking in our design paradigms. The paper describes the development of a participatory method and research kit, to help designers explore how human and AI strengths can be designed together in a coevolving, collaborative relationship.

The research kit is a glossary of human and AI strengths designed as a game with 50 cards. These were developed through an iterative design process and refined through a series of workshops with MBA students, Business Managers and Chief Finance Officers from the steel industry. Initial findings from the use of this participatory method show promising results. It is found to stimulate a dialogue between designers and business professionals on how AI and human relationship can be designed in the future of work. However, further quantitative and qualitative validation is needed, to build on current results and bring rich insights into the current design paradigms of human and AI interaction.

There are two research directions currently pursued: a) further validation with an ongoing research study within a postgraduate transdisciplinary design research educational context, complemented by quantitative data captured through a dedicated online app and b) a further investigation on how cultural differences affect AI design. The latter is currently explored through a UK/Japan collaboration, on differences in AI and human relationship in the two countries, to bring new thinking into current human and AI interaction design paradigms. Designing the Relationship of humans and AI at work remains a significant topic of research and the work presented in this paper is a timely investigation of this research topic.

5 References

Amico, L. (2017). Designing with AI. Retrieved March 11, 2019, from https://uniform.net/about/blog/designing-with-ai

Belbin, R. M. (2010). *Team roles at work*. Butterworth-Heinemann.

Bhatnagar, S., Cotton, T., Brundage, M., Avin, S., Clark, J., Toner, H., … Amodei, D. (2018). *The Malicious Use of Artificial Intelligence: Forecasting, Prevention, and Mitigation Authors are listed in order of contribution Design Direction*. Retrieved from https://img1.wsimg.com/blobby/go/3d82daa4-97fe-4096-9c6b-376b92c619de/downloads/1c6q2kc4v_50335.pdf

Bloodworth, J. (2018). *Hired : six months undercover in low-wage Britain*. Antlantic Books.

Bostrom, N. (2014). *Superintelligence : paths, dangers, strategies*. Oxford University Press.

Deloitte Review. (2017). *Navigating the future of work*. Retrieved from https://documents.deloitte.com/insights/DeloitteReview21

Eikeland, O. (2001). Action research as the hidden curriculum of the western tradition. In *Handbook of Action Research*. https://doi.org/0432

Emmerson, P., & Young, R. (2017). Taking aim at 'wicked problems' A practical philosophy for educating designers in the making of wise decisions. In *International Association of Societies of Design Research Conference*. Cincinnati. Retrieved from https://scholar.uc.edu/concern/articles/41687h449?locale=en

Godfrey-Smith, P. (2017). *Other minds : the octopus and the evolution of intelligent life*.

Google. (2019). PAIR – Google AI. Retrieved March 11, 2019, from https://ai.google/research/teams/brain/pair

Harari, Y. N. (2018). *21 lessons for the 21st century*. Vintage, Jonathan Cape.

Huxley, J. (1957). *Transhumanism*. Chatto & Windus.

Ito, J. (2018). Why Westerners Fear Robots and the Japanese Do Not | WIRED. Retrieved March 11, 2019, from https://www.wired.com/story/ideas-joi-ito-robot-overlords/?mbid=social_fb

Jones, M. (2018). Centaurs or Butlers? Designing for Human Relationships with Non-Human Intelligences - Artificial Intelligence Videos. AI Videos. Retrieved from https://www.artificial-intelligence.video/centaurs-or-butlers-designing-for-human-relationships-with-non-human-intelligences

Jung, C. G. (1971). *Psychologicqal Types: Collected Works of C.G. Jung*. Prinston University Press. Retrieved from http://www.taylorandfrancis.com/catalogs/jung_and_analytical_psychology_2013_online_catalog/4/

Kharpal, A. (2017). Japan has no fear of AI — it could boost growth despite population decline, Abe says. Retrieved March 11, 2019, from https://www.cnbc.com/2017/03/19/japan-has-no-fear-of-ai--it-could-boost-growth-despite-population-decline-abe-says.html

Koch, J. (2017). *Design implications for Designing with a Collaborative AI. The AAAI 2017 Spring Symposium on Designing the User Experience of Machine Learning Systems Technical Report SS-17-04 Design*.
Lee, B., Cooper, R. F. D., & Hands, D. (2018). Are Traditional NPD Processes Relevant to IoT Product and Service Development Activities ? A Critical Examination. In *Design Research Society Conference*. https://doi.org/10.21606/dma.2018.244
McKinsey Global Institute. (2017). *What is the future of work?* Retrieved from https://www.mckinsey.com/featured-insights/future-of-work/what-is-the-future-of-work
Medeiros, J. (2017). Exclusive Interview with Stephen Hawking. *WIRED*.
Montgomery, S. (2015). *The soul of an octopus : a surprising exploration into the wonder of consciousness*. Retrieved from https://www.simonandschuster.com/books/The-Soul-of-an-Octopus/Sy-Montgomery/9781451697711
Myers-Briggs, I., & Myers, P. B. (1980). *Gifts differing : understanding personality type*. Consulting Psychologists Press.
Olivia Solon. (2018). Amazon patents wristband that tracks warehouse workers' movements | Technology | The Guardian. *Guardian* . Retrieved from https://www.theguardian.com/technology/2018/jan/31/amazon-warehouse-wristband-tracking
PwC. (2018). *UK Economic outlook: What will be the next impact of AI and related technologies on jobs in the UK?* Retrieved from https://www.pwc.co.uk/economic-services/ukeo/ukeo-july18-full-report.pdf
Rapacki, K. (2018). Precarious by Design. *Disegno*, Vol. 19.
Sanders, L. (2006). Design Research in 2006. *Design Research Quarterly*. https://doi.org/10.1007/s10195-015-0335-1
Sanders, L. (2008). ON MODELINGAn evolving map of design practice and design research. *Interactions*. https://doi.org/10.1145/1409040.1409043
Schodt, F. L. (2007). *The Astro Boy essays : Osamu Tezuka, Mighty Atom, and the manga/anime revolution*. Stone Bridge Press.
Shapiro, S. M. (2010). *Personality poker : the playing card tool for driving high-performance teamwork and innovation*. Portfolio Penguin.
Simonite, T. (2018). When It Comes to Gorillas, Google Photos Remains Blind | WIRED. Retrieved February 15, 2019, from https://www.wired.com/story/when-it-comes-to-gorillas-google-photos-remains-blind/
Stewart, J. (2018). Tesla's Self-Driving Autopilot Was Turned On In Deadly California Crash. Retrieved February 15, 2019, from https://www.wired.com/story/tesla-autopilot-self-driving-crash-california/
Suleyman, M. (2017). RSA President's Lecture: The Technologist's Dilemma - RSA. Royal Society of Art and Manufacture (RSA). Retrieved from https://www.thersa.org/events/2017/11/rsa-presidents-lecture-the-technologists-dilemma
Tett, G. (2018, July 12). The Cambridge Analytica scandal echoes the financial crisis. *Financial Times*. Retrieved from https://www.ft.com/content/b21ffb20-85b1-11e8-96dd-fa565ec55929

About the Authors:

Lalioti, Vali: Vali has a high-profile career in academic and corporate research, with a PhD, Computer Science, MRes Design and an MBA. She worked in Europe, USA, Africa and Asia in senior posts in industry, national research institutes and as University Professor.

IASDR 2019

International Association of Societies of
Design Research Conference 2019
DESIGN REVOLUTIONS

Manchester School of Art
Manchester Metropolitan University
02-05 September 2019

Roles of 2.5D Interactive Scenario Prototyping in Digital Experience Design Practice and Education

Kim, Han-Jong; Nam, Tek-Jin*

Department of Industrial Design, KAIST, Daejeon, Republic of Korea
* tjnam@kaist.ac.kr

Digital experience design, involving various digital products, systems, and underlying services, has become a popular subject matter in design. Prototyping in the early stage is an important activity because it allows designers to concretize and deliver their ideas of future experiences. In digital experience design, however, prototypes are fragmented into diverse means, such as physical, visual, and sequential forms. In this paper, we present a 2.5D interactive scenario prototyping tool for facilitating the synthetic design of digital experience in the early phases. The tool allows designers to easily and rapidly create 2.5D interactive scenarios using 2D sketches (of spaces, artifacts, and mobile interfaces) and 3D character animations (for users' movements, gestures, and emotions) while specifying users' spatiotemporal journeys. We released the tool via public Web to readily support design practice and education. From the interview study with seven design experts, we identified the potential leverage of 2.5D interactive scenario prototyping that enables synthetic, synergic, and collaborative design. We then discuss further issues regarding the tool's engagement in design practice and education.

Keywords: digital experience, design scenario, prototyping tool, user experience, service design, expert interview

1 Introduction

Recently, subject matters of design have been diverse as various digital products and systems have appeared. The interactive products and systems have widely spread into our everyday lives so that we can enjoy beneficial and convenient experiences. Such experiences served by diverse digital artifacts involve not only the physical and virtual interfaces but also their underlying services. For instance, recent online-to-offline services (e.g., marketplaces, car-sharing, and hospitality) provide an experiential journey to users through various digital components, including mobile apps, kiosks, public displays, and smart sensors. To derive beneficial digital experiences for users, it is essential to envision the comprehensive experiences in the early conceptual design. How can we effectively concretize and deliver such sophisticated experiences?

In the service design domain, customer journey maps and service blueprints are common methods to illustrate specific experiences of target users. They, however, present difficulties in addressing the apparent and interactive aspects of service components for digital experiences. Buchenau and Suri (2000) presented *experience prototyping* that represents a process of conveying an experience with a product, system, and environment. Currently, prototypes for digital experiences have fragmented into various means according to the target purposes—for example, physical prototypes, interface mock-ups, service blueprints, and storyboards. It is necessary to discover an experience-prototyping tool for deriving integrated design deliverables involving interactive artifacts and service flows.

We focused on adopting scenario-based prototyping (Rosson & Carroll, 2002) to concretize and deliver digital experiences. In this paper, we present a scenario-prototyping tool, SketchStudio, for creating 2.5D interactive scenarios. The tool facilitates creating an interactive, animated scenario in a virtual world from spatiotemporal journeys, simple 2D graphics, and 3D character animations. Based on our previous study of the tool (Kim, Kim, & Nam, 2018), we revised SketchStudio to be ready to use for designing various experiential subjects involving interactive artifacts and service journeys. Specifically, we updated the tool to effectively support digital experience design by adding interactivity to users' experience flows; it also enables diverse scales of sketches from environmental features to mobile interfaces. The tool was implemented to be fully operated via public Web so that designers can freely use it (http://sketchstud.io).

This paper also presents implications of 2.5D interactive scenario prototyping in digital experience design through reflecting on SketchStudio. From interviews with seven design experts, we report the leverage and advantages of 2.5D interactive scenarios as well as improvement areas while understanding the nature of design practice and education. The interview study reveals that such scenario prototyping has the potential to facilitate the synthetic design of multiscale experiences regarding users, systems, interactions, and physical environments. It also presents the importance of symbiotic prototyping with other means to create synergies throughout the entire design process. We also found that the tool is applicable to effectively support the interdisciplinary nature of experience design. We further discuss issues regarding the tool's usage and adoption in design practice and education.

2 Related Works

2.1 Storyboard-based Prototyping in the Ubicomp Domain

In the ubicomp domain, one approach for envisioning complicated experiences involving ubiquitous systems is using storyboards instead of technical implementations. The storyboard metaphor allows designers to intuitively deal with the interactions by describing states and situations. *BrickRoad* (Liu & Li, 2007) and *Topiary* (Li, Hong, & Landay, 2004) are tools for simulating mobile interfaces for location-based systems using interactive storyboards controlled by Wizard of Oz technique. Li and Landay (2008) presented *AcitivityDesigner*, a prototyping tool for modeling human activities in which the interface transitions can be composed of storyboards and triggered by the activity events. *DemoScript* (Chi, Li, & Hartmann, 2016) adopts storyboard-based illustrations for prototyping cross-device interactions among mobile and wearable systems. The storyboards succinctly depict the conditions and responses of the system (Dow, Saponas, Li, & Landay, 2006) so that it has the potential to specify complex experiences within interactive systems. Previous prototyping tools focused on using 2D storyboards to manage the transitions of system states. We extend such a feature of storyboards to convey the comprehensive narrative of interactions in digital experiences implemented in a 2.5D virtual world.

2.2 Sketches in Interactive Prototyping

Sketches are a familiar means of prototyping for designers to concretize and deliver ideas rapidly at a higher representation level. Several design tools have attempted to enable sketches to depict the dynamic and interactive attributes of digital products and systems. *DEMAIS* (Bailey, Konstan, & Carlis, 2001) and *Anecdote* (Harada, Tanaka, Ogawa, & Hara, 1996) are sketching tools for designing the content and interface of interactive multimedia by using the metaphor of a 2D paper sketch. Beyond the context of media production, interactive sketches can be found in tools for software design or interactive product design. *SILK* (Landay & Myers, 2001), *DENIM* (Lin, Newman, Hong, & Landay, 2000), and *STCTools* (Nam, 2005) enable the rapid prototyping of interactive products by using sketches and their state transitions. These prototyping tools enable designers to compose high-fidelity interactive prototypes with only rough sketches, which have a similar purpose to paper prototypes. In this research, we adopted 2D sketches for visualizing people and artifacts as well as their states and interfaces. The transition of sketches is adopted to represent not only spatial configurations of environmental artifacts but also experiential contexts including behaviors and emotions.

2.3 Virtual 3D Prototyping for Interactive Simulations

Some studies have used 3D animations and simulations to visualize detailed experiences for large-scale systems and services. Winterbottom and Blake (2008) presented a tool for designing interactions in virtual 3D environments simulating complex interactions. It features a simple floorplan view and authoring scheme of sequence diagrams to construct the virtual interactive environment. Xu, Creighton, Boulila, and Bruegge (2012) adopted the virtual world platform *OpenSim* to create a design scenario on an airport scale. *DollhouseVR* (Ibayashi et al., 2015) is a collaborative interior design system that supports real-time immersive review with virtual reality. In several studies, the *Unity3D* game engine was adopted for building- and city-level designs (Cristie, Berger, Bus, Kumar, & Klein, 2015; Kumar, Hedrick, Wiacek, & Messner, 2011). These virtual prototyping techniques are inefficient in the early design phases because constructing virtual 3D content requires significant time and effort, involving 3D asset modeling and programming. In this research, we applied 2.5D interactive scenarios in virtual worlds, using simple 2D sketches and premade 3D human characters, to support rapid prototyping for large-scale subjects.

2.4 Animatics Design

This research is related to the techniques conveying experiential narratives, which is called animatics design. Several commercial tools exist for creating animatics and storyboards for comics, animations, and films. Clip Studio Paint[1] is a professional drawing tool for comics that includes a specialized feature for 3D assets for human poses. Toon Boom Storyboards Pro[2] provides frameworks for organizing flow and camera walk for creating animations. ComiPo[3] supports the rapid creation of comic-style storyboards using blending 3D characters, background images, and visual effects. Some storyboarding tools, FrameForge[4] and PowerProduction Storyboard[5], enable filmmakers to rapidly produce storyboards using

[1] CELSYS, Inc. Clip Studio Paint. Retrieved from https://www.clipstudio.net

[2] Toon Boom Animation Inc. Storyboard Pro. Retrieved from https://www.toonboom.com/products/storyboardpro

[3] Web Technology Corp. ComiPo. Retrieved from https://www.comipo.com

[4] Innoventive Software, LLC. FrameForge 4. Retrieved from https://www.frameforge.com

[5] PowerProduction Software. Storyboard Apps. Retrieved from https://www.powerproduction.com

premade 3D actors and props before actual shooting. Several studies support designers in creating interactive and immersive animatics. Henrikson, De Araujo, Chevalier, Singh, and Balakrishnan (2016a) presented a multi-device storyboarding system for the early sketches of cinematic narratives in virtual reality. It adopted concentric cylinders as a sketching plane for rendering panoramic storyboards. *Storeoboard* (Henrikson, De Araujo, Chevalier, Singh, & Balakrishnan, 2016b) enabled the creation of early animatics for stereoscopic media by using multiple stacked planes. These offer the ability to provide an immersive review of early narratives with 3D attributes.

The aforementioned tools facilitated the creation of animatics and storyboards to deliver a certain narrative. However, they involved fewer considerations regarding the spatial conditions and dynamics of users and surroundings to be used for digital experience design. In our research, we aimed to concretize and deliver narratives dealing with entire contexts, including the details of spatial layouts and simultaneous interactions among people and digital artifacts.

3 Revised SketchStudio for Digital Experience Design

To support the early conceptual design of digital experiences, involving multiple users and digital artifacts, we present SketchStudio, an exemplary scenario prototyping tool. It is a Web-based tool for rapidly creating a 2.5D interactive scenario using simple 2D sketches and 3D human characters (Figure 1). It was evolved from our previous study (Kim et al., 2018) to be usable in actual design practice and education. We also revised the previous version with new features to effectively support scenario prototyping in digital experience design. SketchStudio was released for free use on the following domain in August 2018: http://sketchstud.io.

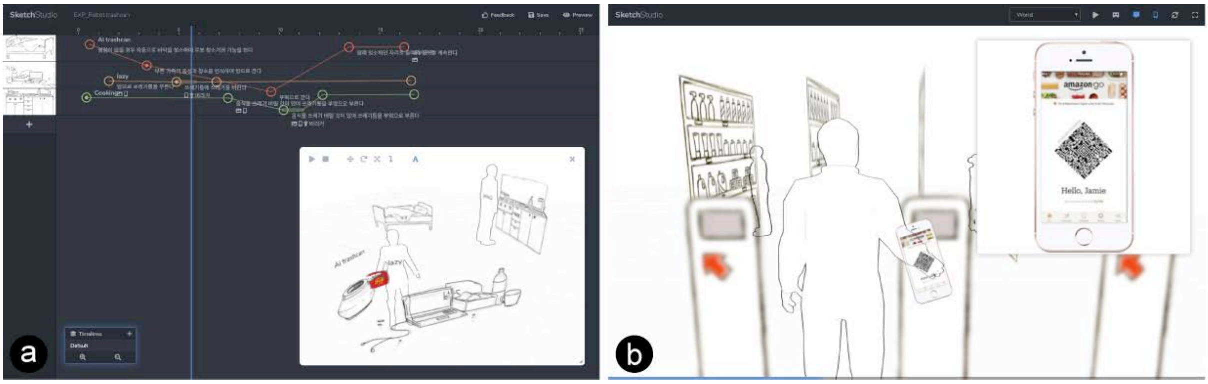


Figure 1. Snapshots of SketchStudio*: (a) the Editor and (b) the Viewer applications.*

3.1 Update of System Features

The previous version of SketchStudio (Kim et al., 2018) was designed to compose a virtual animated scenario by defining the spatiotemporal journey with a node graph. Blending of 2D sketches and 3D character animation was adopted for effective construction and visualization of a virtual 2.5D space. It also allowed designers to experience the created scenario using virtual reality in early conceptual stages. Based on the previous study, we identified several limitations in the expressiveness of experiences, including in representing small artifacts or precise actions. We designed and implemented several additional features for SketchStudio for digital experience design. The new version supports *keyframe-based* *pose editing*—instead of recording with the mobile interface—to get detailed actions for human characters. It also supports *portable sketches* for representing small, handheld artifacts including mobile devices carried by users. Moreover, the new version allows designers to assign interactivity to scenario streams so that they can explore various alternatives within a scenario prototype. The tool's interface was also updated to integrate fragmented components into two main applications—the Editor and Viewer (as shown in Figure 1)—for better work efficiency. The details of five key features and how they were updated in the scope of this work are described in Table 1.

Table 1. Five key features of SketchStudio

Features	Details	Updates
Spatiotemporal Experience Authoring	This enables specifying a spatiotemporal experience flow using node graphs (Figure 1a). A node, located on time-object dimension, represents which person interacts with which object at which moment. The system automatically generates an animated scenario according to the composed node graphs.	Same as the previous version.
Active 2.5D Sketches	To construct a scenario scene rapidly, simple 2D sketches can be located in 3D virtual space. The sketches can be continuously replaced for dynamic representation of artifacts (interface) and people (context), as shown in Figure 2b.	Drawing a portable sketch representing a handheld-sized artifact was added (Figure 2c).
Hybrid Action Creation	This supports creation of high-resolution character animation with two modes: rigging with virtual joysticks and keyframe-based pose editing. The created actions can be assigned to the node and triggered while playing the scenario.	The action-creating application was integrated into the main Editor application.
Interactive Scenario Stream	This adopts a stacked timeline, inspired by the concept of the parallel universe, for assigning interactivity to the animated scenario. It switches the timelines to make one visible according to the decision at a specific moment (Figure 2a). This approach has been used in interactive storytelling for various media such as games and films (Glassner, 2004; Miller, 2014).	Newly added.
Immersive VR Playback	This renders the virtual scenario in the third-person view while chasing the target human character (Figure 1b). Using Google Cardboard with a smartphone provides an immersive experience to review the initial ideas from the potential stakeholders' perspectives.	Same as the previous version.

3.2 Prototyping Steps.

Scenario prototyping with SketchStudio consists of five major steps: creating spatial objects, composing spatiotemporal experiences, specifying states, adding interactivity, and playing the scenario. The overview of the prototyping steps is illustrated in Table 2 and Figure 3. Figure 3 shows the process to create an exemplary digital experience scenario, a smart ordering service (illustrated in Figure 2)—related to kiosks and smartphones—in a café.

Table 2. Activities in prototyping steps

Steps	Activities
Creating Spatial Objects	• Drawing sketch objects and locating them in virtual 3D space.
Composing Spatiotemporal Experiences	• Composing a node graph for each human character. • Specifying the characters using sketches.
Specifying States	• Creating character actions and assigning each action to the composed nodes. • Assigning sketches to each node to visualize contextual information around a human character. • Assigning portable sketches to each node to represent states of small-scale handheld artefacts. • Adding overlaid sketches for visualizing states of the sketch objects at specific moments.
Adding Interactivity	• Composing the alternative timeline streams. • Adding triggers at certain moments for shifting timelines
Playing the Scenario	• Playing the created scenario while navigating the virtual 3D space. • Selecting a human character to follow during playback. • Using Google Cardboard for an immersive experience from the target character's viewpoint.

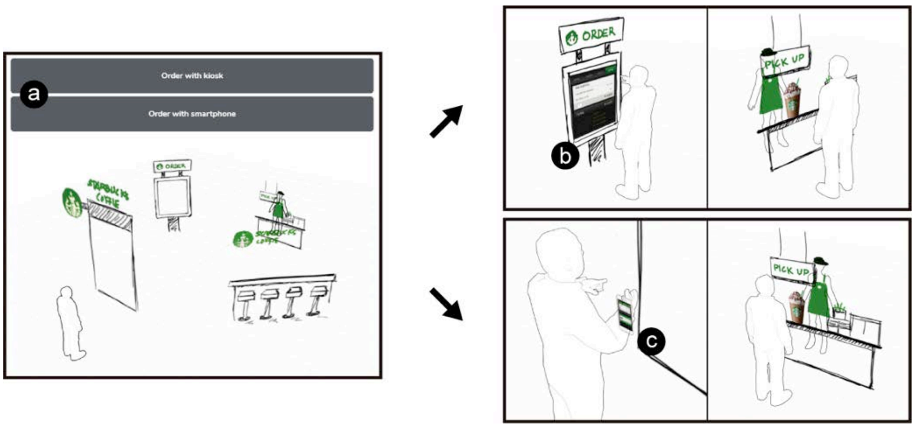


Figure 2. Exemplary digital experience scenario of smart ordering service created by SketchStudio.

4 Roles of 2.5D Interactive Scenario Prototyping

After releasing SketchStudio, it was necessary to discover how the tool can be actively adopted in real design activities. The goal of this study was to understand the roles of 2.5D interactive scenario prototyping in digital experience design practice and education. We interviewed design experts to identify potential leverage and advantages of such prototyping in real contexts through reflecting on the exemplary tool. The design experts including practitioners and professors described several strategies the tool can involve in design practice and education regarding digital experiences.

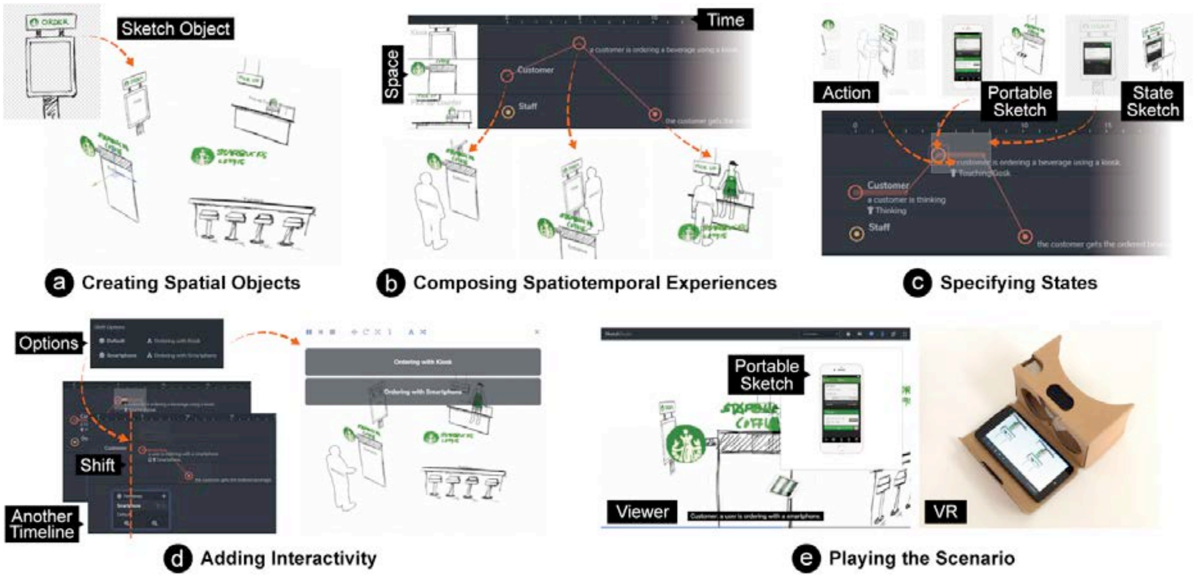


Figure 3. How a 2.5D interactive scenario can be created using SketchStudio.

4.1 Design Experts

Seven design experts were recruited for the interviews. Four were professional design practitioners at a design agency, working across the domains of strategy, product innovation, and user experience. Three were professors in universities' design-related departments, involving service design, interactive product design, and design-convergence innovation. The experts had commonly experienced various design projects related to envisioning future digital experiences using various design methods and tools.

4.2 Method

We carried out in-depth interviews with the design experts at their workplaces. The experts briefly explained their working and teaching approaches in terms of methods and tools in early conceptual design. We then introduced SketchStudio's key features and demonstrated them with several example scenarios regarding conceptual digital experiences. The main topic of the interview was the tool's applicability for resolving existing challenges in real design practice and education. We also asked about the expected application domain and further improvement areas of the tool. The interviews (which took 30-60 minutes each) were transcribed and analyzed through thematic analysis. Each theme was synthesized as roles and potential leverage of interactive scenario prototyping for digital experience design in practical contexts.

4.3 Findings

4.3.1 Synthesizing Multi-Scale Experiences

Nowadays, designers should consider how successive experiences can be delivered beyond the apparent aspects of products and interfaces. SketchStudio was regarded as having great potential for simultaneously dealing with multi-scale aspects involving the environment, components, and dynamics. D1 mentioned, "*Such animation is really necessary in a phase of composing entire scenarios, including, for example, getting on a plane, showing a ticket, finding a seat, and putting baggage in the overhead bin.*" Conventional service-design methods can concretize an experiential flow according to touchpoints, but they lack the visualization of the overall composition of physical artifacts and surroundings. L1 remarked on the importance of synthesizing space, journey, and interactions: “*Here we can talk about the scene, while it shows the journey there. It also describes detailed interactions. It is very important to explain all the different scales at the same time.*”

Synthesizing multi-scale aspects of a digital experience can provide benefits to designers in various domains. A typical role of an interactive scenario is supporting intuitive communication through detailed animation including spatiotemporal dynamics and visual transitions. Creating such a scenario, however, is a resource-heavy activity. It is necessary to explore new tools that can allow designers to represent complicated dynamics on scales of space, interaction, and interface at a single glance. Beyond communication, such synthetic design can provide an advantage for idea concretization. Designers should consider numerous aspects to envision digital experiences. Sometimes, they might miss some aspects while focusing on the details of interaction or aesthetics. Creating and reviewing an interactive scenario can allow designers to naturally consider multi-scale aspects at the same time. D2 said such activities can be beneficial to prospective designers: “*It forces students to think about what the service concept is and how the service flow occurs. They should always create a scenario with the spatial context in mind.*” In line with the previous studies on scenario-based design (Dow et al., 2006; Rosson & Carroll, 2002), 2.5D interactive scenarios would play a great role for establishing high-level goals in user experience design.

4.3.2 Building Symbiotic Relationships with Other Means

Scenario prototyping can be actively adopted in the early phase of design. SketchStudio was designed to enable scenario creation using rough sketches and the basic journey in the early phases. Compared to other methods and tools, deriving visually intuitive deliverables from low-fidelity means can provide a significant advantage in the conceptual design. D2 said, “*Anyway, I have to think about which scene to show using only one cut image in the storyboarding phase… But this has the advantage of creating rough animation very quickly.*” However, the conceptual design phase is relatively short in the entire design process. The experts mentioned that designers highly value tools of which the results can be used throughout the entire process. D1 said, “*For this to be competitive, ensure users know their first effort will be used continuously until the final presentation.*”

One possible approach to extend a tool’s engagement is to adopt various prototyping means according to the design process. For example, scenario prototypes can involve various high-fidelity visual elements including product renderings, interface mock-ups, and real-world photos. The experts mentioned that scenarios have often been used for final presentations although they are not a core deliverable. Scenario prototypes can be naturally evolved with other visual assets produced during a design process. D2 commented, “*If an animation is necessary as a final result, I can roughly sketch it first, and the only task I have to do later is replacing cast images.*” We also figured out that it is difficult to support all important design work in a single tool (Houde & Hill, 1997). To derive higher fidelity for scenarios, SketchStudio can import external image files, and the experts strongly suggested building synergy with an interface design tool (e.g., Sketch[6] and Adobe XD[7]). Building symbiotic relationships with specialized tools can be one of the promising strategies for adopting 2.5D interactive scenario prototyping.

[6] Bohemian B.V. Sketch. Retrieved from https://www.sketchapp.com

[7] Adobe. Adobe XD. Retrieved from https://www.adobe.com/products/xd.html

4.3.3 Reflecting the Interdisciplinary Nature of User Experience Design

Most of the experts responded that scenario-prototyping tools, such as SketchStudio, would be more effective if used by interdisciplinary teams than by professional designers. The professional design practitioners can instead use rough sketches and storyboards, which is enough to represent and understand ideas, so as to rapidly move toward the next stage. Meanwhile, user experience design for innovative products and services is usually carried out by an interdisciplinary team, so rich visualization is essential for communication with non-designers (e.g., persuading engineers and researchers or building a shared goal) in collaborative situations. D3 said, reflecting on her previous experience, "*It was very challenging to verbally convince technology teams of the flows of how to interact with the displays and how to reach the goods.*"

In addition to communication, scenario-prototyping tools can be applicable to non-designers' conceptual designs. In the industry today, lots of professionals who are not trained as typical designers are already active in various innovative projects for digital experiences. Such innovative thinkers often have difficulty visualizing their ideas. The experts highly valued SketchStudio regarding scenario creation blending 3D human characters and simple 2D images. D1 said, "*It is a very good tool for designers who have a lot of ideas but feel anxious about rendering them by hand.*" D2 added, "*For nonexperts who cannot sketch at all, it is very effective in terms of doing what they could not do before.*" To support such users, it is necessary for design tools to provide various resources for rapid prototyping. Many commercial design tools already provide various templates and high-quality premade assets for beginners. Scenario prototyping tools might be actively adopted when designers, especially nonexperts in visual representation, can get better results with less effort than they expected.

5 Discussion

From the interview study, we identified the expected roles of 2.5D interactive scenario prototyping in digital experience design practice and education. Table 3 depicts the identified leverages and limitations of rapid prototyping using 2.5D interactive scenarios. While covering the implications from the experts, there are also practical issues to be considered to facilitate the usage of SketchStudio.

Table 3. Leverages and limitations of SketchStudio

Aspect	Leverage	Limitation
Subject	Synthesizing design aspects of digital experience involving environment, components (products and interfaces), and dynamics	Lack of considering numerous, detailed circumstances derived from interactions among various users and components
Means	Supporting rapid creation of intuitive, interactive scenarios with rough sketches and animations	Relatively short lifetime of rough conceptual scenario prototypes as compared with the entire design process
Usage	Helping non-designers and interdisciplinary teams to effectively design digital experiences	Need for various templates and high-quality premade assets for beginners

5.1 Aspects to Be Synthesized

The experts stressed the synthesis of multi-scale aspects of user experience. We explored visualizing various aspects of digital experience for creating 2.5D interactive scenario prototypes using our tool. Three designers created several scenario prototypes to envision future products and systems using our tool. Based on them, we discuss how the tool can represent various aspects of scenario prototyping.

5.1.1 Sketches: Appearances and Interfaces

The sketches were originally adopted as a means to represent apparent changes of spatial objects. Background sketches and overlaid state sketches can be used to represent visual aspects, including the look and feel of physical artefacts themselves as well as their interfaces (e.g., physical buttons and screens). Such sketches can also be used to illustrate invisible information, such as the auditory response of systems (Figure 4a). Sketches are flexible means, so that one can be emphasized with color and quality to distinguish from others. Thus, they can be used in different fidelities to effectively indicate the dynamics throughout the scenario scenes.

5.1.2 Scripts: Contextual Information

In addition to visual aspects, implicit information can play a great role to deliver sophisticated contexts for scenario prototypes. For instance, speech and thought bubbles (Figure 4b), which are often used in conventional storyboarding, can deliver conversations among people as well as the emotional states of users. In SketchStudio, sketches involving in human characters have the potential to express scripts for supplementing the implicit experiential context instead of visualization of the physical surroundings.

5.1.3 Gestures: Interactions and Manipulations

Animated actions, carried out by 3D human characters, can be used to describe interactions with a certain object, as shown in Figure 4c. They can intuitively illustrate gestural interactions including mid-air and touch gestures. When they are combined with appropriate sketches (e.g., handheld devices), the experiences of usage can be effectively represented. However, the actions are limited in accurately delivering a user's manipulation in terms of expressiveness. For instance, it is challenging to precisely represent which button on the screen was selected using the character actions.

5.1.4 Movements: Spatiotemporal Dynamics

In scenario prototyping, locations of elements and their spatial relationships are significantly important. The close gathering of people and artifacts can represent a situation of their interactions. Such spatial grouping can be composed as a single event—like a scene in storyboarding—to manage the experience flows. Each grouped location can signify distinct experiences, like touchpoints in service design (Figure 4d). The movement of people can manifest the flow of experience along such groups. Meanwhile, the movement can also play a role to ventilate the surroundings. For instance, conceptual stages, which do not reflect the realistic distances, can also be located in virtual space to represent scenario flows.

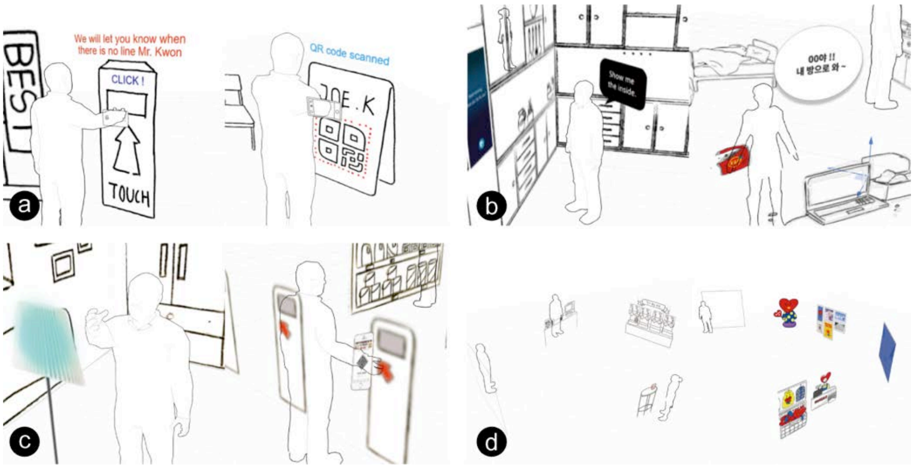


Figure 4. Aspects of scenario prototypes visualized using SketchStudio:
(a) invisible information, (b) speech bubbles, (c) gestural interactions, and (b) spatial groups.

5.2 Applicable Domains

5.2.1 Reflective Design Education

Scenario prototyping has a great potential to be used as a means for training design. As the experts mentioned, scenario creation through considering various aspects can let students naturally learn how to deal with multi-scale perspectives. It also helps students keep understanding target users in reflective design activities. Meanwhile, the design scenario itself can be an effective medium for communication in educational contexts. Conventional university design courses involve design critiques in which an instructor discusses deliverables with a group of students. In such a critique, the interactive scenario prototypes can be used to precisely deliver ideas and stimulate constructive discussions. It is necessary to investigate the impact of interactive scenario prototyping through further case studies of actual design courses.

5.2.2 Appropriate Design Subjects

We present SketchStudio for scenario prototyping of digital experiences involving multiple users and digital artifacts. A promising subject is a smart environment (e.g., smart homes and public facilities) that involves various smart devices and multi-user interactions in a certain physical space. A scenario prototype is one of the most flexible and versatile means for design, so our tool also has the potential to be adopted for various design domains. Another possible application domain is layout design, including interior design and architecture. Beyond considerations of technology, the feature of configuring spatial attributes itself, involving the movement of people and the placement of objects, can be useful for the initial design of such spatial subject matter. In addition, our tool can be used for narrative design, such as film, theater, and performance. Such subjects also involve actors and stages that can be rapidly concretized using our tool. The scenario-prototyping tool is expected to enhance communication between producers and staff in rapid and intuitive ways, compared to conventional storyboards and animatics.

5.3 Limitations and Future Works

In this research, we deployed a usable prototyping tool for creating 2.5D interactive scenarios and investigated its roles and applicability. Based on the interview study, we identified several directions for improving our tool. To support effective scenario prototyping, future works to find a connection with other visual design tools and to develop useful, exemplary assets can be considered. Meantime, this study has a limitation in evaluating the actual impact of the tool in practical domains. The experts partially used the tool during the limited interview time and then discussed while reflecting on their previous experiences. It is necessary to evaluate the tool's capability and usability as in other tool design studies. For the next step, a further study investigating case studies regarding how the tool can affect designers and their activities in the wild can be carried out.

6 Conclusion

In this paper, we present a 2.5D interactive scenario prototyping tool for digital experience design practice and education. The tool enables designers to concretize and deliver ideas of such experience involving multiple users and artifacts using 2D sketches and 3D human characters in a virtual world. This work reveals the practical roles and potential leverage of 2.5D interactive scenarios from the interview study with design experts. We also discuss further issues for the tool's applicability and engagement regarding scenario prototyping. This work contributes to design by providing a readily usable tool for various experience design projects. We expect that this tool and implications from the study will benefit digital experience design for future products, systems, and services.

7 References

Bailey, B. P., Konstan, J. A., & Carlis, J. V. (2001). DEMAIS: Designing Multimedia Applications with Interactive Storyboards. In *Proceedings of the Ninth ACM International Conference on Multimedia*, 241–250. ACM. doi: 10.1145/500141.500179

Buchenau, M., & Suri, J. F. (2000). Experience Prototyping. In *Proceedings of the 3rd Conference on Designing Interactive Systems: Processes, Practices, Methods, and Techniques*, 424–433. ACM. doi: 10.1145/347642.347802

Chi, P.-Y. (Peggy), Li, Y., & Hartmann, B. (2016). Enhancing Cross-Device Interaction Scripting with Interactive Illustrations. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, 5482–5493. ACM. doi: 10.1145/2858036.2858382

Cristie, V., Berger, M., Bus, P., Kumar, A., & Klein, B. (2015). CityHeat: Visualizing Cellular Automata-based Traffic Heat in Unity3D. In *SIGGRAPH Asia 2015 Visualization in High Performance Computing*, 6:1–6:4. ACM. doi: 10.1145/2818517.2818527

Dow, S., Saponas, T. S., Li, Y., & Landay, J. A. (2006). External Representations in Ubiquitous Computing Design and the Implications for Design Tools. In *Proceedings of the 6th ACM Conference on Designing Interactive Systems*, 241–250. ACM. doi: 10.1145/1142405.1142443

Glassner, A. (2004). Interactive Storytelling: Techniques for 21st Century Fiction. A K Peters/CRC Press.

Harada, K., Tanaka, E., Ogawa, R., & Hara, Y. (1996). Anecdote: A Multimedia Storyboarding System with Seamless Authoring Support. In *Proceedings of the Fourth ACM International Conference on Multimedia*, 341–351. ACM. doi: 10.1145/244130.244235

Henrikson, R., Araujo, B., Chevalier, F., Singh, K., & Balakrishnan, R. (2016a). Multi-Device Storyboards for Cinematic Narratives in VR. In *Proceedings of the 29th Annual Symposium on User Interface Software and Technology*, 787–796. ACM. doi: 10.1145/2984511.2984539

Henrikson, R., De Araujo, B., Chevalier, F., Singh, K., & Balakrishnan, R. (2016b). Storeoboard: Sketching Stereoscopic Storyboards. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, 4587–4598. ACM. doi: 10.1145/2858036.2858079

Houde, S., & Hill, C. (1997). What Do Prototypes Prototype? In *Handbook of Human-Computer Interaction (2nd Ed.)*, 367–381. North-Holland. doi: 10.1016/B978-044481862-1.50082-0

Ibayashi, H., Sugiura, Y., Sakamoto, D., Miyata, N., Tada, M., Okuma, T., … Igarashi, T. (2015). Dollhouse VR: A Multi-view, Multi-user Collaborative Design Workspace with VR Technology. SIGGRAPH Asia 2015 Emerging Technologies, 8:1--8:2. https://doi.org/10.1145/2818466.2818480

Kim, H. J., Kim, C. M., & Nam, T. J. (2018). SketchStudio: Experience Prototyping with 2.5-Dimensional Animated Design Scenarios. In *Proceedings of the 2018 on Designing Interactive Systems Conference*, 831–843. ACM. doi: 10.1145/3196709.3196736

Kumar, S., Hedrick, M., Wiacek, C., & Messner, J. I. (2011). Developing an Experienced-based Design Review Application for Healthcare Facilities Using a 3D Game Engine. *Journal of Information Technology in Construction*, 16(6), 85–104.

Landay, J. A., & Myers, B. A. (2001). Sketching Interfaces: Toward More Human Interface Design. *Computer*, 34(3), 56–64. doi: 10.1109/2.910894

Li, Y., Hong, J. I., & Landay, J. A. (2004). Topiary: A Tool for Prototyping Location-enhanced Applications. In *Proceedings of the 17th Annual ACM Symposium on User Interface Software and Technology*, 217–226. ACM. doi: 10.1145/1029632.1029671

Li, Y., & Landay, J. A. (2008). Activity-based Prototyping of Ubicomp Applications for Long-lived, Everyday Human Activities. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 1303. ACM. doi: 10.1145/1357054.1357259

Lin, J., Newman, M. W., Hong, J. I., & Landay, J. A. (2000). DENIM: Finding a Tighter Fit between Tools and Practice for Web Site Design, In *Proceedings of the SIGCHI conference on Human Factors in Computing Systems*, 510–517. ACM. doi: 10.1145/332040.332486

Liu, A. L., & Li, Y. (2007). BrickRoad: A Light-weight Tool for Spontaneous Design of Location-enhanced Applications. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 295–298. ACM. doi: 10.1145/1240624.1240673

Miller, C. H. (2014). Digital Storytelling: A Creator's Guide to Interactive Entertainment. Routledge.

Nam, T.-J. (2005). Sketch-based Rapid Prototyping Platform for Hardware-software Integrated Interactive Products. In *Extended Abstracts on Human Factors in Computing Systems*, 1689–1692. ACM. doi: 10.1145/1056808.1056998

Rosson, M. B., & Carroll, J. M. (2002). Scenario-based Design. In *The Human-computer Interaction Handbook (J. A. Jacko & A. Sears, Eds.)*. 1032-1050.

Winterbottom, C., & Blake, E. (2008). Constructivism, Virtual Reality and Tools to Support Design. In *Proceedings of the 7th ACM Conference on Designing Interactive Systems*, 230–239. ACM. doi: 10.1145/1394445.1394470

Xu, H., Creighton, O., Boulila, N., & Bruegge, B. (2012). From Pixels to Bytes: Evolutionary Scenario Based Design with Video. In *Proceedings of the ACM SIGSOFT 20th International Symposium on the Foundations of Software Engineering*, 31:1–31:4. doi: 10.1145/2393596.2393631

The Future Is Metahistory: Using Spime-based Design Fiction As A Research Lens For Designing Sustainable Internet of Things Devices

Stead, Michael*; Coulton, Paul; Lindley, Joseph

ImaginationLancaster, Lancaster University, Lancaster, UK
* m.stead1@lancaster.ac.uk

A spime describes a device that could generate data about itself throughout its entire life-cycle and this 'metahistory' would be saved and remain searchable and mineable. Given growing Internet of Things (IoT) device e-waste and material scarcity issues, the concept of spimes provides a useful approach to addressing the current lack of consideration of sustainability in the IoT. Using Design Fiction, we generated a series of near future artefacts that help concretise a world in which the UK Government sanctions the use of blockchain technologies to sustainably manage spime metahistories. The Government's so called 'Open Traceability Protocol' enables citizens to securely trade data-rich spime objects, use recycling apps to search for replacement spime components, and to access spime devices' provenance information. The paper outlines the design of the artefacts that ask whether increased data transparency would place greater accountably upon designers and producers in relation to the resources they deplete to manufacture connected products, while at the same time making such issues explicit to users of IoT devices. We also discuss how reflecting upon our design process enabled us to develop a theoretical lens – *IoT Design Ethics and IoT Data Ownership* – through which aspects of IoT unsustainability can be more thoroughly considered. Finally, we argue that viewing this lens alongside two previously developed spime research lenses allows the formation of an overarching *multidimensional lens for spimes*, which we contend researchers and practitioners can harness in order to begin reframing IoT design culture as a more sustainable paradigm for design practice.

Keywords: spimes; metahistory; sustainability; digital technology; data; design fiction

1 Introduction

With the Internet of Things (IoT) rapidly expanding, people are accumulating increasing numbers of physical-digital assets and artefacts, that is, everyday objects whose material elements are augmented by internet connectivity which allows them to be readable, recognisable, locatable, addressable, and/or controllable by computers. Thus, everyday devices like fridges, kettles and locks, not only perform their traditional function but they also collect and exchange data (Rowland et al, 2015). Whilst societies have long established value cultures in regards to 'purely' physical items, we argue that the different types of value propositions Internet-connected artefacts facilitate are less understood. The manner in which technology providers such as Google, Amazon and Apple surreptitiously harvest and monetise the personal data that people generate when using their connected product-services, is perhaps the most prominent example of how the IoT is changing our relationships with objects and artefacts. As Coulton, Lindley & Cooper (2018) have shown, the often simple and user-friendly nature of IoT devices' interfaces is in reality a frontage for extremely complex *constellations* of virtual processes and interactions. The *visible* elements of the IoT – the physical products – work in conjunction with the *invisible* aspects – creating expansive digital infrastructures which share peoples' personal data through a plethora of algorithms, 3rd party platforms, data concentrators and server networks.

The 'invisibility' of these processes and infrastructures is a source of growing concern (Sadowski, 2016). Recent controversies like Cambridge Analytica's alleged misuse of 87 million peoples' Facebook data to influence voting patterns during the 2016 US presidential election (Solon, 2018), highlights the privacy and security risks, and indeed ethical issues, which stem from internet platforms capturing, selling and manipulating users' personal data. Debate has thus begun regards the regulation of access to IoT product-service data and how such information may be put to purpose (Brass, Carr & Blackstock, 2017). In light of such discourse, we developed upon Sterling's concept of *spimes* (2005) as a way to explore alternate value propositions arising from the acquisition and sharing of people's personal connected product-service data.

2 Spime-based Design Fictions

When viewed simply, spimes are a class of near future, internet-connected objects, but unlike the disposable IoT products that permeate our society today, these devices would be designed so that they can be managed sustainably throughout their entire lifecycle, from their initial production to having their components recycled and reused at the end of their life. Spimes, in essence, would aim to make the implicit consequences of product obsolescence and unsustainable disposal explicit to potential users (Stead, 2017). Figure 1 and 2 depict two previous spime-based design fictions – the *Toaster For Life* and *HealthBand* Do-It-Yourself (DIY) wearable health device. Both are examples of using the emergent method *Design Fiction* (Bleecker, 2009, Coulton, Lindley & Cooper, 2018) to concretise near future worlds in which spime product-services *plausibly* exist, as well as to consider the different types of sustainable people-product relationships such devices and their associated technological features may possibly facilitate (Stead, 2016; Stead, Coulton & Lindley, 2018). Most designers actively try to solve 'actual' problems and make things better (e.g. products, services and infrastructure), or aim to produce something for sale or consumption. Dunne & Raby (2013) have used the term *affirmative design* to describe this commercial and normative type of design practice. Design Fiction is different to *affirmative design* because rather than solving existing problems, through this method we can use design practice to ask questions, specifically *what if* questions, or, in other words, *questions about the future*. Practitioners and researchers can apply Design Fiction as a research method to design fictional prototypes but instead of them being created to be put into production, these prototypes are used to encourage people to think critically about the issues that they embody. Through such fictional prototypes we can ask how things might be in the future, why things might be that way, with a view to highlighting potential problems and opportunities. Thus, Design Fiction can help us to gain a better understanding about the meanings and values that emerging technologies and products might bring into play should they be adopted by society in the future (Bleecker, 2009; Coulton, Lindley, Sturdee & Stead, 2017). We used Design Fiction methods to start to envision what the world would be like if spime-like devices and services actually existed. Whilst the below fictions examine different aspects of the spime concept, both extrapolate from present day emergent technologies and design practices. This approach is significant as the origins of spimes are *in the present* as they are a *rebuttal* to today's unsustainable product design culture. The earliest, near future spime objects would therefore likely share some technological attributes with present day IoT devices (Stead, 2016). As with Design Fiction, we have not designed the spime prototypes with the intention of putting them into production, nor are they finalized 'end products' or concrete sustainable solutions. Our Spime-based Design Fictions aim to critique the growing unsustainability of the IoT whilst also imagining how connected objects could be designed to be more sustainable in the near future.

Figure 1. The Toaster For Life (2016). This fictitious sustainable mass produced connected toaster affords effective repair, upgrade, customisation, recycling, and its parts and components are all inherently trackable. Source: Authors.

As people often find it difficult to imagine how disruptive technologies and practices can bring about change that is different to their present and past experiences, we decided to first embody the notion of a spime object in the form of a mundane and everyday product, the humble toaster (Figure 1). Whilst household consumer products like smart TVs and smart speakers are some of the most visible and commonplace types of IoT devices that people use today, we felt that redesigning a toaster to be spime-like would be a good way to make the sustainable features of a potential spime object appear plausible in an object with no apparent need to be connected to the internet. To make the prototype relatable to peoples' everyday lives, we presented the near future spime toaster within its own product launch catalogue. As such, the *Toaster For Life* explores three *key classifying design criteria for a* *spime objects* (Stead, 2017), namely *sustainability*, *technology* and *temporality*. The basis for the fiction are disparities identified between contemporary sustainable design theory and unsustainable *centralised* product manufacturing processes. This incongruity is represented through the extrapolation of emerging present day technologies including RFID, GPS and 3D printing which are married with fictitious sustainable characteristics, and then incorporated as features into the spime toaster's design. Consequently, within the design fiction, the 'mass produced' toaster affords effective repair, upgrade, customisation, recycling, and its parts and components are all inherently trackable. The fiction demonstrates how manufacturers might begin to embrace new cyclical product-service relationships with customers, akin to circular economy thinking (Webster, 2015). In doing so, it proposes provocative alternatives to *planned obsolescence* being an integral part of IoT products' lifecycles, which ultimately creates copious amounts of e-waste.

Figure 2. The HealthBand Do-It-Yourself medical wearable (2018) is a fictional crowdfunded, open source device which explores the sustainable potential of social innovation and localised production channels. Source: Authors.

The *HealthBand* fiction was a means to further unpack the spime design criteria *synchronicity* and *wrangling*. In recent years, practices and technologies like open source hardware, crowdfunding and the maker movement have increasingly been cited as a more environmentally friendly alternative to the long established centralised strategies that currently characterise the IoT (Smith & Light, 2017; Kohtala & Hyysalo, 2015). This is primarily because decentralised products are usually designed for specific purposes in short production runs which cuts out the huge environmental impacts that result from mass manufactured and widely distributed devices. To embody these ideas, *HealthBand* explores the relationship between *decentralised* and *democratised innovation* design activities (von Hippel, 2005) and the IoT. To develop a spime prototype which embodies decentralised principles, we chose to frame our design as a Do-It-Yourself (DIY) medical wearable device called HealthBand. Like the 'spime toaster', we thought a spime-like wearable would be another type of IoT product that people would readily identify with given the popularity of fitness and activity trackers from brands like FitBit and Garmin. In accordance with a Design Fiction as World Building (DFasWB) approach (Coulton, Lindley, Sturdee & Stead, 2017), a range of related artefacts were generated to provide various 'points of entry' for audiences to engage with the fiction's near future world where DIY health devices are commonplace. The fiction also aims to emphasise the broader social, ethical and sustainable implications of decentralised design practices and technologies – particularly in relation to future product manufacturing policy and legislation.

3 Metahistory: A Spime Design Criteria

Our third spime-based Design Fiction explores how *metahistory* could become a central design criteria. In doing so, *The Future Is Metahistory* fiction examines the possible sustainable implications of the data driven 'digital instantiation' of a spime. To begin defining metahistory as a criteria, we studied Csikzentmihalyi and Rochberg-Halton's (1981) work on the psychology of material culture. They have concluded that people have substantial personal histories with each and every material thing that they own. On the whole, such histories are only recorded on the objects themselves as patina – signs of age and use – and as thoughts and memories to which, by and large, only the user(s) of the artefacts are aware of. As Stead (2017) notes, a spime device, conversely, would generate important data about itself and its interactions with its user(s) throughout its entire life-cycle and this rich and complex metahistory would be saved and remain searchable, trackable and mineable at any time. Sterling (2005) argues that moving to a spime-based paradigm would deepen the relationships people have with their material products as this future would see silos of metahistories becoming 'informational resources [which are] manipulable in real time'.

At this juncture, it would not be unreasonable to argue that through its expanding array of networked artefacts, sensors and AI capabilities, the IoT is beginning to bring forth eventualities which are similar to those which spimes might potentially yield. Indeed, the enormous growth in the use of data sensing physical IoT devices such as smart phones, voice activated speakers, connected televisions and fitness wearables has led to a thriving information economy. Like would-be spime objects, the digital histories generated by people as they use their IoT products are being captured, stored and mined. However, whereas the likes of Google and Facebook interrogate this 'big data' for commercial gain, the principal value of the 'informational resources' spimes would create would manifest through means to support *environmental sustainability* (Stead, 2017). Sterling (2005) believes that mining spime metahistories would help inform sustainable decision-making, particularly in relation to the lifecycle of material goods. He envisages that, once recorded, a spime object's metahistory data would remain 'available online for historical analysis by [its user] and any other interested parties'. Stead (2017) contends, that, rather than the profits of big data, Sterling was likely inspired by the altruistic value inherent to 'open data'. Such datasets are often shared and mined to help inform decision-making with regards to public policy or legislation.

As a concept, spimes shares similarities with Iishi & Ullmer's (1997) notion of 'tangible bits', in that, by imbuing material artefacts with virtual properties, the boundary between our physical, man-made environment (atoms) and cyberspace (bits) will become more *seamless* and *symbiotic*. Importantly however, a near future spime object's design would seamlessly intersect physical and digital parameters along with that of *sustainability* (natural environment) – all three attributes being of equal importance within the spime design process (Figure 3). Further, we contend that the confluence of the three parameters results in what we call the *Spime-based Design Fiction practice space*.

In the next section, we will go into more detail with regards to how we used Design Fiction to concretise a plausible world in which the transparency of spime data is every day and mundane. In our design fiction, it is *sustainable accountability*, with a view to countering connected product e-waste and material scarcity, as opposed to monetary value, that is the principal resource obtained from data sharing practices. As such, *The Future Is Metahistory* seeks to ask whether increased data transparency, alongside the adoption of particular emergent technologies and practices, would influence people to embrace new, more sustainable modes of product ownership? Likewise, would transparent lifecycles place greater accountably upon designers and producers in relation to the resources they deplete to design and manufacture connected devices?

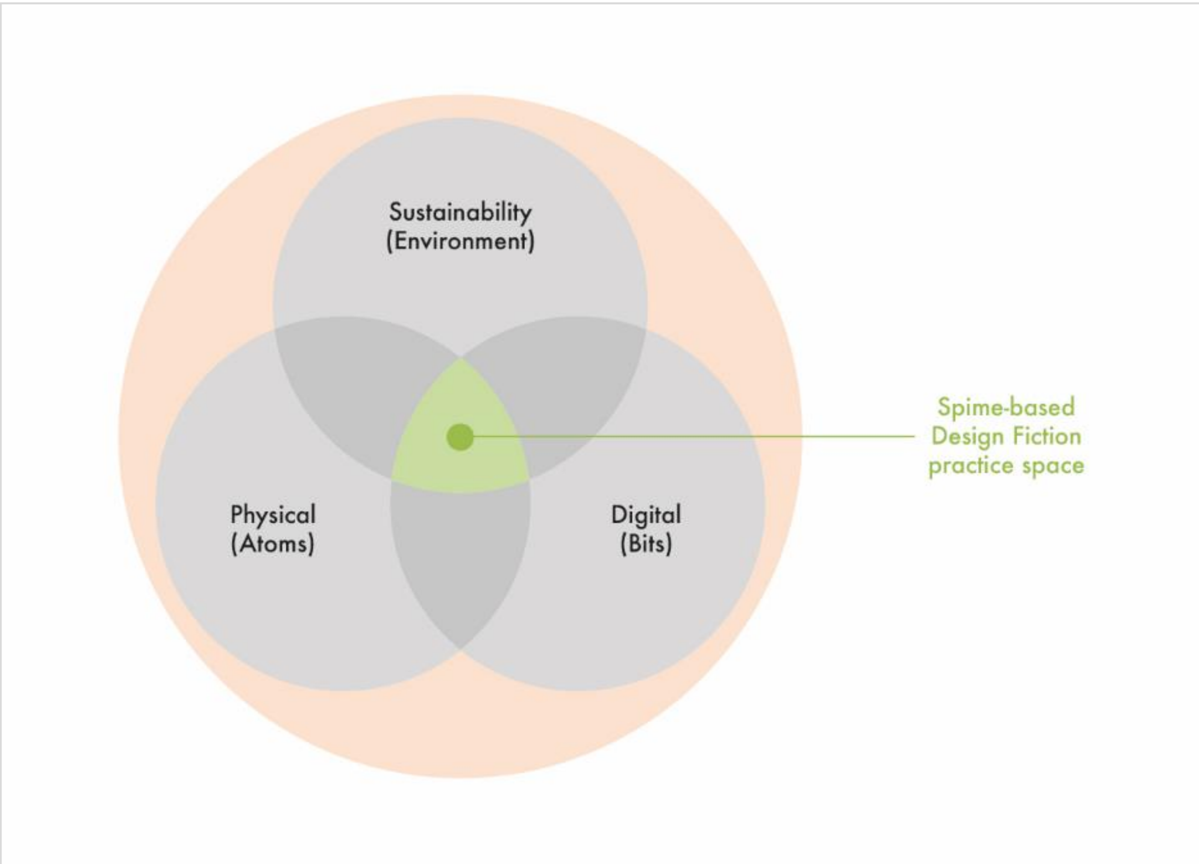


Figure 3. A Venn diagram illustrating the seamless intersection between three design attributes for near future spime objects. The confluence of the 3 attributes results in the Spime-based Design Fiction practice space. Source: Authors.

4 Concretising Metahistory

Design Fiction is different to normative design practice, in that, rather than trying to solve existing problems or to produce something for sale or consumption, we use the method to create fictional prototypes which aim to encourage people to think critically about the issues that the prototypes embody. Applying Design Fiction can help us to gain a better understanding about the meanings and values that emerging technologies and products might bring into play should they be adopted by society in the future. Like Speculative Design and Critical Design, early iterations of Design Fiction focussed on the creation of a singular, particular prototype or artefact. DFasWB on the other hand, uses multiple artefacts to critique present day issues while probing potential futures. When brought together, these artefacts can be used to start to define multiple entry points to an artificially created world. Each entry point describes that world at a different scale. The effect is a reciprocal prototyping relationship, where the world is prototyping the artefacts and the artefacts are prototyping the world.

Figure 4 depicts our first artefact - an advertisement for a spime-like Internet-connected clothes iron called the Bosch Meta-Glide 3000. This prototype is designed to emphasise the types of routine 'metahistorical product data' that users' would potentially be privy to in a spime-centric near future world. Unlike today, where consumers' know very little about the origins and history of their IoT products, in this future where spimes are commonplace, people would have the capability to know much more about the physical-digital objects that they buy. The *Meta-Glide 3000* advertisement is an example of how metahistory data would create transparency in regards to the device's provenance and allow users to discover the 'untold story' of the product, for example, by providing information such as the materials the device is manufactured from, the supply chains it has travelled through to market, and its past and current data usage.

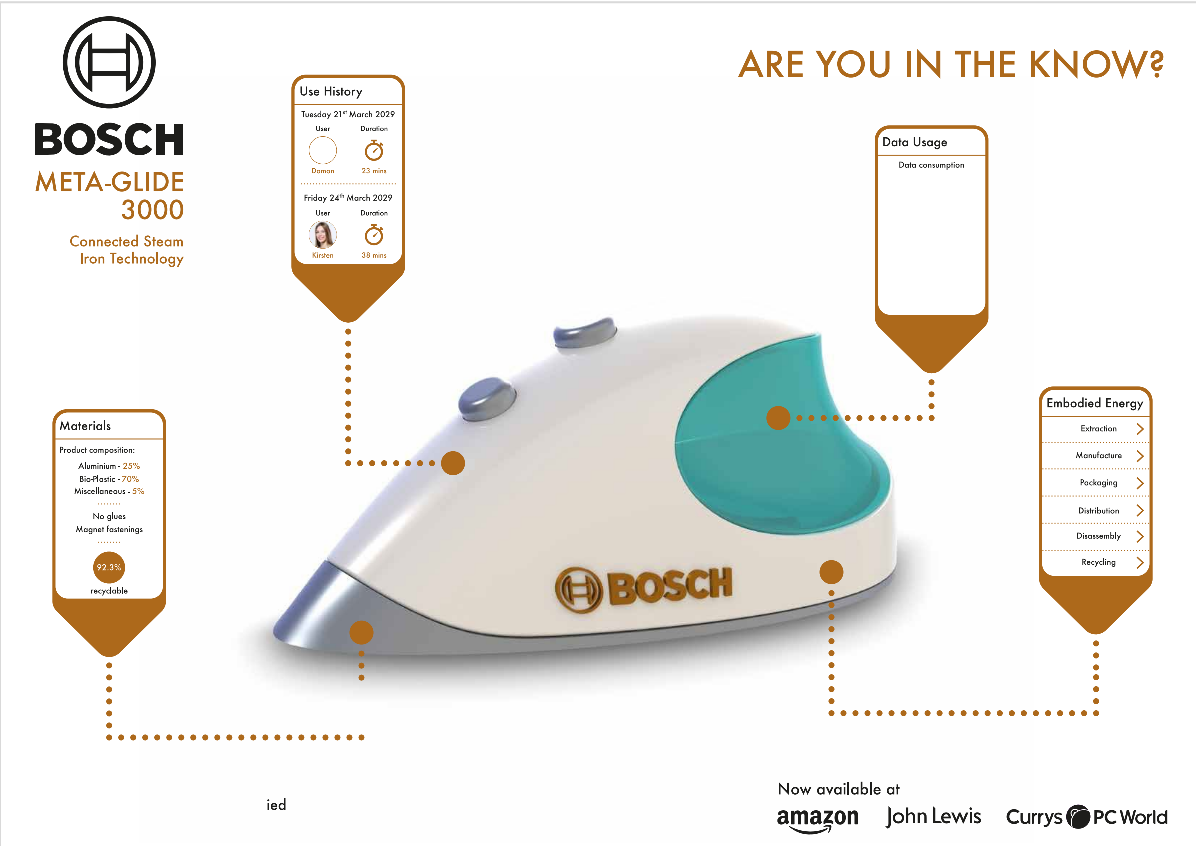


Figure 4. Everyday spime-like devices such this steam iron would generate metahistory data which when made accessible to users could facilitate sustainable behaviour. Source: Authors.

We noted earlier that if spimes were to come into existence in the near future, it is probable that their early 'instantiations' would share some technological and design attributes with present day IoT devices. Thus, like the *Toaster For Life* and *HealthBand*, within the fiction we also chose to extrapolate a notable emergent technology – *blockchain*. A *blockchain* is a publicly distributed digital ledger whose immutable nature makes it a highly secure method for managing data transactions between different parties. It is the technology that underpins the much-publicised cryptocurrency *Bitcoin*. Blockchains are broadcast across global peer-to-peer networks which typically consist of thousands of computers and servers. Transactions are verified by *consensus*, that is, participants on the network confirm any changes between one another. This *decentralised* process eliminates the need for a *centralised* certifying authority, such as an established bank or financial broker. Once verified, a transaction is combined with others to create a new data block for the ledger, which is then added to the existing blockchain. In doing so, *cryptography* ensures the enclosed data becomes permanent and unalterable. Proponents argue, that as well as removing bureaucracy, reducing costs and increasing the speed of transactions, blockchain also makes data processes *transparent* and *traceable*. Many envision a plethora of future applications for the technology in addition to cryptocurrency. These include medical records management, the control of governmental voting activities, utility tokens granting access to resources like energy and water, and the trading of commodities and investments (Stallings, 2017; Morrison & Sinha, 2018).

Whilst acknowledging the current issues of Blockchain in relation to the consumption of resources and energy (Stead, Coulton, Lindley & Coulton, 2019), we felt it was still a useful way of approaching the potential of *The Future Is Metahistory* as it helps us concretise both the transparency of would-be spime product metahistories, and the inherent traceability of such devices throughout their entire lifecycle. Although a relatively young sector, several IoT manufacturers and platforms have already gone out of business and as has been seen with defunct firms such as *Jawbone* and *Berg*, all of the data and support services associated with these companies and their products, is consequently no longer available to their customers (Graham, 2017; Fairs, 2014). Having data stored on a blockchain would ensure that it is independent from manufacturers and service providers, and, as is an essential attribute of spime objects, this data would remain accessible to users should a connected product firm cease trading.

Despite the hyperbole currently surrounding blockchain, we argue that the technology has yet to enter the mainstream consciousness. Our second artefact is therefore a fictional Which? help guide entitled *Buying and selling your devices securely: Blockchain and Smart Contracts made easy* (Figure 5). Similar to the technology advice guides that are available today (Which?, 2019), it serves as a means to introduce broader audiences to the technology and explain its complexities and advantages in terms that can be easily understood. 'Published' in 2029, the guide gives examples of near future applications for blockchain including crypto-transfers, speed voting, energy resource betting and, most significant for the purposes of our fiction, *the trading of physical-digital goods*. Within the fiction, the document has been produced together with present day technological bodies, the UK Government's *Digital Service* and the *Citizens Advice Bureau*, alongside the fictional *Alliance for Sustainable Blockchain Stewardship* (AfSBS).

Figure 5. A near future Which? help guide for buying and selling physical-digital devices securely using blockchain and smart contract technologies. Source: Authors.

While distant visions of the future can be worthwhile, we contend that plausible proximate futures are more useful for exploring the meanings and implications of emergent technologies and practices (Lindley, Coulton & Sturdee, 2017). With this in mind, we referenced the first two organisations, and indeed *Which?*, to ‘root’ the guide within an ‘everyday’ and mundane future. We argue that this sense of plausibility lessens the potential for the spime and metahistory concepts to appear fantastical, unreal or ‘too futured’. In turn, we believe that building from familiar formats (Coulton, Lindley & Akmal, 2016) enables the speculation to more meaningfully contribute to broader social, ethical and sustainability debates that are relevant to the implications of adopting spimes. We followed this approach when conceiving all of our artefacts. For example, to establish verisimilitude, we chose to brand the fictional steam iron as a *Bosch* appliance as opposed to fabricating a manufacturing firm. However, in other instances, our fictional motifs are as equally as important as details appropriated from the present, such as the creation of the *AsFBS* which subtly relates the guide to our other artefacts and, thus, also helps to bolster plausibility and explicate a fuller, more rounded world.

Similarly, our third artefact (Figure 6) is a press release written by fictional UK Government Chief Scientific Adviser, Dr Clement Benway, on behalf of the *Council for Science and Technology* and the imagined body *Better IoT Global*. Echoing the rhetoric that often besets new technologies, in our fictional world, metahistory data, in conjunction with blockchain, is considered to hold ‘transformative possibilities for environmental sustainability’. Accordingly, the press release outlines how the sustainable benefits of these technologies will be ‘optimised’ by the UK Government. After a successful trial period, blockchain, with its transparency and traceability competencies, is deemed to be a secure and robust method for storing and transferring peoples' product metahistory data. The Government therefore seeks to implement its so called 'Open Traceability Protocol' which will allow retailers and platforms to trade in new or used physical-digital devices while ensuring secure and sustainable transfer of said devices' metahistories. To manage this initiative, the Government has sanctioned the formation of an accrediting body – the *AsFBS* – which retains the power to issue the *Secure Metahistory Certification Mark* (SMC Mark) to regulate any retailers or platforms intending to enter the sector.

COUNCIL FOR SCIENCE AND TECHNOLOGY

better IoT global

Alliance for Sustainable Blockchain Stewardship

The Council and BIG announce the formation of the *Alliance for Sustainable Blockchain Stewardship* and the creation of the *Secure Metahistory Certification Mark*

For Immediate Release: 23/02/2026

The Council for Science and Technology and Better IoT Global are pleased to announce the formation of the *Alliance for Sustainable Blockchain Stewardship* and the creation of the *Secure Metahistory Certification Mark*. The announcement comes after implementation strategies for both initiatives were approved by Government following a year of research and consultation:

- The Department for Science and Technology's white paper *The Future is Metahistory: Blockchain, Ecology and the Economy* was published 18/01/25 and outlined potential benefits and possible issues with regard to corporate and public adoption and acceptability of Blockchain and the optimisation of consumers' metahistories.

- Technology and consumer trials held across summer 2025 were successful and provided valuable insights for efficient and secure implementation.

- *Open Traceability Protocol* and knowledge exchange - the increased transparency granted by metahistory data regards physical and digital materials is deemed to hold transformative possibilities for environmental sustainability.

- Optimisation will also create new markets and generate opportunities for platform development and data mining jobs which in turn will boost the overall economy.

- Blockchain's inherent decentralisation is a proven secure and robust alternative to traditional centralised transaction systems. There has been growing mistrust amongst the wider public for conventional banking culture since the UK was again plunged into a recession by banking malpractice in spring 2023.

The alliance will work closely with product manufacturers, data platforms and sustainable bodies on advancing open traceability for sustainable benefit.

The certification mark will be used by stores, platforms and applications to denote a secure and sustainable transfer of consumer's personal metahistories using blockchain and smart contracting processes.

Dr Clement Benway,
Government Chief Scientific Adviser (GCSA),
c.benway@gov.uk

Figure 6. In our fictional world, the transparency of product meta-histories underpinned by blockchain technologies have been identified as having considerable sustainable benefits. This has led the UK Government to implement the 'Open Traceability Protocol'. Source: Authors.

In the document the UK Government envisages that an optimisation of metahistories will create new markets, generate opportunities for platform development and increase employment in the data mining sector, all of which is expected to boost the UK's economy. Figure 7 depicts a user experience tableaux for a near future mobile app called *Lazarus* which has been developed under the auspices of the 'Open Traceability Protocol'. Built on blockchain technologies, *Lazarus* enables people to grant access to the metahistories of transferred products. Consequently, users will be able to view gifted devices' provenance data and 'use-stories' – details of how previous users have interacted with such products during their period of ownership. Inspired by popular 'gifting' websites like *Freecycle* and *TrashNothing*, as well as 'buy and sell' platforms like *Gumtree* and *Craigslist*, we wanted this artefact to provoke questions regarding how spime objects might be designed to negotiate the complexities of being traded through second-hand markets. *Lazarus* would facilitate greater 'asset transparency' by tracking the origins and histories of physical-digital products, verifying their provenance through blockchain and keeping the ‘digital instantiation’ of the product ‘secured’ to the ‘physical instantiation’ of the same product throughout its entire lifecycle. As Sterling (2005) asserts, spimes are ‘always associated with a story. [They] have identities, they are protagonists of a documented process’. An app like *Lazarus* might help to empower sustainable behaviour by affording people the opportunity to easily and *securely* recycle, reuse and repurpose data-rich spime objects when they are no longer wanted or considered to be at the end of their useful life. This process sits contrary to the disposable nature of the IoT, where the underlying sustainable value of physical-digital assets are not maximised. An IoT product’s data is often simply erased before its material elements are lost to landfill.

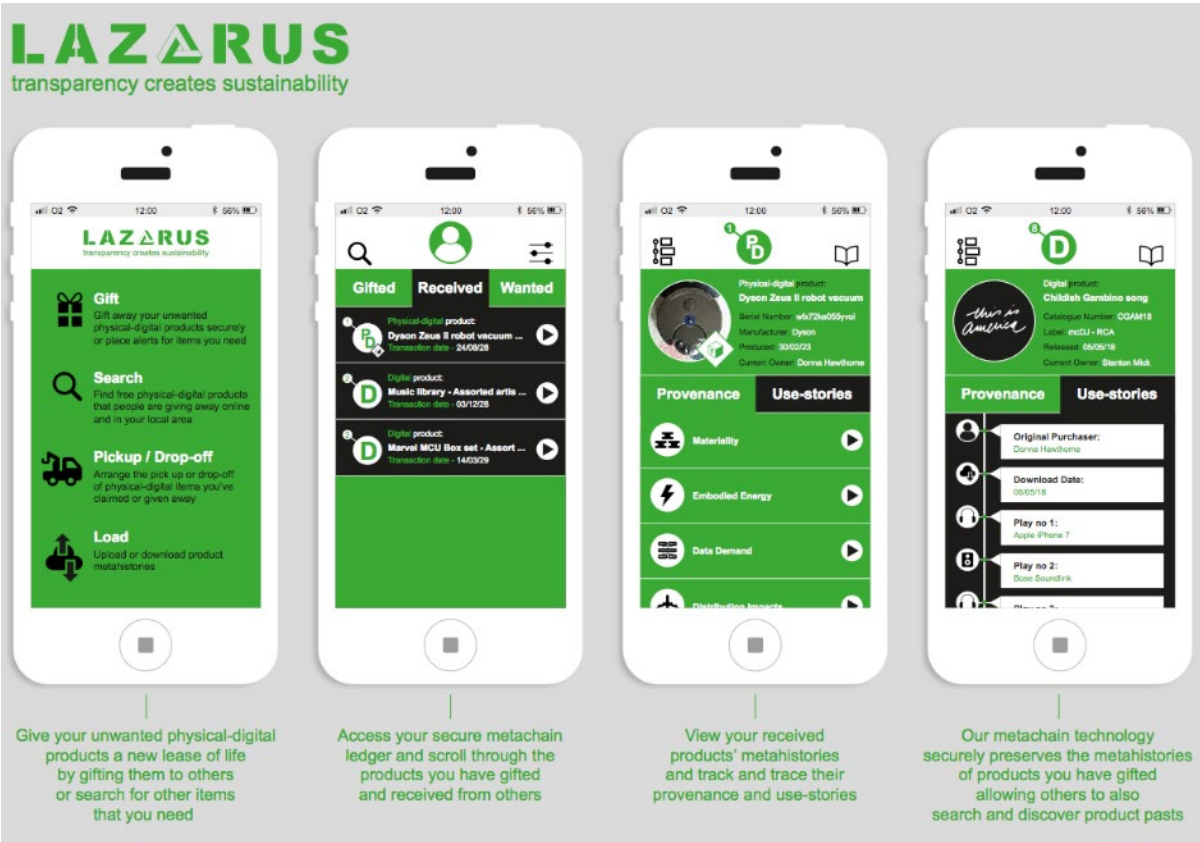


Figure 7. A user experience tableaux for Lazarus, a blockchain/metahistory based platform which promotes sustainable consumer behaviour. Lazarus enables people to securely gift away data rich physical-digital objects, search for recycled items and access product metahistories which include important provenance data. Source: Authors.

As per Sterling’s outline, access to spime metahistories could aid people to make more sustainably informed decisions. People should understand that they, as individuals, are also *accountable* for the unsustainability of the connected products they purchase, through how they use them and, perhaps most importantly, through how they dispose of these devices. Likewise, could embracing metahistory also empower retailers and platforms to become a driving force for reducing e-waste and material scarcity? Figure 8 features a fictional customer email receipt from eBay detailing the purchase of a second-hand Internet-connected toaster. We can see that eBay has complied with the Government’s protocol and included the *SMC Mark* on the receipt to denote that the transaction involves blockchain processes in the transfer of the toaster’s metahistory from its previous to new owner.

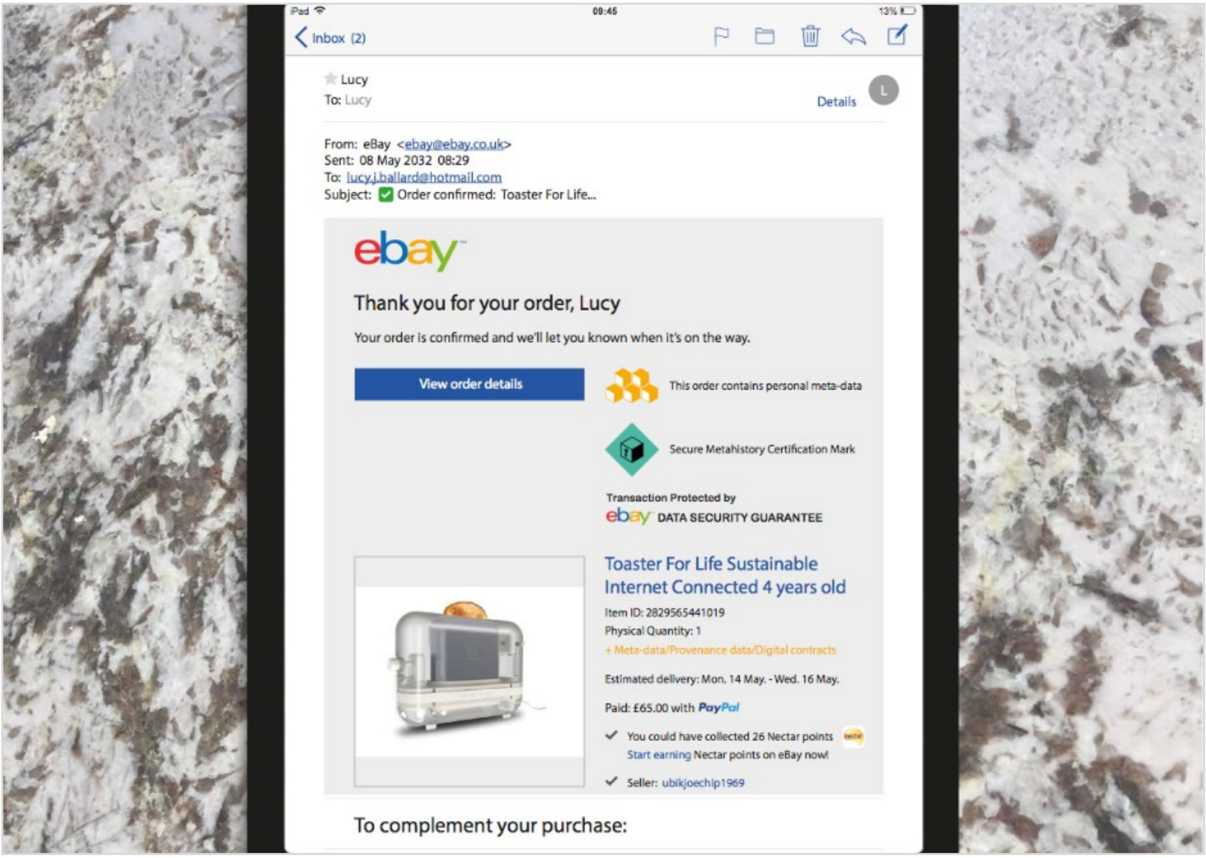


Figure 8. An eBay customer receipt for the purchase of a second-hand spime toaster.. As per the Governments 'Open Traceability Protocol', eBay has included the Secure Meta-History Certification Mark as this transaction involves blockchain processes and the transfer of the toaster's seller's personal meta-history data. Source: Authors.

Despite such compliance, some companies might seek to gain from mining the vast silos of metahistory data generated by billions of spime products. Figure 9 is a web interface for a cloud data mining platform operated by the internet giant *Amazon*. So-called 'excavators' can sign up to mine the spime silos for crypto-rewards with Amazon accumulating fees and percentages from their members who successfully mine metahistory blockchains. Through building our world, we have sought to frame metahistory as a counterpoint to the increasing anxieties presently being felt towards how Internet platforms acquire, share, and mine IoT data for profit. The transparency of metahistory data has therefore been presented in a positive light through the majority of our artefacts. The Amazon platform and Figure 10's *Change.org* petition however, begin to raise questions about the manner in which we have concretised metahistory, particularly concerning our extrapolation of blockchain technologies and data-mining activities. In the next section, we will discuss these issues further and argue that our framing of metahistory facilitates the building of a *plausible* world, as opposed to one which is *preferable*, and why making this distinction is critical when using the spimes concept as a means to envision sustainable connected product futures.

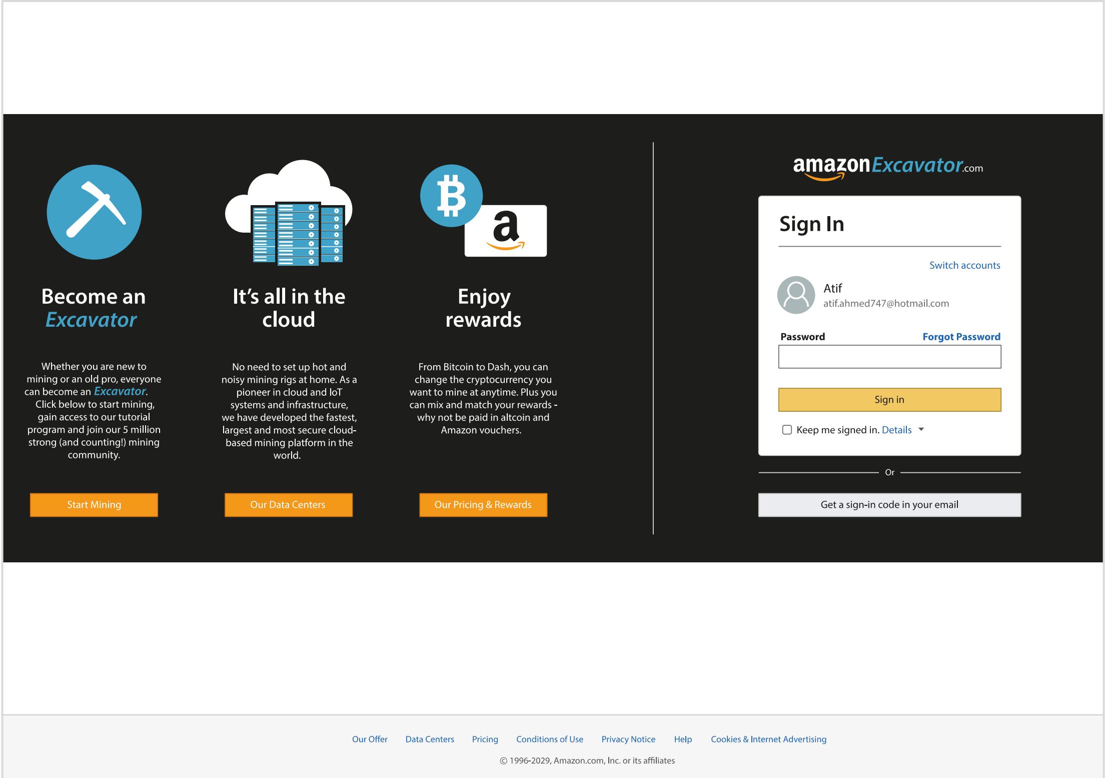


Figure 9. A web interface for a fictional cloud data-mining platform operated by the Internet giant Amazon. So called 'excavators' can sign up to mine the vast silos of spime product metahistories for crypto-rewards. In our world, Amazon would accumulate membership fees and percentages from successfully mined metahistory blockchains. Source: Authors.

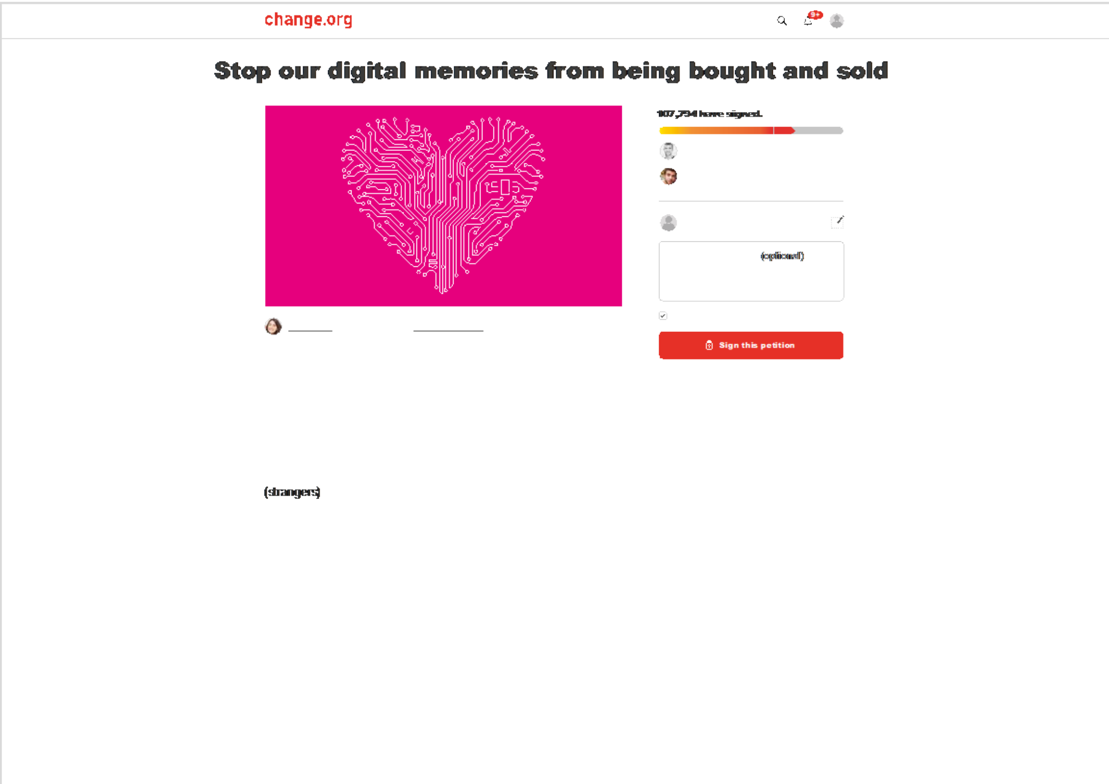


Figure 10. This petition highlights concerns that some people might have regards future 'open traceability' and the widespread adoption of blockchain enabled meta-transactions. Source: Authors.

5 A Plausible As Opposed To Preferable World

Established thinking suggests that the side of the IoT that we do not see – the 'invisible' digital processes and infrastructure which covertly distribute peoples' data – should be made more explicit to *individual users* in order to restore and maintain user privacy and security (Coulton, Lindley & Cooper, 2018). Through *The Future Is Metahistory* fiction, we have envisioned how the use of immutable blockchain technologies to permanently record and share spime metahistories could be a plausible means of achieving such a goal. But spimes would also go further. To return to Sterling's (2005) original synopsis, metahistory data would remain 'available online for historical analysis by [its user] and *any other interested parties*'. The latter characteristic is problematic, in that it suggests that metahistories would be explicit, not only to a product's owner, or the succeeding owner(s) of the device, but in fact, explicit to *everyone*. Indeed, the caveat of the metahistory concept is that such data would be accessible, searchable and mineable by anyone who is interested in doing so. This seeming contradiction rightly provokes the question – *if everyone has the ability to access metahistories, how is our personal data any more private or secure within the fictional future than it is today?* Emphasising the commercial rewards that could be made from mining personal metahistories, the Amazon platform begins to allude to this issue. The fictional *Change.org* petition is more overt, highlighting the concerns that people might have regards the widespread adoption of 'open transparency' and 'asset traceability'. Should the adoption of metahistory be viewed as a trade-off then? The data would be secure and unalterable when stored in a blockchain but it appears privacy would still be comprised. In our spime-based paradigm, are improved sustainability credentials more important than the users' privacy?

Another issue we must also reflect upon is the known unsustainability of data mining practices. This is more subtly referenced within our fictional world through the anti-metahistory badges and photo of protestors with 'Say No To Server Farms' placards at the *Make Metahistory HISTORY* march through London in June, 2028 (Figure 11). While the impacts of blockchain technologies themselves are not of specific detriment to the environment, some of the mining activities that they facilitate – Bitcoin being a prominent example – have been shown to be incredibly resource intensive. Mining crypto-currencies consumes copious amounts of energy, increases carbon emissions, and generates large amounts of heat (O'Dwyer & Malone, 2014). Do the negative impacts of mining practices in general, and by association metahistory nullify any sustainable benefits that might result from adopting spimes as an alternative to the IoT?

Figure 11. Protest badges and a photo of protestors at the Make Metahistory HISTORY march through London, June 2028. Source: Authors.

Our design fiction does not aim to answer the preceding questions, but it does seek to provoke a debate around such issues. We have purposely included the artefacts in Figures 9 - 11 to connote to audiences that the fictional world we have built is not a *sustainable utopia*. Instead, we have aimed to build a mundane, *plausible* and sometimes messy world – not a pristine, didactic nor unquestionably *preferable* future. The world depicted within our fiction is *one* of *many* plausible spime-based paradigms. To make more sense of the differences between *plausible* and *preferable* futures, Dunne and Raby appropriated a diagram – the *Futures Cone* – which was first put forward by Voros in 2001. They note that the idea of envisioning preferable futures presents difficulties because the practice raises the question ‘what does *preferable* mean, for whom, and who decides?’ (Dunne and Raby, 2013). In their interpretation, the diagram is separated into four ‘design futures cones’ – probable, plausible, possible and preferable. The preferable cone (purple) intersects both the probable and plausible. Figure 12 depicts our own version of the diagram which is based upon our reflection of our design process for *The Future Is Metahistory* fiction, and our previous research into spimes.

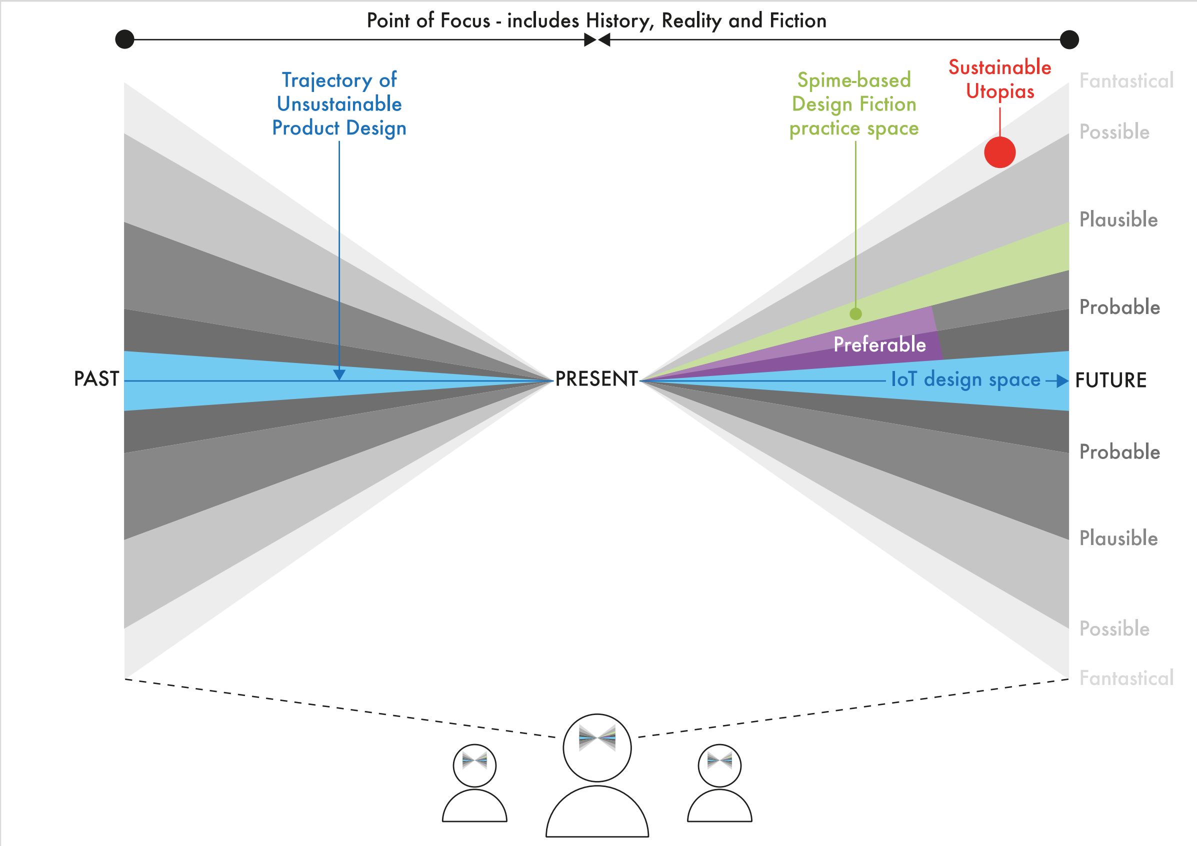


Figure 12. The Futures Cone diagram which distinguishes Spime-based Design Fiction practice from unsustainable IoT design practice and the notion of a sustainable utopia. Source: Authors.

We have positioned spime-based design fictions entirely within the plausible cone (green) and have also posited where we consider the ongoing trajectory of IoT design practice (blue) to be situated. As we outlined earlier, currently, the design of IoT devices follows long established models of production, consumption and disposal which are proven to be profoundly damaging to the environment (Papanek, 1971; Fry, 2009). As a result, we have positioned the IoT on a fixed path within the probable cone. This *Trajectory of Unsustainable Product Design* extends from the end of World War Two and is defined by mass-production, conspicuous consumption, free markets, globalisation and the adoption of the Internet. Augmenting the diagram further, we have included an additional *fantastical cone* within which we have placed the notion of sustainable utopias (red). This is to clearly distinguish mundane and plausible spime-based design fictions from these more chimerical visions of the future which are often marked by technological ‘solutionism’ (Morozov, 2013). Our diagram also makes reference to both the past and *pluralities of design futures*, that is, the notion that people interpret speculative futures and design fictions in their own individual way, based upon their past and current lived experiences. The benefit of this plurality is that different interpretations can lead to new insights and fresh discourse beyond the scope of what those who have envisioned the futures might have originally intended.

6 Spimes As A Lens

As we noted when introducing the concept, it would be easy to view spimes merely as a type of potential internet connected device which would be designed to be more sustainable than present day IoT products. Having produced our series of spime-based fictions, we contend that the real *design value* of the spime approach lies when it is applied as a *theoretical lens*. While the artefacts that make up the *Toaster for Life*, *HealthBand* and *The Future Is Metahistory* fictions centre on highlighting potential sustainable design *attributes* of spime objects, applying the concept as a lens allows us to consider the broader sustainable, societal and ethical *implications* of adopting a spime culture. For example, we incorporated design specifications like repair and recycling into the *Toaster for Life* prototype as a way to help us envision an environmentally sustainable connected product. More importantly however, by reflecting upon the prototype and the Design Fiction process that we followed to produce it, we have been able to develop a broader theoretical lens which emphasises the wider impact such sustainable design specifications could potentially have on *IoT Product Business Models* and *IoT Product User Behaviour*. Similarly, looking back upon *HealthBand's* fictional crowdsourcing campaign and design process allows us to more thoroughly consider what sustainable impact democratised technologies and practices may have on connected product design legislation and social innovation user engagement. This analysis resulted in the development of a second lens – *IoT Design Policy and IoT User Innovation*.

Through *The Future Is Metahistory* fiction, we have aimed to highlight the potential sustainable advantages and disadvantages of making connected product data more transparent and traceable. Reflecting upon our process has enabled us to identify a third theoretical lens for spimes – *IoT Data Ethics and IoT Data Ownership*. For spime metahistories to become optimised in the near future, and, to subsequently help bring about sustainable change, technology platforms and services would have to make all their data processes and digital infrastructures more open and transparent to users. As outlined in our introduction, the way in which peoples' personal data is handled throughout the IoT today is incredibly complex. Dense constellations of algorithms, 3rd party platforms, data concentrators and server networks make personal data difficult to trace and almost invisible to users. Such methods are probably unlawful in certain aspects. In light of recent breaches like the Facebook/Cambridge Analytica scandal, the ethical parameters of IoT data transparency is something tech firms need to consider with a matter of urgency. In addition, as it is very difficult to understand and keep track of what happens to it, IoT data is something we, as users of connected products and services need to consider more thoroughly. We need to start taking back ownership of our IoT data and do more to protect it, perhaps by being more careful in regards to how we interact online and what information we share.

The interdependency of our three theoretical lenses is illustrated in Figure 13. One can see that when positioned together, they form an overarching *multidimensional lens for spimes*. It is through this multidimensional lens that we are able to demonstrate that spimes as a concept, is concerned with more than the technical specifications of near future connected devices. Spimes can, as we have evidenced through our work, be applied as a credible and purposeful research lens through which design researcher-practitioners can explore the meanings and implications of sustainable connected product futures.

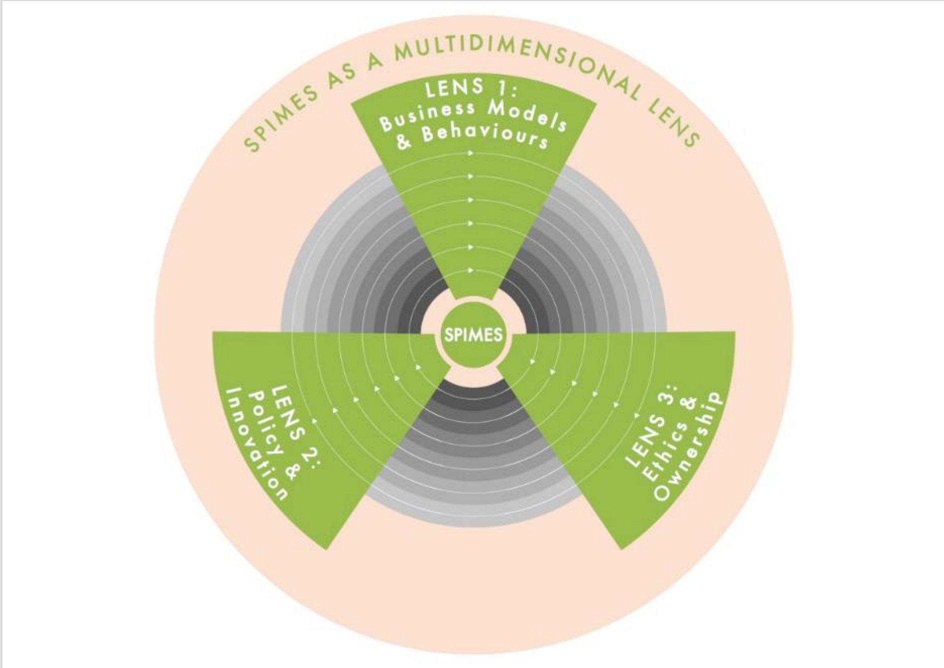


Figure 13. When viewed together, our three sub-lenses form the macro Spimes As A Multidimensional Lens. Source: Authors.

7 Conclusion

Despite our reframing of the *Futures Cone* diagram, Design Fiction should not be viewed as a method for *predicting* the future but rather it is an effective way of extrapolating emerging technologies and practices in order to raise questions about the implications of adopting them in the present. We generated our range of artefacts for *The Future Is Metahistory* fiction as a means to emphasise how IoT product manufacturers, governments, Internet service providers and ordinary citizens often brazenly embrace a developing technology like blockchain, yet never consider the wider impacts of such action, particularly the potential consequences for sustainability. Our intent is not to provide the 'answers' nor an end solution to the unsustainability of the IoT, but to present a provocation that empowers and drives forward discourse about the growing problems of e-waste and material scarcity. We have sought to do this by positing that increased transparency of connected product data would place greater accountably upon designers and producers in relation to the resources they deplete to manufacture connected products as well as making these issues more explicit to the users of such devices. Through fictional artefacts like the *Amazon Excavators* interface and *Change.org* petition, we have aimed to build a more fully rounded world in which spimes can be shown to plausibly exist.

We believe that through our design process we have contributed to the theoretical underpinnings of the spimes concept. We utilized the DFasWB approach to unpack the metahistory criteria and, in doing so, like our two previous spime Design Fictions, we developed a third sub-lens for spimes-based research – *IoT Data Ethics and IoT Data Ownership.* When viewed together, our three lenses form the macro *Spimes As A Multidimensional Lens*. To this end, we argue that spimes should not only be seen as a class of sustainable devices built on nascent technologies and practices but more so as a rhetorical lens which design practitioners and researchers can possibly harness in an effort to move away from a focus on device obsolescence, and instead begin to reframe their design practices and use of technologies around the creation of a more sustainable IoT product paradigm. Ultimately, by focusing on strategies for incorporating sustainability into the design of IoT devices, we hope to galvanise product designers, interaction designers, creative technologists and makers into action - the people who have the skills and know how to use materials and technologies to design future sustainable connected products. Further to this, our research may also be of interest to environmentalists, connected product manufacturers, tech firms, politicians and legislators - those who campaign for sustainable change and those who have the power to deliver it.

8 References

Bleecker, J. (2009). Design Fiction: A Short Essay On Design, Science, Fact & Fiction. Available from: http://drbfw5wfjlxon.cloudfront.net/writing/DesignFiction_WebEdition.pdf [Accessed: 01 Apr 2019].

Brass, I., Carr, M., & Blackstock, J. (2017). The IoT Effect: The Future of Data Protection and Information Security in the UK, *Proceedings of Political Studies Association (PSA) 67th Annual International Conference*, 10-12 April 2017, Glasgow, EU and UK Regulation in Transition Panel.

Coulton, P., Lindley, J., & Akmal, H. A. (2016). Design fiction: does the search for plausibility lead to deception? In P. Lloyd, & E. Bohemia (Eds.), *Proceedings of Design Research Society Conference 2016* (pp. 369-384). (Proceedings of DRS 2016; Vol. 1). Design Research Society. https://doi.org/10.21606/drs.2016.148

Coulton, P., Lindley, J. G., Sturdee, M., & Stead, M. (2017). Design Fiction as World Building, *Proceedings of Research through Design Conference 2017*, 163-179, DOI: 10.6084/m9.figshare.4746964

Coulton, P., Lindley, J., & Cooper, R. (2018). *The Little Book of Design Fiction for the Internet of Things*. Lancaster: Lancaster University. 46 p.

Dunne, A., & Raby, F. (2013). *Speculative Everything*. Cambridge, MA: MIT Press.

Fairs, M. (2014). BERG, The Design Company Behind Little Printer, To Close. Available from: https://www.dezeen.com/2014/09/09/little-printer-design-company-berg-to-close/ [Accessed: 01 Apr 2019].

Frayling, C. (1993). Research in Art and Design. *Royal College of Art and Design Papers*, 1(1), 1-5. Available from: http://researchonline.rca.ac.uk/384/3/frayling_research_in_art_and_design_1993.pdf [Accessed: 01 Apr 2019].

Fry, T. (2009). *Design Futuring: Sustainability, Ethics & New Practice*. Oxford, UK: Berg.

Gaver, W. (2012). What Should We Expect From Research Through Design?, *Proceedings of ACM Conference on Human Factors in Computing Systems (CHI 2012)*. New York: ACM Press, 937-946.

Graham, J. (2017). Jawbone, Out of Business, Leaves Customers Hanging. Available from: https://eu.usatoday.com/story/tech/talkingtech/2017/07/10/jawbone-out-business-leaves-customers-hanging/461159001/ [Accessed: 01 Apr 2019].

Hales, D. (2013). Design Fictions: An Introduction and Provisional Taxonomy. *Digital Creativity*, *21*(1), 1-9.

Iishi, H., & Ullmer, B. (1997). Tangible Bits: Towards Seamless Interfaces between People, Bits and Atoms, *Proceedings of CHI ‘97*, 22 -27 March 1997, New York: ACM Press.

Kohtala, C., & Hyysalo, S. (2015). Anticipated Environmental Sustainability of Personal Fabrication. *Journal of Cleaner Production*, *99*, 333–344.

Lindley, J. G., Coulton, P., & Sturdee, M. (2017). Implications for Adoption, *CHI '17 Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*. ACM, New York, (CHI 2017). May 6-11, Denver, Colorado, USA. 265-277.

McEwen, A., & Cassimally, H. (2013). *Designing The Internet Of Things*. London: John Wiley & Sons.

Morozov, E. (2013). *To Save Everything, Click Here: Technology, Solutionism, and the Urge to Fix Problems that Don’t Exist*. London: Allan Lane.

Morrison, A., & Sinha, S. (2018). How Blockchain Works. Available from: http://usblogs.pwc.com/emerging-technology/a-primer-on-blockchain-infographic/ [Accessed: 01 Apr 2019].

O’Dwyer , K. J., & Malone, D. (2014). Bitcoin Mining and its Energy Footprint. *Proceedings of 25th ISSC/CIICT Conference*, 26–27 June 2014, Limerick.

Papanek, V. (1971). *Design For The Real World*. St Albarns, UK: Paladin.

Rowland, C., Goodman, E., Charlier, M., Light, A., & Lui, A. (2015). *Designing Connected Products: UX For The Consumer Internet of Things.* Sebastopol, USA: O'Reilly Media, Inc.
Sadowski. J. (2016). Companies Are Making Money From Our Personal Data – But At What Cost? Available at: https://www.theguardian.com/technology/2016/aug/31/personal-data-corporate-use-google-amazon [Accessed: 01 Apr 2019].
Smith, A., & Light, A. (2017). Cultivating Sustainable Developments With Makerspaces. *Liinc Em Revista*, *13*(1),162-174.
Solon, O. (2018). Facebook Says Cambridge Analytica May Have Gained 37m More Users' Data. Available at: https://www.theguardian.com/technology/2018/apr/04/facebook-cambridge-analytica-user-data-latest-more-than-thought [Accessed: 01 Apr 2019].
Stallings, W. (2017). A Blockchain Tutorial. *The Internet Protocol Journal*, *20*(3).
Stead, M. (2016). A Toaster for Life: Using Design Fiction to facilitate discussion on the creation of a Sustainable Internet Of Things, *Proceedings of Design Research Society Conference 2016*. Lloyd, P. & Bohemia, E. (eds.). Design Research Society, Vol. 8. p. 3049-3068 20 p. (Proceedings of DRS 2016; vol. 8).
Stead, M. (2017). Spimes and Speculative Design: Sustainable Product Futures Today, Strategic Design Research Journal, 10(1), 12-22.
Stead, M., Coulton, P., & Lindley, J. (2018). Do-It-Yourself Medical Devices: Exploring Their Potential Futures Through Design Fiction, *Proceedings of the Design Research Society Conference 2018*. Storni, C., Leahy, K., McMahon, M., Lloyd, P. & Bohemia, E. (eds.). Limerick: Design Research Society, Vol. 6. p. 2511-2523 13 p.(Design Research Society Conference Proceedings 2018; vol. 6).
Stead, M., Coulton, P., Lindley, J., & Coulton, C. (2019). *The Little Book of Sustainability for the Internet of Things*. Lancaster: Lancaster University. 49 p.
Sterling, B. (2004). Dumbing down smart objects. Available at: https://www.wired.com/2004/10 /dumbing-down-smart-objects/ [Accessed: 01 Apr 2019].
Sterling, B. (2005). *Shaping Things*. Cambridge, MA: MIT Press.
Sterling, B. (2014). *The Epic Struggle Of The Internet Of Things*. London: Strelka Press.
von Hippel, E. (2005). *Democratizing Innovation*. Cambridge, MA: MIT Press.
Voros, J. (2001). A Primer on Futures Studies, Foresight and the Use of Scenarios. *Prospect*, *6*. Available at: https://static1.squarespace.com/static/580c492820099e7e75b9c3b4/t/58abbe7c29687fbaf4a03324/1487650430788/A+Primer+on+Futures+Studies.pdf Accessed: 01 Apr 2019].
Webster, K. (2015). *The Circular Economy: A Wealth of Flows*. London: Ellen MacArthur Foundation Publishing.
Which?. (2019). Get your free Which? guide. Available at: https://computing.which.co.uk/hc/en-gb/articles/115003169609-Get-your-free-Which-guide [Accessed: 01 Apr 2019].

About the Authors:

Michael Stead is a PhD Candidate at Lancaster University's HighWire Center for Digital Innovation whose doctoral research focuses on the sustainability of the Internet of Things.

Paul Coulton is Chair of Speculative and Game design at Lancaster University's exploratory design-led research lab, Imagination.

Joseph Lindley is a postdoctoral researcher applying his doctoral research into Design Fiction as part of the PETRAS Cyber Security for the Internet of Things Research Hub.

Acknowledgement: This work is funded by the Digital Economy programme (RCUK Grant EP/G037582/1) supporting the HighWire Centre for Doctoral Training (http://highwire.lancs.ac.uk) and the PETRAS Cyber Security Hub for the Internet of Things (RCUK Grant EP/N02334X/1).

THE CONCEPT OF DESIGN THINKING HAS BECOME UBIQUITOUS WITHIN THE DESIGN, BUSINESS AND INNOVATION FIELDS. WHILE DESIGNERS ARE ABLE TO CONSIDER COMPLEX AND OFTEN COMPETING DEMANDS, THE NATURE OF HOW THEY THINK WHEN DOING SO IS LESS UNDERSTOOD. WHAT ARE THE RELATIONSHIPS BETWEEN THINKING AND DOING IN DESIGN? CAN THINKING BY, FOR OR THROUGH DESIGN ADDRESS SOCIETAL CHALLENGES AND UNLOCK INNOVATION?? HAS DESIGN THINKING PASSED ITS SELL BY DATE OR IS IT STILL A VALUABLE PROPOSITION?

THINKING

A New Approach for Mapping Stakeholders

Han, Jia-Xuan*; Ma, Min-yuan; Hsieh, Eric Chen-F

National Cheng Kung University, Tainan City 701, Taiwan (R.O.C)
* hanjiaxuan66@gmail.com

The stakeholder technology is mainly criticized for being grounded in informal and unscientific data, the usefulness and ease of use of the technology are often questioned. Therefore, the purpose of this study is to design a new method to define stakeholders by using scientific data. The new approach could be used to clarify the connection factors between core factors and stakeholder in the process of adolescent tobacco hazards prevention（ATHP） issue. The feasibility of this method will be validated through the design thinking workshop(Discover Insight for Adolescent Tobacco Hazards Prevention Issue). This study first uses design thinking workshop to discover the issues in the process of adolescent tobacco hazards prevention. After that, the problem is classified and merged by qualitative research techniques, and ATHP's "core factors" and "key stakeholders" are generated. Based on ATHP's "core factors" and "key stakeholders", ATHP image map is drawn by quantitative approach. From the ATHP image map, the relevant personnel can clearly understand the position of each stakeholder in ATHP issue, the relationship between each stakeholder and the influence of each stakeholder on the different "core factors" of ATHP. The new method redefines stakeholders in a formal and scientific way, which makes up for the shortcoming of defining stakeholder purely by qualitative research technology.

Keywords: design thinking; stakeholder; adolescent tobacco hazards prevention workshop

1 Introduction

Smoking is an increasingly serious problem among Taiwanese adolescents. The harm caused by smoking and secondhand smoke is a major factor affecting adolescents' health. Studies have shown that air pollution caused by smoking not only impairs the health of adolescent smokers, but also do damage to those who are exposed to second-hand smoke (Ittermann, T., Thamm, M., Schipf, S., John, U., Rettig, R., and Vlzke, H, 2013). Therefore, how to effectively prevent and control adolescent smoking, reduce the rate of adolescent smoking, and protect the health of adolescents is an urgent mission of public health service providers. However, the flexibility and effectiveness of the formulation and promotion of many existing tobacco hazards prevention strategies are relatively low. The strategies and regulations of tobacco hazards prevention need to be amended urgently. Therefore, the National Health Administration hopes to train the frontline executives of smoking cessation project in design thinking to help them think from the perspective of design thinking and to revise and improve the existing smoking prevention and control strategies. In the formulation of tobacco hazards prevention strategies, the corresponding stakeholder plays an important role in the formulation and implementation of strategies. Proper use of persona enables strategy-makers to better understand the needs of target users (Cooper, 1999, Grudin and Pruitt, 2002, Long, 2009, Ma and LeRouge, 2007, Pruitt and Adlin, 2006). Stakeholder involvement has become an integral part of many strategy-making processes (Arnstein, 1969). However the stakeholder technology is mainly criticized for being grounded in informal and unscientific data, the usefulness and ease of use of the technology are often questioned. This study takes the design thinking workshop as an example.

The purpose of this study is to design a new method to define key stakeholders by using scientific data.

The new approach can collect the problems in the process of tobacco hazard prevention and control, and find the key stakeholders and core factors for adolescent tobacco hazard prevention and control. And the new approach could be used to clarify the connection factors between Core Factors and Stakeholder in the process of tobacco hazards prevention.

2 Literature Review

According to the literature, related theories, and research results, this chapter can be divided into five parts: ATHP's theoretical research, design thinking workshop, design thinking, the 'Double Diamond' design process model and research methods.

2.1 Design Thinking Value of Adolescent Tobacco Hazards Prevention

Article 20 of Taiwan's Tobacco Harm Prevention Law stipulates that government agencies and schools must actively provide education on tobacco hazard prevention and carry out publicity activities. Studies have shown that tobacco hazards prevention should be the highest educational priority for schools and communities (Little, M. A., Pokhrel, P., Sussman, S., Derefinko, K. J., Bursac, Z., and Rohrbach, L. A., 2017). It is not difficult to find that the government attaches great importance to the prevention and control of tobacco among adolescents. Therefore, how to formulate more targeted and effective strategic planning is particularly important.

Most of the existing literature on adolescent smoking focuses on health care, smoking behavior and attitudes, the impact of smoking on adolescents, and the prevention and control of adolescent smoking hazards (Chen, M. L., Chou, L. N., & Zheng, Y. C., 2017). Few studies have considered the prevention and control of tobacco hazards from the perspective of Design Thinking. Starting from the needs of "Human," the problem of tobacco hazards prevention and its related Stakeholder are treated in the same way. Design Thinking transforms the system-oriented approach in strategic management into a human-oriented approach. It plays a key role in the rationality and comprehensiveness of the formulation of the strategy. Junginger (2006), Burns et al. (2005) and Junginger and Sangiorgi (2009) demonstrate the role of design in organizational change. In various contexts, including social innovation, the design has the opportunity to act as a facilitator or an agent for change. Design Thinking can become a new methodology in the contemporary strategy-making process.

2.2 Workshop

The workshop is an activity that allows many people to gather in the same space at the same time and think together, solve problems, communicate with each other and reach consensus in a short time (Webster, 1977). The focus of the workshop is co-working. The workshop can be aimed at individuals, groups and even organizations. In the process of organizing the workshop, participants' face-to-face communication and communication can not only increase mutual understanding and understanding but also build a team atmosphere and culture to promote deep learning and innovation (Byham,2008). Workshops can also be seen as a form of education, aiming at promoting understanding, defining and exploring different design issues, generating new ideas in exploration and making solutions in a short time (Turgut, H. & Cantyurk, E, 2015). The workshop provides a free and interactive environment that is not restricted by formal education (Civaro lu, 2003). For enterprises, the higher value of workshops is to provide participants with the background and environment to communicate with each other and to establish a creative work culture. By organizing workshops, the participation of internal staff can be enhanced, as well as Team Building activities (Zheng Jie, 2018) that show the results of work.

2.3 Design Thinking

Design thinking is a "human-centered design" methodology that aims to solve problems and seek innovative solutions and create more possibilities for a variety of issues, starting with people's needs. (Brown, T, 2008).Design thinking is a non-linear, iterative process which seeks to understand users, challenge assumptions, redefine problems and create innovative solutions to prototype and test. The method consists of 5 phases—Empathize, Define, Ideate, Prototype, and Test and is most useful when you want to tackle problems that are ill-defined or unknown(Brown,2010; d.School Stanford,2018).

This research hopes that the method of design thinking allows ATHP 's inspector and relevant project personnel to think in the way of design thinking. To make the appropriate prevention and strategies more in line with the "human center design" needs.

2.3.1 Design Thinking: Getting Started with Empathy

Identifying users' needs and further approaching users' feelings are gradually accepted and introduced into the design process. IDEO, an international design company, emphasizes empathy as the core mindset as the first step of design (IDEO, 2015) by using Human-Centered Design operation. Stanford D. School also uses Empathize as the starting point in the design process, which includes three stages: Observe, Engage and Immerse. The gradual experience of the target users (Scott et al., 2018). Involves empathizing with the people you are designing, understanding what they need, what they want, how they behave, feel and think, and why they behave, feel and think like this when interacting with products in the real world. Understanding the real needs of users has become an important new topic in contemporary design.

2.3.2 Design Thinking With Stakeholder

Stakeholders are usually accompanied by user journey. Relevant stakeholders are used to helping designers or planners analyze different roles in a project, to locate the concerns of different roles, and then to sort out the problems arising from complex interpersonal interactions, ensuring that the needs of different people can be met as much as possible.

Characters and organizations have direct or indirect interest relationships, groups or organizations because they may or may be affected by organizational actions, goals, and policies (Business Dictionary, 2007). About this Stakeholder, research lists may include one or more of the following: adolescent smokers, scholar experts, school instructors, parents, smokers' classmates, smoking public figures, counselors, smoking prevention and control personnel, hospital nurses, tobacco buyers, community volunteers.

2.4 The 'Double Diamond' Design Process Model

'Double Diamond' was developed by the Design Committee in 2005 as a simple graphical way to describe the design process. It is divided into four different stages, Discover, Define, Develop and Deliver. It shows the divergence and convergence stages of the design process. It shows the different thinking modes of the designers. The Double Diamond Design Process can be used in conjunction with Design Thinking, thinking about problem definition in the design process in a better way. Compared with design thinking, the double diamond process emphasizes the two divergent thinking and Convergent thinking in the design process, which are less emphasized and easily neglected in design thinking. We can reinforce the Empathize-Define and Ideate-Prototype-Test phases in the design thinking through the double diamond mode, so as to avoid falling into the "wrong definition problem" or the dilemma of "getting too fast into problem-solving and ignoring other better solutions". This study will use the first Diamond, Discover Problem Space in the "Double Diamond" design process. Combining Empathize and Define in Design Thinking, the problems in tobacco hazards prevention were found. The specific design process is shown in figure 1.

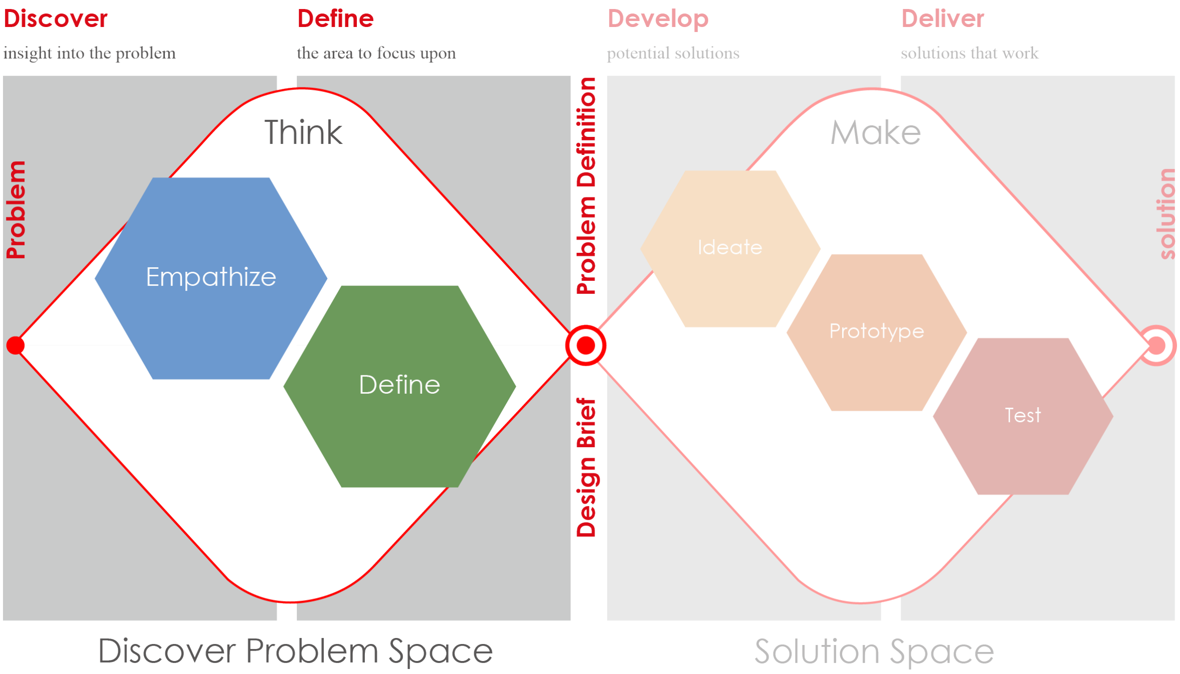


Figure 1. Design Thinking Models： Double Diamond Design Process
（d.school from IDEO,2001 ； British Design Council,2005）

2.4.1 Discover insight into the problem

The beginning of the double diamond model. This starts with initial ideas or inspirations, aiming at understanding the discovery phase of user needs. These include market research, user research, management information, design research groups.

2.4.2 Define the area to focus upon

Important information, the aim is to provide a standardized framework for user-centered design or design processes, which can facilitate the follow-up implementation.

2.5 Methodology

In this study, Focus group, KJ Method, Quantification Theory Type III and Cluster Analysis are used to discuss the prevention and control of tobacco hazards among adolescents in

Taiwan. It is very important to select methods to define and explore real problems through design thinking.

2.5.1 Focus Group

Focus group is a qualitative research method. Researchers invite a group of participants with homogeneous backgrounds to discuss freely under the leadership of a moderator to discover their ideas, opinions, perceptions, attitudes and beliefs about products, services and strategies. (Morgan, D. L., 1997).

2.5.2 KJ Method

Jiro Kawakita was developed in 1960. The main feature is to seek innovation from synthesis on the basis of comparative classification. When synthesizing cards, they can be discussed individually or collectively (Scupin, R. 1997). The basic steps are: 1. card making; 2. classification and naming; 3. Sub-classification; chart making; explanation. The KJ method is simple and easy to implement, which enables the team to concentrate on the work at hand. Features: Good at eliminating unnecessary discussions and reducing the probability of divergent targets.

2.5.3 Quantification Theory Type III

Hayashi's quantitative method is Japan's unique multi-party data analysis technology, developed by Chikio Hayashi, director of the Institute of Statistical Mathematics, from the late 1940s to the 1950s. Category III of quantitative methods is mainly used to simplify data structures (Manabu Iwasaki, 1989). Category is a complex category contained in most variables (Item). The method is to categorize most variables and provide research analysts' interpretation of the overall data. It is an analytical method to explore the relationship between variables and variables. In the theory of quantitative analysis, it belongs to the method of "interdependence". It is a kind of operation and analysis method of "vector algorithm". The meaning of numerical value is the degree of relativity between variables, not absoluteness. Quantitative encoding methods are generally "yes and no" and "yes and no" problems, which can be in the form of "0" and "1" encoding data. According to the "characteristics" of "samples", the similarity between the "characteristics" and the "characteristics" of "samples" is explained (Hayashi, C., 1956).

2.5.4 Cluster Analysis

Cluster analysis is a method to simplify data. According to the common attributes of samples, similar samples are clustered to form clusters. The phenomena of similar nature are categorized so as to find out the existing regularity after classifying a large number of complex features. (Capra, M. G. 2005).

3 Research Procedure and Methodology

3.1 Research Process and Steps

This study is divided into two stages: 1. Discover Problem (Data Collection) 2. Define Problem (Data Analysis). The specific research process and steps are shown in figure 2.

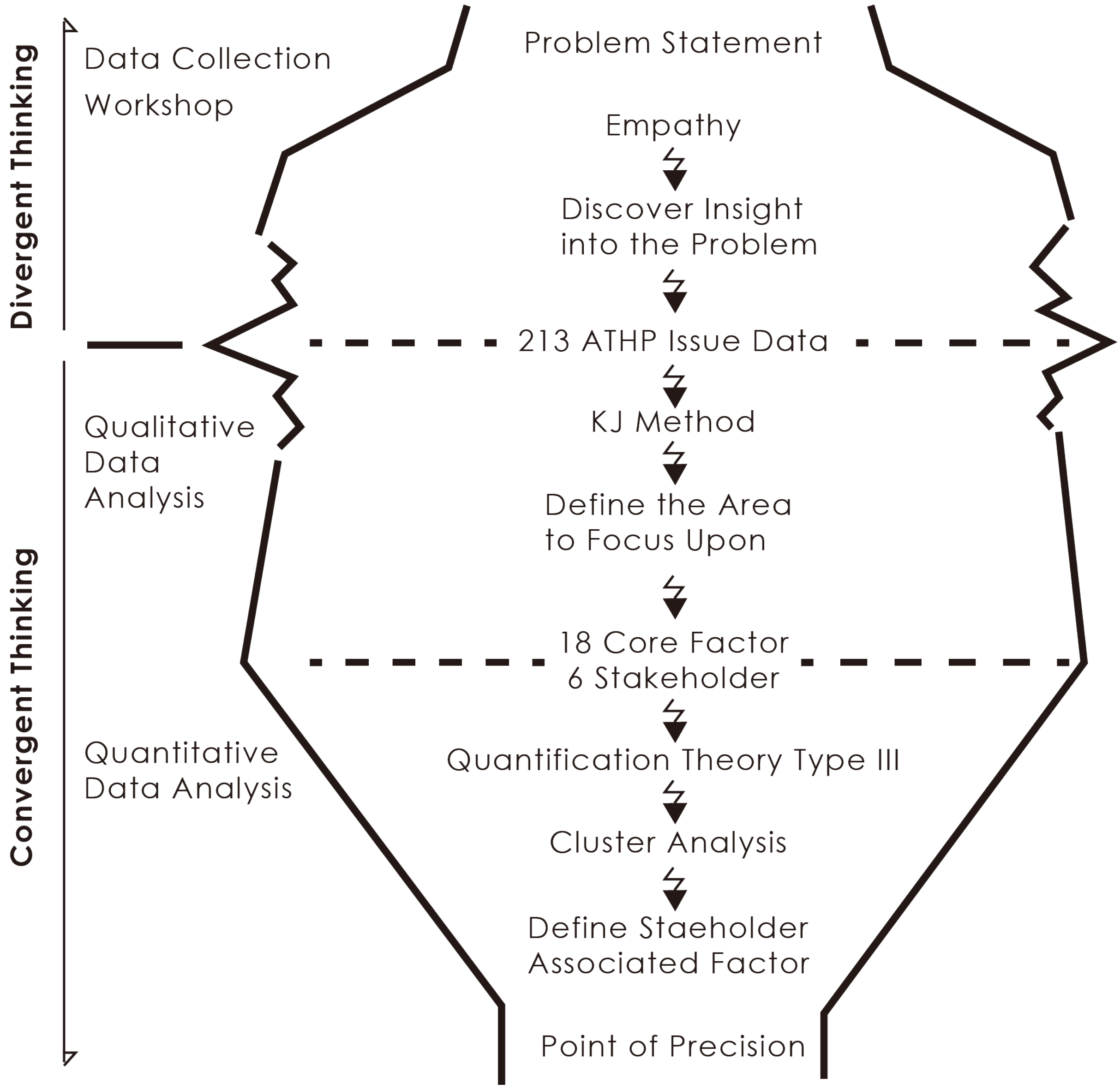


Figure 2. Research Process and steps

3.2 Discover Problem (Data Collection)

This stage discovers insight into the problem in the form of design thinking workshop.

3.2.1 Subject

The subject of workshop is Design Thinking Workshop: Discover Insight for Adolescent Tobacco Hazards Prevention Issue (see figure 3). This workshop is co-organized by the R&D team from National Cheng Kung University (NCKU) and the National Health Promotion Administration (Ministry of Health and Welfare, Taiwan). The workshop aims to introduce the design thinking process to the inspectors in tobacco hazards prevention field.

Figure 3. Design Thinking Workshop：Discover Insight for Adolescent Tobacco Hazards Prevention Issue

3.2.2 Participants

There were in total 71 participants join the workshop, 8 participants from Health Promotion Administration (HPA), and others from 21 local public health bureaus around Taiwan except for Taichung city.

The workshops are staffed by the R&D team from NCKU. The R&D team is composed of nine students led by a professor. Eight students were the workshop's group facilitator and one student was the workshop's photographer. During the workshop, a facilitator will guide the workshop. As a guide, he must be familiar with the purpose, process operation and other details of the workshop, and maintain the flow of the workshop process and guide the workshop before interfering with the design development of each group (Schein, 1999). How to use methods and tools skillfully is an integral part of the planning and implementation of design workshops (Utamura, S., Vontin, N., Takeda, K., Hirabaru, S., 2018).

Therefore, the workshop has eight doctoral and graduate students who have been trained in design thinking for many years as guides to help DT Workshop participants in design thinking training.

3.2.3 Design Thinking Workshop Planning

Intensive and short-term design is one of the characteristics of the workshop. The complete design process lasts from half a day to two days (Harris and Stock, 1999; Sork 1984;

Steinert et al. 2008). This workshop is planned for half a day. The specific planning time is shown in Table 1.

Table 1 Workshop Planning Schedule

Time	Workshop Activities	Stage of Design Thinking
13:00-13:15	Design Thinking Lecture	
13:15-13:30	Ice Breaking Toolkit Introduction: Empathy Map	
13:30-14:30	Discover Problem Space with Empathy	Discover Stage (Empathize)
14:30-16:00	Toolkit Introduction: KJ Method Define insights by Sorting problems though KJ Method	Define Stage (Define)
16:00-17:00	Presentation	

Before the workshop, the R&D team grouped 71 Workshop Participators into eight groups, each with 8 to 9 members. Each group will be assigned a facilitator, who will be responsible for the process description and guidance of the whole group. The group structure of the workshop is shown in figure 4.

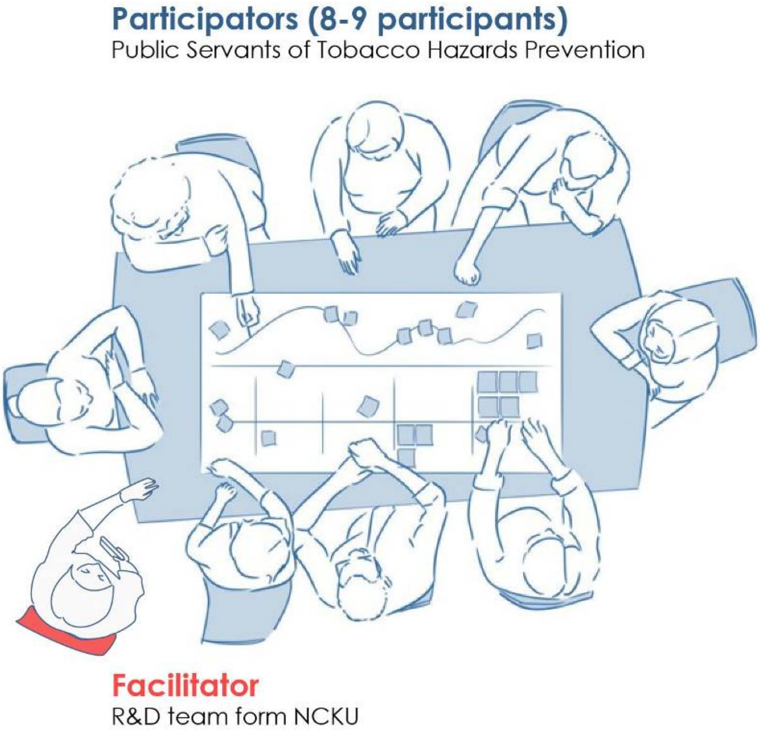


Figure 4. Group Structure of Workshop

After the workshop started, the whole workshop was divided into five stages.

Stage 1: Lecture. Professors present the concepts, methods, and processes of design thinking.

Stage 2: Ice Breaking and Toolkit Introduction: empathy map. Ice Breaking is a game of role cards to familiarize civil servants from different counties and cities with tobacco hazard prevention and control with the aim of breaking the diaphragm between each other and conveniently promoting the follow-up exchanges. After that, each group of guides will introduce the empathy map and the way it operates. Empathy Map is a framework tool for thinking, which can help civil servants to think and analyze empathize about the Stakeholders involved in the initial stage of problem formulation.

Stage 3: Discover Problem Space with Empathy. (1) A respondent will be selected in a group and other members interviewed him in the way of Empathy Map to find out the problem of tobacco hazards prevention from the perspective of Empathize. (2) Discover the present situation of ATHP by Focus Group.

Stage 4: Define insights by Sorting problems though KJ method. The activity scenarios for the first four stages of the workshop are shown in figure 5.

Figure 5. Workshop activity scenario for four phases

Stage 5: Group presentation and ideas sharing

At the end of the workshop, the R&D team will sort out the problems found by eight groups. Finally, 213 Adolescent Tobacco Hazards Prevention Issues were collected. Subsequently, the qualitative and quantitative analysis of the data will be carried out.

3.3 Define Problem (Data Analysis)

Data analysis is divided into two parts. Part I: Qualitative Data Analysis. Define Adolescent Tobacco Hazards Prevention Issue and Stakeholders involved in the issue. Part II: Quantitative Data Analysis. Clear up the similarities and characteristics of different Adolescent Tobacco Hazards Prevention(ATHP) Issues or different Stakeholders. Define the degree of correlation and influence between the two.

3.3.1 Qualitative Data Analysis

At the stage of qualitative data analysis, in order to enable Adolescent Tobacco Hazards Prevention(ATHP) issue to be accurately grouped by induction, eight students (3 Ph.D. students and 5 M.S. students) trained in professional KJ method were invited to form an expert group to classify and merge 213 ATHP issues by holding Focus Group. After the focus group discussion, 213 original data (Adolescent Tobacco Hazards Prevention Issue) was sorted into 18 groups. After that, 18 groups were renamed to form the final 18 core factors. (see. Table 2) The core factor of ATHP issue generated in this section reflects the whole problem space and states the critical issue related to the ATHP issue field.

Through the study of 18 core factors and their subordinate factories, this study found that the problems encountered in the prevention and control of smoking among adolescents can be divided into five stages: Stage 1 Start Smoking Before-Stage 2 Start Smoking-Stage 3 Form the Habit of Smoking-Stage 4 Continuous Smoking-Stage 5 Hard to Quit Smoking. This study named these five stages of user journey stages. Specific user journey stages and their corresponding core factors are shown in Table 2.

Table 2 User Journey Stages

User Journey Stages	Core Factors
Stage1 Start Smoking Before	01 Smoking is an attractive and fascinating thing.
	02 Advising underage to quit smoking is just inviting trouble.
	03 Neglect of and indifference to the issue of underage smoking behavior.
Stage2 Start Smoking	04 Smoking behavior could be easily imitated.
	05 It is ashamed to refuse smoking invitation from others.
	06 Escaping from the pressure of the reality.
Stage3 Form the Habit of Smoking	07 Cigarettes (e-cigarettes) is easily to purchase and obtain.
Stage4 Continuous Smoking	08 The attitude toward smoking is hard to be flipped.
	09 Underage smokers denied and refused to face the tobacco hazards.
	10 Underage smokers tend to ignore the regulations of THP.
	11 Difficulty in inspection caused by limited human resources.
	12 Insufficient regulations limits the inspectors from precise execution.
	13 It is difficult to verify the illegal facts of underage smoking.
	14 Insufficient awareness of the harm caused by smoking behaviour.
	15 Tobacco cessation intervention couldn’t significantly influence youth.
	16 Tobacco cessation intervention would be boring for underage smoker.
	17 Lacking of resources and guidance of tobacco cessation.
Stage5 Hard to Quit Smoking	18 It’s not easy to quit but repeat smoking behaviour.

Stakeholders can help you visualize the key players in the project and prepare for future communication and user-centered research and design. Especially when the project involves many roles and complex interests, we need methods to help us clarify the relationship between the roles and their impact on the project. Subsequent expert groups extracted stakeholders from 18 core factors. Six key stakeholders, adolescent smoker, friends and family, counselor, inspector, cigarette seller, and public figure has been identified and shown in figure 6.

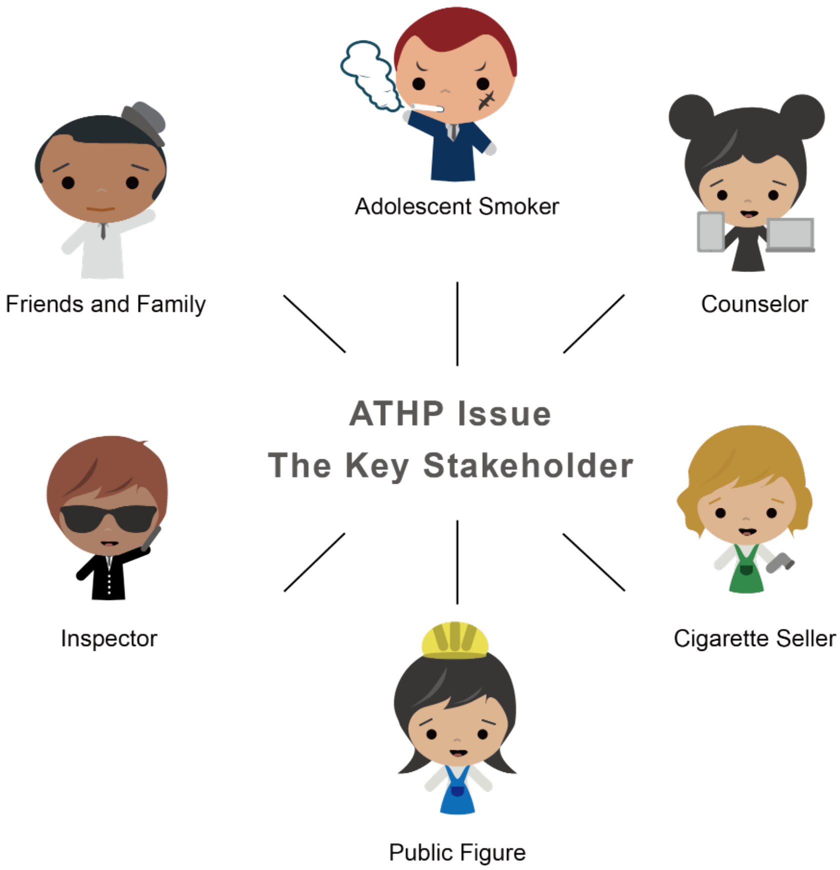


Figure 6. Six key ATHP Stakeholders

3.3.2 Quantitative Data Analysis

Based on qualitative data analysis, 18 ATHP core factors and 6 key stakeholders are analyzed by quantification theory type III. Quantification method type III is applied majorly to simplify data structure (sample and characteristics) and is one of the multivariate analysis methods. (Manabu Iwasaki, 1989). Eighteen ATHP issue core factors and six key stakeholders were coded in the form of "0" and "1" coded data respectively. The results will show the characteristics of core factors and the relativity between core factors and key stakeholders.

Cluster analysis is then used to group similar "Core Factors". By finding common attributes of core factors and combining the methods discussed above, we can find the similarities and characteristics of different core factors or stakeholders. Additionally, the correlation degree and influence between core factors and stakeholders in the process of ATHP can be explained with the visual image map.

4 Results and Discussion

4.1 Quantification Theory Type III Analysis Results

According to the results of quantification theory type III, the first four axes are meaningful axes. Effective eigenvalue refers to the weight of "vector function" in vector space. Between 0 and 1, the closer to 1, the higher the importance. (General experience greater than 0.25 is the meaningful axis.) Specific intrinsic value data are shown in Table 3.

Table 3 Data of Eigenvalue

	Eigenvalues	R
1	0.65887	0.81171
2	0.56006	0.74837
3	0.45764	0.67649
4	0.28405	0.53297
5	0.16953	0.41175

The following table is the result of six ATHP issue key stakeholders (Category). It represents the degree of correlation between "Key Stakeholders" and vector functions (simplified feature plane). (see. Table 4)

Table 4. Category of Key Stakeholders

Key Stakeholders	1	2	3	4	5
Adolescent Smoker	0.59664	0.87614	-0.87055	-0.35841	-0.43598
Friends and Family	-1.26711	0.11077	-0.04483	1.58894	-0.43449
Inspector	0.59419	-0.33	1.9122	-0.37101	-1.06953
Counselor	0.12869	-1.6793	-0.60679	-0.27997	0.53687
Cigarette Seller	0.58405	1.01896	1.04394	0.5148	2.63295
Public Figure	-3.98776	0.92219	0.52921	-3.67901	0.65738

The following table is a sample of 18 ATHP issue Core Factors: it represents the value projected on the vector space by "Core Factors". (see.Table5)

Table 5. Sample of Core Factor

Core Factors	1	2	3	4	5
01 Smoking is an attractive and fascinating thing.	-0.41299	0.65937	0.67657	1.15441	-1.05704
02 Advising underage to quit smoking is just inviting trouble.	-0.22349	0.84563	0.62113	0.58662	0.78296
03 Neglect of and indifference to the issue of underage smoking behaviour.	-0.70124	1.04797	0.48162	1.22799	0.12433
04 Smoking behavior could be easily imitated.	3.23691	0.69014	0.358	1.96079	0.27067
05 It is ashamed to refuse smoking invitation from others.	1.56103	0.14801	0.06628	2.9813	1.05523
06 Escaping from the pressure of the reality.	0.73505	1.17074	1.28686	0.67248	1.05886
07 Cigarettes (e-cigarettes) is easily to purchase and obtain.	0.03548	0.89344	0.06335	1.09157	1.42684
08 The attitude toward smoking is hard to be flipped.	0.4468	0.53661	1.09191	0.5989	0.12252
09 Underage smokers denied and refused to face the tobacco hazards.	0.73505	1.17074	1.28686	0.67248	1.05886
10 Underage smokers tend to ignore the regulations of THP.	0.72887	0.69712	1.02765	0.13423	0.91274
11 Difficulty in inspection caused by limited human resources.	0.44528	1.34245	0.96484	0.61072	0.64683
12 Insufficient regulations limits the inspectors from precise execution.	0.73202	0.44096	2.82664	0.69612	2.59755
13 It is difficult to verify the illegal facts of underage smoking.	0.72887	0.69712	1.02765	0.13423	0.91274
14 Insufficient awareness of the harm caused by smoking behaviour.	0.73505	1.17074	1.28686	0.67248	1.05886
15 Tobacco cessation intervention couldn't significantly influence youth.	0.15855	2.24395	0.89697	0.52531	1.3039
16 Tobacco cessation intervention would be boring for underage smoker.	0.15855	2.24395	0.89697	0.52531	1.3039
17 Lacking of resources and guidance of tobacco cessation.	0.4468	0.53661	1.09191	0.5989	0.12252
18 It's not easy to quit but repeat smoking behaviour.	0.73505	1.17074	1.28686	0.67248	1.05886

Based on the above two sets of data: "Core Factors" and "Key Stakeholders" projected on the vector space, the final image map of "Core Factors" and "Key Stakeholders" can be drawn. (see. figure 7)

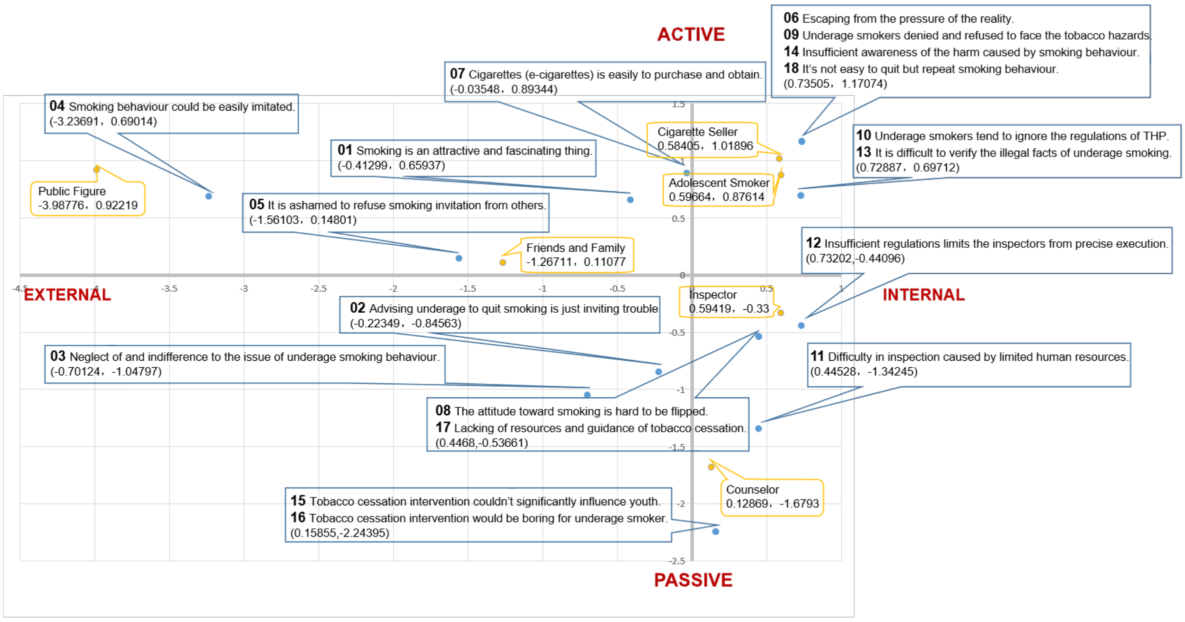


Figure 7. Image Map of Quantification Theory Type III Results

According to the image map, the coordinate axis is defined and quadrant analysis is carried out. On the left is factors that are biased towards external causes in the ATHP issue process, such as 04. Smoking behaviour can be easily imitated (-3.23691, 0.69014). Left-sided bias in ATHP issue process, related stakeholders affected by internal causes (self-reasons) such as 06. Escaping from the pressure of the reality at the far right; 09. Underage smokers denied and refused to face the tobacco hazards; 14. Insufficient awareness of the harm caused by smoking behavior; 18. It's not easy to repeat smoking behaves without smoking. (0.73505, 1.17074). At the same time, in the process of ATHP issue, the relative stakeholder's ATHP issue factors are caused by active behavior, such as the top 06; 09; 14; 18 (0.73505, 1.17074). In the process of ATHP issue, the lower part of the transverse axis centerline deviates to the related stakeholder's ATHP issue factors caused by passive behavior. For example, the lowest factor is 15. Tobacco cessation intervention couldn't influence significantly youth; 16. Tobacco cessation intervention would be boring for the underage smoker. Therefore, the left side of the transverse axis is named exterior and the right side is named interior. The upper side of the longitudinal axis is named active, and the lower side of the longitudinal axis is named passive. (see. figure 7)

From the image map, it can be seen that in the first quadrant, Public Figure (-3.98776, 0.92219), Friends and Family (-1.26711, 0.11077) are all the external reasons. In the second quadrant, Adolescent Smoker (0.59664, 0.87614) and Cigarette Seller (0.58405, 1.01896) are the main factors that actively affect the prevention and control of tobacco hazards among adolescents. In the fourth quadrant, the internal causes are adolescent smoker (0.59664, 0.87614) and cigarette seller (0.58405, 1.01896). Stakeholder is mainly inspector (0.59419, -0.33) and counselor (0.12869, -1.6793).

4.2 Cluster Analysis Results

Cluster analysis is used to group similar "Core Factors." As can be seen from the results of cluster analysis, "18 Core Factors" can eventually be divided into five groups.（see figure 8）.

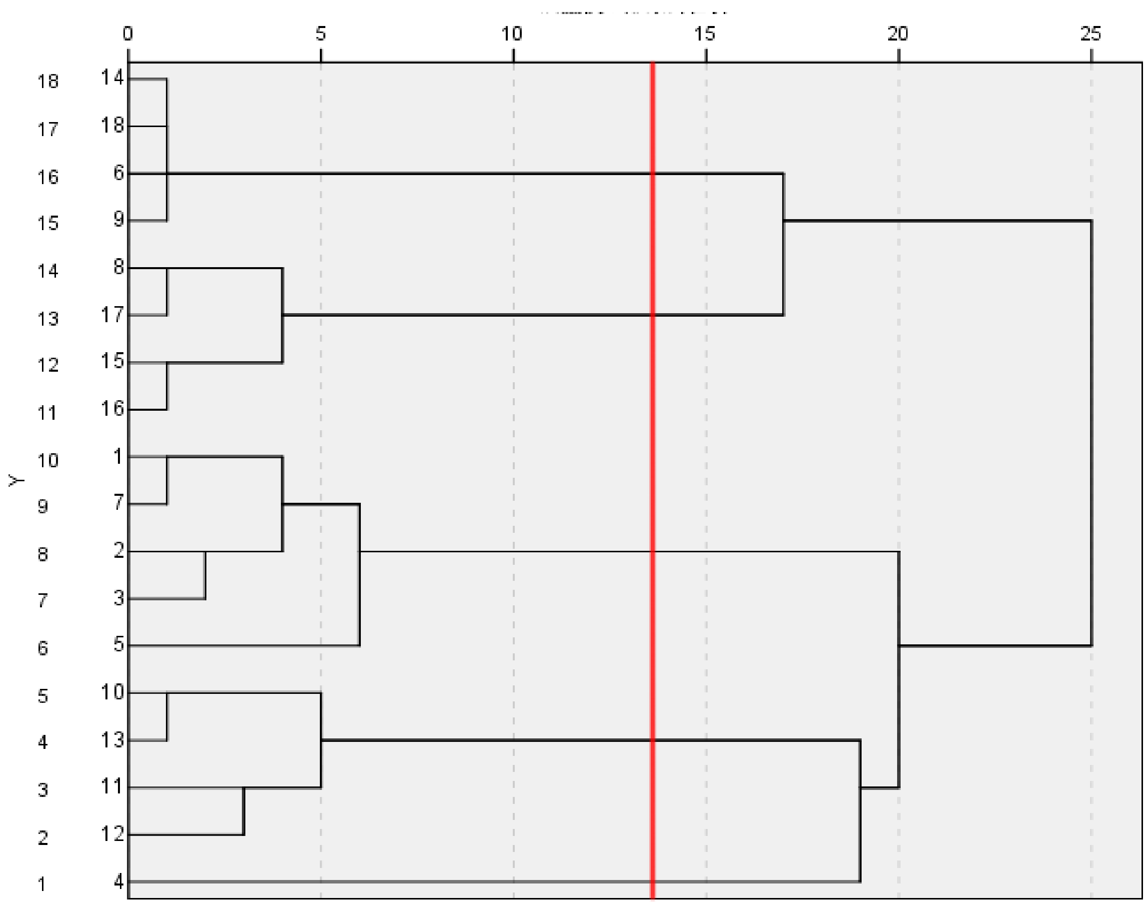


Figure 8. Dendrogram for「Core Factors」

Five groups of "Core Factors" and the stakeholders involved are shown in Table 6.

Table 6 Five categories of Core Factors

Core Factors	Key Stakeholders		
Cluster 1 (Adolescents' Smoking Characteristic-easy to smoke and not easy to quit)			
06 Escaping from the pressure of the reality.	Adolescent Smoker		
09 Underage smokers denied and refused to face the tobacco hazards.	Adolescent Smoker		
14 Insufficient awareness of the harm caused by smoking behaviour.	Adolescent Smoker		
18 It's not easy to quit but repeat smoking behaviour.	Adolescent Smoker		
Cluster 2 (Effectiveness of Smoking-quitting Education)			
08 The attitude toward smoking is hard to be flipped.	Counselor	Adolescent Smoker	
15 Tobacco cessation intervention couldn't significantly influence youth.	Counselor		
16 Tobacco cessation intervention would be boring for underage smoker.	Counselor		
17 Lacking of resources and guidance of tobacco cessation.	Counselor	Adolescent Smoker	

Cluster 3（Family Friends' Influence on Adolescent' Smoking Behaviour）			
01 Smoking is an attractive and fascinating thing.	Friends and Family	Adolescent Smoker	
02 Advising underage to quit smoking is just inviting trouble.	Friends and Family	Counselor	Inspector
03 Neglect of and indifference to the issue of underage smoking behaviour.	Friends and Family	Counselor	
06 Escaping from the pressure of the reality.	Friends and Family		
07 Cigarettes (e-cigarettes) is easily to purchase and obtain.	Friends and Family	Adolescent Smoker	Cigarette Seller
Cluster 4（Law Enforcement & Inspection Difficulties）			
10 Underage smokers tend to ignore the regulations of THP.	Inspector	Cigarette Seller	Adolescent Smoker
11 Difficulty in inspection caused by limited human resources.	Inspector	Counselor	
12 Insufficient regulations limits the inspectors from precise execution.	Inspector		
13 It is difficult to verify the illegal facts of underage smoking.	Inspector	Cigarette Seller	
Cluster 5（Imitation of Smoking Behavior）			
04 Smoking behavior could be easily imitated.	Public Figure	Friends and Family	Adolescent Smoker

According to the cluster analysis results, it can be found that the problems of ATHP can be divided into five categories. According to the details of each group, five groups can be named Cluster 1 (Adolescents' Smoking Characteristic-easy to smoke and not easy to quit); Cluster 2 (Effectiveness of Smoking-quitting Education); Cluster 3 (Family Friends' Influence on Adolescent' Smoking Behaviour); Cluster 4 (Law Enforcement & Inspection Difficulties); Cluster 5 (Imitation of Smoking Behavior) respectively. According to the results of qualitative research, the "Key Stakeholders" involved in each "Core Factors" are shown in Table 6. The four "Core Factors" in cluster 1 (the problem of smoking cessation among adolescents) are adolescent smoker; the four "Core Factors" in cluster 2 (the effect of smoking cessation education) are counselor, and the four "Core Factors" in cluster 3 are counselor. The stakeholders involved in the five core factors are friends and family, and the stakeholders involved in the four core factors in cluster 4 are inspectors. In cluster 5, core factors 04 Smoking behavior can be easily imitated and independently grouped. This "Core Factors" has its stakeholder public figure.

4.3 Discussion

Based on the quantification theory type III analysis results and cluster analysis results mentioned above, the final image map presented in this study is shown in figure 9.

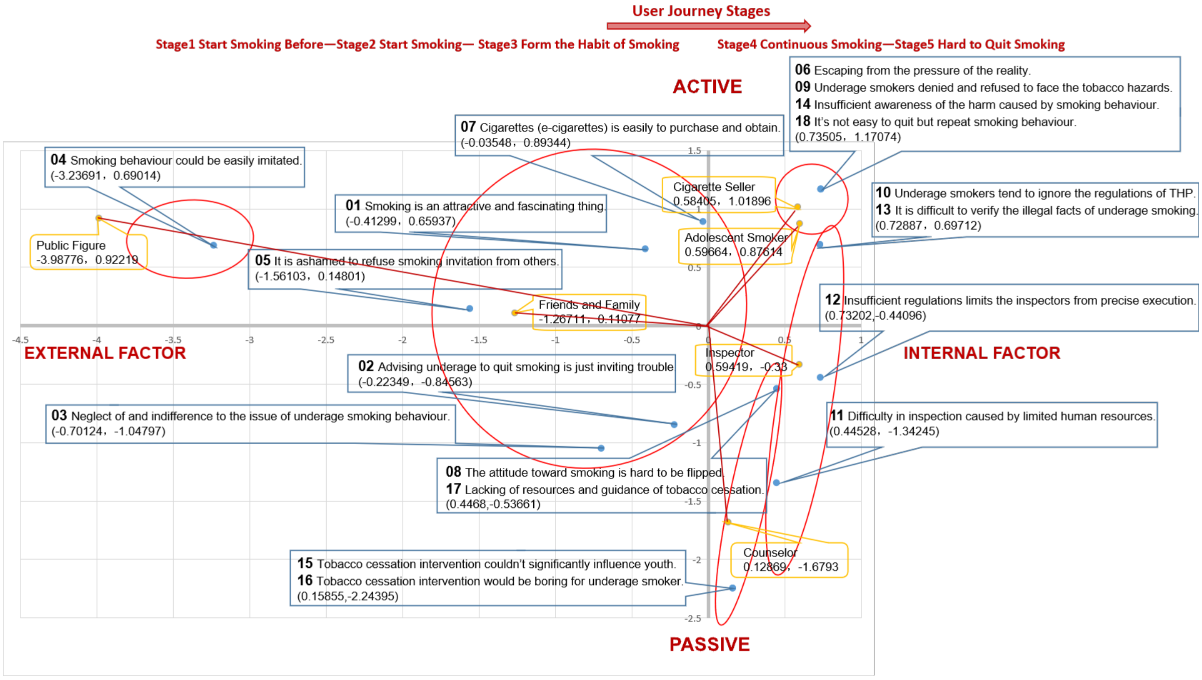


Figure 9.Image Map of Adolescent Tobacco Hazards Prevention Issue

As can be seen from the figure above, in user journey stages, the core factors of cluster 5 and cluster 3 on the left side of the vertical axis are stage 1, stage 2 and stage 3 in user journey stages. The core factors of cluster 1, cluster 4 and cluster 2 on the right side of the vertical axis are all stage 4 and stage 5 in user journey stages except 06 escaping from the pressure of the reality. According to the location of "Key Stakeholders", we can see that public figure and friends and family often appear as important stakeholders in the first stage of to the third stage of the user's journey. Adolescent smoker, cigarette seller, inspector, and counselor often appear as important stakeholders in the later stage of the ATHP process(Continuous smoking to Hard to quit smoking). From the above analysis, inspector and counselor should be more closely linked with the preceding stage of the prevention and control process (before adolescents develop smoking habits). More "Key Stakeholders" are needed to work together to prevent smoking among adolescents in advance. Stifle issue before stage 3 form the habit of smoking.

To clarify where each stakeholder in ATHP issue image map is located in ATHP issue and how stakeholders influence on ATHP core factors, this study is conducted to do the interpretation of image map in details. Take the point of core factors 10 and 13 as an example, from the center point to 10. Underage smokers tend to ignore the regulations of ATHP. 13. It is difficult to verify the illegal facts of underage smoking. This point is vector, and then let all stakeholders perpendicular to this vector and extension line. The closer the perpendicular point is to the vector line, the greater the influence of stakeholders on this core factor. As shown in figure 10, the order of influence on core factors 10 and 13 is adolescent smoker, cigarette seller, inspector, friends and family, counselor and public figure. Of course, you can also use the center as a vector to all stakeholders and get the ranking of each stakeholder's influence on 18 core factors. Using other ATHP core factors as vector points can be interpreted as well.

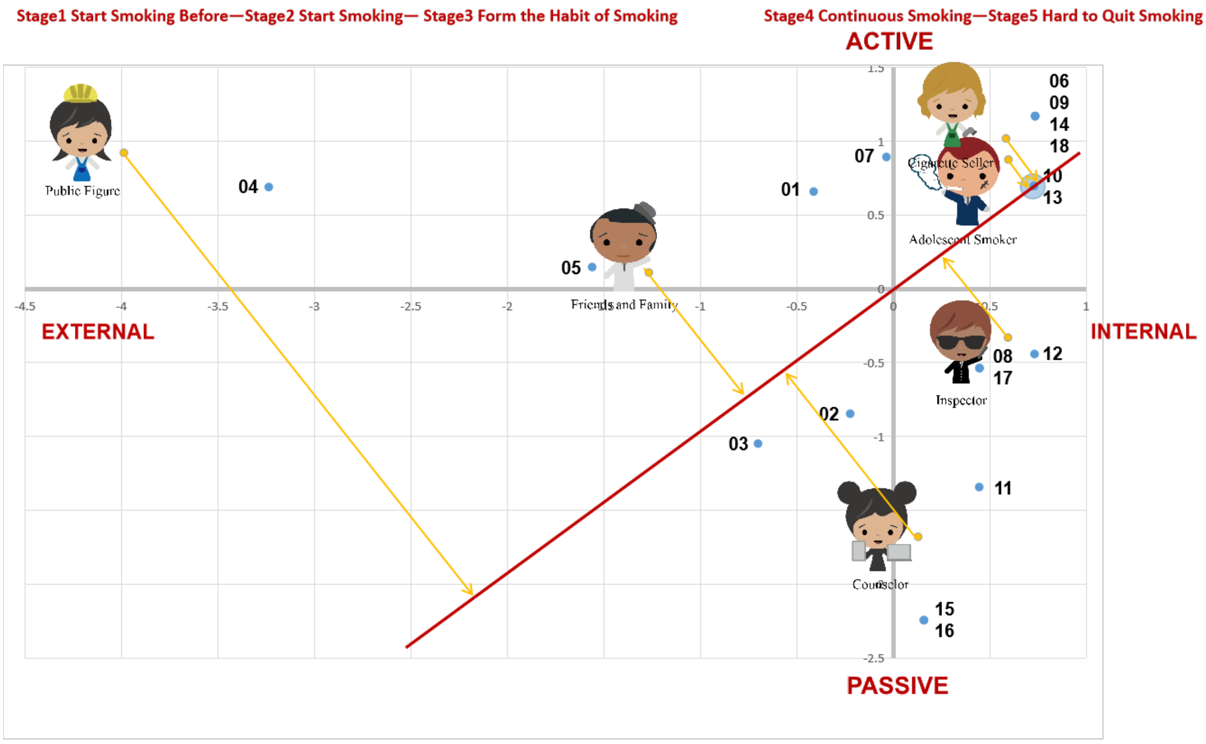


Figure 10. Image Map of Adolescent Tobacco Hazards Prevention Issue (Stakeholders Influence)

Secondly, the similar relationship between stakeholders can be found through image map of Adolescent Tobacco Hazards Prevention (ATHP)issue. In this study, we can see the similarity between different stakeholders from the angle of the vector angle, and the similarity from the angle of cosine theorem, as shown in figure 9. The smaller the angle is, the more similar the vector is. For example, the angle between adolescent smoker and cigarette seller is very small, which indicates that they are similar and closely related. Inspector and public figure are very different, and the angle between them is almost flat. The results showed that there was no close relationship between them in the process of tobacco prevention and control among adolescents. There is little connection. At the same time, we can see from figure 11 that if we take adolescent smoker as the location point, adolescent smoker as the center of the circle, and its benefit as the radius, then we can draw the conclusion that the more first stakeholder circles in, the more direct stakeholder of adolescent smoker. On the contrary, the farther away it is, the more indirect stakeholder of adolescent smoker. If other stakeholders are used as the locating points, they can be interpreted as well.

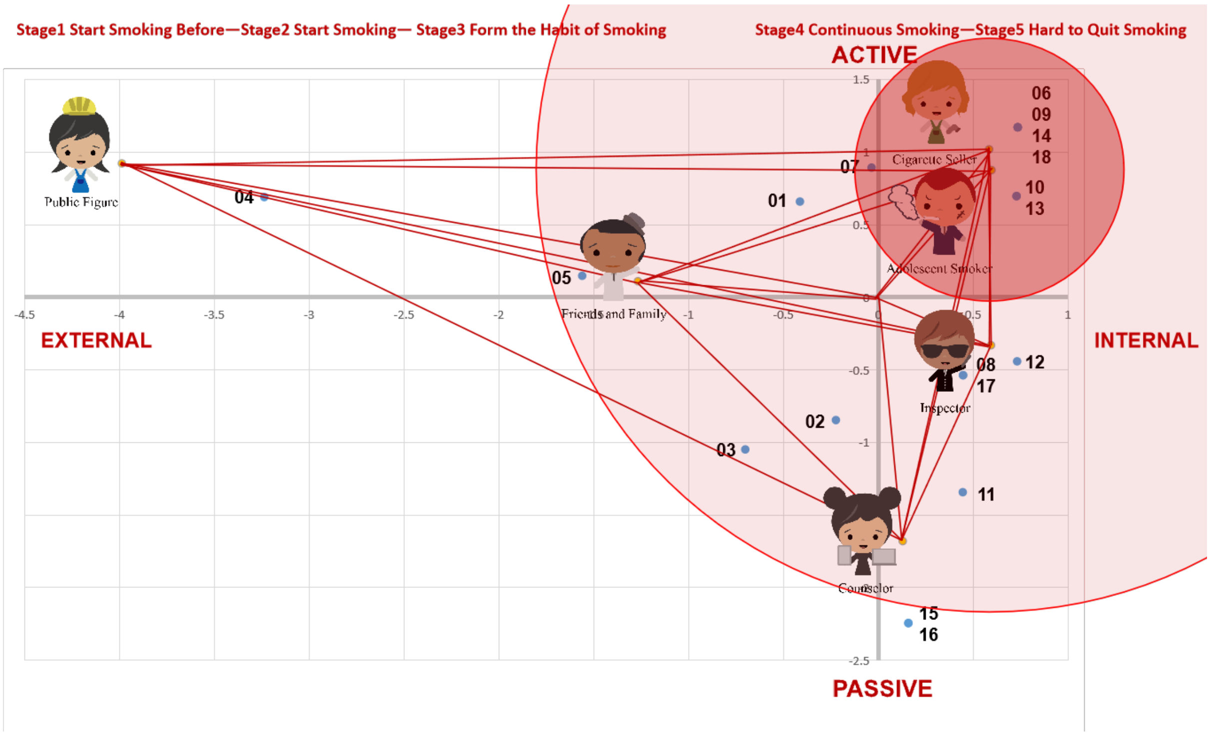


*Figure 11.Image Map of Adolescent Tobacco Hazards Prevention Issue (*Stakeholders *Similarity)*

By interpreting ATHP issue image map, the youth smoke hazards prevention and control personnel can clearly understand the position of each stakeholder in the smoke hazard prevention and control related issues, the similar relationships among different stakeholders and the strength of each stakeholder's influence on 18 core factors. Knowing these clearly will be helpful for the youth tobacco prevention and control related personnel to subdivide the strategy, find the target Stakeholders or core factors positioning for analysis. Finally, they can select different target groups or problems, and formulate targeted prevention and control strategies.

5 Conclusions

In this study, a new method was designed to redefine the problem and stakeholders in the event, taking the prevention and control of tobacco hazards among adolescents in Taiwan as an example. The biggest difference between this method and the previous way of defining stakeholders is that this method can accurately define "Core Factors" and "Key Stakeholders" in events, clearly locate the location of each "Core Factors" or "Key Stakeholders" in the event, understand the similarities of each "Core Factors" or "Key Stakeholders" and clear up the influence of each stakeholder on different core factors. This method can be applied to various fields where stakeholders analysis is needed. This study will summarize the operation process of this method, which is convenient for future references. (see. Figure 12)

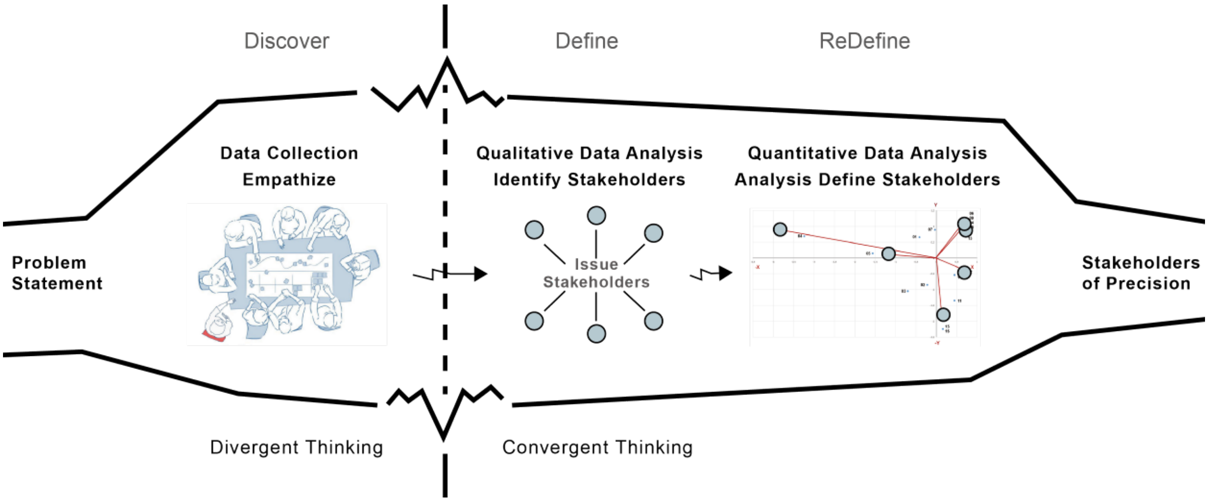


Figure 12.A New Approach to Re-define Stakeholders

1. Discover Problem: Finding problems by using design thinking: empathy as the core mindset.

2. Identify Stakeholders: Categorizing and merging the issues which have been found and defining the core issues and key stakeholders.

3. Analysis Define Stakeholders: Drawing stakeholders image map through three kinds of quantitative analysis and cluster analysis results. From the image map, you can see where each stakeholder is in the event, understand the relationship among stakeholders, and know the strength and weakness of different stakeholders' influence on each issue.

6 References

Brown, T. (2008). Design thinking. *Harvard business review*, *86*(6), 84.

Brown, T., & Wyatt, J. (2010). Design thinking for social innovation. *Development Outreach*, *12*(1), 29-43.

Billestrup, J., Stage, J., Bruun, A., Nielsen, L., & Nielsen, K. S. (2014, September). Creating and using personas in software development: experiences from practice. In *International Conference on Human-Centred Software Engineering* (pp. 251-258). Springer, Berlin, Heidelberg.

Bennett, C., & Rosner, D. K. (2018). The Promise of Empathy: Design, Disability, and Knowing the Other. In *Proceedings of the 2018 CHI conference on human factors in computing systems*.

Chen, M. L., Chou, L. N., & Zheng, Y. C. (2017). Providing a Clean Environment for Adolescents: Evaluation of the Tobacco Hazards Prevention Act in Taiwan. *International journal of environmental research and public health*, *14*(6), 634.

Chen, J. M., Hwang, B. F., Chen, Y. C., & Lee, Y. L. (2014). Active smoking, environmental tobacco smoke and bronchitic symptoms among adolescents in Taiwan: a prospective cohort study. *Preventive medicine*, *65*, 116-121.

Council, B. D. (2016). " Eleven lessons. A study of the design process.

Capra, M. G. (2005, September). Factor analysis of card sort data: an alternative to hierarchical cluster analysis. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 49, No. 5, pp. 691-695). Sage CA: Los Angeles, CA: SAGE Publications.

Ferreira, B., Silva, W., Oliveira Jr, E. A., & Conte, T. (2015, July). Designing Personas with Empathy Map. In *SEKE* (Vol. 152).

Hayashi, C. (1956). Theory and example of quantification (II). *Proceedings of the Institute of Statistical Mathematics*, *4*, 19-30.

Ittermann, T., Thamm, M., Schipf, S., John, U., Rettig, R., & Völzke, H. (2013). Relationship of smoking and/or passive exposure to tobacco smoke on the association between serum thyrotropin and body mass index in large groups of adolescents and children. *Thyroid*, *23*(3), 262-268.

IDEO, E. (2015). The field guide to human-centered design: design kit.

Junginger, S. (2006). *Change in the making: Organizational change through human-centered product development*. ProQuest.
Lee, G. C., Kim, Y. J., Shin, Y. K., Eun, B. L., Park, S. H., & Tockgo, Y. C. (1997). The state of smoking and alcohol usein Korean adolescent. *Journal of the Korean Pediatric Society*, *40*(3), 307-317.
Little, M. A., Pokhrel, P., Sussman, S., Derefinko, K. J., Bursac, Z., & Rohrbach, L. A. (2017). Factors Associated with the Adoption of Tobacco Cessation Programmes in Schools. *Journal of Smoking Cessation*, *12*(1), 55-62.
Morgan, D. L. (1997). *The focus group guidebook* (Vol. 1). Sage publications.
Norman, D. (2010). Design thinking: A useful myth. *Retrieved January*, *25*, 2015.
Norman, D. (2010). Design thinking: A useful myth. *Retrieved January*, *25*, 2015.
Park, H. K. (1967). The social-politic consideration about youngmen's drinking and smoking. *J Korean Med Assoc*, *10*, 545-548.
Poursafa, P., Mansourian, M., Motlagh, M. E., Ardalan, G., & Kelishadi, R. (2014). Is air quality index associated with cardiometabolic risk factors in adolescents? The CASPIAN-III study. *Environmental research*, *134*, 105-109.
Scupin, R. (1997). The KJ method: A technique for analyzing data derived from Japanese ethnology. *Human organization*, 233-237.
Spool, J. M. (2004). The KJ-technique: A group process for establishing priorities. *User interface engineering*.
Schein, E. H. (1999). *Process consultation revisited: Building the helping relationship*. Reading, MA: Addison-Wesley.
Thinking Bookleg (2018).https://dschool.stanford.edu/resources/design-thinking-bootleg
Utamura, S., Vontin, N., Takeda, K., & Hirabaru, S. (2018). Global Roll-out of Unique Methods and Tools for Co-creation Workshops. *FUJITSU Sci. Tech. J*, *54*(1), 40-45.
Zhang, H., Guerrero, C., Wheatley, D., & Lee, Y. S. (2010, September). Privacy issues and user attitudes towards targeted advertising: A focus group study. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 54, No. 19, pp. 1416-1420). Sage CA: Los Angeles, CA: SAGE Publications.

About the Authors:

Jia-Xuan Han: Jia-Xuan Han is currently a Ph.D. student at the Industrial Design, National Cheng Kung University (NCKU). Her research interest is focus on Kansei & Miryoku Engineering, Design Thinking Education and Product Innovation & Design.

Min-yuan Ma: Min-yuan Ma, Ph.D., is a professor of dept. of Industrial Design of National Cheng Kung University. He is currently the Vice-Dean of College of Design and Planning, NCKU. His research focus on Design Evaluation and Tools development, Innovation Education, Kansei & Miryoku Engineering and Product Innovation & Design.

Eric Chen-F Hsieh: Eric Chen-F Hsieh is currently a doctoral student at the Industrial Design, National Cheng Kung University (NCKU) in Taiwan. His research interest is focus on Kansei Experience and Evaluation, Design Education and Product innovation & Design.

Acknowledgement: We want to thank all those who provided their time to participate in this study. This research was supported by the Health Promotion Administration, Ministry of Health and Welfare.

IASDR 2019

International Association of Societies of
Design Research Conference 2019
DESIGN REVOLUTIONS

Manchester School of Art
Manchester Metropolitan University
02-05 September 2019

A study on comparing design behaviors of experts and novices in the design process

Chen, Yan-Ting; Chen, Hsi-Jen*;

National Cheng Kung University, Tainan, Taiwan
* hsijen_chen@mail.ncku.edu.tw

The importance of design is increasing in many industries. The design process could dominate the outcome of the design to some extent. It is obvious that expert and novice designers work in different ways and also have varied behaviors during the design process. In order to have a better understanding of how they behave during the design process, the objective of this paper is to explore the differences in their behaviors. The study adopted a protocol method to examine the sequence of the design phase and design activity, along with the time spent and the occurrences. The results are revealed by protocol analysis with sequence maps, and quantitative data. It should be noted that although the paths of experts and novices were both iterative, they were executed in different ways. Additionally, experts could spend more time than novices on the Design phase because they could evaluate the problems precisely based on their experience and knowledge. The outcomes of this paper provide new insights for not only designers themselves but also educators and team managers of companies.

Keywords: design process; design behavior; expert and novice

1 Introduction

Maciver (2016) indicated that design and designers have become more important roles recently. Design is a sequence of processes (Kotler & Rath, 1984) and the design elements are for meeting the needs of the clients and the company benefits (Bruce & Bessant, 2002). During product development in a company, the designers have a great impact on the product, which can significantly influence the performance of the company. Designers develop products by different design processes, and the design process is dynamic and complex. Browning (2018) mentioned that people who thoroughly understand the design process could have advantages in order to get the leading status. Thus, it's valuable for people to focus more on the design process.

Based on the research by Green, Southee, and Boult (2014), the design process is located between input and output. The design process includes different phases and the ways that designers execute them are varied, resulting in different design behaviors. There have been discussions about the differences between experts and novices. Many studies have addressed the comparison of the problem-solving strategy and problem analysis of experts and novices (Brand-Gruwel, Wopereis, & Vermetten, 2005; Kim & Ryu, 2014), which are related to the earlier phases in the design process. Some researchers mainly focus on comparing expert and novice designers' design behaviors (Chen, 2007; Kavakli & Gero, 2002).

Although we can learn from these articles which are focusing on earlier phases and the actual design phase to understand more about how expert and novice designers work during the design process respectively, it's still hard to have a holistic understanding of how designers work from phase to phase because there is lack of studies into how these two phases work together. There is a need to have a continuous study to understand the process as a whole.

Therefore, the objective of this paper is to explore the differences in behavior between the expert and novice designers during the design process. The study would be conducted with these following research questions: How do they execute the different phases in sequence? What phases do they emphasize on more? What do they do in each phase? The findings in this study can help novice designers learn from expert designers and help expert designers understand how novice designers act during the design process. This should result in better communication in order to improve the design quality and increase efficiency.

2 Literature review

2.1 Understanding of the design process

Design is considered an inevitable element in the creative industry and in new product development. The design process determines the quality of the product. If designers would like to improve the product, they also need to improve their design process, because the better the design process is, the better the creation will be (Chapman, 2006). Dubberly (2004) states that the purpose of having a comprehensive understanding of design process is (1) decreasing the risk of failure and increasing the possibility of success, (2) setting the expected result and decreasing uncertainty, and eventually (3) increasing the repeatability to make improvement easier.

2.2 The development of the design process

The first design process originated around 1920, when it was used for the development of battleships. Research of the design process began in the post-war period, starting with new technologies such as the computer and military technologies, and then the complexity of these inventions required standardization. Afterwards, standardization led to the engineering design process, which formed the basis of the design process in the field of product design. Recently, the engineering design process is gradually comparing and combining with the design process in the field of product design. Cross (2001) defined that the design process has a scientific basis and supports 'designerly ways of knowing'. However, Blessing and Chakrabarti (2002) indicated that there are many uncertainties and confusions in the design process. Dorst (2008) also mentioned that the design process lacks comprehension. During the evolution of the design process, Green et al. (2014) proposed Interim Design Ontology (Figure 2.1) based on the research about critical points in a design process.

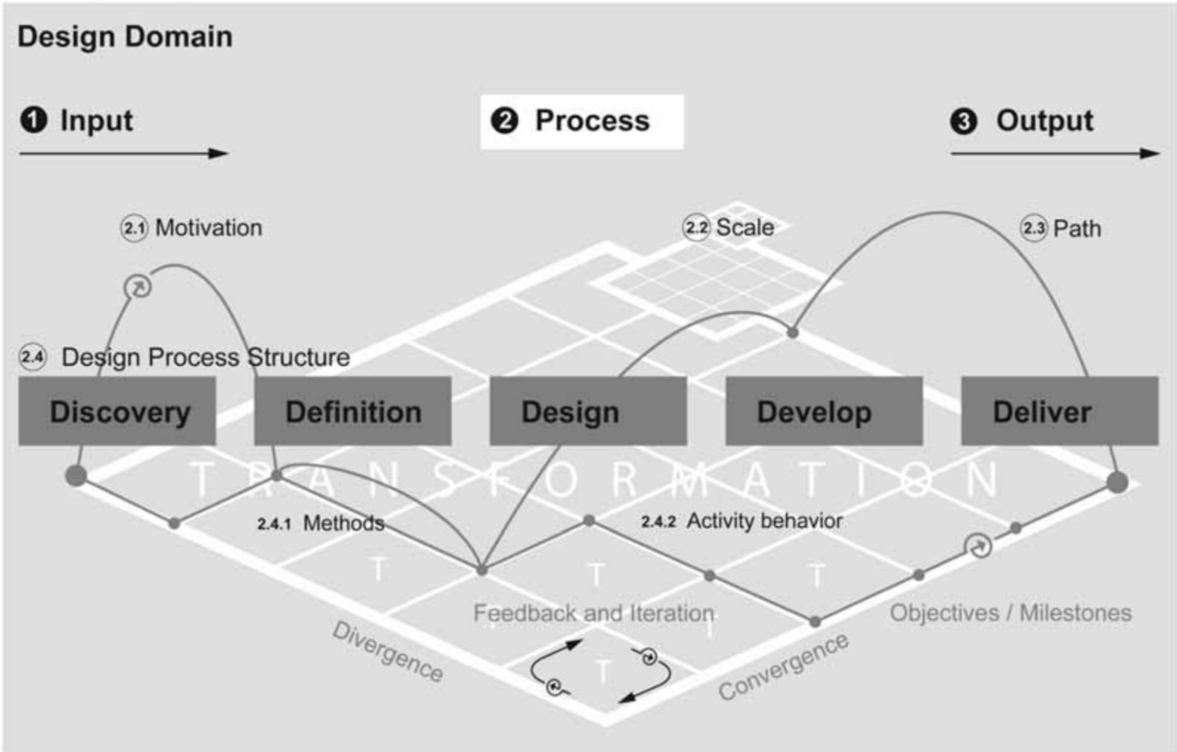


Figure 2.1. Visualization derived from the Interim Design Ontology (Green et al., 2014).

According to the Interim Design Ontology, the design process is divided into five phases: Discovery, Definition, Design, Develop and Deliver, which is called the 5D model. Additionally, 'the Path' is the way that designers execute these five phases. They can be executed in linear, iterative and crossing ways. Furthermore, the Interim Design Ontology defined activity behavior, which is the characteristics of how design process methods are carried out, is under the five phases. The design process model is proposed clearly and comprehensive. It's also useful to help people have a better understanding of how the design process works. However, Green et al. (2014) were still unsure how this design process would be executed in reality and what the behavior of the designers during the process would be.

2.3 Expert and novice designers

An expert is a person who is professionally trained or has the experience to have professional knowledge in a certain field (Chi & Glaser, 1980). Compared with an expert, a novice is a person who lacks experience, knowledge and skills. The novice designers tend to use trial and error to conduct design and their design processes tend to be iterative. The expert designers tend to solve the problem and have the solution at the same time. In addition, the expert designers are good at evaluating the moment when they need to move on to another phase to control their design result. However, the actual executive situation and behavior of the experts and novices in the design process have not been fully discussed and understood (Cross, 2004).

2.4 Summary

Overall, there are few papers discussing how designers conduct the design in a design process and fewer papers comparing expert and novice behaviors in a comprehensive design process. As a result, this study compares 'the Path' and 'the Activity' behavior between expert and novice designers by adopting the Interim Design Ontology as the design process model. Besides, this study also uses time spent on each phase and behavior to deeply evaluate the difference.

Last but not least, although the Interim Design Ontology has the 5D model of the design process, this study only focuses on the first three phases: Discovery, Define and Design to analyze the result, because the Develop and Delivery phase cannot be observed in a short time. That is long-term research. Additionally, these phases are more about manufacturing and business, which is beyond the scope of the study. Therefore, this study only compares the data within these first three phases.

3 Methodology

The study of the article is to compare the behavior differences of experts and novices in the design process to help novices learn from the experts efficiently and help the experts understand the novices' behaviors. This study focuses on: (1) the sequence of the experts and novices, (2) the time they each spent on different phases, and (3) exploration of the detailed behaviors within each phase.

3.1 Participants

Based on the methodology research review, two experts and two novices are selected for this study. The experts should have more than ten years of working experience in the product design field. As for the novices, in order to make sure that they have enough knowledge in design, the novices should be the third-year college students who are majoring in product design and have done more than 4 projects or have finished their internship.

3.2 Tools

The experiment is conducted with two cameras and one voice recorder to record the videos, images and verbal data. This set of tools is the same as the use of previous research (Kim & Ryu, 2014). A computer, white papers and drawing utensils are provided for participants during the experiment.

3.3 Experimental design

Before the formal experiment, the participants will practice the Think-aloud protocol for ten minutes by designing a USB for an office worker. At the same time, the researcher will remind the participants to speak their thoughts out loud simultaneously. After the practice, the topic of the formal experiment is to design an alarm for hearing-impaired people. This product is obviously aiming at a specific target group, so that will need some additional research to have a better understanding. The participants will not skip the phases of discovery and definition. In addition, because the product is a common item that most people are familiar with, it will avoid extreme design due to misunderstanding. The experiment will last around sixty minutes, but not more than one hundred minutes or less than forty minutes.

During the experiment, the researcher will stay with the participants in the same room. The researcher will remind the participants with a question like "Could you tell me what you are thinking about?", which is commonly used in Think-aloud protocol when the participants stop talking over thirty seconds (Laing, Apperley, & Masoodian, 2017). When the Think-aloud protocol is done, the retrospective protocol will be conducted with a semi-structured interview to make up the missing data (Coley, Houseman, & Roy, 2007). According to the advice by Lindlof and Taylor (2002), the researcher can ask questions based on their record or participants' design by open-ended interview. All the interviews will be one-on-one in order to prevent interference.

3.4 Procedure

The experiment is divided into three steps. The first step is the warm-up to make participants feel familiar with the Think-aloud protocol, to make the data more precise. The second step is the Think-aloud protocol during the formal experiment. The participants will conduct the provided design topic in a laboratory with the researcher. The last step is the retrospective interview in both semi-structured and open-ended way.

3.5 Data analysis

This study will conduct the protocol analysis with the coding scheme. The 5D model in Interim Design Ontology (Green et al., 2014) will be used for this study to determine the first three phases of the design process: Discovery, Definition, and Design. For evaluating the details among each phase, the study combines the coding scheme from Gero and Neill (1998), Salman, Laing, and Conniff (2014), Kim and Ryu (2014), and Schön and Wiggins (1992) to make the observation of the behavior more precise, as shown in Table 3.1.

Table 3.1 Codes of phase and design activity

Code	Phase of design process	Code	Design activity
Dc	Discovery	Ap	Analyzing the Problem
		Cp	Consulting Information About the Problem
		Ep	Evaluating the Problem
		Pb	Postponing Analysis of the Problem
Df	Definition	Ru	Retrieval of Functional Description
		Ro	Retrieval of Form Description
		Rs	Retrieval of Semantic Description
		Al	Analogy
Ds	Design	Cr	Creating and Revising Figure
		Cs	Creating Symbol Word
		Ms	Moving Same Object

Source: Gero and Neill (1998), Salman, Laing, and Conniff (2014), Kim and Ryu (2014), and Schön and Wiggins (1992).

4 Results

Based on the research questions and objectives, the study addressed the experiments by using the Think-aloud protocol method with experts and novices individually. Table 4.1 shows the general description of participants. The durations of the whole the design processes were varied, and the two experts had the longest and the shortest duration among these four. The longest duration (59:30) had the most proposals. Novices acted differently from the experts. Novice 1 spent less time but had more ideas than Novice 2.

Table 4.1 General description of participants

	Age	sex	Years of design expertise	Area of expertise	Design process duration (min:sec)	Number of design proposals
Expert 1	37	male	13	Industrial design	59:30	3
Expert 2	37	male	15	Industrial design	39:10	1
Novice 1	22	female	3	Industrial design	42:26	2
Novice 2	23	female	3	Industrial design	51:02	1

4.1 Sequence of design phases

The first research question concerned the sequences during the design process, and data is clearly shown in Figure 4.1 The data shows some similarities between the experts and novices. The experts and novices all began with the Discovery phase (Dc) and the Define phase (Df) occurred several times during their Dc. They all did the Design Phase (Ds) at the end of the process.

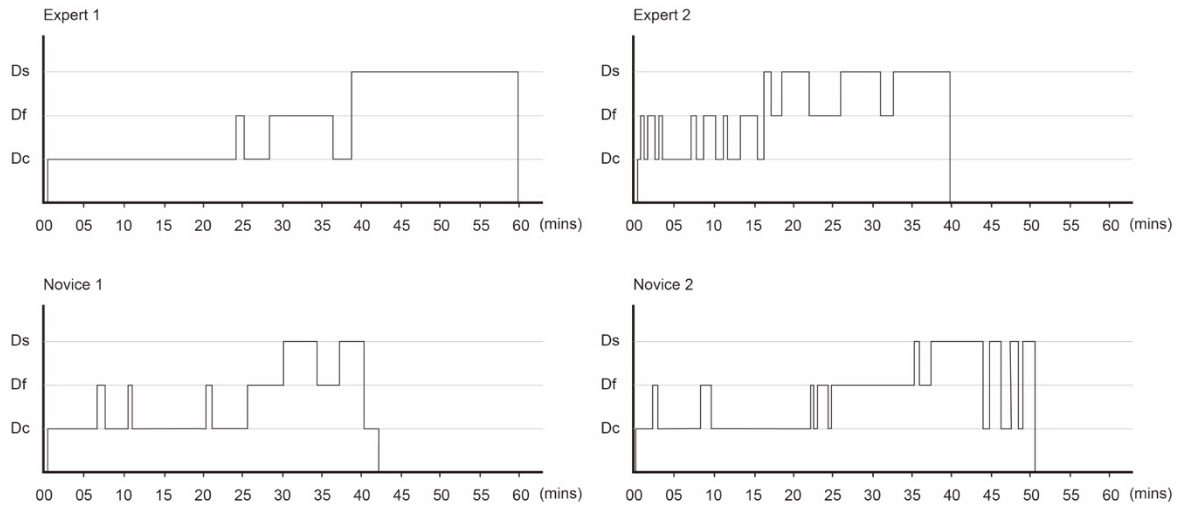


Figure 4.1. Sequence of phase.

Expert 1 started from Dc and then moved to Ds, and there were only two Df occurrences during Dc. Within Ds, there was no interruption in this phase for him. Expert 1 tended to stick to each phase for a long time. As for Expert 2, he went to Df at very beginning right after the short Dc, and he was going back and forth between Dc and Df. When he started to Ds, he also sometimes went back to Df and then continued the design again. It is obvious that the Df ran through his whole design process.

On the other hand, novice designers were more iterative than experts. Novice 1 started from Dc with a short Df and shortly went back to Df during Ds. Novice 2 also began with Dc, and she went into Df within the first few minutes. Before moving on to Ds, she kept spending time on Df. Furthermore, she not only went back to Df but also back to Dc several times during

Ds. It was noticed that the novices tended to turn back to Dc in the last moment after they almost finished the design proposals.

4.2 Occurrences and time spent during the design process

In order to address the question about how much emphasis that participants put on each phase, time spent is a factor to observe. Table 4.2 presents that both experts spent about 40% of the time on Ds during the whole design process, which is two times more than the novice designers. Focusing on the experts, Expert 1, compared to Expert 2, spent more time on Dc, which was approximately half of the time of the design process. However, Expert 2 spent his time more even on Dc and Df. Focusing on the novices, they both spent more than half of the process on Dc, especially Novice 1, who spent almost 60% on this phase. Additionally, the novices spent the least time on Ds, which was less than 20% of the total time.

Table 4.2 Occurrences and time spent (min:sec) of each phase

	Dc	Df	Ds	Total
Expert 1	3	2	1	6
	28:59 48.71%	09:05 15.27%	21:26 36.02%	59:30 100%
Expert 2	8	11	4	23
	11:16 28.43%	12:19 31.59%	15:35 39.97%	39:10 100%
Novice 1	5	5	2	12
	25:24 59.86%	10:22 24.43%	06:40 15.71%	42:26 100%
Novice 2	8	6	5	19
	25:04 51.33%	14:39 30%	06:40 18.67%	51:02 100%

For more details, the occurrences could also help to illuminate the emphasis that participants put on each phase. Once there is a transition between each phase or activity, it is defined as an occurrence. According to the same table, the results show that the total occurrence numbers of the experts were significantly varied. Expert 1 had six occurrences during the design process and Expert 2 had twenty-three. For Expert 1, most occurrences happened in Dc, while for Expert 2 most occurrences were in Df. As for the novices, the numbers of occurrences (12 and 19) were in between the ones of Expert 1 and Expert 2(6 and 23).

4.3 Design behaviors in each phase

On top of the data about how designers worked during the three design phases, the study also had a deeper investigation into the detailed activities of each phase that experts and novices had, in order to understand more about their actual design behaviors.

4.3.1 Sequence of design activity

Figure 4.2 shows that both experts and novices started with Analyzing the Problem (Ap) in the phase of Dc, but worked differently afterwards. Within the phase of Dc, the experts tended to Consult Information to the Problem (Cp) and Evaluate the Problem (Ep) earlier than novices. Expert 2 started to Ep in the very beginning, however, Novice 1 did not Ep during the whole process. Furthermore, these two experts ended the Dc phase with Ep before the phase of Ds, whereas novices ended the Dc phase after Ds phase with Ap and Cp, respectively.

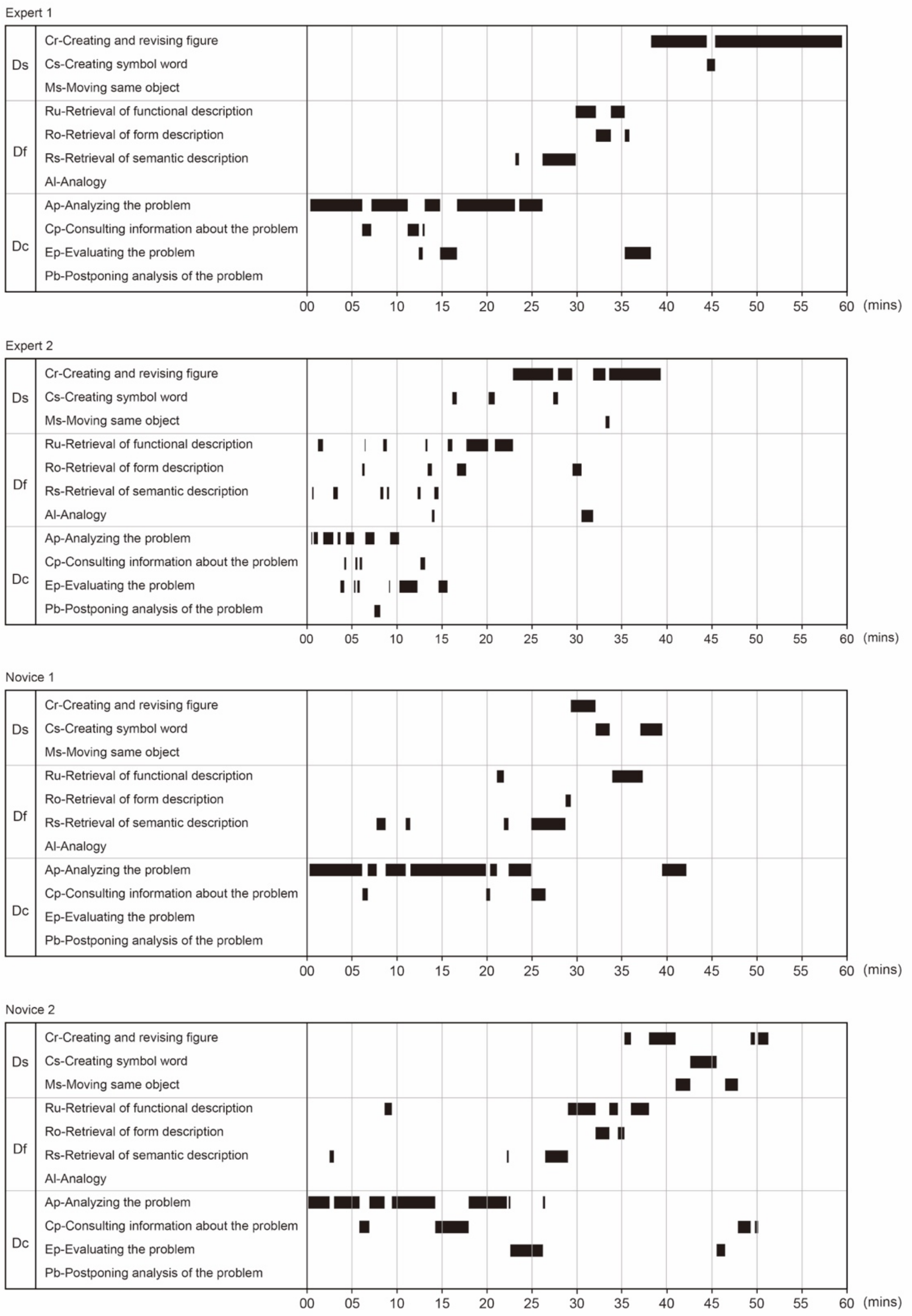


Figure 4.2. Sequence of design activity.

As for the phase of Df, Retrieval of Semantic Description (Rs) was the activity that both experts and novices did first, followed by Retrieval of Functional Description (Ru) and Retrieval of Form Description (Ro). It is obvious that the path of the activities of Expert 2 was the most diverse; he made a lot of transitions among Df. Experts tended to finish Df with Ro, and the last step of Expert 2 was Analogy (Al). Novices finished Df with Ru, instead. In the phase of Ds, Expert 2 started with Creating Symbol Word (Cs), and others started with

Creating and Revising Figure (Cr). For the expert side, they tended to stick to Cr for a period of time, however, novices were doing the activities more evenly during Ds phase.

4.3.2 Occurrences and time spent of design activity

The occurrences and time investments were used to evaluate their design behaviors. In terms of the Discovery phase, novices spent most of their time Analyzing the Problem (Ap), especially Novice 1 who spent 91% of the time to Ap. Novices also had the highest number of the occurrences in Ap. As for experts, although they also spent more time on Ap, they also put efforts into Evaluating the Problem (Ep). However, Expert 2 spent two times more than Expert 1 in Ep. Novices spent more time on Consulting information about the Problem (Cp) than experts. Novice 2 spent almost 30% of her time on it. Additionally, both experts and novices nearly Postpone the Problem (Pb). This is shown in Table 4.3.

Table 4.3 Occurrences and time spent in Discovery phase

	Ap	Cp	Ep	Pb	Total
Expert 1	6	4	3	0	13
	22:05 76.19%	02:45 9.49%	04:09 14.32%	00:00 0%	28:59 100%
Expert 2	7	4	6	1	18
	05:23 46.30%	01:22 12.13%	04:03 35.95%	00:38 5.62%	11:16 100%
Novice 1	7	3	0	0	10
	23:07 91.01%	02:07 9.88%	00:00 0%	00:00 0%	25:24 100%
Novice 2	7	4	2	0	13
	17:14 68.75%	06:55 27.59%	00:55 3.66%	00:00 0%	25:04 100%

In the Define phase, on the expert side, both experts spent more than 40% of the time on Retrieval of Function (Ru). Although Expert 1 had two occurrences and Expert 2 had seven. Expert 1 spent more time on Retrieval of Semantic Description (Rs) than Expert 2, whereas Expert 2 had more occurrences than expert1. Only Expert 2 was spending time on Analog (Al). As for the novices, Novice 1 emphasized more on Rs, while Novice 2 put more efforts into Ru. None of them carried out Al. Besides, it is obvious that there is not always a positive correlation between the occurrences and the time spent. For example, Expert 1 had the same number of occurrences during each Ru, Retrieval of Form Description (Ro) and Rs while the time spent was respectively 40.37%, 23.85% and 35.98%. Another evidence is that Expert 2 had three occurrences during Ro with 20.03% of time spent, whereas he spent less time on Rs with two times more occurrences. This is shown in Table 4.4.

Table 4.4 Occurrences and time spent in Define phase

	Ru	Ro	Rs	Al	Total
Expert 1	2	2	2	0	6
	03:40 40.37%	02:10 23.85%	03:15 35.98%	00:00 0%	21:26 100%
Expert 2	7	3	6	3	19
	05:59 48.58%	02:28 20.03%	02:11 17.73%	01:41 13.67%	12:19 100%
Novice 1	2	1	4	0	7

	04:00 38.59%	00:35 5.63%	05:47 55.79%	00:00 0%	06:40 100%
Novice 2	4	2	4	0	10
	07:06 48.46%	02:18 20.03%	05:15 17.73%	00:00 0%	14:39 100%

Table 4.5 is about the behaviors in the Design phase. Both of the experts focused most of the time on Creating and Revising Figure (Cr), especially for Expert 1 (95.72%). Expert 2 also spent around 20% of his time on Creating Symbol Word (Cs) and he was the person who had the highest number of occurrences in total. Novice 1 also emphasized more on Cr, which is similar to Expert 2. Novice 2 spent half of her time on Cr and the rest of her time more evenly on Cs and Moving Same Object (Ms).

Table 4.5 Occurrences and time spent in Design phase

	Cr	Cs	Ms	Total
Expert 1	2	1	0	3
	20:31 95.72%	00:55 4.28%	00:00 0%	21:26 100%
Expert 2	5	2	1	8
	11:34 74.22%	03:36 23.10%	00:55 2.67%	15:35 100%
Novice 1	2	1	0	3
	05:05 76.25%	01:35 23.75%	00:00 0%	06:40 100%
Novice 2	4	1	2	7
	05:35 49.34%	02:24 21.21%	03:20 29.46%	11:19 100%

4.4 Summary

The results present both similarities and differences between expert and novice designers. Looking at the sequence of the design phases, all of them started with the Dc phase, and ended the design process by the Ds phase. However, novices tended to turn back to the Dc phase before they finished their design proposals. Expert designers spent more time on Ds than novices and novice designers spent more time on Dc, as shown in Figure 4.2. Furthermore, the occurrences can show us how iterative that designers work, but does not always have a positive correlation with the time spent. In terms of design activity during the different phases, both experts and novices started the design process with Analyzing the Problem (Ap) of the Dc phase. Nevertheless, experts tended to get to Consulting information about the Problem (Cp) and Evaluating the Problem (Ep) earlier than novices. Novices did Ep late or did not do it at all. Before moving to the phase of Ds, experts finished the Dc phase by Ep, but novices were still in Ap and Cp of the Dc phase in the very end. In phase of Dc, experts and novices spent most of their time on Ap, but experts focused more on Ep than novices. The time spent on Ep by the experts was two times more than that of the novices. Most of the experts and novices spent the most time on Retrieval of Function (Ru) during the Df phase; only one of the novices focused more on Semantic Description (Rs). In the Ds phase, both experts and novices emphasized the most on Creating and Revising Figure (Cr), especially the experts. The total number of occurrences during Ds were the least among the three phases; the participants tended to have fewer transitions between each activity.

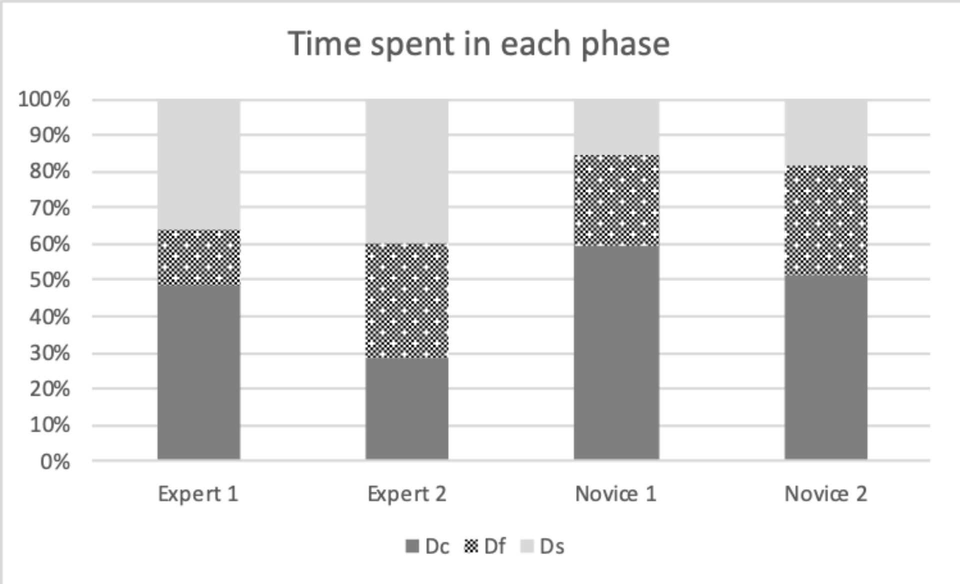


Figure 4.3. Time spent in each phase.

5 Discussion

This study empirically demonstrates how expert and novice designers behave during the Discovery, Define and Design phases of the design process. In order to see how experts and novice designers differentiate from each other by dealing with the tasks in their own ways, the study examines the sequence of the phases and activities. This can provide an understanding of what their priorities are and how they deal with the relationship between each phase and the activities in this phase. Furthermore, the occurrences could help to show how iterative their processes are. The study also would like to examine which phases and activities they spent the most time on. Additionally, by measuring the occurrences and time spent during these occurrences, the total duration of time spent on a specific phase or activity could be revealed.

According to the results of the sequence of the design phases, both experts and novices started with Analyzing the problem (Ap) during Dc phase. It shows that the first step of beginning a design process is usually Ap, no matter what experience the designer has. The phase of Dc often has a back-and-forth relationship with the Df phase. Expert and novice designers are used to discovering things during creating definitions. For example, when Expert 2 was browsing the existing alarm products for hearing-impaired people, he often stopped browsing to take notes for the different kinds of definitions, and then continued to look up other products. Discovery was like an inspiration for him to make a definition and keep revising his design direction and prove his idea was on the right track. Although novice designers also moved back and forth between Dc and Df, they often searched without clear purpose and the definitions were repeatedly deleted and replaced with new ones. Experts tended to know what they should look for and what helped their definitions. The results also show the different behaviors between the two experts in the Dc and Df phases. There were many transitions between Dc and Df for Expert 2, however, Expert 1 had only two transitions.

Expert 1 was focusing on one phase at a time. Once he felt satisfied with what he did and had a holistic understanding, he would make some summaries or decisions and then move to another phase. As for Expert 2, his behaviors were more iterative, and he spent less time on each activity.

It is interesting that these different behaviors also influenced the numbers of ideas for them. Expert 1 gathered more ideas during the Dc phase without interruption by considering the definitions. Afterwards, he started to sort his different ideas during the phase of Df and he finally had three proposals. Expert 2 was using more discoveries to optimize his one idea. For him, Dc was not only for exploration, it was also for supportive information. He used Dc to revise the definition; the process was more convergent.

After the Dc and Df phases, both expert and novice designers went to the phase of Ds. Expert 2 and novices had transitions between Ds and Df, except for Expert 1, who was focusing more on one phase at a time. When they were designing their ideas, they needed to check their definitions or they would refine the definitions when something was incorrect. Both experts ended the design process with the Ds phase. However, it should be noted that the Dc phase occurred at the very end of the novices' processes. These two novices found some issues, so they wanted to change their concepts and redo their designs. This behavior can be explained by Trial and Error because novice designers often have less confidence in their decisions, hence the two novices tended to redo things during the process (Ahmed, Wallace &, Blessing, 2003).

The results show that the experts spent most of the time on Ds phase, which is two times more than the novices. However, the result is different from a previous research by Brand-Gruwel, Wopereis, and Vermetten (2005). They found that experts would spend more time on definition than novices. The reason why experts spend more time on definition is, according to the research, because the experts have more knowledge and experience to make a quicker and more precise decision about the definition. Therefore, they had more time to develop their Ds. As for the design activity, the experts performed sooner and better at Evaluating the Problem (Ep) than novices. The novices often reached an impasse when they evaluated things because it was harder for the novices to evaluate and come up with design proposals (Kim & Ryu, 2014).

6 Conclusion

For novices, learning from how experts work is one of the most efficient ways to become more professional. When a novice designer is trying hard to improve their expertise to become an expert, to some extent, this study provides a holistic perspective to build the bridge for the leap. Although every expert has their own preference for work, we still found some similarities between experts and their design behavior patterns. The knowledge and experience behind the expert subtly influenced their behaviors during the design process. During the experiments, sometimes experts did not even know that they were in a certain phase or activity, but this research revealed their actual behavior explicitly by protocol analysis.

However, this research might not completely interpret design behaviours. The research was conducted in the laboratory and was a short-term experiment. Also the amount of data and the limited time period were limitations of the study by protocol methodology. Behavior could be different in the real workplace since the factors of Develop and Deliver phase could also influence how designers work in the first three phases in the 5D model.

On top of the research outcomes, there is something we can explore more to have a deeper understanding of the participants, and it might be critical and influential for in-depth research. Therefore, here are recommendations for future research:

- To understand why experts or novices make the decision to move on or go back between phases and activities at a specific moment.
- To have a study on how experts and novices work in five phases in the 5D model.
- To find out in what way phases and activities influence each other and the reasons why.

Nevertheless, this study still contributes to the data and discussion that can help expert and novice designers examine how they might work differently. By means of comparisons, this research could provide new insights for not only experts or novices themselves but also the educators or team managers of companies.

7 References

Maciver, F. (2016). Reversing the Design-Marketing Hierarchy: Mapping New Roles and Responsibilities in 'Designer-Led' New Product Development. *The Design Journal, 19*(4), 625-646. doi:10.1080/14606925.2016.1176340

Kotler, P., & Rath, G. A. (1984). Design: A Powerful But Neglected Strategic Tool. J*ournal of Business Strategy, 5*(2), 16-21. doi:10.1108/eb039054

Bruce, M., & Bessant, J. (2002), Managing design as a process, in Bruce, M. and Bessant, J. (Eds), *Design in Business: Strategic Innovation Through Design*, Prentice Hall, Hemel Hempstead, 36-58.

Browning, T. R. (2018). Building models of product development processes: An integrative approach to managing organizational knowledge. *Systems Engineering, 21*(1), 70-87. doi:10.1002/sys.21421

Green, S., Southee, D., & Boult, J. (2014). Towards a Design Process Ontology. *The Design Journal, 17*(4), 515-537. doi:10.2752/175630614x14056185480032

Brand-Gruwel, S., Wopereis, I., & Vermetten, Y. (2005). Information problem solving by experts and novices: Analysis of a complex cognitive skill. *Computers in Human Behavior, 21*(3), 487-508. doi:10.1016/j.chb.2004.10.005

Kim, J., & Ryu, H. (2014). A Design Thinking Rationality Framework: Framing and Solving Design Problems in Early Concept Generation. *Human–Computer Interaction, 29*(5-6), 516-553. doi:10.1080/07370024.2014.896706

Hui-Hsia Chen, Man-Lai You (2007). Evaluation and Analysis of Designer Experts and Novices' Sketching Activities with Traditional and Digital Tools. *Research in Arts Education, 14, 61-99.*

Kavakli, M., & Gero, J. S. (2002). The structure of concurrent cognitive actions: A case study on novice and expert designers. *Design Studies, 23*(1), 25-40. doi:10.1016/s0142-694x(01)00021-7

A. Chapman. Managing The Design Process. (2006). *Design Management*. doi:10.5040/9781474223522.0011

Dubberly, H. (2004). How do you design? *Dubberly Design Office.* Retrieved August 30, 2011. Retrieved from http://www.dubberly.com/articles/how-do-you-design.html

Cross, N. (2001). Designerly Ways of Knowing: Design Discipline Versus Design Science. *Design Issues, 17*(3), 49-55. doi:10.1162/074793601750357196

Bender, B., Reinicke, T., Wünsche, T., & Blessing, L. (2002). Application of Methods from Social Sciences in Design Research. In *Proceedings of Design*. Dubrovnik,Croatia.

Dorst, K. (2008). Design research: A revolution-waiting-to-happen. *Design Studies*, 29(1), 4-11. doi:10.1016/j.destud.2007.12.001

Chi, M. T. H., & Glaser, R. (1980). The measurement of expertise: Analysis of the development of knowledge and skill as a basis for assessing achievement. In E. L. Baker & E. S. Quellmalz (Eds.), *Educationul testing and evaluation: Design analysis und policy* (37-47). Beverly Hills, CA: Sage.

Cross, N. (2004). Expertise in design: An overview. *Design Studies, 25*(5), 427-441. doi:10.1016/j.destud.2004.06.002

Laing, S., Apperley, M., & Masoodian, M. (2017). Investigating the effects of client imagery on the ideation process of graphic design. *Design Studies, 53*, 78-98. doi:10.1016/j.destud.2017.08.001

Coley, F., Houseman, O., & Roy, R. (2007). An introduction to capturing and understanding the cognitive behaviour of design engineers. *Journal of Engineering Design, 18*(4), 311-325. doi:10.1080/09544820600963412

Lindlof, TR, & Taylor, BC. (2002). *Qualitative communication research methods* (2nd ed.). Thousand Oaks, CA: Sage.

Gero, J. S., & Neill, T. M. (1998). An approach to the analysis of design protocols. *Design Studies, 19*(1), 21-61. doi:10.1016/s0142-694x(97)00015-x

Salman, H. S., Laing, R., & Conniff, A. (2014). The impact of computer aided architectural design programs on conceptual design in an educational context. *Design Studies, 35*(4), 412-439. doi:10.1016/j.destud.2014.02.002

Schön, D. A., & Wiggins, G. (1992). Kinds of seeing and their functions in designing. *Design Studies, 13*(2), 135-156. doi:10.1016/0142-694x(92)90268-f

Ahmed, S., Wallace, K. M., & Blessing, L. T. (2003). Understanding the differences between how novice and experienced designers approach design tasks. *Research in Engineering Design, 14*(1), 1-11. doi:10.1007/s00163-002-0023-z

About the Authors:

Chen, Yan-Ting: Yan-Ting is currently a second-year master's student of Industrial Design in Cheng Kung University. She has a diverse array of work experience in design companies, including Microsoft. She mainly focuses on studying design processes and methods.

Chen, Hsi-Jen: Hsi-Jen graduated from Bauhaus-Universität Weimar with a PhD in Art and Design, and he is currently an assistant professor of Industrial Design at National Cheng Kung University. He has expertise in Human-Computer Interaction, Science Technology & Society, and Cross-Culture Design.

Acknowledgement: We would like to express our thanks towards instructors, friends, families and those who supported us.

Brain Activities of Idea Generation Types Using Sketch

Kato, Takeo*[a]; Koike, Jio[a]; Ashizawa, Yusuke[b]

[a] Keio University, Yokohama, Japan
[b] Shibaura Institute of Technology, Tokyo, Japan
* kato@mech.keio.ac.jp

Designers' problem-solving activities and the thinking process has attracted attention and the tool development and education for it are carried out in various places. Their effectiveness, however, is evaluated only by subjective way (e.g. interview and questionnaire), and to develop the objective evaluation method is required. This study focuses on the idea generation using sketches and aims to clarify the relationship between the idea generation and brain activities. This study defined the three types of idea generation using sketch and compared the brain activities (the concentration change in the oxygenated hemoglobin of the prefrontal cortex) of the participants conducting them using a NIRS (Near Infrared Spectroscopy) apparatus. The grand-average of the NIRS signal of them were calculated and suggests the more the task becomes creative, the more the prefrontal cortex activates. This indicates the possibilities to differentiate the sketch idea generation types on the basis of the creativity.

Keywords: sketch; idea generation; NIRS

1 Introduction

Design is said to be an activity to solve the inverse problem and difficult to be solved. Designers generate/choose the design attributes (causal factors) that satisfy a set of design requirements (result) from multiple alternatives. Designers' problem-solving activities and the thinking process for deriving the design solution (hereinafter called design thinking) has been studied from 1950s. Most researchers have pointed out that designer heuristically repeats the three-stage process: analysis, synthesis and evaluation (Cross, 1984; March, 1984; Mesarović, 1964, Page, 1953). Recently, the word "design thinking" attracts attention among various fields due to the activities of "d.school" established by IDEO and Stanford University, and the tool development and the education regarding design thinking are carried out in various places (Plattner, Meinel, & Leifer, 2011). Their effectiveness, however, is evaluated only by subjective way (e.g. interview and questionnaire) and difficult to be confirmed. This causes the need to develop the way to analyze and evaluate it objectively.

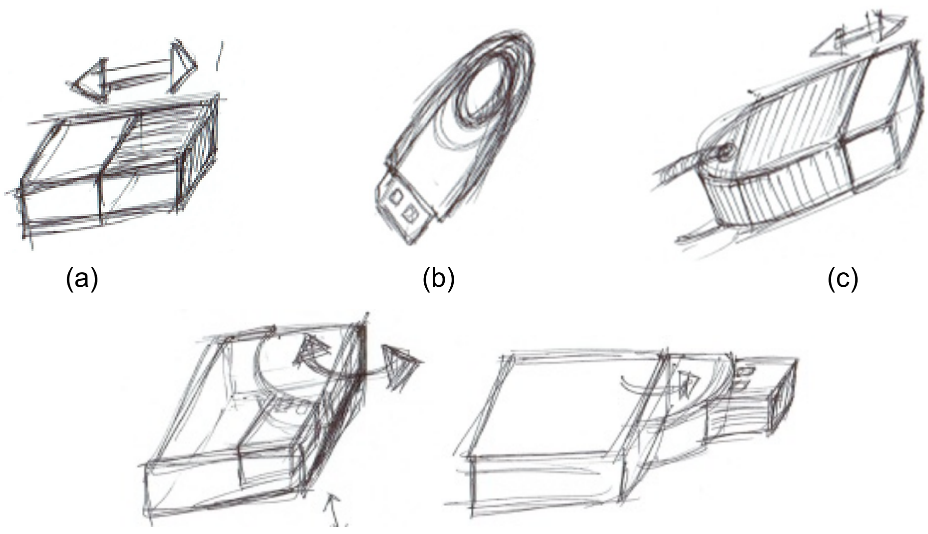
Due to the development of the brain activity measurement devices, the research measuring the brain activities of the participants doing design tasks has become popular. Alexiou, Zamenopoulous, and Gilbert (2011) compared the brain activities between the ill- and well-structured design problems of furniture layout, using a function Magnetic Resonance Imaging (fMRI) apparatus and suggested that the former problem whose evaluation criteria is not well specified activates more brain regions than the latter one. Particularly, the former task activated the two types of the brain regions: one includes the areas involved in visual imagery, semantic processing, and multi-sensory integration, such as the temporal, occipital, and parietal regions; the other is the prefrontal cortex (PFC) for constructing executive schemes of action. Kowatari et al. (2009) measured the brain activities of the undergraduate/graduate students designing the shape of a pen using a Magnetic Resonance Imaging (MRI) device and concluded the design task facilitated and suppressed the right and left PFCs, respectively. Folley and Park (2005) utilized a Near Infrared Spectroscopy (NIRS) apparatus and compared the brain activities between schizophrenic patients and healthy participants during the task to generate new uses of the objects shown in the computer screen. As a result, compared to the healthy participants, the patients generated more uses, and the more brain regions in both the right and left PFCs were activated. Gibson, Folley, and Park (2009) also compared the brain activities between the creative individuals (musicians) and healthy participants. The result reveals that the musicians also derived more uses and activated more brain regions in the PFCs, same as the patients. Nagamori, Nakajima, Yokoi, and Yamanaka (2009) measured the brain activities of the undergraduate/graduate students when they work on the following two creative tasks using NIRS apparatus. Task 1 is to select and arrange one or three colors which are fit to the given concept (adjective phrase, such as “cool” and “cute”). Task 2 is to make a “cute chair” using single- or multi-color blocks. The results of the two tasks show some task conditions (e.g., selecting one color in Task 1 and using multi-color blocks in Task 2) activate the PFC more than the others. In other words, the more creativity the task requires, the more brain regions in the PFC activate. Kato, Otagiri, Nagamori, and Izu (2016) compared the brain activities of the participants conducting the Finke’s pattern generation (form assemble) task (Finke, Ward, & Smith, 1996) employing the hand drawing and computer operation. The result shows the latter one activates the right PFC more, and the activation seems to be occurred by the ways of idea transformations (not occurred by the assembling methods: hand drawing and computer operation).

These studies confirmed the design tasks activate the brain regions in the PFC, suggesting the possibilities to evaluate how the person is creative state during the design task by measuring them. This study focuses on the brain activities regarding the design using sketches which is a common tool in the product design activities, and aims to clarify the relationship between the design activity and brain activities. This paper is organized as follows. Section 2 illustrates the types of the idea generations by sketching. Section 3 presents the method to measure the brain activities. Section 4 describes the result and discussion of the brain activity measurement experiment, while Section 5 provides conclusions and future tasks.

2 Idea generation types using sketches

This study focuses on the classification of the sketch (drawing) generation proposed by Goel (1995). This classification includes two types of drawing generations as follows. One is “new generation (NG)” that generates a drawing (idea) using the long-term memory (LTM) of the person. LTM stores the information regarding what the parson has encountered and is used to make logical deductions, to understand ideas, as well as to memorize fact. The other is “transformation” which translates a drawing from the previously generated drawings. The transformation is further classified into two types: “lateral transformation (LT)” that modifies a drawing into another related, but distinctly different drawing; “vertical transformation (VT)” which reiterates and reinforces an existing drawing through explication and detailing. Note that Goel defines one more type of transformation: “reinterpretation” that generates the drawing having different meaning (object) from the previous drawings. However, this study eliminated it because the change of meaning (design object) seldom happens in product design. The three types of the drawing generations are illustrated using some sketch examples in order from the sketch generated earlier Figure 1(a)-(f). These sketches were drawn for the idea generation of USB flash memory during the experiment described in Section 4. Sketch (a) was drawn firstly (i.e. drawn without referring any sketch) and is categorized as NG. Sketch (b) was drawn secondly but drawn without referring Sketch (a) and is also categorized as NG. Sketch (c) was generated based on the function and shape of the sketches (a) and (b) (slider mechanism and hole) and is categorized as LT. Sketch (d) is categorized as NG for the same reason of sketch (b). Sketch (e) is categorized as VT because it illustrates the detail (parts action) of Sketch (d). Note that the categorization requires the opinion (concept) of the person who draws the sketch. The aforementioned categorization was done using the interview of them.

This study compared the aforementioned idea generation types by using the brain activities measured when the participants conduct the idea generation. The following section illustrates the method to measure the brain activities.



(a) (b) (c)

(d) (e)

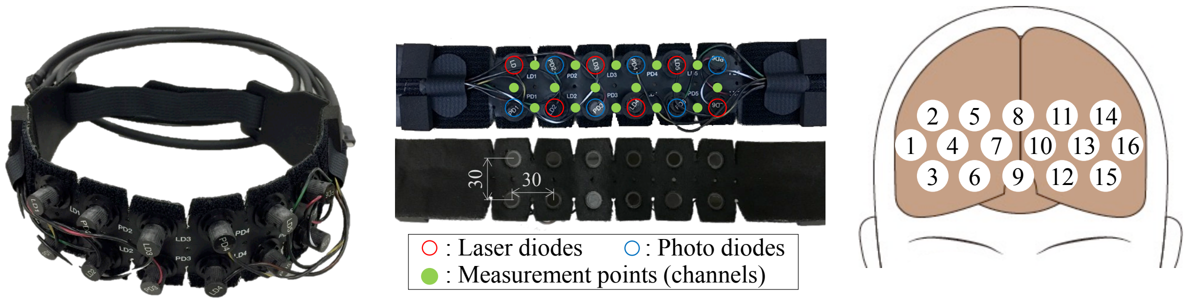
Figure 1. Examples of idea generation types using sketches

3 Brain activity measuring and analysis

3.1 Methods to measure brain activities

This study employed NIRS because NIRS is a no-invasive measurement and does not constrain the participant’s movements (sketching). A NIRS apparatus is composed of some emitter-detector pairs of near infrared light whose wavelength is from 700nm to 1000nm and cannot be easily absorbed in a biological tissue. Each emitter has two continuous laser diodes and irradiates the near infrared light of two different wavelength in order to measure the concentration changes in both oxygenated hemoglobin (oxyHb) and deoxygenated hemoglobin (deoxyHb). While the amounts are calculated on the basis of the modified Beer-Lambert Law (Delpy et al., 1988), which gives the relation equation between the attenuation of light and the density changes in light absorber.

This study employed a NIRS device (SpO2, Spectratech Inc., Tokyo, Japan, Figure 2(a)). This device includes six pairs of laser and photo diodes (illuminators and detectors) whose distance is 30mm (Figure 2(b)). The number of the measurement points is sixteen, and they locate between each pair of laser and photo diodes. The measurement brain regions corresponding to the points, termed as channels (CHs), are in the PFC (Figure 2(c)). The sampling frequency is 1.6Hz.



(a) NIRS (OEG-16) (b) Location of laser and photo diodes (c) Measured regions termed as channels (chs)

Figure 2. NIRS device and its measured region in prefrontal cortex

3.2 Method to analyze NIRS signal

This study adopted the change in oxyHb which is the most sensitive indicators of the change in regional cerebral blood flow (Hoshi et al., 2011) and analyzed the signal using the following four methods

- Bandpass filter (Peña et al., 2003): this processing removes the components originating from the slow fluctuations of cerebral blood flow, heartbeat, and body motion. This study employed the bandpass filter whose pass band is between 0 and 0.2 Hz.
- Base line correction (Peña et al., 2003): this processing removes the component originating from the fatigue of a participant which changes the oxyHb caused linearly with respect to time. In this study, the line connecting the average values of the two control tasks conducted before and after the target task was calculated and was subtracted from the oxyHb signals.
- NIRS signals separation method (Yamada, Ueyama, & Matsuda, 2012): this method can separate the NIRS signals into cerebral functional and systemic (physiological) components based on differences in hemodynamic. This study extracted the cerebral functional components using the method.
- Grand-average event related potential wave form (Hoshi et al., 2011): this processing derives the averaged partial-wave of each event (task) and enables us to visualize the features of each event. This study derived the partial-wave of the three idea generation types whose time range is from 20s before the start point of the sketch to 40s after the point.

The following section presents the brain activity measurement experiment to confirm the relation between the three idea generation types and their brain activities.

4 Experiment to measure the brain activity of idea generation using sketch

4.1 Experimental conditions and procedures

The twelve, right-handed healthy graduate/undergraduate university students, who are in product design course, participated in this experiments (8 male and 4 female). Before each experiment, informed consent was obtained from all of them. The participants were asked to conduct control and idea generating tasks, alternately. In the control task, they stared at a target (black cross mark) on the desk for 60 seconds. Whereas, in the idea generating task, they generated ideas of new products by sketching without limiting the time, on the basis of the five design themes (design objects): scissors, mechanical pencil, USB flash memory, cutter knife, and stapler. They were chosen as everyday things in order to minimize the difference of the knowledge about them between the participants. Additionally, the participants were asked to conduct sketch of the displayed real objects of them before the experiment, in order to minimize the extra brain activity to remind/imagine them using long term memory during the experiment. The presentation order of the design themes was randomized to minimize the order effect.

This study utilized a NIRS apparatus described in the preceding section to measure the cerebral blood flow (the concentration changes in oxyHb). And, an eye tracking system (Talk Eye Lite, Takei scientific instrument Co., Ltd., Niigata, Japan) was employed to measure the points of gaze of the participants. Then, the experimenter performed an interview in order to get the information to classify the idea generations in the tasks into the three types described in Section 2. Note that the measured points of gaze were displayed to the participants for reminding them of the idea generation during the interview. In the interview, the experimenter asked the following two questions for classifying each sketch (idea):

Q.1. Is this sketch/idea related to (generated according to) the previous one?
Q.2. (If the answer of Q.1 is “Yes”,) Is this sketch/idea different from the previous one?

This experiment cannot equalize the start time and the implementation time of each sketch generation because the participants freely generate idea using sketch without time limitation. Additionally, all the sketch generations cannot be arranged between the control tasks. This means that the cerebral blood flow measurement data (the concentration change in oxyHb Δc_{oxy}) of a task (sketch generation) is influenced by that of the previous task. This study, therefore, calculated the grand-average event related potential wave forms using the extracted data on the basis of the following conditions: 1) each event (NG/LT/VT) repeats at least 5 times; 2) the time of sketching is more than 40s; 3) the time gap between events is more than 10s.

4.2 Results and discussions

Figures 3-5 show the calculated the grand-average event related potential wave forms of a participant (No.4). Figures 3, 4, and 5 correspond to the wave forms when the participant conducts NG, LT, and VT, respectively. These waves are standardized by subtracting the average value of the data for 30s before starting drawing. These figures indicate that NG (idea generation with the sketch based on LTM (i.e., without previous drawings)) activates the PFC more than LT/VT (that based on a previous drawing). Additionally, LT activates PFC more, compared with VT. In some previous studies, the activation of PFC was confirmed in creative tasks: furniture layout design (Alexiou et al., 2011) and shape design of pen (Kowatari et al., 2009). This suggests the more the task becomes creative, the more the PFC activates and indicates the possibilities to differentiate the sketch idea generation types on the basis of the creativity. However, the relationship between the types and creativity has not been clearly confirmed because of the following reasons: 1) the lack of the sample number for statistical test (i.e., the need to conduct the experiment whose task types and time are controlled; 2) the lack of the correlation analysis between creativity and brain activities (e.g., comparison of drawings based on the qualitative evaluation of the ideas and comparison of the professional and amateur designer's brain activities). They are the future tasks.

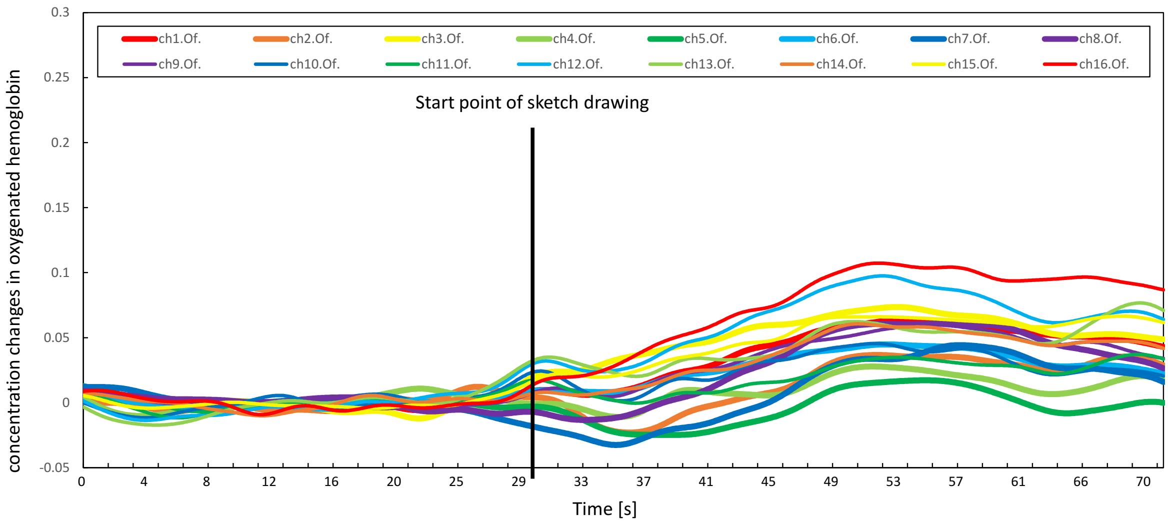


Figure 3. Grand-average event related potential wave form of NG (participant No.4)

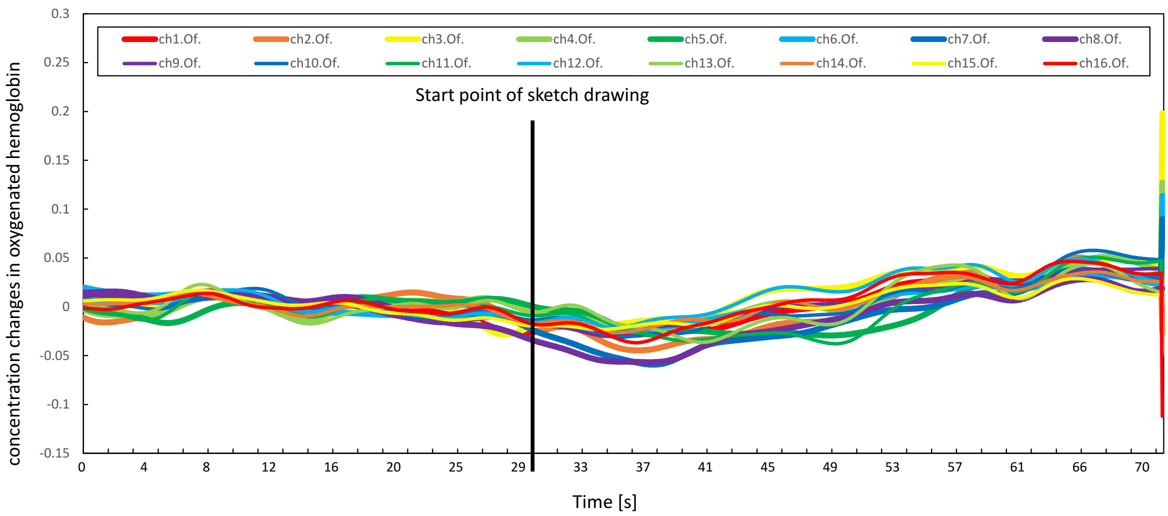


Figure 4. Grand-average event related potential wave form of LT (participant No.4)

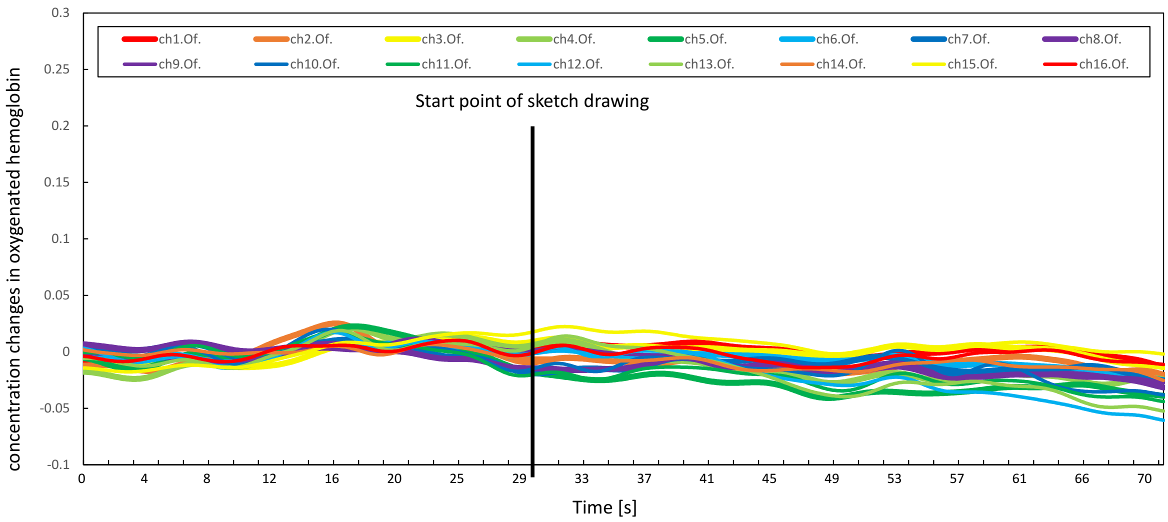


Figure 5. Grand-average event related potential wave form of VT (participant No.4)

5 Conclusions

This study defined the three types of idea generation for product design using sketch based on the Goel's classification and compared the brain activities (the concentration change in the oxygenated hemoglobin of the prefrontal cortex) of the participants conducting them using a NIRS apparatus. The grand-average of the NIRS signal of the three types were calculated and suggests the more the task becomes creative, the more the PFC activates. This indicates the possibilities to differentiate the sketch idea generation types on the basis of the creativity. However, there is a possibility that the difference between the NIRS signals is caused by the use of LTM, and the comparison between the previously and newly generated sketches from LTM is needed. And, if the difference is confirmed, the result of this study can apply to evaluate the skill of idea generation using sketch.

The future tasks are to define some representative values of brain activities calculated from NIRS signals to conduct the statistical test by defining, and to conduct the experiment in which the idea generation types and task time are controlled by experimenter in order to confirm the repeatability of the results of this study. Advanced research includes the followings: 1) comparison of professional and amateur designers' brain activities to analyze the features of creative people; 2) analysis of the correlation between the qualitative evaluation of generated ideas and brain activities; 3) comparing the brain activities of the participants using some idea generation methods/tools to classify them/differentiate from sketch.

6 References

Alexiou, K., Zamenopoulous, T., & Gilbert, S. (2011). Imaging the Designing Brain: A Neurocognitive Exploration of Design Thinking". In J. S. Gero (Ed.), *Design Computing and Cognition'10* (pp. 489-504). doi: 10.1007/978-94-007-0510-4_26

Cross, N. (Ed.) (1984). *Development in Design Methodology*. Chichester: John Wiley & Sons.

Delpy, D. T., Cope, M., Zee, P. V., Arridge, S., Wray, S., & Wyatt, J. (1988). Estimation of Optical Pathlength Through Tissue from Direct Time of Flight Measurement. *Physics in Medicine and Biology, 33*(12), 1433-1442. doi:10.1088/0031-9155/33/12/008

Finke, R. A., Ward, T. B., & Smith, S. M. (1996). *Creative Cognition: Theory, Research, and Applications*. Cambridge: MIT Press.

Folley, B. S., & Park, S. (2005). Verbal Creativity and Schizotypal Personality in Relation to Prefrontal Hemispheric Laterality: A Behavioral and Near-Infrared Optical Imaging Study. *Schizophrenia Research, 80*(2-3), 271-282. doi: 10.1016/j.schres.2005.06.016
Gibson, C., Folley, B. S., & Park, S. (2009). Enhanced Divergent Thinking and Creativity in Musicians: A Behavioral and Near-Infrared Spectroscopy Study. *Brain and Cognition, 69*(1), 162-169. doi: 10.1016/j.bandc.2008.07.009
Goel, V. (1995) .*Sketch of Thought*, MIT Press, London.
Hoshi, Y., Huang, J., Kohri, S., Iguchi, Y., Naya, M., Okamoto, T., & Ono, S. (2011). Recognition of Human Emotions from Cerebral Blood Flow Changes in the Frontal Region: A Study with Event-Related Near-Infrared Spectroscopy. Journal of Neuroimaging, 21(2). doi:10.1111/j.1552-6569.2009.00454.x
Kato, T., Otagiri, S., Nagamori, Y., & Izu, Y. (2016). Comparison of Brain Activities Between Hand and Computer Drawings in Finke's Pattern Generation Task, *Journal of the Science of Design*, *2*(2), 43-52. doi:10.11247/jsd.2.2_2_43
Kowatari, Y., Lee, S. H., Yamamura, H., Nagamori Y., Levy, P., Yamane, S., and Yamamoto, M. (2009), Neural Networks Involved in Artistic Creativity. *Human Brain Mapping, 30*(5), 1678-1690. doi:10.1002/hbm.20633
March, L. (1984). The Logic of Design. In N. Cross (Ed.), *Development in Design Methodology* (pp. 265-276). New York: John Wiley & Sons.
Mesarović, M. D. (1964). Foundations for a General Systems Theory. In M. D. Mesarovic (Ed.), *Views on General Systems Theory* (pp. 1-24). New York: John Wiley & Sons.
Nagamori Y., Nakajima M., Yokoi T., & Yamanaka T. (2009). Analysis of the Brain Activity at the Chair Design Task with Lego Bricks. *Journal of Japan Society of Kansei Engineering, 9* (1), 51-60 (in Japanese). doi: 10.5057/jjske.J090209-1
Page, J. K. (1963). A Review of the Papers Presented at the Conference. In J. C. Jones & D. J. Thornley (Eds.), *Conference on Design Method* (pp. 205-215). Oxford: Pergamon Press.
Peña, M., Maki, A., Kovačić, D., Dehaene-Lambertz, G., Koizumi, H., Bouquet, F., & Mehler, J. (2003). Sounds and Silence: An Optical Topography Study of Language Recognition at Birth. *Proceedings of the National Academy of Sciences, 100*(20), 11702-11705. doi:10.1073/pnas.1934290100
Plattner, H., Meinel, C., & Leifer, L. (2011). *Design thinking: Understand - improve - apply*. Berlin: Springer Berlin.
Yamada, T., Ueyama, S., & Matsuda, K. (2012). Separation of fNIRS Signals into Functional and Systemic Components Based on Differences in Hemodynamic Modalities. PLOS ONE, 7(11). doi: 10.1371/journal.pone.0050271

About the Authors:

Takeo Kato: Ph.D., Assistant professor at Keio University. Resent researches include shape generation method using cellular automata and NURBS surface; quantification of emotion using NIRS; Idea generation using NN for word embedding.

Jio Koike: He is a fourth-year student of Keio University, department of mechanical engineering. He assisted to measure and analyse the cerebral blood flow.

Yusuke Ashizawa: Ph.D., Assistant professor at Shibaura Institute of Technology. he had graduated from department of design, Chiba University, and has specialized in design management and system design. Now he has been trying to reveal brain mechanism of design thinking.

Acknowledgement: This work was supported by JSPS KAKENHI Grant Number 18K18318, and was conducted with the permission from the ethics committee of Keio University and the informed consents from all participants. We would like to our gratitude to all of them.

Creativity and design method in idea generation: the comparison between intuitive approach vs structured approach

Park, Yong Jun [a]; Kim, Chajoong *[a]; Yoon, JungKyoon [b]

[a] UNIST, Ulsan, South Korea
[b] Cornell university, Ithaca, New York, United States
* cjkim@unist.ac.kr

In order to come up with creative ideas, designers have adopted several design methods in the process of idea generation. However, few studies have been conducted about which design method is more efficient for increasing creativity. Therefore, we selected two design methods, Brain Writing and S.C.A.M.P.E.R that are opposite to each other in terms of approach. An experiment was designed in a way that given the same design brief three groups of designers came up with design ideas: one group used brain writing, another S.C.A.M.P.E.R, and the other no particular design method. The design ideas generated from the experiment were assessed by three design experts to judge the ideas in terms of creativity. The results indicate that there is no significant difference in ideas between three groups in terms of creativity while a radical way is more efficient in terms of the quantity of ideas. The limitations and further study are discussed in the end.

Keywords: Creativity; Design method; ideation; Intuitive method; Structuring method; Brain writing; S.C.A.M.P.E.R

1 Introduction

Psychologists have found that creativity is one of the most energetic activities in the brain, along with logical thinking and will (Gailliot et al., 2007). The definition of the creativity in the Oxford dictionary said that it is ‘The use of imagination or original ideas to create something; inventiveness.’ it tried to create something new and it often occurs in unconscious thinking (Csikszentmihalyi, 1997). When people think about an idea, they come up with a new idea by combining various ideas or information that are unconsciously latent. People instinctively hate change and hope to remain intact. But without change, there is no development. Therefore, to develop into a better society, creativity that can make a change becomes essential. Creativity is a phenomenon whereby something new and somehow valuable is formed (Bennett & Bennett, 1975). Without creativity, humanity would not progress (Csikszentmihalyi, 1997). People make creative ideas a little easier when limiting thoughts. (Bhushan, 2017).

Especially, creativity is a core of design activity because design is meant to solve complex problems of our society considering all the pros and cons. So how can we help designers in coming up with these ideas? Many creativity techniques have been created to help generate an idea for a designer. The most representative generation method would be brainstorming that people knew well. This method appeared in the book called Applied Imagination (Author, 1953) and began to become famous, and it became the most popular method among many idea generation methods. The reason for being established most popularly is that this method can be widely used and can be easily applied. However, brainstorming method cannot be creative in every environment and generate creative ideas for every single session. That would be one of the reasons why people try to extract ideas from far more diverse ways than one method (Mackay & Fayard, 1997). Thus, brainstorming, cultural probe, focus group interview and so on was create and tested from the various environments.

1.1 Changing perspective method of idea generation

In addition to design, the method of changing perspective is a method used to solve problems by looking at the problem from a different point of view, exploration from a completely different perspective can provide a completely different solution than what designer or other people have seen so far. By changing perspectives, people instinctively can figure out the solution to the problem. Sub categories are many in the changing perspective method of idea generation, such as transformational, SCAMPER (Eberle, 1996), and etc. S.C.A.M.P.E.R are really focus on the problem analysis and idea generation

1.2 Insight experience methods of idea generation

In the case of the insight experience design method, it is a way of instantly telling people the ideas they come up with, or mapping ideas while writing, exploring the thoughts that are inside people. Examples include such as brain writing, brainstorming, and 5whys. In the case of design methods, it is a way to explore their own experiences and thoughts instinctively.

1.3 Measuring Creativity

To find out which design method is more effective in increasing creativity, a measurement of creativity is needed. There would be various aspects of measurement that quality of ideas and feasibility that needs to define for the measurement of creativity are the example. The categories of creativity used in the research of Christiaan (1992) who has been studies about creatives has developed 5 measurement of creatives which is explain in the table 1. The categories are goodness of example, idea quality, technical quality, attractiveness, and integrating capacity.

Table 1. Measurement of creativity (Christiaans, 1992)

Goodness of example	The extent to which the product is prototypical for its class of products. To exclude the influence of other criteria assessed, it was preferable always to begin with the prototypically criterion.
Idea quality	Quality of idea that comes with method
Technical quality	The extent to which a product meets the necessary technical requirements
Attractiveness	Preference for the outward form.
Integrating capacity	The extent to which the product integrates the underlying aspects of form, function, and construction.

2 Method

From these two categories of ideas generation and changing perspective categories, brain writing and S.C.A.M.P.E.R design method were selected respectively. The brain writing is a more advanced method than the brainstorming method (Litcanu, Prostean, Oros, & Mnerie, 2015). S.C.AM.P.E.R has various method to gathered to stimulate the idea-prompting checklist which stands for Substitute-Combine-Adapt Modify-Put to other Uses-Eliminate-Rearrange (Vehar, Firestien, & Miller, 1999). The experiment was conducted with three groups of designers: a brain-writing group, a S.C.A.M.P.E.R group and a control group that has no design method to use and generate the idea freely.

2.1 Experiment

The experiment is divided into three teams. The two teams applied different design methods, and the last group is control-groups that do not offer any design method so that it can show and compare the creativity of the ideas of the two team. The control-group's creativity would show the average creativity of the idea that can be generated in general occasion. For this research, the design methods for this experiment are used to Brain-writing and S.C.A.M.P.E.R. This method could be explained in the below.

2.1.1 Brain writing

Brain writing is a way to effectively engage everyone and not everyone else has the same influence, but at the same time, there is no stimulating synergy among the participants (Figure 1). It is particularly helpful with a crowd of people who are somewhat hesitant and would be extraordinary to offer many opinions in an open group session. Brain writing method provides equal time to think and write without other people's disruption and conflict. Each of which has 6 to 8 comments on a single sheet, and distributes them, and draws his or her own ideas on the theme on the first three to five minutes on each paper. After 3 ~ 5 minutes, let's pass the sheet to the participant on the left side, and write the other blank space in consideration of the idea that developed the idea written on the sheet. Continue to use the same method until all fields are filled. For the brain writing method, the session with six students may generate 108 ideas can be produced in about 30 minutes (Csikszentmihalyi, 1996). Compared to brainstorming, brain writing tends to result in somewhat fewer, but more fully developed, ideas (Roco, 2004). The benefit of brain writing method would be:

- Less communication opportunity and think deeply by themselves
- Quick and easy to generate the ideas
- Construction of "idea on idea" to generate creativity
- Combination of teamwork and individual works.
- Provide teamwork

2.1.2 S.C.A.M.P.E.R method

S.C.A.M.P.E.R uses seven rules that can be intentionally tested to get ideas: [S = Substitute], [C = Combine], [A = Adapt], [M = modify, minify or magnify], [P = Put to other uses], [E = Eliminate], [R = Reverse, Rearrange], etc., and People have to create ideas within the space set by the S.C.A.M.P.E.R. This method can increase the flexibility of thinking from various perspectives. In the S.C.A.M.P.E.R design method, it is necessary to move each method freely, and no matter how strange idea it is necessary to think less and write down. The goal of the method is by looking at problems from various perspectives, we discover the problems and differences that people have not thought about wildly, and as much as possible, users are looking for new solutions from other perspectives. The S.C.A.M.P.E.R would be explained in Table 2.

Table 2. S.C.A.M.P.E.R method

Method explanation	Description
Substitute	focuses on what would be the part that can be replaceable or substitute.
Combine	combining the ideas, process or product into one more efficient output.
Adapt	adapting an existing idea that might not have worked before to solve a problem.
Modify	modifying an aspect of situation or problem, for example by magnifying or minifying them and see whether it gives a new insight or whether it adds any value.
Put another use	put current processes or products that were intended for a specific purpose to another use to solve the problem.
Eliminate	elimination or simplify a process or idea to get to improve it, but also to identify its most important aspect.
The reverse	reverser the orientation or direction of a process or products do things the other way around, entirely against its original purpose.

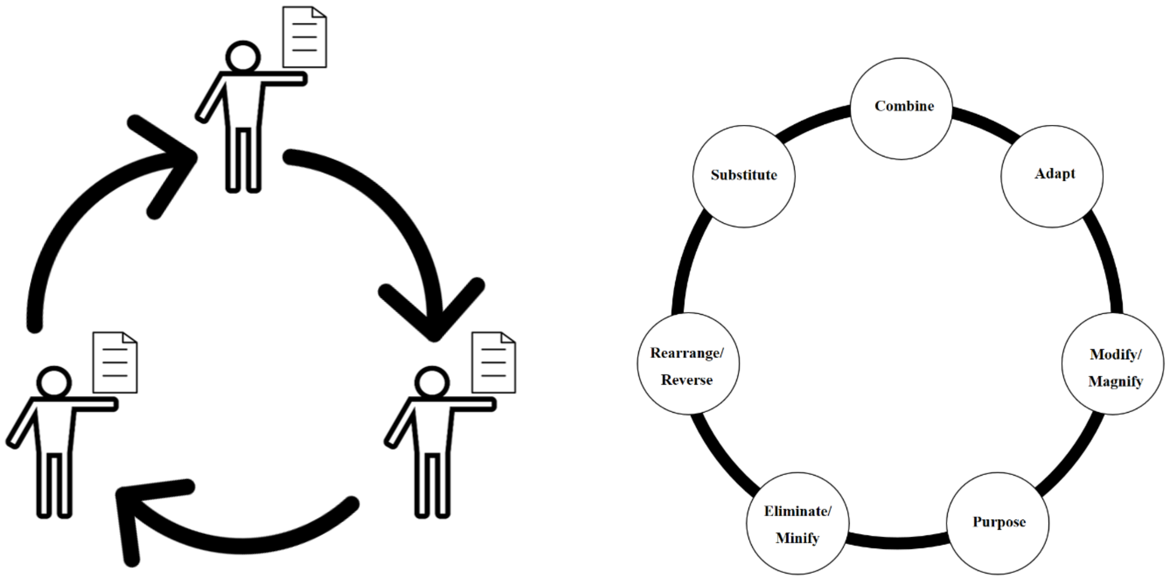


Figure 1. The working mechanisms of Brain writing method (left) and S.C.A.M.P.E.R method (right)

2.2 Participants

In order to confirm the difference in the design method, more than two years' design experienced students chosen to experiment design methods. They studied at the same school for one year, and their experience in design had more than two years and less than six years of experience in common. Nine participants recruited whose age ranged from twenty to thirty years old and consisted of six males and three females. Three groups created as randomly as possible while creating a group including one female and two males in each group to minimize the influence of gender difference. For judging the creativity of ideas generated from the experiment, three professional designers who had more than 10 years of experience in design practice were recruited. They were all male and their age ranged between 40 and 50 years old.

2.3 Materials

To facilitate creativity with ideas a particular design assignment was made. The medical industry has steadily grown and continuously grown and continuously growing field (Aghion, Jones, & Jones, 2017). As life expectancy increases, health-related products developed day by day, and their usage gets diversifying. In addition, the medical field has large studies about weak A.I. development in a medical product. (Negnevitsky, n.d.) There are many various products that designers can think about for future. Creativity may come better when there is freedom to do for the topic. Fusion of this future technology and the medical area is a field where designers can demonstrate a wide range of creativity. Therefore, it became the assignment for the experiment to generate ideas for medical equipment with artificial intelligence aiming at 2030. Based on the theme, three examples for the assignment were made to help participant better understand the concept of AI and applicable solutions to medical equipment:

- Device that helps with cancer detection (Gulshan et al., 2016)
  Usage - Estimation of cancer cells by cancer tissue sample review
  Required data – patient CT or MRI
  How data is used - comparative analysis with thousands of data classified by professional doctors.
  Development Direction - How to advise and supplement doctor's opinions

- Skin cancer diagnosis products (Esteva et al., 2017)
  Usage - 5.4 million new cases of skin cancer created every year in U.S.A, it tests to detect skin cancer early stage.
  Required data recent skin photos (hospital shot) - Image based classification
  How Data is Used-By: contrasting thousands of photographs selected by 21 certified dermatologists,
  Development direction - Provide physicians with data on whether the skin disease is malignant or benign

- Diabetic retinopathy test (Andre E., Brett K., Roberto A. N., Justin K., Susan M. Swetter, 2017)
  Usage - Examination of the retina, examination of the patient's condition
  Data Needed - Patient Retinal Photographs
  How data is used - Contrast with the data that the professional retina physicians have categorized to analyse the current patient condition.
  Development Direction - To see the status of the patient quickly and accurately to doctors.

2.4 Procedure

The S.C.A.M.P.E.R method group was first invited to Home Lab and then the brain writing method group while the third group was the control group (Figure 3). And the purpose of the experiment was introduced. All three groups were given the same assignment that 'if the weak AI included healthcare product enters the home, what kind of product would it be?' An explanation of week AI and related examples were given before they started to come up with ideas. An hour for each team was given for generating ideas and no other resources such as internet and books were not provided except the creativity technique. There was no considerable difference in using a different place to experiment with each test from each group (Liikkanen, Hämäläinen, & Häggman, 2015). Nevertheless, trying to provide fairness to each group, with equal time and experimenting with the same space with providing the same information were provided to the participants. After the participants finished generating ideas, they individually gave full explanations of their ideas. In order to prevent experts at the phase of the evaluation of the ideas from influenced by the participant's drawing skill, a professional sketcher was invited and redrew all the ideas while idea explanation was given. Merging similar idea into one in each group, each idea sketch done by the sketcher was added in a creativity evaluation form (Figure 2) and the forms were randomly rearranged to avoid possible order effect. Then, A set of sketches was provided to the three professional designers for rating the ideas in terms of creativity. They marked on the five Likert scale for each idea.

Figure 2. Experiment scenes of each design method group: S.C.A.M.P.E.R group (left), Brain writing group (middle), and Control group (right)

3. Evaluation of creativity

3.1. Experts

In order to evaluate creativity, three professional designers who chosen based on the design career with at least eight years of professional design experience selected, among which have experienced projects related to medical care., . The selected professional designer were designer professors hired at the university, and it considered appropriate to receive the design evaluation. In addition, chosen professors had experience of teaching creativity and had enough knowledge about it; it could give a more objective evaluation of creativity.

3.2. Materials

In this study used creativity evaluation criteria provided by Christiaan (1992) to evaluate creativity by design experts. Five categories of explanatory provided with five categories were given to the three experts (Figure 3). Also, since the evaluation of the experiment may vary depending on the sketch ability, all the sketches have been resketched by hired sketch specialist. Also, providing A2 paper and tools for drawing for the experiment. From three group, the control group provided a basic white page, and printed form of S.C.A.M.P.E.R and brainstorming method provided to the experiment participants. In addition, before experimenting, they gave them three examples of weak A.I. future medical product that was actually under development, along with a definition of weak A.I.

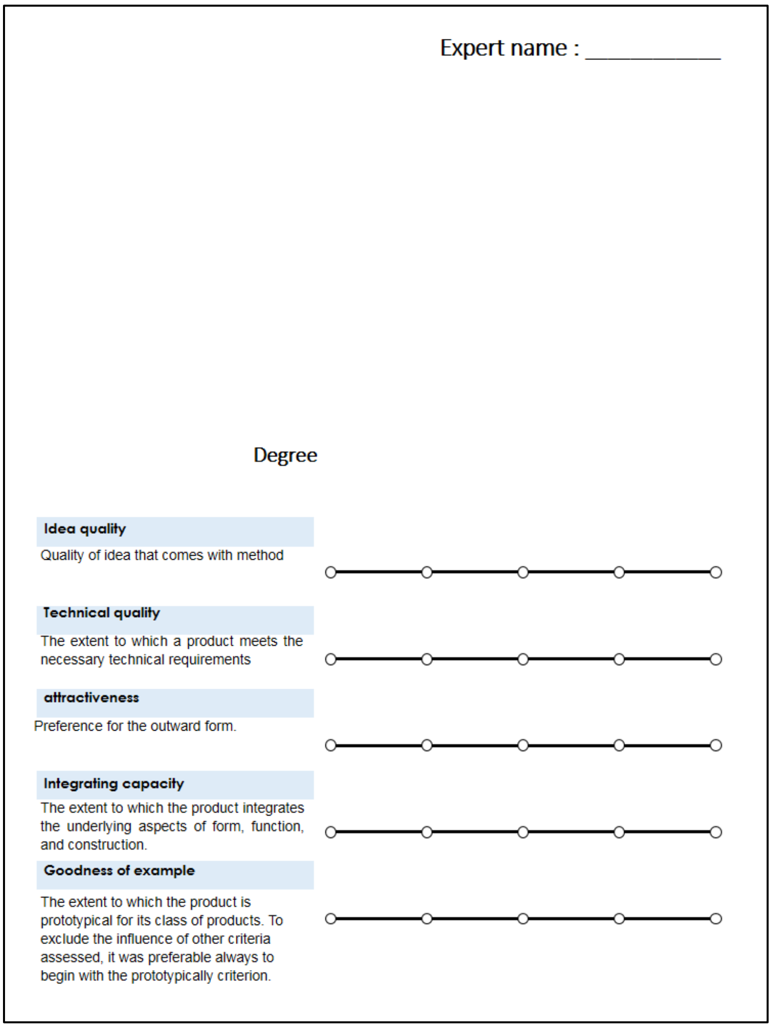


Figure 3. An evaluation sheet for ideas in terms of creativity

4. RESULTS

4.1. GENERATED IDEAS

4.1.1 Brain writing method group

The brain writing team created eighteen ideas. From the eighteen ideas, three for sleeping, two for toilet, one for exercise, three for beauty, three for health check, two for food, one for tooth, two for posture ideas for health care were generated (see examples in Figure 4). There were many ideas and as an example, there is an anal treatment for the bidet. It installed in a toilet like a bidet, and when people sit down, it can check their body condition automatically and perform the appropriate treatment. In addition, post-treatment records also automatically transmitted to the doctor. Other many be, Child health check stroller, exercise check wearable, etc.

In the brain writing method, the three-combined idea that may use was the health care shower booth. It helps people to be healthy while taking a shower by providing perfect shampoo and treatment to the user to have a better experience and health care at the same time.

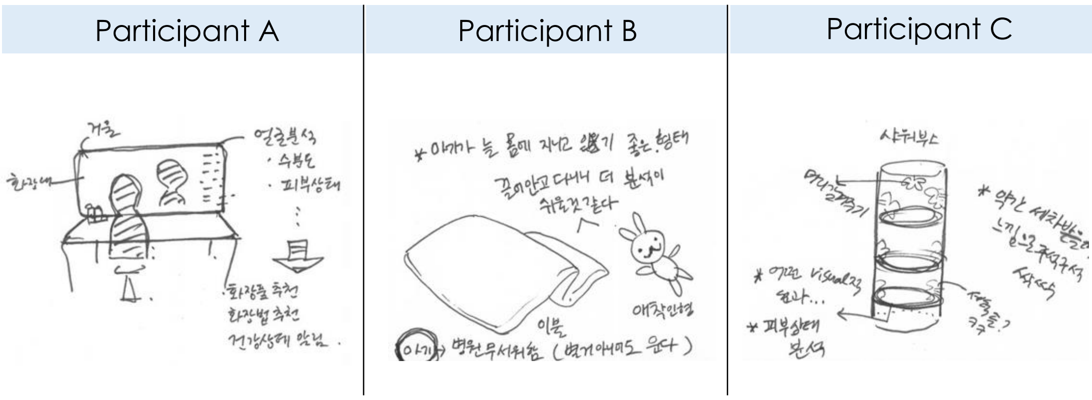


Figure 4. Ideas generated from the brain writing method group

4.1.2 S.C.A.M.P.E.R. method group

Using S.CA.M.P.E.R. team was able to create twenty-seven ideas. Of the twenty-seven ideas, two for toilet-related, two for sleep-related, twelve for health-check, two for beauty related, three for exercise-related, one for air cleaning described, three for food-related, two for posture-related ideas were created. Examples include a sofa that is detecting people's emotion and changes shape by people who is sitting on the sofa and, a robot that makes a mess to make people to moves, a product that checks the color of toilet stools and checks health (Figure 5). This group had the time to gather ideas for each task they have given. An individual method provided about eight minutes to think and proceed to the next practice. Some of the unique idea from S.C.A.M.P.E.R method can be reverse the ideas that the machine creates a mess to make people exercise. The device is not helping people. It provides a mess to develop people to the works would be one of the unique ideas that come up.

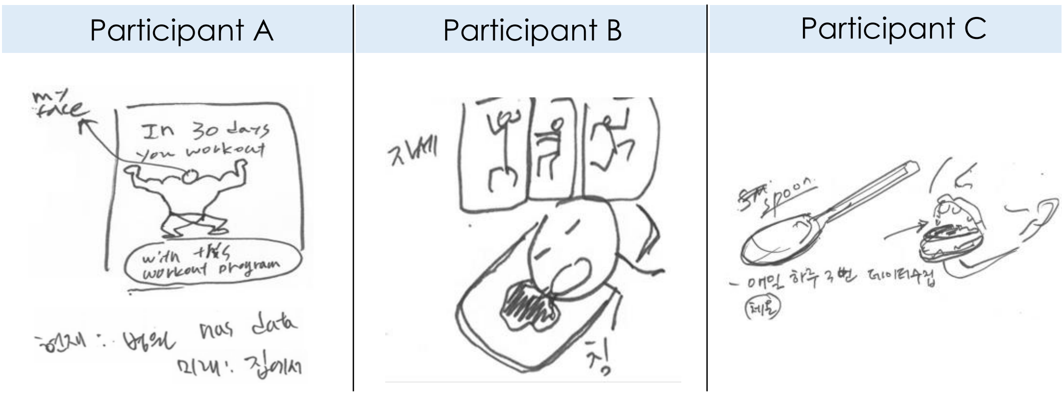


Figure 5. Ideas generated from the S.C.A.M.P.E.R method group

4.1.3 Control group (no particular design method)

The last team is the center group that there are no method or rule to be followed by participants. This team has unlimited freedom to use any method or way to create. However, participants hesitate to lose the track and only thinking so much, which they could create seven ideas, total. Of the seven ideas, two for food-related, one for beauty-related, three for health check-related, one for toilet-related ideas were generated. Example of control group’s idea was the food selection refrigerator (Figure 6). It uses the bid data of the location of the user, their preference, hospital data, current health state, weather, and circumstance to define the best healthy food to the user. Participant's idea was trying to connect everything to provide the best food to the user. From this result, analysis of the data and defining the result can be possible. As a result, there was a distinctive difference from each outcome, and there would be some difference can be observed.

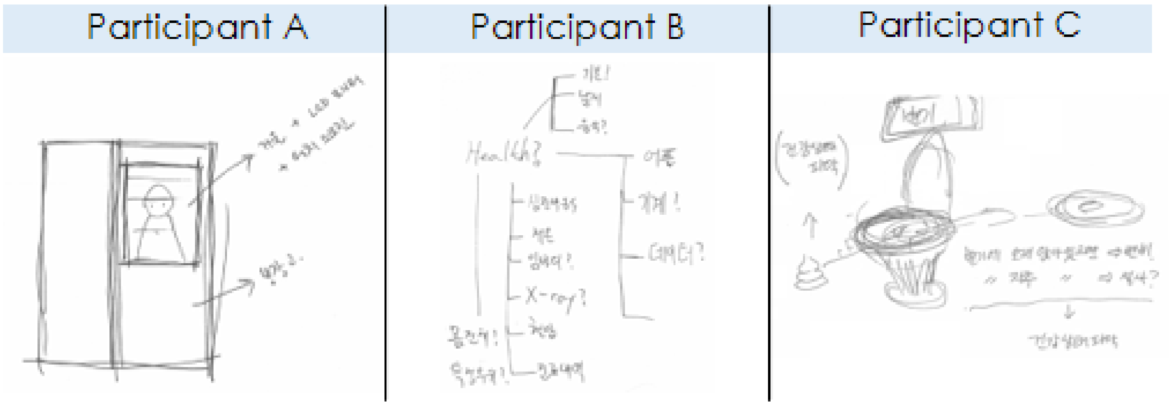


Figure 6. Ideas generated from the control method group

4.2. Creativity evaluation of the ideas

After the results of the experiment, hired a professional drawer to come to the work and draw all the ideas (Figure 7). By letting one-person sketch, this sketch could rule out an evaluation based on painting ability. After that, all the sketches entrusted to the design experts and evaluated for creativity.

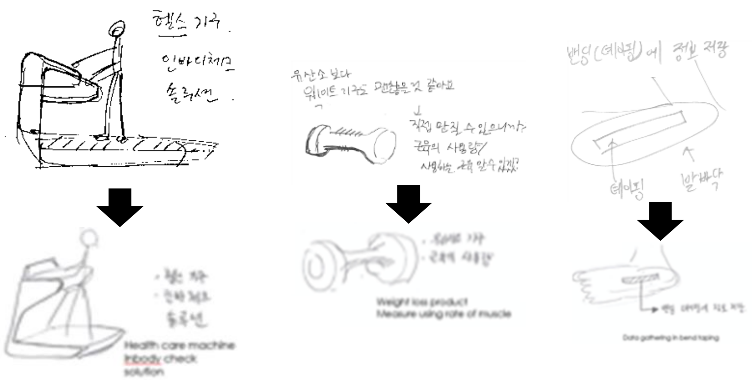


Figure 7. Examples of resketched ideas for the expert evaluation

Fifty-two ideas were created in terms of the five criteria measuring creativity. After the expert's judgement was done, the quantity of all the ideas between groups was identified and the mean value of each group was given to compare which design method has more creative ideas. In addition, the mean value of each criterion of creativity measurement within a group was given to identify what differences there are in terms of the criteria between groups. Although there is a difference in terms of the number of ideas generated from each method (18 ideas from brain writing group, 27 ideas from S.C.A.M.P.E.R group and 7 ideas form the control group, no significant difference in the creativity between groups has been discovered (Figure 8). In addition, there shows no difference between groups in terms of creativity measurement criteria (Figure 9).

In this research, compare and analyse the three designs method to discover what kind of design method has more potential to generate creative ideas. Among three-design method, S.C.A.M.P.E.R method received slightly higher figures than other methods in Technical quality. However, figure seven and eight shows that there is no huge significant difference in creativity. The grade was not able to find such a big creativity difference in the way of each design. When viewed from a qualitative point of view, the average value that appeared in the experts' evaluation shows a similar score that does not have a huge difference in each design method's creativity score.

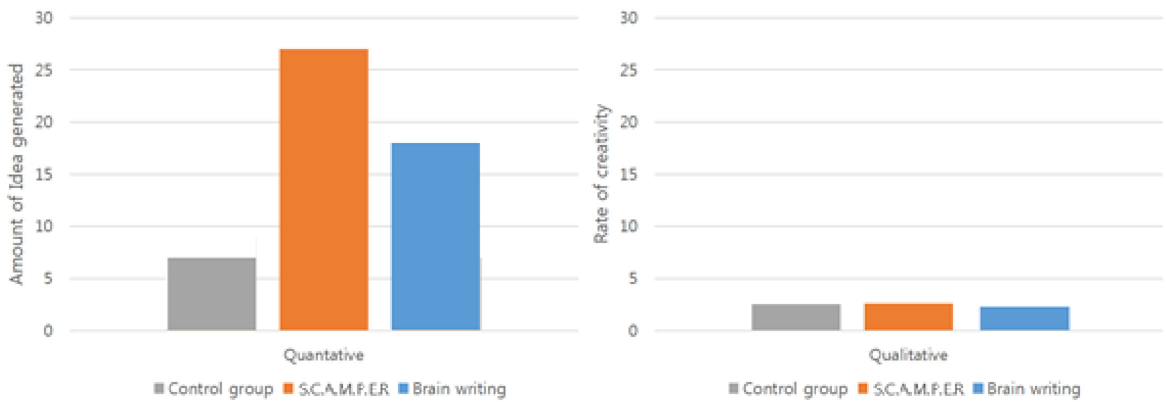


Figure 8. Comparison groups in terms of quantity (left) and creativity (right)

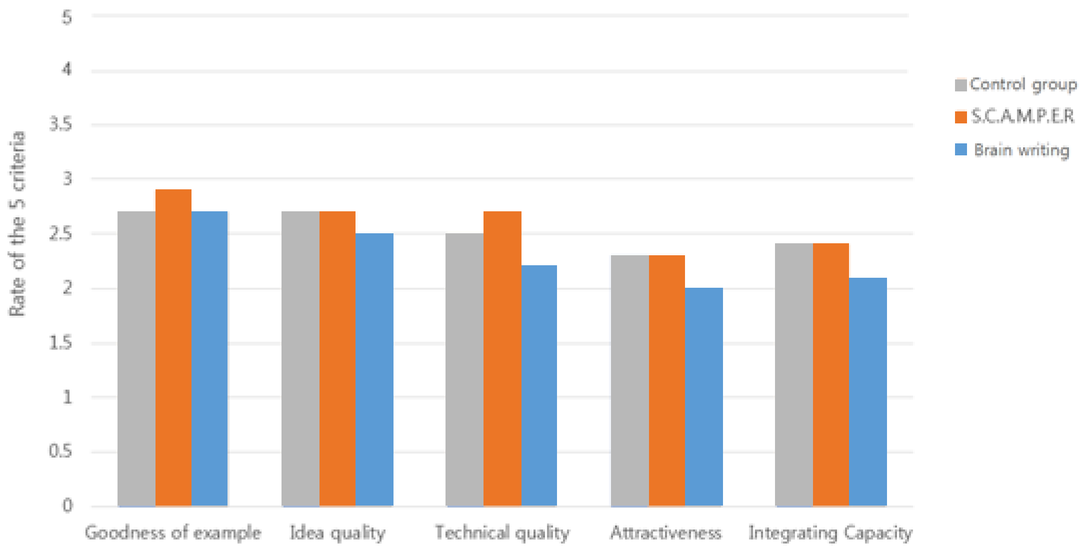


Figure 9. Comparison between groups per creativity measurement criterion

5. Discussion

The reason for the difference in the quantity of idea shows that each design method's limitation of how many ideas can generate can be seen. For example, in the case of 6-3-5 brain writing design method, the number of ideas with a definite number of 108 ideas generated in 30 minutes was informed. From this result, there are two key finding, which is:

First, there were similar ideas that appealed from the individual method that was the toilet. All three groups had the idea of defining their health by researching user's dung. No example nor data provided to the participants and there was common sense to each other and created a similar idea. It can point out; there would be commons knowledge that people know in a particular field would be similar.

Second, there was a different method to generate ideas. However, depending on the participant's attitude, there was a different amount of idea generated even with the format provided. Therefore, there would be some different quantitative idea may create from each different idea generation.

From this finding, extracting ideas in limited time and cost will not make a huge difference in creating creative ideas using the design method. Thus, in this study, even if various design methods extracted ideas, participants with similar experiences could extract ideas with similar creativity.

6. Conclusions

The purpose of this study was to discover which of the design methods could be more creative in future-oriented design. For this purpose, two design method, which is Brain writing, and S.C.A.M.P.E.R. picked and tested. The creativity of the two design methods evaluated through Christiaans(1992)'s creativity evaluation. As a result, there is not much difference in the qualitative aspect that done by the expert's judgment. In the quantitative difference, but the quantity difference in generated ideas could be different according to the method's maximum limitation of generating ideas. From the results, the creativity of different design method is similar with a single major of the designer who lives in one country. Therefore, for a company or a school to gather various people in various fields to create a creative idea would be valid.

In conclusion, though quantitatively it can be a big difference, creativity in terms of quality did not make such a big difference. This research had fundamentally based on research on future-oriented design products, and the result of a small amount of qualitative research, which is the result created by the masters and the doctor between the ages of the 20s and 30s who have the design experience for more than one years. In addition, participants studied together for more than a year in the same area and experimented with Koreans only has been selected. That is why the creativity they create can be similar. Even if their experiences have the difference, experiences in similar places may cause them to draw inspiration from a similar aspect. Further research needs to gather people from various backgrounds, and conduct research would provide different results. Also, result from the professional designers who know the did future medical design and other different major would be different. For a more reliable research result, it is necessary to experiment with other design methods or different professional design judger to get the more reliable result to find a way of increasing the quality of creativity. Further studies are need.

References

Andre E., Brett K., Roberto A. N., Justin K., Susan M. Swetter, H. M. B. & S. T. (2017). Dermatologist-level classification of skin cancer with deep neural networks. . . *Nature International Journal of Science*, *542*(6.Lily, P., Varun G), 115–118.

Bennett, J. G., & Bennett, J. G. (1975). *Creative thinking*. Coombe Springs Press.

Bhushan, B. (2017). *Springer handbook of nanotechnology*. Springer.

Christiaans, H. H. C. M. (1992). (1992). Measuring creativity. *In T. Rickards, S.Moger & P. Colemont*, *Creativity*(december 1992), 119–124.
Csikszentmihalyi, M. (1997). *Finding flow: The psychology of engagement with everyday life.* Basic Books.
Eberle, B. (1996). *Scamper on: Games for imagination development*. Prufrock Press Inc.
Esteva, A., Kuprel, B., Novoa, R. A., Ko, J., Swetter, S. M., Blau, H. M., & Thrun, S. (2017). Dermatologist-level classification of skin cancer with deep neural networks. *Nature*, *542*(7639), 115.
Gailliot, M. T., Baumeister, R. F., DeWall, C. N., Maner, J. K., Plant, E. A., Tice, D. M., … Schmeichel, B. J. (2007). Self-control relies on glucose as a limited energy source: willpower is more than a metaphor. *Journal of Personality and Social Psychology*, *92*(2), 325.
Gulshan, V., Peng, L., Coram, M., Stumpe, M. C., Wu, D., Narayanaswamy, A., … Cuadros, J. (2016). Development and validation of a deep learning algorithm for detection of diabetic retinopathy in retinal fundus photographs. *Jama*, *316*(22), 2402–2410.
Liikkanen, L. A., Hämäläinen, M. M., & Häggman, A. (2015). Quantitative Evaluation of the Effectiveness of Idea Generation in the Wild Quantitative Evaluation of the Effectiveness of Idea Generation in the Wild, (April). https://doi.org/10.1007/978-3-642-21753-1
Mackay, W. E., & Fayard, A.-L. (1997). HCI, natural science and design: a framework for triangulation across disciplines. In *Symposium on Designing Interactive Systems: Proceedings of the 2 nd conference on Designing interactive systems: processes, practices, methods, and techniques* (Vol. 18, pp. 223–234).
Reich, Y., Hatchuel, A., Shai, O., & Subrahmanian, E. (2012). A theoretical analysis of creativity methods in engineering design: casting and improving ASIT within C–K theory. *Journal of Engineering Design*, *23*(2), 137–158.
Shah, J. J., Smith, S. M., Vargas-Hernandez, N., Gerkens, D. R., & Wulan, M. (n.d.). Empirical studies of design ideation: Alignment of design experiments with lab experiments. Citeseer.
Vehar, J., Firestien, R., & Miller, B. (1999). Creativity unbound. *An Introduction to Creative Problem Solving (Innovation Systems Group)*.

About the Authors:

Yong Jun Park: earned a bachelor degree in Sculpture from Ulsan University and get degree of graduation from UNIST. He likes to craft something with various tools and materials.

Chajoong Kim: He is associate professor in the department of Industrial Design and the founder of Emotion Lab at UNIST. Based upon an understanding of human-product interaction, his main research interests are in user experience design, emotional design, sustainable design and design for behavioral change.

JungKyoon Yoon: is Assistant professor in the Department of Design + Environmental Analysis at Cornell University. His research focuses on experience design with an emphasis on affective experiences, subjective wellbeing, and design-mediated behavior change.

Acknowledgement: This work was supported by the 'Promotion of Graduate School of Creative Design Engineering' of the Korea Institute of Design Promotion with a grant from the Ministry of the Trade, Industry & Energy, Republic of Korea. (N0001436).

'Editorial thinking' for design research

Ikeda, Minako

Kyushu University, Fukuoka, Japan
ikeda@design.kyushu-u.ac.jp

This paper examines the effectiveness of applying the editorial thinking methodology based on practical editor thinking patterns to design research. Design thinking first became popular in the 1990s at which time many alternative design methodologies were devised and shared with design researchers and practitioners. However, design thinking had also been recognised as a useful methodology to creatively identify and resolve problems in areas outside the design and engineering professions such as business. At the same time, more intuitive and creative approaches were being developed such as the critical design and speculative design concepts that were rooted in art. This paper defines editing as a series of tasks that involves the observation and collection of information and objects from around the world and the determining of novel contexts by taking new viewpoints when classifying, organising and restructuring them to create new values. Therefore, three experimental exercises were conducted to assess the viability of editorial thinking as a new design methodology.

Keywords: design research methodology; practical thinking patterns; contextualisation; innovation of meaning

1 Background

Since the 1990s, multidisciplinary and diverse design methods and tools such as design ethnography, scenario, personas, storyboard, storytelling, participant observation, participant design, customer journey maps and contextual design have been proposed to enhance design research protocols(Kumar, 2012; Hanington and Martin, 2012; Van Boeijen, Daalhuizen, Zijlstra, Van Der Schoor, 2014; Stickdorn and Schneider, 2011). To accompany these innovations, there has been an explosion in the number of suggested design genres; universal design, inclusive design, speculative design, critical design, design fiction, social design, service design, conceptual design and design thinking. Design thinking, in particular, has become internationally influential as it can be customised to suit every country and culture and as it encompasses areas other than design, has involved a wide range of specialists, all of which has significantly expanded design horizons. Design thinking was seen as an innovative process that could solve social problems by reframing issues using abductive approaches based on observation and hypotheses development rather than reductive simplistic approaches that focus on a solution. Therefore, design thinking involves systematically organising the various design tools so that they can be appropriately applied to each individual case, which could be products, services, business strategies, or social systems.

Following Design 0.0, which was the age of the artisan; Design 1.0, which was the age of styling design; and Design 2.0, which was the age of human-centred design based on design research, came the Design 3.0 concept proposed by Industrial design department, Korea Advanced Institute of Science and Technology (ID KAIST), which is defined as the age of empowering design in which users are engaged in the design with the designers who assist them in realising their visions (Lee, 2017).

In1971, the U.S. designer, Papanek, stated that 'All men are designers. All that we do, almost all the time, is design, for design is basic to all human activity' (Papanek, 1984). Around the same time in 1972, the German artist Josef Beuys announced that 'everyone is an artist' (Stachelhaus, 1991). While these novel discourses were greeted with surprise at the time, Design3.0 has encompassed these ideas into a practical working idea that everyone is creative, which has encouraged community involvement in design using the innovative digital machine tools that have become accessible to all in recent years, and which have allowed ordinary people to create what they want when they want; therefore, Design3.0 is beyond user-centred design or user-participatory design.

Forlizzi and others stated that 'over the last two decades, constructive design research (CDR)—also known as research through design—has become an accepted and popular mode' and further noted that there were three distinct design research genres: the lab, the field and the showroom; in which design action was the mode of inquiry (Forlizzi, Koskinen, Hekkert and Zimmerman, 2017). While both the lab and field constructive design research approaches take pragmatic stances when seeking to understand a situation, identify the problems to be solved and then design the solutions, the showroom approach to critical design or speculative design generates debates to reveal the hidden issues behind the design solutions. These two stances—constructive design research and critical design or speculative design or design fictions—have been recognised as creating undesirable conflicts (Forlizzi, Koskinen, Hekkert and Zimmerman, 2017).

In essence, the development of these ideas was as follows;

- Since the 1990s, various design methods and tools have been proposed as the ideas associated with Human-Centred Design began to be widely disseminated.
- The emergence of design thinking made it possible to extend objects of design, systematise existing design methods and tools, and develop a methodology accessible to a wide range of people other than design experts.
- The possibility of users being directly involved in design activities emerged along with the new technology that encouraged creativity in ordinary people.
- In the scholarly design research community, there was a negative conflict between the constructive design research concept that had a pragmatic orientation and the controversial critical design concept, which sought to find new values.

This paper, therefore, considers this background to focus specifically on practical editorial thinking and its applicability to design research. There were four reasons for the specific focus on editorial thinking:

- Editing may be the basis of the thinking or the skills needed to leverage a wide variety of the design methods and tools proposed so far.
- Editorial thinking could be useful for design thinking that tries to involve target users in the design process using a variety of design methods and tools.

- It is necessary to explore the possibility of developing editing skills in ordinary people, who are expected to become involved in main design activities, and to consider the education needed for this development.
- Editing, which includes information classification, association and context construction, is an integral part of many existing design practices and is applicable to both constructive design and critical design research. For example, for methods such as user journey maps, personas and scenarios, which have become key design research methods, the quality of editing directly affects the research results, which is also true for critical design, and especially in design fictions and the creation of future stories that require knowledge of the creative context.

2 Research purpose and methodology

The aim of this research was to focus on practical editorial thinking by modelling the process, developing a design research method and clarifying its applicability and effectiveness. First, the editing concept is defined, and then, based on an analysis of the segmentation and abstractions associated with the editorial practice workflow, a model is proposed. By examining each process in the model, the meanings and roles associated with each step are clarified and an editorial thinking methodology elucidated. To further examine editorial thinking, three exercises are described and practised, the results considered and the editorial thinking methodological implications examined.

3 Definition of editing

In this paper, editing is defined as a series of tasks that involve the observation and collection of information and objects from around the world and the determining of novel contexts by taking new viewpoints when classifying, organising and restructuring them to create new values. Editorial activities can be divided into three levels; the editorial practices of professional editors, the editorial act as thinking and the editorial act as a general living skill (Ikeda, 2019).

The editorial practice of professional editors is related to the skills and know-how necessary to edit printed and visual materials such as books, magazines, websites and videos, and encompasses a practical way of thinking about and the skills and knowledge required for planning, text rewriting, proofreading up to layout and printing direction or coding. In this paper, these editorial skills and knowledge are seen as the necessary resources for the abstraction of the thinking and skills to construct an editorial thinking methodology. In addition, the possibility of its application as a skill set for materialising and visualising editorial thinking is also considered.

The editorial act as thinking refers to the abstraction and generalisation model associated with the ‘editorial thinking’ process and practice of professional editors. Based on this model, we attempt to identify an editorial thinking method. Editorial thinking is the method used to place design objects in testing contexts to assess their viability. For example, techniques such as case use studies, customer journey maps and scenarios have been proposed as contextual design development methods that can be used to develop more appropriate, realistic, contextual stories by editing the information (material) obtained from observation, interview surveys and log analysis.

Editorial activity as a skill for general living is a creative activity closely associated with Design 3.0 and the ideas of Papanek and Beuys. For example, drawing on the general information literacy skills of utilising and then editing the vast information on the Internet, editorial thinking supports the user's creative design activities and user-participatory design in design research.

4 Process of editorial thinking

First, the editorial practice workflow, which includes the thoughts and practices needed to develop print media products such as books, magazines or websites, is analysed and articulated. These editorial work processes were re-constructed based on observation when I was a member of the editorial department of a magazine from 1997 to 2001, the experience of my editing activities, other editors' remarks in several Japanese references about their own editing experiences, editing methods and editorial theories (Nakamata, 2011; Sugatsuke, 2012; Shimuta and Hayakawa, 2014), and based on discussions at a symposium (Design Philosophy Bar; 'Provoke bar—Designing with Continuous Editing', held on 30th August 2018 at Konya 2023 in Fukuoka, Japan) on the theme of editing and design. The editorial thinking process was modelled on the editorial workflow obtained from the above-mentioned references and materials, as shown in Figure 1 (Ikeda, 2019). It is necessary to note that the editing flow shown here reflects the actual situation in Japan. Japanese uses the noun 'Henshu' for editing, which indicates all editorial actions such as concept development and ways of thinking for 'editing'. In English, 'editing' is referred to using the noun from the verb 'edit'. German uses the word 'Redaktion', which tends to indicate an editorial department or an entity that edits. Therefore, the nuances are different from the Japanese 'Henshu' (=editing), as it appears that the English and German meanings of editing emphasise the more practical work of arranging content and text rather than editorial thinking. In this paper, 'editing' refers to all editing activities including thinking.

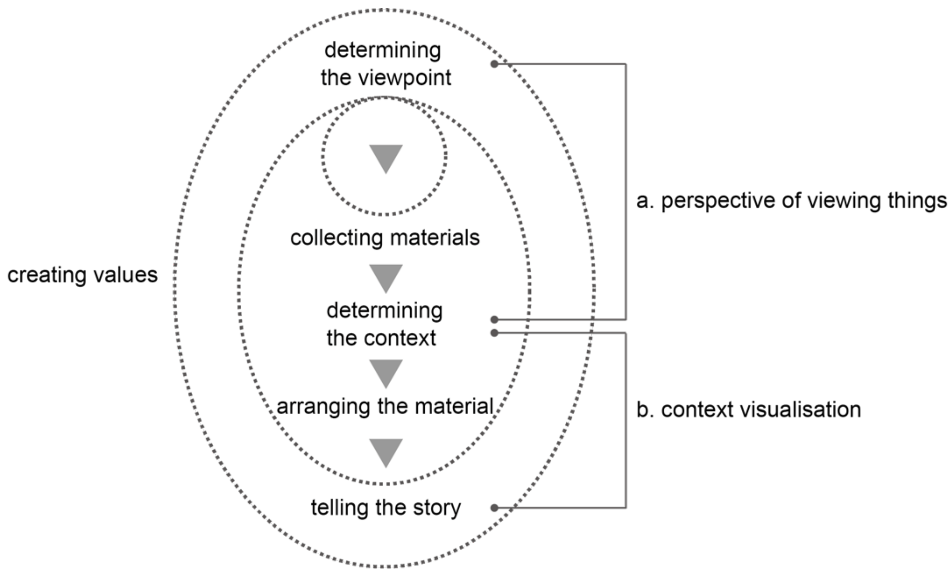


Figure 1 Model of editorial thinking process by the author

As shown in Figure1, editing starts by determining the theme and the viewpoint, after which objects or materials related to the information to be edited are collected based on the considered viewpoint. The 'viewpoint' is focused specifically on the identified theme, and can be reworded to interpret the things around the theme. The ‘materials’ are individual object examples related to the theme. However, ‘determining the viewpoint and collecting the materials’ does not proceed in a straight line, but is a circular process as shown in figure1. Sometimes, important things and examples are found that do not fit the initial perspective but cannot be ignored, and sometimes, things are found that were not expected to be deeply related to the theme but appear to be relevant. Therefore, it is often necessary to shift or adjust the initial perspective, and depending on the materials collected, the original viewpoint may also change significantly, and may be abandoned to re-set a new viewpoint. In this way, until the editor as a creator is convinced that the materials, the decided viewpoint and the theme are connected without contradiction, the theme and the viewpoint are constantly being considered in the circular process between the viewpoint and the materials collection.

Once the viewpoint is fixed and the materials fully aligned, the context appears, thereby revealing the thematic development path and the message. The individual materials (cases) that have been collected and selected based on the viewpoint (theme) are then linked to a causal relationship, and if there is a contradiction-free context identified, the context visualisation process commences. Context recognition is basically ‘the potential tendency for humans to make lines from points, combine fragments and fragments and sublimate them into a continuous illusion’ (Toyama, 1975); that is, the daily life editing activities associated with basic human thinking is the root of editing. Once the context is fully understood, the collected materials are arranged, shaped and put on the media to tell a story that is accessible to an audience.

The above describes the overall editorial thinking process flow, which can be roughly divided into two stages; ‘a. perspective of viewing things’ and ‘b. context visualisation’, as shown in Figure 1.

The steps for ‘a. perspective of viewing things’ are fixing a viewpoint, collecting material and determining the context, and the steps for ‘b. context visualisation’ involve further determination of the context, arranging the material in line with the determined context and telling the story. Therefore, the determination of the context connects these two stages because as editorial thinking is the act of connecting individual things (materials), context determination is at the centre of all editing processes.

5 Two approaches to the perspective of viewing things

Looking more closely at the first stage; a. perspective of viewing things’; there are two approaches to deciding on the theme and viewpoint; a deductive approach, as shown in Figure 2 (left), in which the viewpoint is decided on and then interpreted with an image from the outside world that matches that viewpoint, or an inductive approach, as shown in Figure 2 (right), in which things in common to a specific thing in the outside world are converged to represent the viewpoint (Ikeda, 2019).

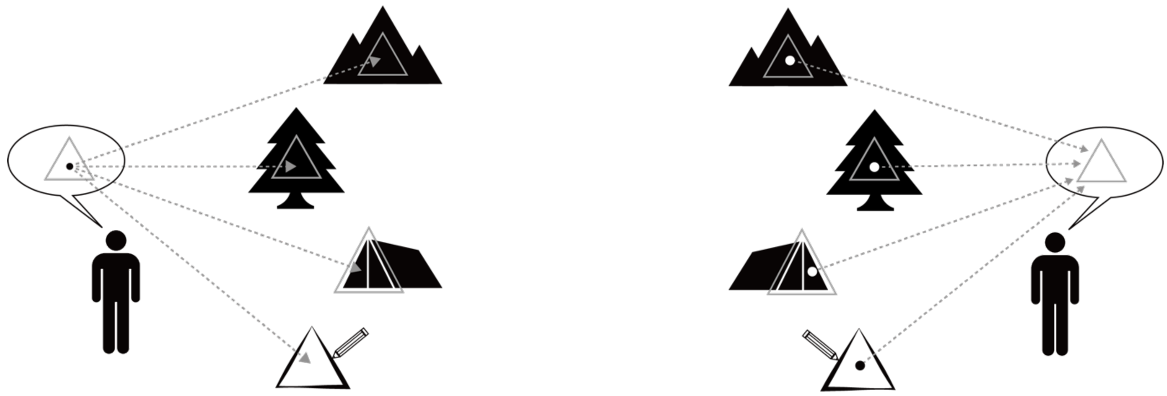


Figure 2 deductive approach (left) and inductive approach (right) to the perspective of viewing things

In the deductive approach shown in Figure 2 (left), for example, if a ‘triangle’ is the theme or the viewpoint, materials are collected from the real world that accord with the image of the triangle; that is, a consciousness of the triangle as the viewpoint makes it possible to see and collect triangles in the environment that may not have been seen before. While observing the materials related to the triangle collected in this way and moving between the viewpoint and materials collection, the original triangle that was set as the first viewpoint becomes adjusted to the real world and the viewpoint made clearer and more persuasive.

In the inductive approach shown in Figure 2 (right), something common to specific events is noticed while observing the real world, and a natural human flow that tends to associate individual events with each other emerges to relate these widely scattered individual things to reveal stories and analogies.

Therefore, the deductive approach that looks to the outside world after the assumption of the triangle is first established and the inductive approach that realises the triangle by looking at the outside world seem to be in contrast; however, in the editorial process, the two approaches are connected and merged, and often repeat the loop between the viewpoint and the collected materials.

6 Editorial thinking methodology

In the previous section, a model was presented to explore the design process application possibilities while organising the editorial practice thinking (figure1). In this section, the development of an editorial thinking methodology based on practical knowledge is explored. The methodological base for the editorial thinking model was applied in three exercises based on three themes; ‘unexpected catalogue’, ‘editing of fragments’ and ‘dissimilating daily lives’. These exercises were implemented through trial and error and improvement from 2008 to 2018 in an editing class. The purpose of this study was to focus on the editorial act as thinking, the editorial act as skills for general life, and to formalise the ‘perspective of viewing things’ that editors have as tacit knowledge. The background of the students who participated in these editorial exercises ranged from product design, graphic design, architecture, language, philosophy, sports science, information science and economics.

6.1 Exercise 1: Unexpected catalogue

6.1.1 Outline

The purpose of this exercise was to experience the basic model for the editorial thinking process flow (figure1) to examine whether the editorial thinking process worked and the possible outcomes. The catalogue as a format was selected as the outcome of this exercise and contained all editing process steps. The tasks given to the students were as follows:

1. Find a viewpoint;
2. Collect materials according to your viewpoint;
3. Arrange the collected material according to the context;
4. Express the intended message through the collected material.

Historically, a typical catalogue media is a product catalogue, for which the materials must be collected, selected, edited and presented in a lineup to attract consumers. The lineup, therefore, is a visualisation of the dealer's world view through the actual goods. Further, product catalogues need to provide consumers with the information necessary to easily find, compare and make a purchase decision. Therefore, the following requirements were set for the 'unexpected catalogue' exercise.

1. Easy to compare items
2. Searchability
3. Items are classified
4. All items are treated equally
5. Consistency in the information provided

The catalogue content in this exercise was not necessarily limited to a product catalogue. It is a structure in which steps 3 to 5 can realise tasks 1 and 2. The most important challenge for this exercise was to create the 'unexpected' condition. What was unexpected was related to the editor's creativity as the value of the information transfer. The unexpected aspect came from the information asymmetry; that is, the value of the communication was established by the difference between what you know and what the other party does not know. This gap can make the unexpected condition valuable. However, mere surprise was considered insufficient as thinking should be built to the point where the audience feels empathy or sharing.

6.1.2 Outcome and evaluation

One student with a design background attempted to edit a catalogue of useless things. As the mission of design is to make something useful, these students were usually trying to realise designs that were functional and beautiful and could contribute to society. The theme was decided based on the idea that it would be better to refer to things that weren't useful so as to understand what it meant to be useful. However, from the uselessness point of view, the student hit a brick wall when collecting the examples of useless things as the material to be edited, which gave rise to the fundamental question as to whether there was anything in the world that was useless in the first place. For example, Marcel Duchamp's work <Fountain>, which has been exhibited at the Tate Modern in London and in other famous museums worldwide, is a sideways mounted male urinal that does not naturally function as a toilet; however, it is an important work when talking about art.

In this editing process, as the thinking was not limited to the concepts, richer thinking developed through the collecting, classifying, analysing and realising the worth of the specific materials in front of them. While the concept-only operation seemed free, in practice it was found to have limitations. This exercise confirmed the usefulness of the inductive approach to editing as a thinking method. It was suggested that this editorial thinking model could work to generate discussions on the critical design process highlighted by Dunn and Raby (2013).

6.2 Exercise 2: Editing the fragments

6.2.1 Outline

In this exercise, pieces of information that were independently scattered were collected from a natural point of view with as little control as possible, from which a context was then derived and narratively expressed. As mentioned earlier, people tend to involuntarily seek causal relationships even if they appear unrelated. For example, when adults and children talk about their experiences to people, they usually generate narratives so that many selected events are reported as a single story. However, with the spread of the Internet, there has been an exponential explosion in fragmented information, which means that situations arise in which contextualisation is not possible, and therefore, there is a large amount of information in people's lives that is not meaningful. Therefore, to ensure a peaceful everyday life in modern society, it is now necessary for people to acquire high information editing skills. At the same time, it is ideal for high quality design research if users are able to explain their lives, thoughts and experiences in rich stories.

The tasks given to the students were as follows:

1. Select an optional 'one day'- it is better not to select a special day, but rather a common day;
2. Gather information related to 'one day' from social networks, blogs and archives such as newspapers, magazines and video sites;
3. Look over the collected information and imagine a story for 'one day';
4. Set a narrator and reproduce it narratively.

6.2.2 Outcome and evaluation

The outcome formats were diverse, such as a movie that showed a fictional type story that incorporated real events, novels, radio programmes that reproduced family conversations and poster collages representing various episodes that was accompanied by an impromptu talk. Therefore, the usual everyday events were given an attractive story character and the work of students, who were neither writers nor poets nor actors, was able to arouse audience sympathy.

This task demonstrated the potential of storytelling by ordinary people and their desire for expression through the selection and utilisation of media. Using easy-to-use digital tools such as smartphones for photography and video, graphics and editing software allowed for an expansion of the possibilities for expression by non-experts; therefore, this exercise proved effective in demonstrating that an 'editing ability in everyone' could be cultivated. As a design research method, it suggested that user-participant field research in constructive design research could provide storytelling insights into the target users and the possibility of its application to scenario making and storyboards.

6.3 Exercise 3: Dissimilating the daily lives

6.3.1 Outline

While ‘editing the fragments’ required the students to connect pieces of information to create context, in this exercise, the context was broken and the students were required to reconnect the pieces to reveal a new context. Editing is an act of repeating connections and disconnections and the continual discovery of new contexts. Therefore, the editing acts of cutting and linearisation can update and shift contexts, reshape reality perceptions and present new values. ‘Dissimilating the daily lives’ was an attempt to create a moment when the everyday suddenly became unusual, and habits or a matter of course that people were believing were removed and the undoubted context broken and then re-constructed. By shifting the everyday life values and meanings, the usefulness of editorial thinking as a trigger for ‘innovation by making sense of things’ (Verganti, 2009) was examined.

The students were instructed to do the following tasks:

1. Enumerate what you are looking at without paying attention;
2. Enumerate actions that you have not previously thought of;
3. Observe and disassemble the listed daily events into a work of different scope and with different resolutions;
4. Reconstruct the decomposed events in another context.

6.3.2 Outcome and evaluation

Many works were produced that appealed to the senses rather than being explanatory. One specific example was a work called ‘moyashi’ as shown in Figure 3. Moyashi refers to an ordinary and inexpensive soybean sprout food product that is packaged in a plastic bag and sold at most supermarkets in Japan. This student’s work involved a simple slide show in which the bean sprouts had been taken from the package and carefully photographed one by one to produce an effect similar to time-lapse animation that made it look as if the bean sprouts were dancing on the screen. The inexpensive bean sprouts that are usually recognised in a one bag unit were separated into individual units and the different shapes and sizes emphasised and projected on a large screen, which provided a new perspective in which the everyday life was made humorous and a little strange.

Figure 3 Student work ‘moyashi’ (soybean sprout) for ‘dissimilating the daily lives’

This exercise was useful in removing preconceptions and changing the way things are viewed, and proved to be particularly effective for the 'field' genre of constructive design research and the 'showroom' genre as it involved finding and expressing an alternative critical design perspective. It would also be suitable as a design research thinking process when trying to gain new insights from everyday things and actions or when looking for clues to create 'meaningful innovation' (Verganti, 2009).

7 Conclusion

The purpose of this research was to focus on an editorial thinking model process as a possible design research method and to clarify its applicability and effectiveness. First, the editorial process was defined, then the framework was clarified and the editorial thinking model derived from the identified editorial workflow. Three exercises were then conducted to explore the feasibility and effectiveness of this model; an 'unexpected catalogue' to confirm the validity of the editorial thinking model flow and the possibility of discovering a new viewpoint, 'editing the fragments' to confirm the usefulness of collecting fragmented information and contextualising them as a storytelling technique and 'dissimilating the daily lives' to explore the possibility of creating innovative meanings by updating existing context and creating a new context. The suggestions obtained from these exercises were as follows.

- The inductive approach that involves extracting specific materials (things and examples) and developing ideas based on these concrete materials, which is a feature of editorial thinking, gave rise to richer thinking and new points of view.
- Editorial thinking was found to support storytelling by ordinary people and design experts and could be used for a variety of existing user-participated design methods.
- Editorial thinking was found to encourage the updating and restructuring of existing contexts and was a useful thinking process for exploring new value in things and creating innovative meanings.

Therefore, it could be concluded that this professional editor thinking model could be applied to design research as editorial thinking. Future research will combine this model with existing design methods and explore the possibility of new methods based on editorial thinking.

8 References

Kumar, V. (2012). *101 Design Methods: A Structured Approach for Driving Innovation in Your Organization.* New Jersey: John Willey & Sons.

Hanington, B. and Martin, B. (2012). *Universal Methods of Design: 100 Ways to Research Complex Problems, Develop Innovative Ideas, and Design Effective Solutions.* Massachusetts: Rockport Publishers.

Van Boeijen, A., Daalhuizen,J., Zijlstra, J., Van Der Schoor, R. (2013). *Delft Design Guide: Design Methods.* Delft University of Technology Faculty of Industrial Design Engineering, Delft: Bis Publishers, TU Delft.

Stickdorn, M., Schneider, J. (2011). *This is service design thinking.* New Jersey: John Willey & Sons.

Sugatsuke, M. (2012), *初めての編集.* Tokyo:Artes publishing.

Shimuta, N., Hayakawa, K. (2014). *編集学－つなげる思考・発見の技法.* Tokyo: 幻冬社.

Nakamata, A. (2011). *起動せよと雑誌はいう.* Osaka: 京阪神エルマガジン社.

Lee, K. (2017). Design 3.0 What we should teach, research, and practice in the future. *K2 Dialogues 01 Envisioning Urban Futures.* pp.102-123. Fukuoka: Faculty of Design, Kyushu University. https://www.kidnext.design.kyushu-u.ac.jp/contents_file/contents_files/loader/0/Publication/21/publication/a0db5df3620411a063bd0a7b21d3eca3c603d9ec/default/K2dialogues01.pdf accessed April, 2019.

Papanek, V. (1984). *Design for the real world - Human ecology and social change.* New York: Van Nostrand Reinhold.
Forlizzi, J., Koskinen, I., Hekkert, P., Zimmerman, J. (2017). Let's Get Divorced: Pragmatic and Critical Constructive Design Research. *IASDR Conference 2017 Proceedings (389-402)*. Cincinnati: University of Cincinnati. doi: 10.7945/C22Q3C https://scholar.uc.edu/concern/articles/v692t620b?locale=en accessed April, 2019
Dunne, A., & Raby, F. (2013). *Speculative everything: design, fiction, and social dreaming.* Massachusetts: MIT Press.
Ikeda,M.(2019). 編集とデザイン－パラレルワールドが出会うとき. In T.Koga (Eds.), *デザインに哲学は必要か* (pp.207-239). Tokyo: 武蔵野美術大学出版局
Toyama, S. (1975). *エディターシップ.* Tokyo: みすず書房
Verganti,R. (2009). *Design-driven innovation: changing the rules of competition by radially innovating what things mean.* Massachusetts: Harvard business school publishing corporation.
Stachelhaus, H. (1991). *Joseph Beuys*, Düsseldorf: Classen Verlag

About the Author:

Ikeda, Minako: She teaches design history and information and editorial design as Associate Professor at Kyushu University. She is conducting several design research projects for revitalizing local traditional crafts in contemporary society.

Acknowledgement: The author would lie to thank Enago (www.enago.jp) for the English language review.

Exploring the problem space with Problem Exploration Strategies

Creeger, Samantha[a]; McKilligan, Seda*[a], Seifert, Colleen[b]

[a] Iowa State University, Ames, USA
[b] University of Michigan, Ann Arbor, USA
* seda@iastate.edu

The problem generation space is a critical stage in the design process impacting the quality of the outcomes. However, there's limited research on how to explore the problem space. This research reports on designing a tool for problem exploration strategies identified in a prior study and its impact on student designers' problem formulations. This research uncovers how these strategies were used and how certain strategies led to diversity in the newly formulated problem statements.

Keywords: problem exploration; cognitive strategies; design education

1 Introduction

Spurring innovation and creativity is the ultimate objective of the design process. At first glance, many design problems can be simple to solve in their presented form; however, the first ideas are typically obvious solutions and do not lead the designers to explore innovative solutions. Instead, the problem must be reframed to provide new solution opportunities. What does spur innovation is the ability to looking beyond the original problem in order to uncover the true problem, a process known as problem exploration. This includes restructuring problems as it defines the set of possible solutions; as a result, it is crucial in order to search for innovative solutions of this constrained set. Empirical studies have shown that creative solutions derive from a 'co-evolution' of understanding the underlying problem during the development of the solution (Dorst & Cross, 2001).

Through design education, students are taught the fundamentals of the design process from beginning with a design brief to eventually resulting in a technical and thoughtful solution. In order to continually generate creative solutions, it is imperative for students to be taught ways to engage in creative thinking through design processes. Within the problem generation space, there are multiple alternative views to reframe a problem statement. Previous research has shown there are strategies that have been used as ways to frame a problem, which have found to be helpful. However, there is minimal research on how the students make decisions based on the strategies and which ones are most effective.

This paper focuses on such strategies evidenced by prior research, developing a digital tool to facilitate using the strategies and the impact of this tool on students' exploration of the problem space. The goal of the study is to identify strategies that are most influential to problem generation.

2 Literature Review

Design solution space has been explored in detail by design cognition researchers, however there is little emphasis on the design problem space and how exploring the problem space influence solution space creativity. It is important for designers to generate a thoughtful problem statement as it is the foundation for the rest of the design process. Problem exploration is beneficial in the beginning of the design process of a project so that all of the building blocks of design criteria are grounded around a deep understanding of the problem (Snider, Culley, & Dekoninck, 2013). However, in an academic setting, students are already provided with a 'perfect-case' scenario for a design problem where the student mostly needs to focus on the solution. This means that the problem space gets little attention and neglects creative learning and perception of the complete picture (Cropley, 2003).

Not only is it considered a building block, it is suggested to be a contributor of innovative solutions. According to (Einstein & Infeld, 1938), "…the formulation of the problem is often more essential than its solution… To raise new questions, new possibilities, to regard old problems from a new angle requires creative imagination and marks real advances in science" (p. 92). One component of innovation is to look beyond the presented problem in order to fully explore the "real" problem at hand, a process called 'problem exploration'. When a problem is restructured, this process of exploration can lead to new discoveries and ultimately aid in novel solutions to the problem. In order to encourage this process of exploration, there needs to be a way to help design students receive different perspectives on design problems. This requires a deep understanding of the cognitive processes students use to redefine their statements (Getzels & Csikszentmihalyi, 1976).

Problem exploration involves asking questions of design problems to determine the principal components and the underlying issues to drive the search for creative solutions (Duncker, 1945). Problem exploration is necessary for design contexts as these problems are considered ill-structured; therefore, they must be articulated and reframed throughout the process. Well-structured problems, on the other hand, have articulated problem descriptions that lead to straightforward solutions. These routine problems generate ordinary solutions that may be effective but not creative (Cropley, 2015). With ill-structured problems, where the solution path and resulting solution is unknown, problems must be explored to form novel solutions, resulting in creative and innovative solutions (Reitman, Grove, & Shoup, 1964).

Understanding problem exploration and how it affects learning and creativity can positively impact design education and design practices in the industry. Vasconcelos, et.al. (2016) states that "…although the design literature often promotes the importance of problem exploration activities, the benefits these activities bring have not previously been investigated in depth". Research has shown the importance of problem exploration in design, however little is known about how problems are discovered and formulated (Getzels, 1979).

2.1 Problem Exploration in Design Education

Most of the work that has been conducted around problem exploration processes and heuristics within design education is developed from Studer, et.al. (2017), Wright, et.al. (2015), and Yilmaz, et.al. (2010). Through a large collection of verbal transcripts and written statements, researchers were able to analyse the data and find common characteristics among the responses to develop heuristics. This research is important for design education as it will provide a unique lens to further understand the role of innovation in the design process. Everyone has potential to innovate; it is just a matter of providing the necessary resources in order to confidently design and solve problems. This work is also significant not just in the design field because these strategies could be implemented across a variety of disciplines at a systematic level of thinking.

2.2 Current Problem Exploration Techniques

Some design texts and popular books offer techniques to help guide designers in framing and redefining design problems, however they do not provide empirical evidence. All of the existing problem exploration techniques, shown in Table 1, propose trigger questions that may assist the student in critically assessing the presented problem and further defining it. One approach offered by MacCrimmon and Taylor (1976) identified complexity as being a limitation in problem formulation and provided four decision strategies: 1) determining problem boundaries, or examining the assumptions; 2) examining changes, or focusing on any alterations changes in the problem description; 3) factoring into sub-problems, such as using methods including morphological analysis (Hall, 1962) and attribute listing (Rickards, 1975); and 4) focusing on the controllable components, or selective focusing (Shull, Delbecq, & Cummings, 1970). Fogler and LeBlanc (2008) proposed strategies for defining "the real problem" underlying a given engineering problem. The "5 Whys" (Bulsuk, 2011) technique, used by the Toyota Motor Corporation, repeatedly asks "Why?" question in order to explore the cause and effect relationships underlying a problem. Abstraction laddering (Autodesk, 2017), is also used to better understand the problem space based on the data gathered from stakeholders. It focuses on asking a series of 'how' and 'why' questions to describe the design problem at increasing or decreasing levels of abstraction. Parnes' (1967) restatement method varies how the problem is stated using prompts, such as 'vary the stress pattern by placing emphasis on different words and phrases in the problem', and finally, the Kepner-Tregoe (Kepner & Tregoe, 1981) pushes the designers to distinguish what the problem 'is' and 'is not'.

Table 1 Problem Exploration Techniques

Technique	*Description*	*Sources*
Present state/desired state analysis and Duncker diagram	Means to determine the real problem by first describing the present state (where you are) and then describing the desired state (where you want to go)	(Duncker, 1945; Higgins et al., 1989)
Critical Thinking Algorithm	Process to recognize underlying assumption, scrutinize arguments, and assess ideas and statements using Socratic Questions to prompt the designer	(Fogler & LeBlanc, 2008; Paul & Elder, 2006)
Parnes' statement-restatement method	Method to evolve the problem statement to its most accurate representation of the problem using different triggers such as "place emphasis on different words and phrases"	(Parnes, 1967)
Kepner-Tregoe problem	Technique that determines the "four dimensions of the problem" including identify,	(Kepner & Tregoe,

analysis technique	locate, timing, and magnitude by determining the distinction between “is” and “is not”	1981)
5 Whys	Technique that involves asking questions (“Why?”) until you get to the root cause of the problem	(Bulsuk, 2011)
Attribute listing	Method that involves listing attributes of the problem space, considering the value of each attribute (“what does this give?”), and modifying attributes to increase value, decrease negative value or create new value	(Rickards, 1975)
Selective focusing	Technique that focuses on the problem components that can be manipulated	(Shull et al., 1970)
Spradlin’s Problem-Definition Process	Process that includes establishing the need for a solution, justifying the need, contextualizing the problem, and writing the problem statement	(Spradlin, 2012)

All these techniques propose trigger questions that may assist designers in further defining the presented problem; however, they are lacking the empirical evidence of their use in creating innovative solutions. In order to understand the impact of heuristics within the problem exploration space, two studies using empirical data were conducted.

3 Synthesizing Problem Exploration Strategies

The strategies used in this study were a compilation from two studies that initially began in 2015. The first phase investigated existing problem statements that derived from design competitions that provided open source briefs, such as open IDEO. This was a content analysis of what people relied on and how they reframed the original problem statements with many variables and constraints (Studer et al., 2017). The second phase was a protocol study that collected data from 35 engineering practitioners and students, as well as 15 industrial design practitioners and students (Studer et al., 2018). Through various stages of thematic analysis twenty-eight strategies were methodically narrowed down. Strategies from both studies were organized by themes. Once the strategies were categorized, a new proposed list was created. An important feature of this compilation of strategies across studies is that each strategy was observed multiple times. Even though the design problem and setting changed with each study, a great number of previously identified strategies were observed in each study. This suggests the identification of strategies had reached a point of saturation across the entire set of concepts in this compiled dataset. This thematic analysis led to twenty-eight strategies across the two studies.

For the study reported in this paper, we chose 12 strategies to test with a tool, to observe their impact. Several identified heuristics were combined to provide simplicity and accessibility. The twelve strategies used are described in Table 2.

Table 2 Strategy Number, Name, and Questions prompting problem exploration

	Title	**Questions prompting problem exploration**
1	Describe the Characteristics of the User and their Needs	What are the needs, tasks, and environments of the people to design a playground? What are the characteristics and attributes of the people using the playground?
2	Substitute the Primary Stakeholder with Another Stakeholder	Who are the others who might replace the primary users of the playground? Who else will be affected by the design? In what capacity? Consider both the individuals and the groups.
3	Describe Cultural Implications	How can the solution move beyond its functionality to serve other purposes and support the entire context of use? What requirements does the marketplace impose on the playground design?
4	Rely on Existing Solutions	What are similar existing solutions that target solving the playground? How can these solutions be used in exploring different problem directions? How can you modify an existing solution to shape the problem definition? What are comparable solutions or problems, and how can they help you build analogies on them?
5	Describe Visual Attributes	How does the problem determine aesthetic qualities of the playground? What are the material choices that will be visible to the people using the playground? What is the desired size in relation to other solutions around and the environment it will function in?
6	Describe the Context	What are potential scenarios where this playground could occur in? What are unique or unexpected ways the playground could be interacted with beyond its primary function or scenario? What is the context which the problem takes place?
7	Describe the Users' Interaction	How does the user(s) interact with the playground? How can their interaction be integrated into the solution?
8	Describe the Functionality	What are the main functions the design of the playground has to focus on? How do you characterize these functions?
9	Examine Assumptions	What are the items or actions that are already known to be true for the design of the playground? How can you challenge them? How can you narrow the scope of the playground?
10	Determine the Underlying Issue	Does the design of the playground solve the right problem at the right level?
11	Describe Mobility Characteristics	How do the mobility features or concerns affect the playground?
12	Describe Maintenance Needs	How will the playground be tested during design and fabrication? To what extent of testing is needed? What kinds of tests are needed?

An online tool was designed and developed for each student to complete the study on their own laptops. A customized website was created using Visual Studio Code for programming and GitHub pages to host the website. Multiple mock-ups and prototypes were created before the tool was released for the study. The website also went through several iterations to ensure seamless accessibility and usability for the students. The figures below demonstrate part of the tool in chronological order. The introductory page provided a brief of the study and the importance of the problem generation space. This information also helped the student understand what tasks they were expected to accomplish. The second slide displayed the provided problem statement shown in Figure 1. All students received the exact same scenario to ensure cohesive coding.

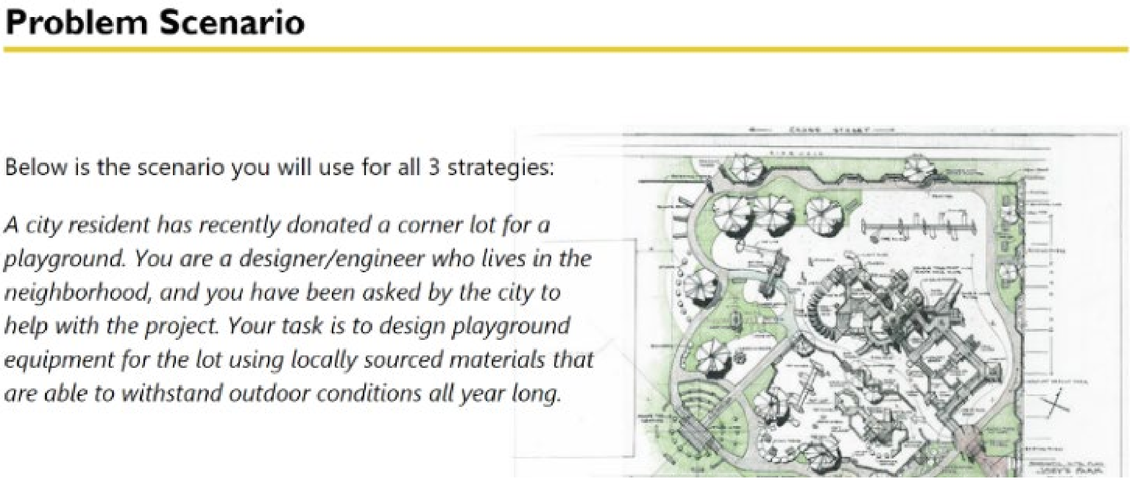


Figure 1 Original Problem Scenario

The student was then directed onto the Strategy Generator page in Figure 2. The page instructed the student to press on the compass to receive a random strategy, however the three strategies were already pre-determined based on the URL they entered.

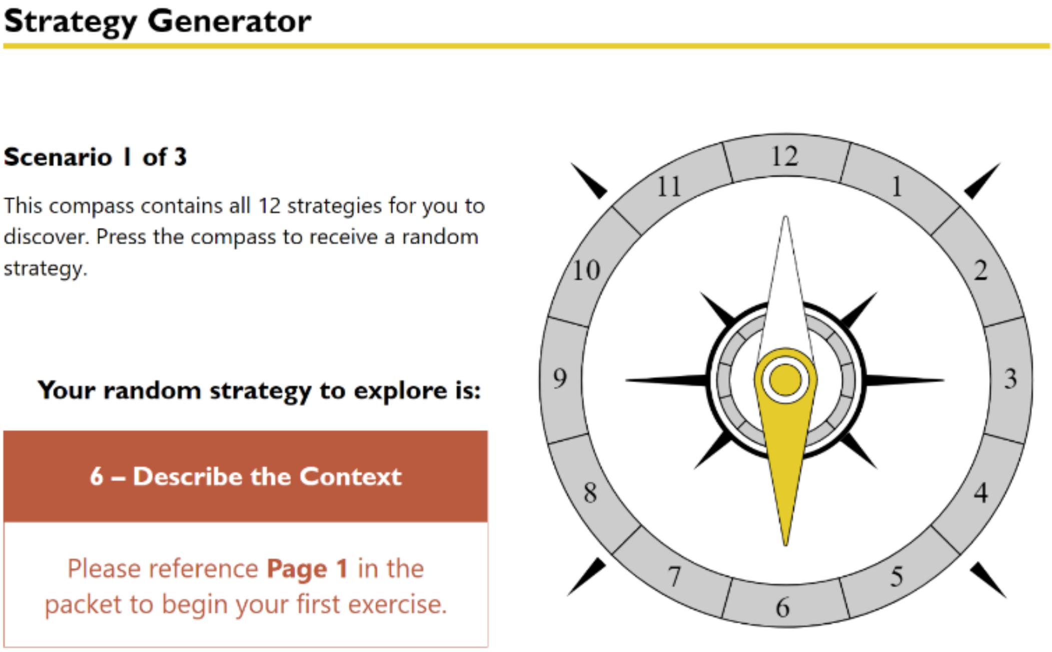


Figure 2 'Random' Strategy Generator

The next step of the study was learning about that provided strategy in Figure 3. There were three steps to this page: questions prompting problem exploration, thought starters, and examples unrelated to the given project. The prompted questions stemmed from previous research (Studer et al., 2018; Studer et al., 2017). Thought starters were broad descriptors to aid the student to think of how this strategy could be implemented. Finally, the three examples were created to help them see how it could be used. The examples, shown in Figure 4, were unrelated to the provided statement to further understand how each strategy could be applied to a potential problem.

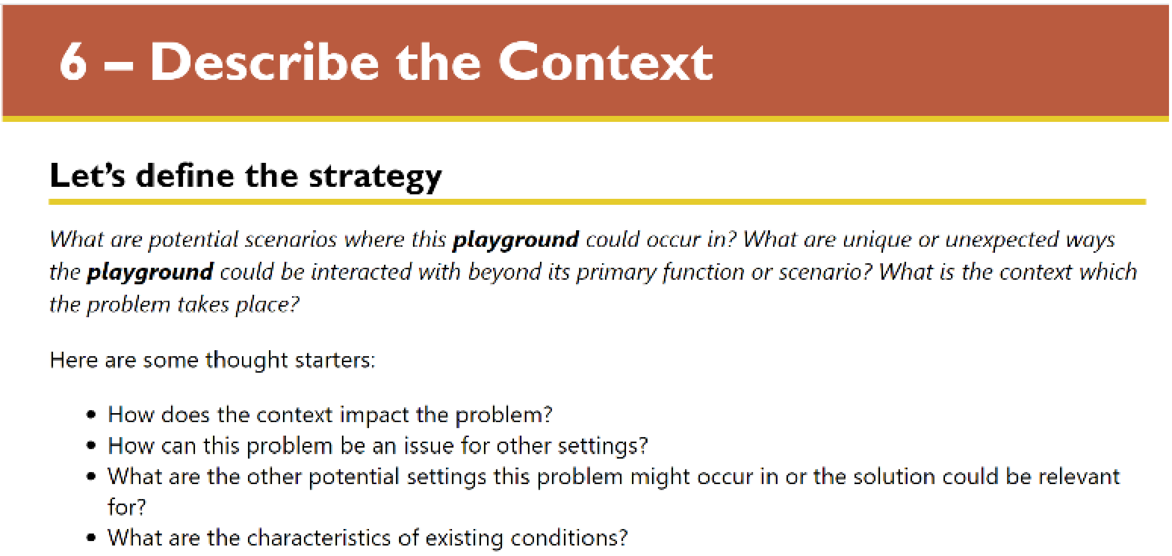


Figure 3 Definition Page

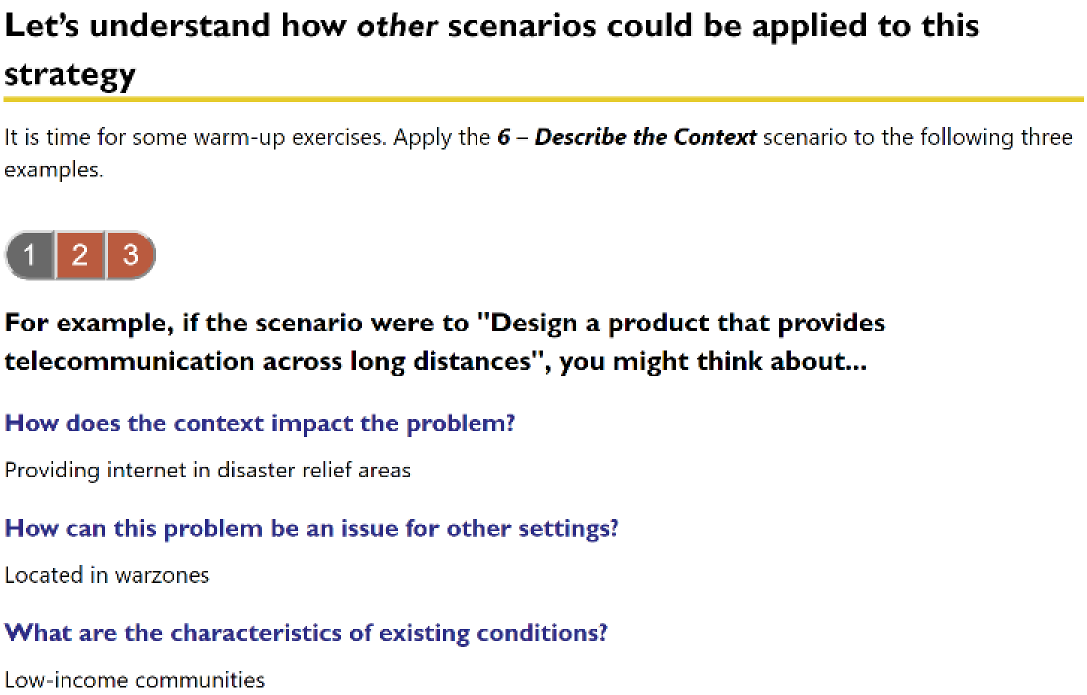


Figure 4 Examples to Familiarize Strategy

When the student felt comfortable to continue, they were then asked to generate as many problem statements using that strategy. A 'plus' button was clicked to allow for more submissions in Figure 5. When the student felt content with the submissions, the tool repeated to the Strategy Generator in Figure 2 to repeat the same steps for two more strategies.

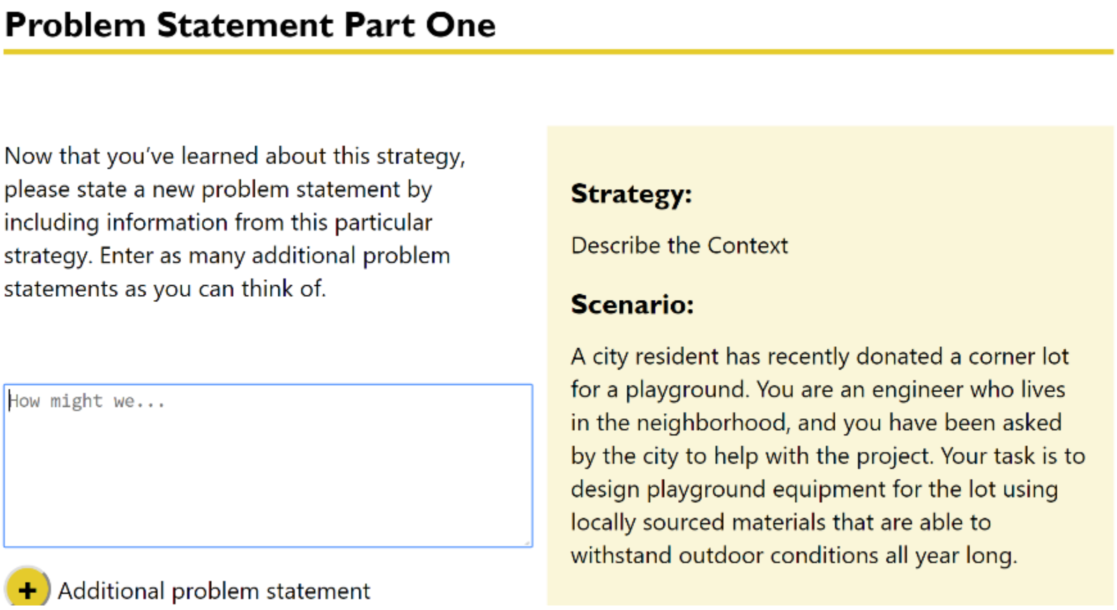


Figure 5 Forum to Enter Statements

4 Experimental Method

In this study, we extend our previous work to design and engineering students working on a new design problem, using the digital tool as an intervention to expand their problem spaces. Our goals were to gain evidence that the problem exploration strategies indeed assist in this expansion, and if so, how they were used and the outcomes they led the students to. The research reported here examined the problem exploration strategies in classroom settings. The students were given the online tool that introduced them a subset of strategies and were asked to work on an open-ended design problem, using the strategies introduced with the tool. We collected their reformulated problem statements after they applied each strategy.

The research questions led this study are:

Q1: Did the students utilize the strategies provided?
Q2: How did the students perceive the benefit of using the strategies?
Q3: How did the students use each?
Q4: How much diversity is created among the new problems after strategy use?

4.1 Participants

In total, 43 students studying industrial design or human computer interaction with engineering background participated in the study. Of the 43 that participated, 40 of the participants' data were collected due to incomplete or missing data. Students in Human Computer Interaction with engineering backgrounds were pursuing a graduate degree (3 female, 6 male). 17 student Industrial Design were seniors (8 female, 9 male) and 14 were juniors (8 female, 6 male). The overall average age was 22.92, SD=3.13.

4.2 Data Collection and Analysis

This study was conducted in a classroom setting under the supervision of the instructors. Students of the same major were gathered together to ensure consistent directions and explanation. Each participant was asked to rewrite the given problem statement using three strategies on their laptops. The newly formulated problems were either iterations of the previous problems, or entirely new ones. Participants were asked to work individually on their own devices. The participants only focused on understanding the true problems, not on solving the actual problem.

Before the study, each student was provided a packet, which included a unique URL and paper to write thoughts and notes for each strategy. The URL took the student to the main page of the tool. Four different URLs were provided in the packet as the students were randomly assigned to one of four groups: Group A, Group B, Group C, and Group D. Each group received three strategies that were different from the other groups. Since twelve heuristics were generated, all strategies would ensure for equal use. Students were initially provided a brief and problem statement to understand the context of the study “A city resident has recently donated a corner lot for a playground. You are a designer that lives in the neighbourhood and you have been asked by the city to help with the project. Your task is to design playground equipment for your neighbourhood.” This problem was chosen since no participant should be limited by lack of knowledge when designing playgrounds and was considered an optimal brief to code mentioned in Studer, et. al (2018). For each strategy, the student had an opportunity to learn all necessary information about that strategy. Once they felt comfortable understanding the material, they were asked to generate as many statements as possible relating back to the provided strategy. From there, the process was repeated using two more strategies. Students’ newly formulated problem statements, after applying each of three strategies, in addition to a short survey asking for their perception of the value of these strategies on their problem space exploration, were collected.

Students were asked to print or digitally send their responses, which were then transcribed into a file. Each problem statement used a coding method where the statement was broken down into sub-components to identify which part of the statement was influenced by the strategy. Since participants in each group received the same design problem and strategies, the statements generated were compared against other participant’s responses to see how effective that strategy was in helping them generate diverse statements. Group A received strategies 1, 6, and 10. Group B received strategies 2, 5, and 9. Group C received 3, 8, and 12. Group D received strategies 4, 7, and 11. The answers to final retrospective survey were used to complement the analysis.

5 Results

This portion of the chapter answers each research question in detail. The type of analysis differs among each question and is supplemented with various tables and figures. Table 5.1 is provided as a reference guide when mentioning the strategy numbers. Forty participants generated unique problem statements, resulting in an analysis of 275 innovated design problems.

Q1: Did the students utilize the strategies?

We coded each statement individually, rating if the student did or did not utilize the strategy given to them. Two coders with experience in research and generating problem statements were used to verify the data. Each student was given the same codebook and data within an Excel file. The codebook included the definition of each strategy, the same that all students were given for the study. All statements from each student were coded using a ‘1’ or ‘0’; ‘1’ being the student sufficiently used the strategy and ‘0’ being the student did not accurately use the strategy. For example, students were given a ‘0’ if they were too vague and used the name of the strategy verbatim. As an example, Participant 38 said “How might we build a playground that promotes interaction" when using Strategy 7, Describe the Users' Interaction. This participant did not actually describe what the interaction was, simply saying that there should be interaction. The coders were given the same instructions and asked to complete the task individually. It was noticed that strategies with clear and concise definitions, such as Describe Maintenance Needs, were obvious to spot if the student did or did not use the strategy. The disagreements between the coders were discussed until arrived at a consensus.

Table 3 showcases the percentage of participants successfully using the strategy. The strategies with the highest percentage were Describe Mobility Characteristics (93.75%), Describe the Functionality (93.55%), and Rely on Existing Solutions (90%). The strategies with the least successful implementation were Determine the Underlying Issue (65%), Describe Visual Attributes (68.75%), and Substitute the Primary Stakeholder with Another Stakeholder (73.08%).

Table 3 Percentage of statements using each strategy

	Total	**YES**	**NO**	**% Used**
Strategy 11	16	15	1	93.75
Strategy 8	31	29	2	93.55
Strategy 4	20	18	2	90
Strategy 3	32	28	4	87.5
Strategy 6	24	20	4	83.33
Strategy 12	22	18	4	81.82
Strategy 1	26	20	6	76.92
Strategy 9	17	13	4	76.47
Strategy 7	25	19	6	76
Strategy 2	26	19	7	73.08
Strategy 5	16	11	5	68.75
Strategy 10	20	13	7	65
	275	223	52	

Q2: How did the students perceive the benefit of using the strategies?

After participants completed the study, they received a final page titled 'Feedback and Results'. This page displayed all the statements generated for each strategy, as well as survey questions to gather feedback on how participants perceived the benefit for this tool. Since a retrospective interview could not be conducted for each individual student in a classroom setting, a survey with multiple questions was used to understand the student's opinions and thoughts regarding the study and strategies they were given: "How helpful did you find strategy X" "Overall, how easy was it to use the strategies?" "How creative do you think your new statements are compared to your original statement?" "Which strategy was the most applicable and why?" "Did you find any benefit from learning new strategies?

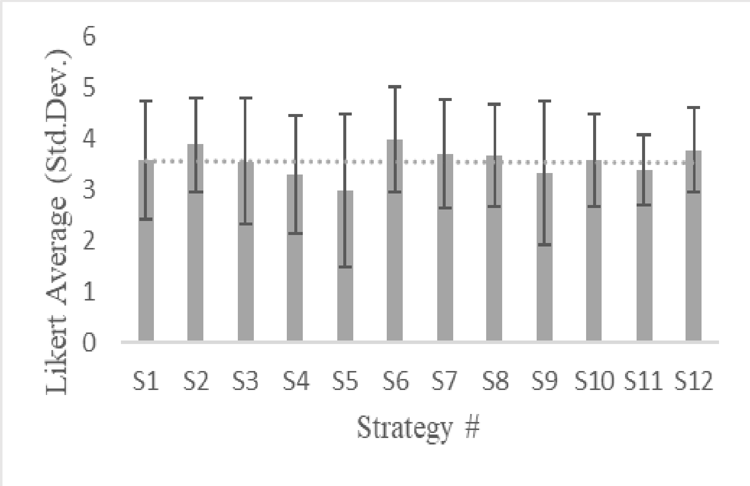


Figure 6 Survey responses for 'How helpful did you find strategy X?'

The data shown in Figure 6 responds to the question "How helpful did you find strategy X." Overall, the students in HCI rated 6 as the most helpful with the least as 5. Strategies 2, 12, and 8 were the highest ranked amongst the juniors, with 9 as the least helpful. The seniors equally ranked 10, 9, 5, and 7 as the highest and 8 and the least. The data among each group was mildly consistent. One data point of interest was Group B, Strategy 5 for HCI students. This data was the most extreme outlier, as it was significantly lower than the design students. On reason could be that the design students have a greater sense of visual attributes and have been trained on aesthetic appearance compared to the HCI students with engineering backgrounds, hence they might not have seen the value of such a strategy helping them.

For the other question "Overall, how easy was it to use the strategies?", the overall average was 3.57, SD=0.90. Figure 7 shows the distribution plot of the responses. When looking at the difference among cohorts, the juniors rated the lowest values, although not significant.

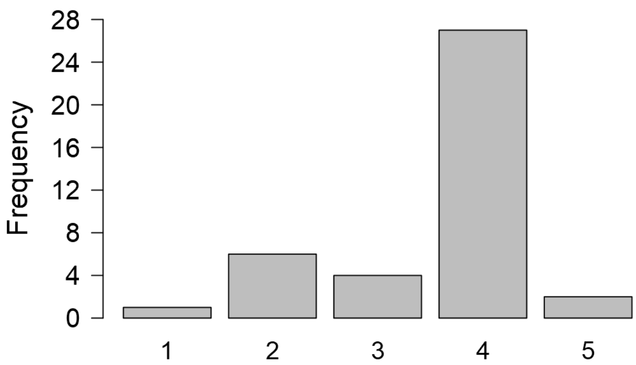


Figure 7 Overall, how easy was it to use the strategies?

The data was also compared against each group and major. Group D voiced that their strategies (4, 7, 11) were the easiest (3.70, SD=.67), whereas Group C (3, 8, 12) had the most difficulty (3.56, SD=.73). The Juniors had the most difficulty (3.00, SD=1.11) out of all the majors, which could reason that they had the least amount of experience reframing statements. Surprisingly, all HCI rated the ease of use at 4, SD=0. Their knowledge and years of school experience could be a reason they thought it was easy. When asked “How creative do you think your new statements are compared to your original statement?”, the overall average was 3.375, SD=0.98 shown in Figure 8.

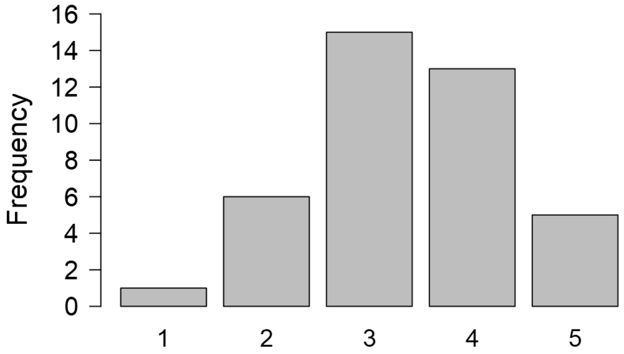


Figure 8 Creativity average

Group A (1, 6, 10) perceived their reframed statements to be the most creative (3.83, SD=.83), whereas Group D (4, 7, 11) perceived their results to be the least creative (3.00, SD=.94). One interesting note is that although Group D considered their strategies the easiest to implement in the previous question, they thought that it did not produce creative results. The juniors also ranked their perceived creativity the lowest at 3.07, SD=1.00). The seniors had the highest average score of 3.65, SD=.93.

When analysing the question, "Which strategy was the most applicable?", since all groups received different strategies, the results were analysed and ordered by each group. Starting with Group A, fifty percent of the students mentioned that 6, Describe the Context, was the most applicable. Participant 39 said: “It made me think of not only playground in my own neighbourhood but at other areas with different users and needs. That could have been because I had begun to be more creative at the different ways to look at designing a playground so it could have just been because it’s the last strategy I used.” Several participants mentioned that order was important when using the strategies. Participant 24 said: “getting to strategy 1 after already using both other strategies allowed me the most time to think about the problem”. Participant 33 also said Strategy 6 was the most applicable because, “It is easier to relate to the context than finding the underlying issue. The thought of ‘finding an issue’ makes it harder to be creative and the thoughts get more complex than it has to be.”

For Group B, all three strategies were equally applicable. One design student said Strategy 5 was more applicable because it was more tangible and possibly more in the realm of what they were used to solving for. Participant 15 said: “I think the scenario 5 - Describe Visual Attributes was the most applicable simply because it was the easiest to translate directly into design criteria, whereas the other methods were a little more abstract.” However, Participant 31 preferred Strategy 2 because, “…it focuses on all the people involved/around a playground, who could use it, and others affected. It allows one to make sure it is as inclusive as possible.” Finally, Participant 5 preferred Strategy 9, Examine Assumptions, because, “I felt like this really helped me to look at any biases I might have and push myself to think more creatively.”

For Group C, Strategy 8, Describe the Functionality, received the highest percentage of applicability: 44.4%. The students who preferred this strategy described as being the building blocks or quintessential piece of the problem statement. Participant 8 said that it "…is the most important thing on designing a product, being able to identify the functions helps a lot in solving problems." Participant 23 also stated that, "I thought the functionality strategy was most applicable. It was key to understand how the playground equipment was going to function before anything else. If you don't know the purpose of the playground then it is more difficult to consider other factors."

For Group D, half of participants said that Strategy 7, Define the Users' Interaction, was the most applicable. Participant 3 had a unique insight saying that Strategy 7, "was the most applicable to design the best solution for a new playground, however, the mobility one helped me get the furthest away from my initial ideas and be the most creative." Others who preferred the mobility strategy said it was the least restrictive which allowed them to think of many ideas.

There were several themes that emerged from the final question, "Overall, how easy was it to use the strategies?" (1) Critical thinking, (2) expanding perspectives and (3) helpful probes were 3 themes uncovered from all responses. *Critical thinking* allowed the students to dig deeper about the problem at hand. Participant 15 from the HCI said, "… it got me thinking more critically about what I had written." Participant 23 said: "It made me critically think about the key factors when it came to the design of the playground equipment." *Expanding perspectives* discussed the ability to think in new ways they may never have explored before. Some students enjoyed the addition of the Thought Provokers section. "The Thought provokers are best for finding a divergent path to explore and generate concepts (P43)." Another student mentioned that, "I could see that my problem statements became richer and more creative after thinking about the strategies (P17)." *Helpful probes* allowed the student to think in new ways they may have never explored before. Participant 42 considered this tool to be beneficial as, "… this approach gave me new avenues in which to frame my problem statements. Avenues in which I would not have thought to consider when reframing the problem." Participant 19 also said: "Sometimes it's difficult to keep all the different strategies in mind. It's nice being probed with the various strategies to help design thinking."

Although many students praised the usefulness of the tool, there was critique for the strategies. One critique was that, "The culture strategy was a little less helpful and I felt like I was really reaching for solutions (P23)." Another participant also critiqued the medium of the tool itself: "I think just having a list of them would have been nice (P27)." As for the applicability of the tool, Participant 31 stated that, "I think using these strategies will have you focus on a specific problem but make you forget about the other design objectives/requirements needed for the playground."

Q3: How did the students use the strategies?

In Table 4, we provided two distinct examples of the application of each strategy. The goal was to understand how the students implemented each strategy within a problem statement.

Table 4 Examples of each Strategy

	Example 1	Example 2
Strategy 1	How might we design a community playground using locally sourced materials that expands kids' imaginations and creativity all year round. (P39)	Design a playground that allows children with disabilities to be able to play? (P12)
Strategy 2	How might we design a playground for pets and their pet owners that is durable and uses locally sourced materials? (P31)	How might we design a playground so that adults can enjoy the playground while their children play? (P19)
Strategy 3	Design a long-lasting playground equipment that brings together people of different cultures? (P34)	Design a playground experience that brings together people of different generations together? (P34)
Strategy 4	Design a game that improves the current color matching game on the playground (P35)	How might we design playground equipment that is inspired by the durability of nature? (P29)
Strategy 5	How might we design a durable, weather resistant playground made of locally sourced materials such as wood, stone, and recycled goods? (P37)	How might we create a playground that is visual representation of the community? (P5)
Strategy 6	How might we make the playground equipment durable in harsh winters? (P26)	How might we design the park to encourage many positive uses and discourage negative uses (e.g. every town has that one park where drug deals often occur). (P20)
Strategy 7	How might we develop playground equipment that is fun and engaging? (P6)	How might we design playground equipment that promotes literacy and learning how to read? (P29)
Strategy 8	How might we design a playground that does not become hot to the touch? (P42)	How might we allow kids to swing on equipment? (P23)
Strategy 9	How might we design a playground using locally sourced materials that are durable? (P31)	How might the park fit within and complement the city's existent parks (P27)
Strategy 10	How might we design a playground that helps kids socialize with one another? (P26)	How might we design cheaper playground equipment that is sustainable? (P43)
Strategy 11	How might we design accessible playground equipment that can be switched out and replaced with different pieces of equipment from season to season? (P29)	How might we create a more action and exercise-based playground with new equipment? (P3)
Strategy 12	Design an equipment that requires minimal maintenance? (P34)	How can we design a playground that will require less than $1,000 in maintenance a year and last 30 years? (P18)

Strategy 1 focused on defining who the user was for the playground and what their needs were. It was noticed that most students defined the user as children since it is the most obvious answer to provide. What did differ among the reframing was the extent of specificity for the user. In Example 1, the student simply stated the user were kids, whereas Example 2 defines the user as ‘children with disabilities’.

For Strategy 2, the students were asked to substitute the primary stakeholder with another stakeholder. Like Strategy 1, most student assumed that children were the primary stakeholder, so most of the statements revolved around the parents or caretakers, shown in Example 2. The only statement that did not define the playground for children or parents was Example 1, which created a playground for pets.

Strategy 3, Describe Cultural Implications, was more open-ended and allowed the student to define ‘culture’ in their own terms. In this sense, the reframed statements varied in specificity and definition. In Example 1, the statement was more on the broader spectrum by creating an inclusive playground for varying cultures. Example 2, however, states that the cultural implications were creating an inclusive playground for varying generations of people.

Strategy 4 asks the students to rely on existing solutions when reframing their statement. Many students described existing infrastructure as a method of inspiration, however students also specified unique examples. In Example 1, a student described a type of game to implement within the playground. Several students also used biomimicry to generate statements, shown in Example 2. Since this strategy heavily relied on a student’s personal experiences, the results greatly varied in specificity.

Strategy 5, Describe Visual Attributes, received statements with varying topics. Some students explained the physicality of the materials, whereas other students where very broad in their descriptions shown in Example 2. Instead of describing the tangible attributes, some described how it would look as a cohesive unit within its community and environment. For

Strategy 6, students were asked to describe the context in which the playground took place. The statements varied in range since the type of scenario and setting was up to the student’s interpretation. Example 1 discusses the weather in which it would take place, compared to Example 2 which discusses the safety and well-being of people using the playground. The students who reframed statements for

Strategy 7, Describe the User’s Interaction, where mostly similar in theme although they varied in specificity. While Example 1 discusses the playground to be engaging, Example 2 further demonstrates how the playground could be engaging through literacy.

Strategy 8 greatly varied in topics as the students were asked to describe the functionality. In this sense, students were able to determine if they wanted to describe the functionality in terms of the playground itself, the user, or other external factors.

For Strategy 9, students were asked to examine the assumptions. Since an original statement was provided to them, most students used the existing information from that statement as assumptions, shown in Example 1. The student mentioned using locally sourced materials which is mentioned in the initial statement provided.

Strategy 10, Determine the Underlying Issue, also varied in topics as the students were able to determine how they wanted to discuss the issue at hand. In Example 1, the student describes lack of socialization a main issue compared to Example 2 which describes the price of manufacturing as an issue.

Strategy 11 described the mobility characteristics which discusses how mobility affects the playground. Although many students reframed their statements around exercise, shown in Example 2, there were students who were able to push away from mobility just being for the user. In Example 1, the student describes features of the playground being mobile for changing seasons.

Finally, for Strategy 12, students described the maintenance needs of the playground. The reframed statements were limited in terms of range but varied in specificity. Many students simply stated that minimal maintenance is required, however some students discussed the types of testing or budgets required in Example 2.

Q4: How much diversity is created among the new problems after strategy use?

The final question seeks to understand the distance in which the statements can be pulled apart. For this stage in the analysis, all of the statements that accurately depicted the given strategy were analysed (Creswell & Creswell, 2013).

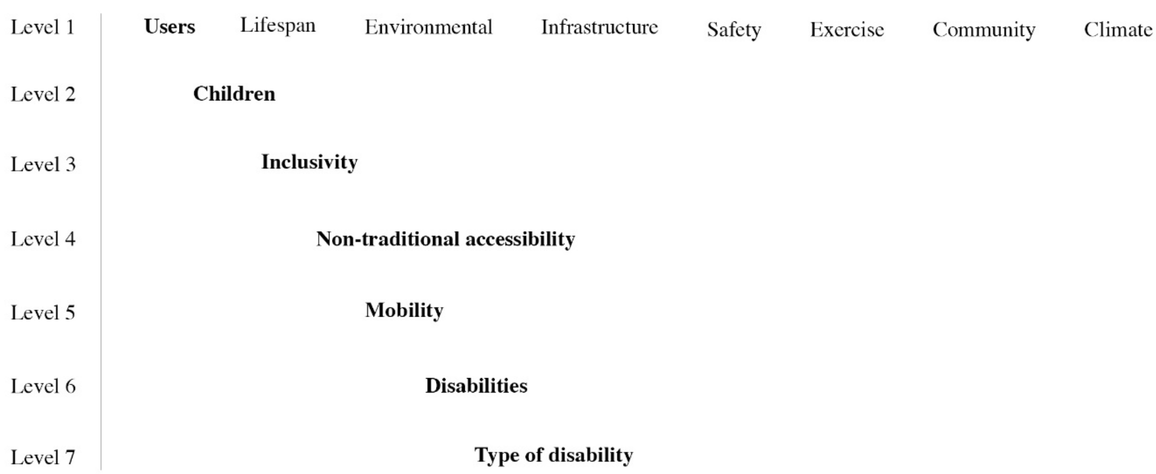


Figure 9 Titles of Themes and Levels of Diversity Tree

In the first stage, the statements were grouped together by themes, such as ‘Community Oriented’ or ‘Location and Safety’. Once all statements were grouped accordingly, it was noticed that common themes were emerging across multiple strategies. All statements regardless of strategy were combined to form more coherent thematic groups. Within each theme, the statements were then ranked based on how similar or different the re-written statements were compared to the provided problem statement. The statements closest to the original were placed on level one. As the more novel the statements were, the lower the level the statement was placed. After several rounds of iterations, the farthest level acquired was seven. Overall, there were eight themes ranging in size and complexity. Figure 9 shows the eight themes as well as an example of the levels used in bold. The themes on the right-hand side lacked depth and diversity compared to the themes on the left, which created more of a matrix with its complexity. When organizing the statements, the ones that were similar in topic and description were place next to each other in rows. When a statement was of similar theme, but provided more detail or explanation, that statement was then placed below on a new level. The number of strategies organized on each level were counted to analyse which strategies were most prominent on each level. Once the number of strategies were counted, the total amount of statements for each strategy were then converted into percentages. Table 5 highlights in grey which strategies had the greatest percentage of use on each level.

Table 5 Percentage of Statements used on each Level

	% S1	% S2	% S3	% S4	% S5	% S6	% S7	% S8	% S9	% S10	% S11	% S12
L1	0	5	7	16	9	15	5	3	15	13	20	5
L2	10	10	11	16	18	25	21	13	20	20	20	0
L3	25	25	14	16	18	25	21	27	15	27	7	17
L4	30	30	14	5	9	10	0	10	46	20	13	28
L5	20	15	25	10	27	15	16	13	0	7	13	33
L6	15	10	18	26	18	5	10	27	0	13	20	17
L7	0	5	11	10	0	5	26	7	0	0	7	0

Strategy 11, Describe Mobility Characteristics, had the highest percentage out of all the strategies at Level One. One reason why this strategy had a higher representation among the lower levels could be due to its constraint in definition. Since Mobility was a more understood strategy people could can tended to have a limited frame of view. On the other hand, Strategy 7, Describe the Users' Interaction, received the highest percentage for Level 7. This means that statements from Strategy 7 were able to diversify to most from the original statement.

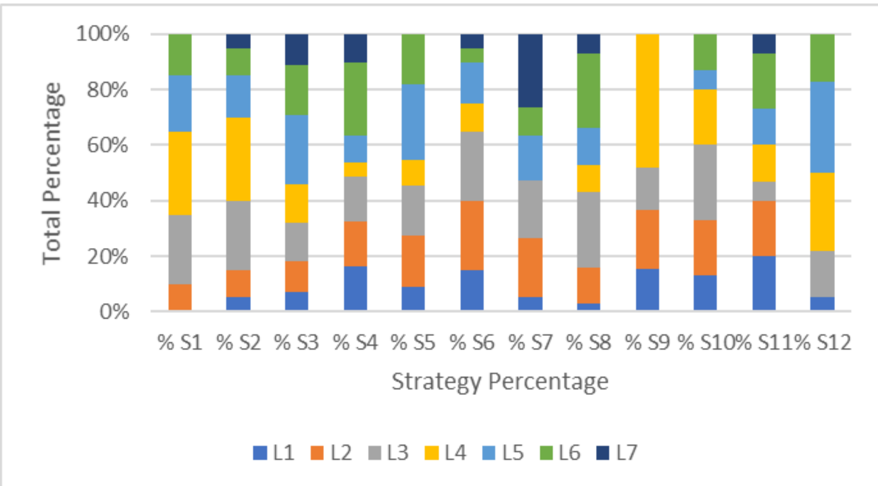


Figure 10 Bar graph displaying percentage of levels for each strategy

As seen in Figure 10, Strategy 9 and 1, Examine Assumptions and Define the Characteristics of the User and their Needs, respectively, had the most representation for the central portion of the levels. For Strategy 9, students are asked to reference the original statement many times since they need to place judgement/assume what is going on in the situation. Since the statements are a complete reference to the original, it makes sense that most of the statements are located at Levels 2, 3, and 4. Strategy 1 asks for the student to define the user and their needs. It was noticed that many of the students generalized the user instead of specifying who it would specifically be, which resulted in most of the statements gathered around Levels 3, 4, and 5.

Our analysis included both the depth and the complexity of cross-pollination among themes. Statements from each strategy were examined to see where they were placed in relation to the tree. Did all statements gather in the same theme, or were they spread out amongst many? The strategies most prominent in staying together as a unit were 4, 11, and 12. Most of their statements were only visible in one or two main themes.

6 CONCLUSION

The study explored the impact of problem exploration strategies on student designers' exploration of diverse reformulations of the problem statement. Although students were introduced to problem exploration strategies for the first time, in addition to an online tool to apply them, there was clear evidence of their use (81%). Students' perception of the value of such a tool in their process was also promising with over average highlighting its potential contribution. The strategies, as demonstrated and applied as a digital tool, helped students to diversify their problem statements while giving them a chance to explore new problem spaces that may not have been investigated before.

Even though there are differences in education and training, students with industrial design and engineering backgrounds were able to use the problem exploration strategies tool to generate diverse and unique problems. This research demonstrates that designed in both domains can use the problem exploration strategies effectively with minimal training as a tool for problem space exploration.

7 References

Autodesk. (2017). *Understanding the abstraction laddering*. Retrieved from https://www.autodesk.com/industry/manufacturing/resources/mechanical-engineer/abstraction-laddering

Bulsuk, K. (2011). *An introduction to 5-why*.

Creswell, J. W., & Creswell, J. W. (2013). *Qualitative inquiry and research design: choosing among five approaches* (3rd ed). Los Angeles: SAGE Publications.

Cropley, A. J. (2003). *Creativity in education & learning: a guide for teachers and educators* (Repr). London: Kogan Page.

Cropley, D. H. (2015). Promoting creativity and innovation in engineering education. *Psychology of Aesthetics, Creativity, and the Arts*, *9*(2), 161–171. https://doi.org/10.1037/aca0000008

Dorst, Kees, & Cross, N. (2001). Creativity in the design process: co-evolution of problem–solution. *Design Studies*, *22*(5), 425–437. https://doi.org/10.1016/S0142-694X(01)00009-6

Duncker, K. (1945). On problem-solving. (L. S. Lees, trans.). *Psychological Monographs*, *58*(5), i–113. https://doi.org/10.1037/h0093599

Einstein, A., & Infeld, L. (1938). *The evolution of physics from early concepts to relativity and quanta*. New York; London; Toronto [etc: Simon and Schuster.

Fogler, S., & LeBlanc, S. (2008). *Strategies for Creative Problem Solving*. Massachusetts: Peason Education Inc.

Getzels, J. W. (1979). Problem Finding: a Theoretical Note. *Cognitive Science*, *3*(2), 167–172. https://doi.org/10.1207/s15516709cog0302_4

Getzels, J. W., & Csikszentmihalyi, M. (1976). *The Creative Vision: A Longitudinal Study of Problem Finding in Art*. New York: Wiley.

Hall, A. (1962). *A Methodology for Systems Engineering*. New York: Litton Educational Publishing Inc.
Higgins, J., Maitland, G., Perkins, J., & Richardson, S. (1989). Identifying and solving problems in engineering design. *Stud High Educ*, *14*(2), 169–181.
Kepner, C., & Tregoe, B. (1981). *The New Rational Manager*. Princeton: Princeton Research Press.
MacCrimmon, K., & Taylor, R. (1976). Decision making and problem solving. *Dunnette MD, Ed. Handbook of Industrial and Organizational Psychology*.
Parnes, S. (1967). *Creative Behavior Guidebook*.
Paul, R., & Elder, L. (2006). *The Thinker's Guide to the Art of Socratic Questioning*. Dillon Beach: Foundation for Critical Theory.
Reitman, W. R., Grove, R. B., & Shoup, R. G. (1964). Argus: An information-processing model of thinking. *Behavioral Science*, *9*(3), 270–281. https://doi.org/10.1002/bs.3830090312
Rickards, T. (1975). *Problem Solving through Creative Analysis*. Essex: Gower Press.
Shull, F., Delbecq, A., & Cummings, L. (1970). *Organizational Decision Making*. New York: McGraw-Hill Book Co.
Snider, C. M., Culley, S. J., & Dekoninck, E. A. (2013). Analysing creative behaviour in the later stage design process. *Design Studies*, *34*(5), 543–574. https://doi.org/10.1016/j.destud.2013.03.001
Spradlin, D. (2012). Are you solving the right problem? *Harvard Business Review*, *90*(9).
Studer, J. A., Daly, S. R., McKilligan, S., & Seifert, C. M. (2018). Evidence of problem exploration in creative designs. *Artificial Intelligence for Engineering Design, Analysis and Manufacturing*, *32*(4), 415–430. https://doi.org/10.1017/S0890060418000124
Studer, J., McKilligan, S., Seifert, C., & Daly, S. (2017). Problem Exploration Strategies during Engineering Design. *Journal of Engineering Education*.
Vasconcelos, L. C., Crilly, N., Chen, C. C., Campos, F., & Kelner, J. (2016). What's the benefit of problem exploration. *DS 84: Proceedings of the DESIGN 2016 14th International Design Conference*.
Wright, S., Silk, E., Daly, S., Jablokow, K. W., & McKilligan, S. (2015). Exploring the Effects of Problem Framing on Solution Shifts: A Case Study. *ASEE Annual Conference & Exposition*.
Yilmaz, S., Daly, S., Seifert, C., & Gonzalez, R. (2010). A Comparison of Cognitive Heuristics Use between Engineers and Industrial Designers. *Design Computing and Cognition*, 16–35.

About the Authors:

Samantha Creeger: Samantha earned her Master of Science degree in the interdisciplinary Human Computer Interaction graduate program. Her research brings her design experience into the UX context where she develops digital interfaces for design pedagogical improvements.

Dr. Seda McKilligan: Dr. McKilligan's research focuses on identifying impacts of different factors on ideation of designers and engineers, developing instructional materials for design problem and solution spaces, and exploring foundations of innovation.

Dr. Colleen Seifert: Dr. Seifert's research interests lie in complex human cognition, including memory, learning, problem solving, and creativity. With her collaborators, she is currently investigating cognitive accounts of creative thinking, and ways to improve the creative process.

IASDR 2019
International Association of Societies of Design Research Conference 2019
DESIGN REVOLUTIONS
Manchester School of Art
Manchester Metropolitan University
02-05 September 2019

Little Designer in Theoryland: A Designer-centric Approach to Understanding Theory

Wood, Dave

Northumbria University, Newcastle Upon Tyne, UK
d.a.wood@northumbria.ac.uk, dave@scouse.scot

This paper sets out the argument for a more proactive design thinking dialogue between designers and theoreticians, to improve the interface between theory and designers' tacit creative practice. To illustrate this problem, it will focus on Peirce's pragmatic semiotic theory of Semiosis, and how designers and Peircean semioticians are beginning to address the barriers around complex theoretical language. The metaphor of a Semiotic Rosetta Stone will be used to demonstrate the central argument for a development of more designer-centric dissemination of theory. Its argument will be supported by historical precedent of the use of a meta-language to bridge between the known and unknown. Such a designer-centric meta-language would refocus complex theory without 'dumbing down,' and help designers who are unschooled in theory to implement it more easily into their design practice, to enhance the effectiveness of visual communication design. An emerging international Semiotic Rosetta Stone network of designers and Peircean semioticians will be explored, and its roots will be mapped to the ground work of others. Outreach work with designers from 2018-19 will be discussed, especially the use of qualitative tools (such as a semiotic probe) to begin mapping designers' tacit language to Peircean terms. The paper will then conclude with a call for more designers and theoreticians to further collaborate to build models on how theory can be applied to design practice. This would afford more freedom of movement within each other's disciplinary territories of *Designland* and *Theoryland*.

Keywords: design thinking; Peirce; theory; Semiosis; visual communication; design

1 Introduction

There seems to be two lands out there - *Designland* and *Theoryland* - and the inhabitants of each land seldom appear to have dual citizenship. In Winsor McCay's classic 1920s strip Little Nemo in Slumberland, Little Nemo famously had fantastic dreams from a vivid imagination, which are then lost when awakening back into the here and now of a daily reality. The here and now reality of design thinking, when designers implement theory into design practice is not easy. Designers and theoreticians do not speak the same language, but designers need to understand relevant theoretical paradigms and research methodologies (applicable to whichever field of design they are engaged in) before they can utilise theory within their design practice.

So, if designers (especially visual communication designers such as illustrators and graphic designers) are to actively apply theory to improve their design practice and outcomes, then it has to be beyond a superficial level of understanding. But what if designers don't have any formal education in theoretical paradigms? How do they begin to take on a theoretician's specialist knowledge while a designer? Design school education specialises in teaching the design practice, and designers leave university with degrees in their chosen practice. When theory is taught it is obviously not at levels that theoreticians are taught at.

Psychology is taught in psychology faculties, philosophy in philosophy faculties, etc. While these students major in their chosen specialisms, they may choose (or be assigned) a minor module from another faculty to expand their specialist knowledge into broader contexts. Designers, who identify their knowledge grounding as 'tacit' honed through a studio-based environment of practical work, learn through doing. To designers (who may never have had any formal classes in theory at design school) theoretical language can be impenetrable. So, how can designers implement more theory into their design practice, if they first cannot understand the specific terminology of the theory?

Theoretical frameworks that are useful to improving design practice are not sufficiently disseminated in designer-centric language. This paper will explore in three coherent steps this elephant in the design studio. Theoreticians are steeped in their relevant theoretical framework, and designers are in their specialist design discipline. To contextualise the issue it will focus on how the pragmatic semiotic theory of Semiosis (Peirce, 1931-34) can enhance visual communication design, if its dissemination can become more designer-centric for designers and illustrators. From a designer's perspective, although Peirce's theory is of a practical use to enhancing visual communication with design solutions, the complexity of his language to explain Semiosis is a barrier for non-semioticians to understand it. Peirce employs very specific words (most of which he invented) in formulating his semiotic theory of signs. He approached his theory as a logical, pragmatic problem, and so it is not written with future designers in mind.

Finally, the paper will conclude with current collaborations between designers and theoreticians engaged in a more concerted dialogue, to develop new frameworks on how to disseminate theory into a more designer-centric dissemination without dumbing down. It frames this collaborative work in exploring a meta-language between high theoretical language and the tacit language of designers, by using the metaphor of a Semiotic Rosetta Stone.

2 The Elephant in the Design Studio?

Theoretical language is, by its nature, complex and often very specific. It can intimidate non-theoreticians. Whether a designer can implement a theory that could enhance their design practice is contingent on if they first can understand the theory. It is unfeasible to expect qualified designers to gain a second university degree before they can. This paper will explore the concept of developing a designer-centric meta-language to interface between the precise language of theory and designers' own tacit knowledge - "a knowledge we cannot tell" (Polanyi, 2009, p5).

Polanyi defines tacit knowledge by four aspects: the functional, the phenomenal, the semantic and the ontological (2009, p13). Designers use design techniques and craft learnt from the design education the received to create design outcomes that 'works,' because they learn that those techniques can be successfully applied to any design problem they have.

Tacitly this is described as ‘knowing what’ (*wissen*) is to be done, which then leads to ‘knowing how’ (*können*) it has been achieved.

Polanyi explains this as the functional aspect of tacit knowledge, a proximal relationship between what needs to be designed and how the solution is designed. This is the phenomenal structure of tacit knowledge. Visual communication designers understand that one thing (designing) leads to another (the solution), but they feel they cannot suitably communicate why it works beyond the tacit level of understanding. The semantic aspect of tacit knowledge is when the meaning of what has been designed is “displaced away from” the designer, and placed into the audience’s power to make sense of it.

The designer may not deem it important to be able to explain how their final design solution works beyond knowing what needs to be designed (*Wissen*), and ‘designing it’ (*Können*) so that it solves the design problem. Even if the designer cannot theorise how the design outcome actually works, the process of designing is grounded a theoretical gestalt even if they do not realise it. Poynor has described graphic design as having had a long “aversion to theory” (2003, p10), but in the practice of visual communication design designers apply colour theory, ethnography, semiotic communication, etc. The relationship between design thinking and doing, has implications and opportunities for improvements to existing design practice. The reality is that for designers who wish to research and apply new theoretical paradigms to enhance and inform their practice, have to learn the relevant theory without formal education.

Matthews and Brereton state that “the field of design research is a marketplace of methodological diversity” (2015, p151), but design practice is not the same as design research. So, to avoid the conflation that practice IS research, Frayling (1993) provided three approaches to design research as a useful guide for both design researchers and practitioners. To quote Frayling directly, so as to establish the original context for his proposition, he named research as either being (a) INTO art and design, (b) THROUGH art and design, and (c) FOR art and design. But Friedman (2008) correctly cautions that Frayling derived his thesis for these three design research approaches from Herbert Read’s earlier work on teaching art and design. Friedman argues that the teaching of art and design practice is the root of the confusion for “those who have come to believe that practice is research” (Friedman, 2008).

So, with a more careful reading of Frayling it can be argued that design research INTO, THROUGH and FOR design goes further than just a tacit understanding ‘knowing how’ to design. This approach to design research is also concerned with understanding the ‘why’ of how design works. This brings designers into the thorny issue of having to applying theories and methodologies that they have had very limited education in. It is very rare that theoreticians become designers, so more concerted dialogue between theoreticians and designers is needed to frame theoretical dissemination from a more designer-centric position. The complexity of theoretical languages to designers is a barrier, as it is like learning a completely new language before theory beginning to understand how to effectively apply it.

For designers to be able to explain the ‘whys’ of their design outcomes with any clarity through theory, this interface between theoreticians and designers is crucial. One current attempt at such an interface between theory and visual communication design practice, using the metaphor of a Semiotic Rosetta Stone, is framed within the philosophical framework of Pragmatism, and Charles Sanders Peirce's pragmatic form of semiotic theory called Semiosis (1931-34).

Pragmatism as a philosophy was founded by Peirce in late 19th century America, predicated on a Pragmatic Maxim at its heart that meaning is dependent upon the experience of understanding. In Pragmatism, meaning emerges through engagement with the effects of the task or problem (Thayer, 1989, p48). From a design perspective, Pragmatism as a practical philosophy provides many framework possibilities for designers from a variety of design disciplines. Moszkowicz describes pragmatics as "the immediate spatio-temporal location of the object of design" (2009, p200). She describes Pragmatism within graphic design's contemporary scene, based on her own reading of Lupton, as "a basic opposition [in] itself, between Postmodern and/or poststructuralist design, and pragmatic or functional design (…) as an effective and responsible model of practice [keeping] in touch with 'real life' situations (Lupton paraphrased in Moszkowicz, 2009, p62).

Pragmatism and Semiosis can bring designers into a self-discursive communicational situation (Frascara, 2004, p13) to understand how their intended audience will experience their design outcomes (Wood 2016). This philosophy has impacted on design since the 1930s. Moholy-Nagy had applied a pragmatic pedagogy to his New Bauhaus School design curriculum, to imbue his design students with a sense of responsibility in their own learning (Findeli, 1990).

3 A Designer-Centric Theory of Semiosis

The paradox of how designers can follow and apply theory, if the complex theoretical language has never been formally taught to designers at design school, is crucial to address. This is the elephant in the design studio. Theory first needs to be learnt and understood by designers, before they can begin applying their chosen theoretical framework into enhancing their design practice. The complexity of theoretical languages is alien to non-theoreticians like designers. Peirce's pragmatic semiotic theory of Semiosis is one example out of many theories that can positively enhance design practice. This paper acknowledges that not all theories applicable to designers are as obfuscated as Peirce is (e.g. colour theory has clearly benefitted designers by being explained in more designer-centric language). But, this it will not spend time listing theories that need designer-centric dissemination, its intent is to use Peirce's Semiosis as an example of this larger issue. By discussing Semiosis and design, this paper is a provocation for designers and other theoreticians (from any theoretical framework) to develop more accessible dissemination for design practitioners.

Semiotics is one of the underlying theories that inform effective visual communication design, but semiotic theory has two diverging theoretical forms that designers can follow. From their design school class, designers can probably identify Semiology - Saussure's structuralist form of semiotic theory that Barthes later developed. This employs the understanding that semiotic signs signify meaning through the code of Signifier | Signifier. It takes into account the object (concept) of the communication within a sign and how it communicates. The second school of thought is a pragmatic semiotic theory called Semiosis, which was developed by Charles Sanders Peirce (1931-34). Coincidentally Peirce developed his Semiosis in the US at the same time as Saussure was developing his Semiology in Europe.

Peirce's pragmatic semiotic theory details the sign-action, or semiosis, of a semiotic sign through a three-way (triadic) relationship. This is a determination flow (see Figure 1) between the concept (*Object*) to be communicated, the form its representation (*Representamen*) takes in communicating the concept, and finally how the concept is finally interpreted (*Interpretant*). This encapsulates Peirce’s Pragmatic Maxim that understanding is an emergent act (Atkin, 2016, p51), as in Semiosis the interpretation of a sign is just as important as the concept or its representational form.

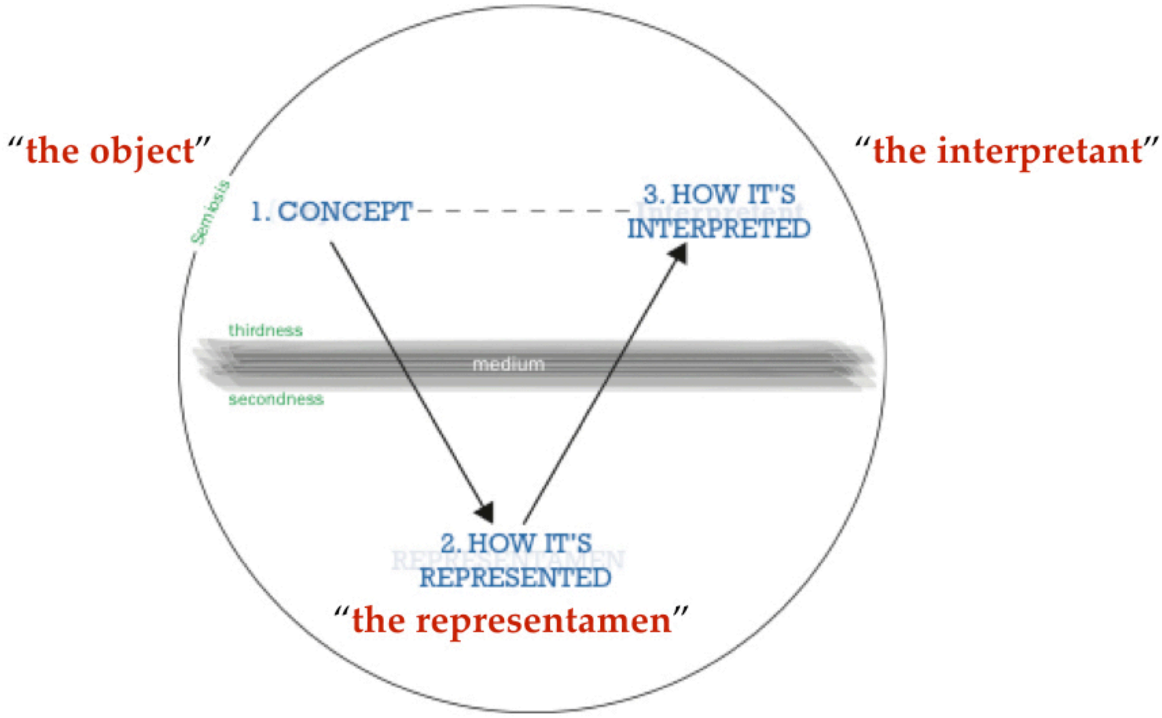


Figure 1. The determination flow in a semiotic sign between an Object, its Representatmen, and its Interpretant.

In 1903, Peirce classified ten ascending classes of semiotic signs (Peirce, 1932, [CP 2.243-254] pp142-146) ranging from the simple to the complex. It is within the action between these dynamic inter-relationships of the *Object*, its *Representamen* and *Interpretant* that each sign communicates meaning. The *Object*, *Representamen*, and *Interpretant* are further defined by three ascending classifications of complexity. An *Object* has three classes of an *icon*, *index* or *symbol*; a *Representamen* - *qualisign*, *sinsign*, *legisign*; and an *Interpretant* - *rheme*, *dicent*, *law*. This hierarchy ascends from its lowest immediate communicational form of familiar qualities, through to proposed dynamic connections to actual things, and up to agreed socio-cultural meanings.

When Peirce defined his ten sign classes in the early 20th century he was clearly not speaking to future designers. In just three terms he loses the attention of designers, and this is the tip of the problem. Once he then begins to explain how each triadic relationship works within a sign-action, his theoretical language then continues with a whole new lexicon of terms which are alien to the tacit language of designers. His three sets of new three new terms (*icon*, *index*, *symbol*; *qualisign*, *sinsign*, *legisign*; and *rheme*, *dicent*, *law*) need further unpacking for designers. Some of these nine new terms have other denotations in design contexts (*icon* and *symbol*), while most are totally unfamiliar to non-semioticians (as Peirce created some of these term names).

For the uninitiated designer approaching Peirce, there are currently no entry level readers aimed at designers. Unlike Saussure's binary code of Signifier | Signifier, pragmatic semiotic theory is a triadic relationship. What Peirce is describing is the relationship in a semiotic sign between the concept to be communicated as a sign, is dependent upon the concept's representation to be successfully interpreted. Peirce calls the concept to be communicated as a semiotic sign the *Object*. Peirce uses the term *Representamen* to refer to the representation of the *Object*, and *Interpretant* for how it is interpreted. The represented form the semiotic sign takes must identify it as a sign to be interpreted, and so the *Representamen* is also interchangeably used to describe the semiotic sign itself.

As can be seen by this description of the very basic mechanics of a pragmatic semiotic sign, complexity emerges very quickly, which needs 'unpacking' into a design context. Already, in order to briefly explain this pragmatic sign-action to a designer reading this paper, it has been necessary to use more familiar tacit terms such as concept for *Object*, representation for *Representamen*, and interpretation for *Interpretant*. As with any new ideas, there are always issues with unfamiliar terms that need to be first understood, terms that are gateways into the deeper knowledge, understanding, and eventual application into practice. Within this introduction to Semiosis, the first three gateway terms used by Peirce are already off-putting to non-theoreticians. Then when taking the next step in understanding how each of these triadic elements operate, that complexity of language gets more obtuse for designers.

Designers enjoy the manipulation of metaphors within visual communication design, and Roderick Munday developed a suitable metaphor to describe Semiosis (Chandler, 2007, p31). Paraphrasing Munday, Chandler describes a labeled opaque box to explain the triadic relationship of sign-action. This opaque box catches our visual attention from how it appears to us (the semiotic sign's representational form). This representational form tells us it's a 'box' and we sense that the box is not an empty container, that there is an object inside (the concept) we cannot yet see or yet understand. The label on the box helps us to form a mental image of the object in the box (the interpretation). If we do not understand the label from our socio-cultural reference points then the semiotic sign fails to communicate successfully, but if the label is attuned to our references we can interpret the concept from just looking at the 'box.' In this act of interpreting, the sign's representational form (the 'box') visually communicates the concept, but only if the designer employs socio-cultural references. These references pragmatically help the interpreter to understand that 'the box' means something more than just 'the box.' By interpreting what is visually represented, the 'hidden' concept emerges from the act of interpreting the semiotic sign.

This box metaphor is useful to begin to visualise the sign-action in a semiotic sign between a concept, its representation and its interpretation. It presents a complex concept and translates it into terms that non-semioticians can understand. Many designers who have embraced Peirce's Semiosis into their design practice first encountered him during doctoral research. The Interaction Design discipline is a good example of how pragmatic semiotics is being applied to design practice. But beyond academic literature, it is still not yet entering the mainstream of entry-level design literature in a designer-centric way. Peircean semioticians, such as Tony Jappy in his 2013 book *Introduction to Peircean Visual Semiotics,* have begun to explain Semiosis to a wider readership. These inroads towards a more non-theoretician dissemination are welcome, but they can and should go deeper for designers if theoreticians and designers collaborate more. The Semiotic Rosetta Stone collaboration is examining how designers' tacit language can connect with Peirce's theory to create a meta-language that communicates without over-simplification its rich theory into rich practice. In the next section this collaboration will be placed into a historical context of scholarly precedents.

4 A Semiotic Rosetta Stone

This paper argues for a new approach for dissemination of theory beyond the tacit of 'knowing what' (*wissen*) to design, and then 'knowing how' (*können*) to achieve it, to bridge the relationship between *thinking* and *doing* in design. It will now discuss how an emergent research network of Peircean semioticians and visual communication designers are using a Rosetta Stone approach to develop such a designer-centric dissemination.

The original Rosetta Stone was found buried in the deserts of Egypt in 1799 (Sole and Valbelle, 2002). On this stone stele three languages were engraved. At its top, the arcane and complex hieroglyphics of ancient Egypt were carved. At its base was Ancient Greek, and on the central carved area of the stone, was a demotic script (a simplified priestly version of hieroglyphics used in later religious contexts). The 18th century scholars could only read and understand Ancient Greek, no-one could read hieroglyphics, and they were aware of the demotic script's legacy. It wasn't until they realised that the stone's Greek message was also written in the middle demotic script. With this realisation, they broke the demotic script and then used it as a bridging language to unlock the hieroglyphic language of Ancient Egypt. After millennia, the knowledge of Ancient Egypt was opened up to the modern age by employing the demotic script as an interface between what was already understood (Ancient Greek) and the obscure (hieroglyphics).

The important lesson to take from this historical example is that a high and arcane language (hieroglyphics) could be unlocked and understood by scholars, through an interface of a 'meta-language' with a language that THEY already used (Ancient Greek). So, by taking inspiration from this historical event the metaphor of a Semiotic Rosetta Stone for the emergent collaboration between Peircean semioticians and designers follows a similar path. By trying to read Peirce directly, designers find the language Peirce uses to be as inaccessible as Ancient Egyptian hieroglyphics. But if his theory is first approached from the tacit language of design practice that a suitable model of designer-centric theoretical dissemination can develop.

This emergent Semiotic Rosetta Stone collaboration between Peircean semioticians and designers is built upon the grounding that others have laid (even if these progenitors do not currently explain Peirce in designer-centric meta-language terms). Cohn, in his book *The Visual Language of Comics* (2013), simplifies some Peircean terminology in order to clarify the theory's application within graphic novels. In *Peirce: A Guide for the Perplexed* (2013) by Cornelis de Waal, his language is clearer and he succeeds to a degree in helping the lay reader to understand the tenets of Peirce's doctrine of signs. But as his primary readership are not visual communication designers, the structure of his exposition of Semiosis still requires designers to extract from the theory what may be relevant to their design practice – which requires knowledge.

More recently Atkin (2016) continues this emergent academic trend of clearer exposition of Peirce's pragmatic philosophy using clearer language. But what is clear is that semioticians cannot write directly for designers without the active participation and collaboration with designers. Pragmatism as a philosophical model, through Peircean semiotic theory, can facilitate designers' enhancement of the effectiveness of their practice. Through beginning with the designers' tacit knowledge (their 'Ancient Greek') a deeper level of visual communication in the design outcomes can be crafted to meet the expectations of their target audience. The pragmatic framework of Semiosis, if understood more easily through clearer dissemination, can be utilised to inform 'how' exactly design decisions can communicate concepts at a deeper, more connotative levels. Unlike in the historical example, this Semiotic Rosetta Stone collaboration has now to define the bridge between Peirce's Semiosis and tacit design knowledge, as the designers' demotic script has not been devised yet. This paper will now outline the initial research between semioticians and designers to influence a future designer-centric dissemination.

5 Toward A Design Meta-Language

Some of the existing groundwork in integrating Peircean semiotics into design practice has been made in the United States. This is not surprising as Peirce is an American philosopher and Pragmatism is an American philosophy. Tom Ockerse's work in "bringing to light methods for perceiving the mechanisms of meaning in visual communication design" (RSID, N.D.) is important to focus on. His groundwork 40 years ago identified some of the issues that needed attention for designers within a Peircean framework, especially the relationship between *thinking* and *doing* in design. In his co-authored paper "Semiotics and Graphic Design Education" (Ockerse and van Dijk, 1979) he detailed the use of Peircean semiotic theory with graphic design pedagogy at Rhode Island School of Design. This paper also references his co-author's Master's thesis *The Role of Semiotics in Graphic Design* (1978). In this thesis van Dijk proposed a system of semiotic design pedagogy which recognised that "factors of sign production, type of representation, and degrees of sign complexity [led] to an overly complex model of continuously shifting nodes of expression." He concluded that this theoretical complexity was not useful to daily design practice, "nor would it clarify much in educating graphic designers" (van Dijk, 1978, p146).

Ockerse's pedagogy at Rhode Island School of Design in the 1970s, is a rare example of attempting to integrate theory into design practice within design education. Other examples of design educators bringing Peircean theory into their curriculum of course exist. One important recent contribution to a more designer-centric dissemination of Peirce's semiotic theory has been in Scotland, at Duncan of Jordanstone College of Art and Design in Dundee (DJCAD). Shaleph O'Neill, in his book *Interactive Media: The Semiotics of Embodied Interaction* (2008) provides case study examples of how Peirce was integrated within DJCAD's Communication Design curriculum. He continues to teach Peircean semiotics to DJCAD design students each year, embedding theory into their future design practice.

It is safe to say that these pedagogical interventions into curricula are designer-led, where designers filter the theory into design practice. As Ockerse and van Dijk's work illustrates, in doing so they highlight areas where theory and practice do not synthesise neatly. In van Dijk's thesis, he concludes that:

> *"Peirce's model of classification, with its added subdivisions, thus far takes adequate care of the immediate needs of graphic designers.* ***This does not mean that the question of classification is resolved.*** *Graphic designers should be open to new approaches and continue to test the current model. It is still a question, for example, whether there exists a true indexical graphic sign. The selected rules or operations of formation and transformation identified thus far are sketchy and tentative" (van Dijk, 1978, p142) .*

Forty years later, the “immediate needs” of visual communication practice from Peirce’s classifications of sign-action have seen very little progress toward a designer-centric literature until very recently with Steven Skaggs’ book, *FireSigns: A Semiotic Theory for Graphic Design* (2017). Skaggs, a typographer and Professor of Design at the Hite Art Institute of the University of Louisville, has spent over a quarter of a century exploring semiotics in design contexts. In his book’s epilogue he states that,

> *“semiotics, as it specifically applies to graphic design, has been largely undeveloped […] A semiotics that flows from the concepts first put forward by C. S. Peirce is particularly well-suited for the purpose. […] But this work is only a beginning.” (Skaggs, 2017, p231) .*

Skaggs is right in stating that more books are needed to do Peirce’s theory justice within a visual communication design context. Peirce has a global reach to designers beyond America, but any examples of good practice of integrating theory into design thinking are like islands within design education and literature. While all the above examples are designer-led, some Peircean semioticians are also keen to see more integration of their work into design practice. There is currently an emergent international dialogue between designers and semioticians, that is leading toward fresh collaborations to address a designer-centric dissemination of theory.

The timely development of an emergent Semiotic Rosetta Stone international network of like-minded visual communication designers and semioticians, is exploring models for a more designer-centric dissemination of theory. Australian semiotician Cathy Legg believes that this fresh collaborative approach to put Peirce’s Semiosis into practice, “is so much what [Peirce] would have wanted” (Legg, 2018). Professor Paul Cobley, a UK-based Peircean semiotician, observes that it “ties in with a fair amount of endeavour [from theorists] which is certainly happening across Europe as well as in South America” (Cobley, 2018). With the design focus of this outreach being on the visual communication within designing, it places illustration firmly within the designer-centric aims of disseminating Peirce. US-based semiotician Elka Kazmierczak appreciates this unifying factor in reviving Peircean theory to benefit creative practice, as in her experience “it is uncommon to see this unifying approach among designers who do not have experience as illustrators” (Kazmierczak, 2018). These collaborations between Peircean semioticians and the design community, are firstly focusing on the design community to map out its tacit terminologies that describe sign-action. Through practical designer-focused theory workshops using qualitative data-gathering tools such as semiotic probes (see Figure 2), designers’ current understanding of Peirce and the tacit language around understanding semiotic theory is being mapped. This will aid the Peircean semioticians to understand the disconnects between theory and practice, and to bring *design thinkers* and *thinkers interested in application of theory* together.

Figure 2. Examples from 2018-19 of Semiotic Rosetta Stone workshop qualitative tools.

This ongoing research through the informal Semiotic Rosetta Stone collaborations, will inform the discourse with theoreticians as to where a new meta-language to help designers connect theory to practice is to be developed. The Semiotic Rosetta Stone approach is intended to become a research framework around which theory and practice can interface in more meaningful ways for design thinking. By embracing a pragmatic approach, the collaborations that emerge to develop a more designer-centric dissemination of theory, follow Peirce's own Pragmatic Maxim. By considering the context of design practice when conceiving new designer-centric dissemination of Peirce's Semiosis, designers and theorists' conception of Peirce emerges through engagement with how theory interfaces with practice. This will result in inhabitants of both *Designland* and *Theoryland* embracing a freedom of movement within each other's disciplinary territories, and in doing so they can experience the perspectives and nuances pertinent to a smoother model for design thinking.

6 Summary

This paper has outlined the need for theory to be reframed for a more designer-centric dissemination. It not only proposes but demonstrates an emergent model to genuinely facilitate designers' understanding of theory to improve their design practice, through a fresh level of collaboration between designers and theoreticians. Its main argument specifically focuses on a collaboration between visual communication designers Peircean semioticians, to find ways to disseminate the semiotic theory of Charles Sanders Peirce without compromising the integrity of the theoretical language. This is proposed using a Semiotic Rosetta Stone metaphor for a new meta-language. This is more than just a superficial taxonomical substitution of a designer-term for a Peircean-term.

This Semiotic Rosetta Stone metaphor is used to frame where and how designers' tacit way of understanding their own practice can successfully interface with the theory that can improve the effectiveness of that practice. It is also the name of a loose international network of designers and Peircean semioticians attempting to demystify Peirce for non-semioticians. This new interface between *Designland* and *Theoryland* is helping to begin the breakdown of the complexity of dissemination from theory to practice. It is currently designer-led, but will develop into a collaborator-led area of design research with theoreticians and design thinkers working ever closer within each other's disciplinary territory.

High theoretical language may be precise in differentiating and explaining one theoretical paradigm from another paradigm, but while the language remains the preserve of scholars, it restricts it from becoming applicable by practitioners unschooled in the theory. With the emergent collaborations between visual communication designers and Peircean semioticians that this paper reviews, there can be no fear of design 'barbarians at the gates' of *Theoryland,* ready to smash and destroy theoretical scholarship through bouts of iconoclastic creative anarchy. A designer-centric dissemination that emerges from active discourse and the workshopping of theory, cannot be negatively viewed as an attack on the integrity and rigour of any theoretical paradigm by non-scholars.

The Semiotic Rosetta Stone approach follows a historical scholarly precedent which 18th century scholars took. These scholars, through an interfacing meta-language, unlocked the arcane hieroglyphic language of Ancient Egypt, and enriched the modern world with seams of hidden knowledge. Their approach began with a language that the scholars understood, from which they then used a meta-language to unlock the higher language. Designers can only achieve this by engaging with theoreticians in collaborations, and vice versa. The current designers and Peircean semioticians who are already collaborating under the Semiotic Rosetta Stone metaphor, need to be joined by more designers and semioticians to help define how this designer-centric dissemination is to manifest itself.

This paper began with two lands - *Designland* and *Theoryland* - and although the inhabitants of each land don't have dual citizenship, there certainly is now more freedom of movement between them. The introduction led with Little Nemo's fantastic dreams which are then lost when awakening. It concludes within a new awakening, where the dream of a clearer dissemination of theory for designers is now lingering on into the reality of a designer's day.

7 References

Atkin, P. (2016) *Peirce*. Abingdon: Routledge.
Chandler, D. (2007) *Semiotics: The Basics* [2nd Edition]. Oxford: Routledge.
Cobley, P. (2018) *Email to Dave Wood*, 16th May.
Cohn, N. (2013) *The Visual Language of Comics: Introduction to the Structure and Cognition of Sequential Images*. London: Bloomsbury Publishing.
de Waal, C. (2013) *Peirce: A Guide for the Perplexed*. London: Bloomsbury.
Findeli, A. (1990) Moholy-Nagy's Design Pedagogy in Chicago (1937-46). *Design Issues*, 7(1), 4-19.
Frascara, J. (2004) *Communication Design: Principles, Methods and Practice*. New York: Allworth Press.
Frayling, C. (1993) Research in Art and Design. *Royal College of Art Research Papers* 1(1), 1-5.
Friedman, K. (2008) *Research Into, By, and For Design*. 21st September. PHD-DESIGN. [Online]. [Accessed 25th May 2016]. Available from: https://www.jiscmail.ac.uk/cgi-bin/webadmin?A2=ind0809&L=PHD-DESIGN&F=&S=&P=63855
Jappy, T. (2013) *Introduction to Peircean Visual Semiotics*. London: Bloomsbury.
Kazmierczak, E. (2018) *Email to Dave Wood*, 22nd May.
Legg, C. (2018) *Email to Dave Wood*, 16th May.
Matthews, B. and Brereton, M. (2015) Navigating the Methodological Mire: Practical Epistemology in Design Research. In: RODGERS, P.A. and YEE, J. (eds). *The Routledge Companion to Design Research*. Abingdon: Routledge, pp151-162.
Moszkowicz, J. (2009) *Phenomenology and Graphic Design Criticism: A Re-evaluation of Historical Precedents in the Age of New Media*. Doctoral dissertation, University West of England, Bristol, UK.

O'Neill, S. (2008) *Interactive Media: The Semiotics of Embodied Interaction.* London: Springer-Verlag.
Ockerse, T. and Hans van Dijk, H. (1979) *Semiotics and Graphic Design Education*. Visible Language, 13(4), 358-378.
Peirce, C.S. (1931) *The Collected Papers of Charles Sanders Peirce. Vol. 1 Principles of Philosophy*. Cambridge: Harvard University Press.
Peirce, C.S. (1932) *The Collected Papers of Charles Sanders Peirce. Vol. 2 Elements of Logic.* Cambridge: Harvard University Press.
Peirce, C.S. (1933) *The Collected Papers of Charles Sanders Peirce. Vol. 3 Exact Logic.* Cambridge: Harvard University Press.
Peirce, C.S. (1934) *The Collected Papers of Charles Sanders Peirce. Vol. 4 The Simplest Mathematics.* Cambridge: Harvard University Press.
Polanyi, M. (2009) *The Tacit Dimension*. Chicago: The University of Chicago Press.
Poynor, R. (2004) Spirit of Independence. In: R. POYNOR, (Ed.) *Communicate: Independent British Graphic Design since the Sixties*. London: Laurence King Publishing Ltd. 12-47.
Skaggs, S. (2017) *Firesigns: A Semiotic Theory for Graphic Design*. Massachusetts: The MIT Press.
Sole, R. and Valbelle, D. (2002) *The Rosetta Stone: The Story of the Decoding of Hieroglyphics.* London: Profile Books.
Thayer, H.S. (1989) *Pragmatism: The Classic Writings*. Indianapolis: Hackett Publishing Company, Inc.
van Dijk, H. (1978) *The Role of Semiotics in Graphic Design Education*. Masters Thesis, Ohio State University.
Wood, D. (2016) *A Visual Phenomenological Methodology: The Repositioning of Visual Communication Design as a Fresh Influence on Interaction Desi*gn. Doctoral dissertation, Edinburgh College of Art, University of Edinburgh.

About the Author:

Dave Wood: has a PhD in Visual Communication from Edinburgh College of Art. He was an illustrator in the 1990s before becoming a design educator/researcher. He is an author, a Senior Lecturer in Graphic Design and teaches on the illustration pathway.

Making Ideation Visible: An Early-Design Tool for Designers

Cheng, Pei-Jung

National Chengchi University, Taipei, Taiwan
admufy@gmail.com

We investigated the effect of an idea generating tool, IDEATOR, on the performance of designers during early-design concept development. We also investigated behavioural differences between designers in the fields of graphic, product, and interior design. To investigate their behaviour when using IDEATOR and satisfaction with its core functions, we conducted behavioural observations on, and usability interviews with designers of those three fields. The results indicate that most designers thought IDEATOR to be user-friendly, and found its most useful feature to be the 'mind map'. Results were as expected, and they fulfilled the preliminary study 'creative concept app (IDEATOR)' requirement. In addition, IDEATOR functions as an effective recording tool for future research on the process of concept ideation.

Keywords: design-supporting tool, ideation, IDEATOR, usability interview

1. Introduction

Segers, de Vries, and Achten (2005) constructed an idea space system to facilitate architects' design thinking. The system's word–image connection inspired designers to think creatively, inhabit more perspectives, and thus, enhance their work efficiency. Siangliulue, Chan, Gajos, and Dow (2015) conducted an online experiment to explore the effects of being offered examples at the right moment. The authors observed that examples provided on demand assisted in the creation of novel ideas. By contrast, examples provided at the wrong moment suppress the generation of ideas. In addition, Ahmed (2005) observed that 24% of engineering designers spent most of their time searching for information. Thus, the author asserted that information searches are vital in the design process and developed a method that enabled the designers to index design knowledge. Westerman and Kaur (2007) examined the retrieval of images from computer databases meant to spark the creative generation of ideas. They propose that creative design tasks require the support through information systems for both convergent and divergent processes. In addition, the use of keywords is integral to finding resources on the Internet. Thus, a 'keyword' is an important concept for researchers to understanding design cognition.

This study focuses on the connection between keyword cognition and design concepts. Compared with the past designers who used books as a resource, the current designers use the Internet, resulting in a considerable shift in how they find resources. Specifically, in a 'thinking first' approach, designers must first identify keywords and require resources to that end. These keywords, necessary for finding the appropriate material, are used in a designer's visualisation. Designers can thus be inspired by numerous resources on the Internet.

Our preliminary research proposed 4 modes of association based on designer behaviour during ideation (Cheng, 2010; Cheng & Yen, 2008). We then developed a creative idea generation tool, 'IDEATOR' (Cheng, 2016, pp.89-95), to support designers during ideation. The main functions of the 'IDEATOR' (Figure 1) underlying designers' behavioural modes and resource searching needs in the ideation, support a designer's formulation of concepts by integrating image searches and stimulates design actions by displaying all the images on an image board. Unlike other studies on design thinking support systems, IDEATOR emphasises recording the designers' word thinking paths and processes (Function A in Figure 1). It assists designers in their repeated input, access, and storage of information. Our preliminary research results indicate that IDEATOR allows designers to add their own ideation sketches and brief descriptions while recording each concept, which made the results of their idea map similar to a designer's self-reports. In the process, keywords, ideation sketches, and images serve as a stimulus or as the object of 'seeing' in the 'seeing–moving–seeing' model (Schön & Wiggins, 1992).

IDEATOR provides designers with copious visual stimulation in idea development (Functions B and C in Figure 1), which is in accordance with research demonstrating that a designer's mental imagery can be triggered by an abundance of visual stimuli (Dorst & Cross, 2001; Suwa, Gero, & Purcell, 2000; Verstijnem, Hennessey, Leeuwen, Hamel, & Goldschmidt, 1998; McGown, Green, & Rodgers, 1998; Goldschmidt, 1994; Herbert, 1993; Schön & Wiggins, 1992). Such mental imagery aids designers in creating new ideas.

Nonetheless, most research on design-supporting tools focus only on designers from a single design field. Thus, this study investigates differences between graphic, product, and interior designers.

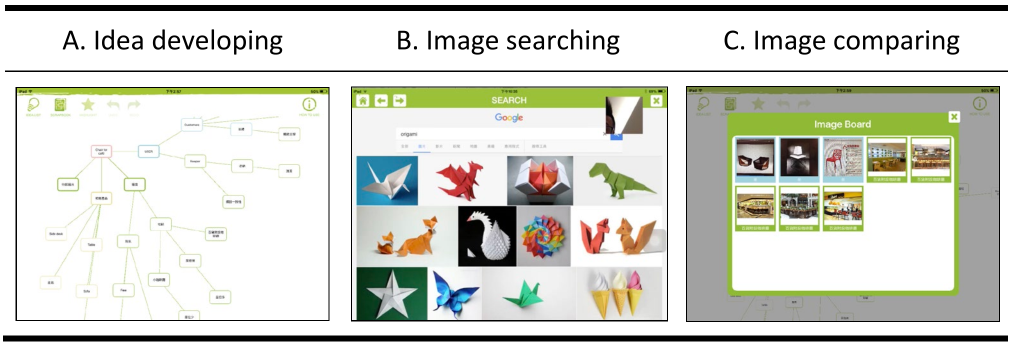


Figure 1. Three main functions of IDEATOR (Screenshot sequences from left to right indicate the functions for 'idea developing-mind map', 'image searching', and 'image comparing').

2. Method

We explored how designers of different fields develop ideas with IDEATOR and the effect the app has on their ideation. We collected data using IDEATOR. Specifically, IDEATOR was adapted to record the designers' idea map, index reference content, concept words of association, and sketch development. Finally, we conducted one-on-one interviews with the designers. We aim to use this data for future revisions of IDEATOR.

2.1. Design Task, Process, and Participants

To ensure consistency, designers performed a design task assigned by us. Regardless of their field, all designers had an assigned task for the same café place. Specifically, they were required to design a logo, chair, and bar for a coffee shop named ‘at Café’.

Before the design task was executed, task instructions, pieces of A4 paper for sketching, and an iPad Mini with the IDEATOR app were provided to each designer. Designers were taught how to operate IDEATOR and were informed that their behavioural data will be collected and analysed. The designers were free to work in an environment of their choice and could use the Internet in any way that they pleased.

Designers had 1 week to finish the task and were allowed to finish ahead of time. In addition, upon completion of the design task, participants were required to turn off the screen-recording app (Shou.TV mobile game streaming 0.7.13) on the received iPad and write down the drawing completion time point for each sketch on the paper (values in Figure 2).

Fifteen designers (10 male and 5 female), with an average of 3 years of experience, were invited to participate. Of them, 5 were graphic designers, 5 product designers, and 5 interior designers.

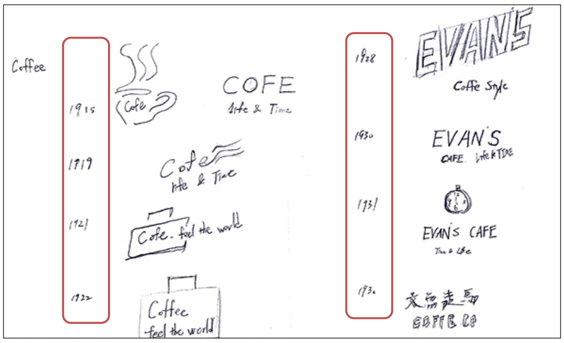


Figure 2. Idea sketches of participant G5 with time record (red rectangles show the time record)

2.2. Usability Interviews

After each designer completed the design task, we conducted one-on-one structured interviews on the user-friendliness of the IDEATOR interface, pertaining specifically to the ‘image search’, ‘mind map’, ‘sketch pad’, and ‘image board’ functions. Information from the interviews was used in an inductive analysis.

2.3. Data Analysis

For data analysis, each participant's IDEATOR data from the mobile device, screen capture recordings, and their developed idea sketches were collected. Video and protocol data analysis was conducted by the researcher and 2 coders, and the internal consistency of the coding results was tested.

The study used behaviour-recording software, The Observer XT, to collect and analyse video data. First, the researcher and 2 coders individually marked the change points of the videotaped behaviour of participants according to the behavioural definitions and coding scheme from our previous study (Cheng, 2016). Subsequently, the 2 coders listed clips that could not be categorised under any behavioural code. Thereafter, the researcher and 2 coders discussed possible revisions to the behavioural definitions and coding scheme.

Designers recorded the video data with IDEATOR to record their self-ideation process. Their operational behaviour has a bit different from the behavioural codes used in the previous study because of the app's revised interface and functions. For example, for sketching behaviour, the behavioural coding in the preliminary study comprised 'Creating new sketch' and 'Continuing to sketch.' The collection of research data was provided by designers, but the mobile screen-recording app (Shou.TV mobile game streaming 0.7.13) was unable to record the designers' sketching process on paper. Therefore, the sketch behaviour in this study was classified under 2 behavioural codes 'Sketching on paper (SOP)' and 'Drawing on sketch pad (DOSP)'.

Our modified behavioural coding scheme is as follows (Table 1). There are 3 behavioural modes. The 'Gathering information (GA)' mode includes the 3 behaviours of 'Retrieving information (RI)', 'Referring to relevant information', and 'Referring to the saved data (RSD)'. The 'Generating ideas (GI)' mode includes the 3 behaviours of SOP, DOSP, and 'Adding a new branch idea (ANI)'. The 'Thinking' mode includes 'Revising a branch idea (RBI)', 'Highlighting a branch idea (HBI)', and 'Purposeless action (PA)'. In addition, participants, in their unfamiliarity with the interface, may have performed an 'Error action', an action that belongs to none of the 3 modes.

Table 1 Behavioural coding scheme (revised from the behaviour codes in previous research [Cheng, 2016])

Behavior mode	Behavior (code)	Definition
Gathering information (GA)	Retrieving information (RI)	Retrieving information on-line for capturing ideas, sketching or drawing; saving the retrieved information in the hard disc to be the reference later.
	Referring to relevant information (RRI)	Referring to the information they have retrieved on-line in advance. Retrieving action is not included in the behavior.
	Referring to the saved data (RSD)	Referring to some saved data that have been retrieved on-line by them in advance.
Generating ideas (GI)	Sketching on paper (SOP)	Creating the new shapes, labels or lines.
	Drawing on sketch pad (DOSP)	Drawing the new shapes, labels or lines on sketch pad.
	Adding a new branch idea (ANI)	Adding an idea in the mind map area of IDEATOR as the new branch to be used or further thinking later.
Thinking (TH)	Revising a branch idea (RBI)	Revising the idea, fixing the words of an idea, adjusting the level of an idea in the mind map area of IDEATOR.
	Highlighting a branch idea (HBI)	Applying different color to a branch idea for highlighting its important or using several colors to those ideas for separating them from each other.
	Purposeless action (PA)	Making a move purposively, such as touching and moving working area back and forth.
None	Error action (EA)	Making a move incorrectly or not accordance with the operational rules of IDEATOR.

3. Results, Discussions and Conclusion

To explore whether the effect of IDEATOR on the design process differs by a designer's field, the data of the graphic, product and interior designers were denoted G1–G5, D1–D5, and I1–I5, respectively. Each designer had a complete set of data comprising screen capture data, hand-drawn sketches, and IDEATOR data.

3.1. Analysis and Comparison of the IDEATOR Operation Records Segment Encoding in 3 Fields of Design

According to our analysis using Observer XT, the mean duration of each designer's ideation was 1873 s (or 31 min). Video Data on the designers' interface operations were divided into 767 segments according to the behavioural coding scheme (Table 1), and the coding results of all the segments are detailed in Table 2. During ideation, the product designers had the most number of segments (M) using IDEATOR (M = 75), whereas graphic designers used IDEATOR the least (M = 33).

ANI had the most segments (M = 288, 37.5%) coded under it, followed by PA (M = 127, 16.6%), and RI (M = 85, 11.1%). The least prevalent types of behaviour were DOSP (M = 12, 1.6%), followed by SOP (M = 17, 2.2%). For the interior designers in particular, the RSD behavioural segment was more prevalent, even more so than PA and RI; DOSP is also more common than SOP.

The designers in our study also spend more than a third of their time generating ideas. GI occurred 41.3% of the time, followed by GA, which occurred 21.5% of the time.

However, when observing differences between the designers of different fields, graphic and product designers spend most of their time on GI. In particular, graphic designers spend 50% of their time on GI, whereas product designers spend more than 40% of their time on GI. However, in the 3 fields, among graphic designers, gathering information (GA) behaviour occurred least frequently, whereas among interior designers, the frequency of the 'gathering information (GA)' behaviour was highest among the 3 modes.

3.2. Usability Interview Results

Participants gave the following feedback during the interview.

1) The most user-friendly part of the interface was the 'interface icon (ICON)', followed by the 'mind map' ideation model. However, users experienced minor difficulties using the 'picture searching' function.

2) The most helpful function for concept ideation was the 'mind map'. Most of the designers believed that this function aided their management of their own ideation-thinking path. In particular, the image searches integrated with the mind map, so that the concept of the development context could be visualised and then the HBI function so that designers could sort out and classify the thinking path on mind map.

3) With the 'image board' function, designers recognised that the relevant images could be presented at the same time as a source of inspiration stimulates the designers. Moreover, they found the function of HBI and 'picture searching' advantageous.

4) IDEATOR's most notable disadvantage was the flexibility of dragging the mind map. Besides, it was less intuitive for them to see the relevant pictures of each concept immediately on the mind map, Followed by 'picture searching', and most of the designers recognised that as they searched for the relevant pictures, and then copied and saved them, they must return to the search screen before they can copy the second picture, which made the operation less streamlined.

Table 2 Encoding of designers' behaviour segments in 3 fields

B-mode	GA			GI			TH			None	Total
B-Code	RI	RRI	RSD	SOP	DOSP	ANI	RBI	HBI	PA	EA	Segs.
G1				1		15		3	2		21
G2				1		12		2	3	2	20
G3	1			1		29	11		14	1	57
G4				1		11	1	3	2		18
G5	4		3	1		20	3		10	7	48
Total	5	0	3	5	0	87	15	8	31	10	164
D1	12		4	3		4	2			2	27
D2	14	5	6	1	2	49	7		38	7	129
D3	14	1	10	1		13	4		2	6	51
D4	2	4		1		50	7	11	16	20	111
D5	7	6		1		31	2		5	5	57
Total	49	16	20	7	2	147	22	11	61	40	375
I1	14	2	14	1	2	2	2		14	2	53
I2			10	1		15	10	7	2	1	46
I3	4	2	3	1	1	12	2	5	13	11	54
I4	6		2	1	1	5			3		18
I5	7	1	7	1	6	20		7	3	5	57
Total	31	5	36	5	10	54	14	19	35	19	228
Segs.	85	21	59	17	12	288	51	38	127	71	767
Pct.(%)	11.1	2.7	7.7	2.2	1.6	37.5	6.6	5.0	16.6	9.0	100
Order	3	8	5	9	10	1	6	7	2	4	

3.3. Conclusion

This study provided the expected results and fulfilled the preliminary study 'creative concept app (IDEATOR)' requirement. In addition, IDEATOR functions as an effective recording tool for future research on concept ideation process. The result shows that GI behaviour in graphic and product designers occurred more frequently than the other 2 types of behaviours. In particular, graphic designers' GI behaviour accounts for more than half of the total number of occurrences. Furthermore, most designers used IDEATOR thought it was understandable and found its most useful feature to be the mental map.

4. References

Ahmed, S. (2005). Encouraging reuse of design knowledge: a method to index knowledge. Design Studies, 26(6), 565-592.

Cheng, P.-J. (2010). A Study on Designers' Searching-retrieving Behavior in the Ideation Process, National Yunlin University of Science &Technology, Unpublished doctoral dissertation.

Cheng, P.-J. (2016). Development of a mobile app for generating creative ideas based on exploring designers' on-line resource searching and retrieval behavior. Design Studies, Vol.44C, 74-99.

Cheng, P.-J. and J. Yen (2008). Study on Searching-retrieving Behaviour in Designers' Ideation Process. Bulletin of Japanese Society for the Science of Design. Vol.55 No.3, 91-98.

Dorst, K. & Cross, N. (2001). Creativity in the design process: co evolution of problem-solution, Design Studies, 22(5), 425-437.

Goldschmidt, G. (1994). On visual design thinking: the vis kids of architecture, Design Studies, 15(2), 159-174.

Herbert, D. (1993). Architectural and study drawings, New York: John Wiley & Sons Inc.

McGown, A., Green, G. & Rodgers, P. (1998). Visible ideas: information patterns of conceptual sketch activity, Design Studies, 19(4), 431-453.

Schön, D. A., & Wiggins, G. (1992). Kinds of seeing and their function in designing. Design Studies, 13(2), 135-156.

Segers, N. M., de Vries, B., & Achten, H. H. (2005). Do word graphs stimulate design? Design Studies, 26(6), 625-647.
Siangliulue, P., Chan, J., Gajos, K. Z., & Dow, S. P. (2015). Providing Timely Examples Improves the Quantity and Quality of Generated Ideas. Paper presented at the Proceedings of the 2015 ACM SIGCHI Conference on Creativity and Cognition, Glasgow, United Kingdom.
Suwa, M., Gero, J. & Purcell, T. (2000). Unexpected discoveries and S-invention of design requirements: Important vehicles for a design process. Design Studies, 21(6), 539-567.
Verstijnem, I., Hennessey, J., Leeuwen, C., Hamel, R. & Goldschmidt, G. (1998). Sketching and Design creative discovery, Design Studies, 19(4), 519-546.
Westerman, S. J., & Kaur, S. (2007). Supporting creative product/commercial design with computer-based image retrieval. Paper presented at the Proceedings of the 14th European conference on Cognitive ergonomics: invent! explore!, London, United Kingdom.

About the Authors:

Cheng, Pei-Jung: She is an associate professor, working for the Department of Advertising at National Chengchi University in Taiwan. Her research interest is to explore designers' cognition and behaviors in ideation. Currently she leads a DCC Lab to develop a brainstorm-supporting tool.

Acknowledgement: The author gratefully acknowledges the support provided by the Ministry of Science and Technology under Grant No. MOST 106-2410-H-036-003-MY2 and MOST107-2622-H-036-001-CC3. Additional thanks go to the 15 designers who participated in this study, and the two coders, Nian-Chen Cai and Tsai-Ping Chang, who participated in the analytic section. This manuscript was edited by Wallace Academic Editing.

Proposed Revision of Airline Corporate Identity Manual: Creating a design that communicates a corporate philosophy formed at inception to an internal and external audience through regional university-industry collaboration

Anzai, Toshinori*; Wakabayashi, Naoki

Sapporo City University, Sapporo, JAPAN
* t.anzai@scu.ac.jp

Japanese regional airline AIRDO Co., Ltd., approached the Sapporo City University School of Design for its cooperation in revising the company's Corporate Identity ("CI") Manual on its 20th anniversary. In order to clarify the concept behind AIRDO's CI, a workshop attended by AIRDO employees and School of Design students to identify the purposes of the company's CI summarized these in a lead statement that was to be placed at the beginning of the manual. The primary feature of this research was that it saw the formation of a "lead statement" that clarified the CI concept and considered its background prior to the revision of the CI Manual. It surveyed ordering departments within the company and external companies (three in total) that receive orders on their use of the CI Manual. Problems were identified, decisions on the revision policy made, and a focus was put on the necessary minimum elements. In addition to the main manual, a digest version concentrating only on use of the logotype and symbol mark and guidelines for external distribution were created. Feedback within the company has been generally positive and the original intention behind the logotype and symbol mark are better understood, and the revised CI Manual is regarded as being easier to read and comprehend.

Keywords: Corporate Identity, Internal communication, Workshop

1 Background

1.1 Current situation and request for revision of Corporate Identity Manual

AIRDO Co., Ltd. ("AIRDO") is a Japanese regional airline established in 1996 and headquartered in Sapporo, Hokkaidō. The company was initially known as Hokkaidō International Airlines, but later renamed AIRDO, the airline's more commonly-known nickname. This name is a play on words that represents both the "*dō*" in "Hokkaidō" and the English verb "do," and evokes the imagery of flying to Japan's northernmost prefecture (Hamada: 1999)[1]. Flight operations commenced in December 1998 and the company recently celebrated 20 years in the air. The logotype and symbol mark were created by graphic designer Shobun Nakashima[2] at the time of the company's founding. Shortly afterwards, a corporate identity ("CI") manual was prepared. However, in the intervening 20 years, various derivations of the logotype and symbol mark have appeared. In 2017, the company made the decision to revise the existing CI manual in the lead-up to its 20th anniversary. AIRDO approached the Sapporo City University School of Design ("School of Design") to engage in a revision of the CI manual through a regional university-industry collaboration request.

1.2 Position of AIRDO and the School of Design

Promoting collaboration between regional industry, academia, government, and financial institutions and contributing to the region is one of the tenets of the School of Design's mission. It engages in student participatory projects closely linked to the region and collaborative research directly connected to the business of regional companies and administrative services related to health, medical care, and welfare. AIRDO, meanwhile, promotes the contribution to regional society in its role as "the wings of Hokkaidō" as a core corporate philosophy. Sharing this philosophy of a desire to contribute to the region, both parties came together to cooperate on this particular project.

1.3 Preliminary survey for CI manual revision

After a preliminary survey (hearing) regarding aspects such as the handling of logo typeface, AIRDO felt that there were several problems in the way of thinking towards corporate identity. Firstly, the question arose as to whether employees correctly understood guidelines concerning logotype and symbol mark or not. It was found that the backdrop to this was a lack of cohesiveness and understanding of the company on the part of employees. Accordingly, ways of expressing the thoughts obtained from employees visually and the possibility of proposing tools to re-familiarize employees with the company were considered. It was thought that perhaps these steps combined could deliver the original intent of the founders when the company was first established to current employees. Based on this thought, a medium by which the thinking behind the company's CI and its concept could be shared both within and outside the company were considered necessary. In view of this, it was decided that a revision of the CI manual would take place based on firmly positioning CI and the CI manual after listening to the thoughts of employees at a workshop.

2 Objective of the Study

In light of the above, it was decided that in this study, revision of the CI Manual would take place after first clarifying the company's CI and the positioning of the CI Manual. For this purpose, the study was to promote further understanding of CI, such as how the company's CI could be understood both internally and externally. Based on this understanding, the aim was to determine how the CI Manual could state simply and clearly how the logotype and symbol mark are to be used. These were the two objectives.

Namely, this was to involve the following two actions:

Objective 1: Propose ways to promote understanding of CI. Have the company's CI understood both internally and externally.

Objective 2: Revise the CI Manual. Transform the current CI Manual to be simpler and easier to understand.

3 Study Method

In accordance with the concept of human-centered design (HCD), the study proceeded along the line of determining the usage situation, clarifying requirements, creating design-based solutions, and verifying that the manual met usage requirements.

To further promote understanding of the company's CI, ideas from employees were elicited at the workshop (see below) and after summarizing these ideas, a list of requirements was created. By documenting these ideas, design-based solutions were formulated, and verification was conducted through a survey of understanding.

In terms of the revision of the CI Manual, the situation regarding usage of the manual was determined through a usage survey (see below) conducted in each department and the results of these surveys identified usage requirements – in other words, it pointed the way towards revision policy. Clarifying the relationship between logotype and symbol mark as originally intended, unnecessary information was deleted and by adding required information, a design-based solution was created and verified by surveying readability and so on.

3.1 Method of Promoting Understanding of AIRDO CI

CI is primarily a concept whereby a company unifies its corporate and organizational philosophies and communicates these externally. In order to communicate a message externally, there first needs to be information to convey and particular media by which it is to be transmitted. The personnel that comprise the company or organization are tasked with this exercise – it is they who best understand the information and content. To communicate better to an external audience, there needs to be loyalty towards and trust in the organization in addition to a correct understanding of the message to be conveyed. Cohesiveness in the organization is required and this should manifest itself in any external messaging.

Consequently, it is vital to achieve 'inner communication' prior to undertaking any 'outer communication'. The inability to undertake inner communication will not lead to optimized outer communication.

As a preliminary process to revising the CI Manual, a proposal was made to create a story about the CI (logotype and symbol mark) to promote the understanding of CI within AIRDO and to further inner communication. The steps specifically taken are outlined below in '4 Promotion of Understanding of CI: Creation of Lead Statement through Workshop'.

3.2 Revision of the Current CI Manual

With the creation of the story of the CI (logotype and symbol mark) described in '3.1 Method of Promoting Understanding of AIRDO CI' to gain further understanding within the company in mind, the following methods were to be undertaken in the revision of the current CI Manual:

- Clarification of objective: Clarify the purpose of the revision through discussions.
- Determine usage situation: Through interviews and so forth, ask about current usage of the CI Manual, areas that are lacking, problem areas, etc.
- Identifying problems: Elucidate problem areas through brainstorming sessions, etc.
- Clarification of requirements: Clarify requirements (goals) by looking at objective of the manual, it's aims, problem areas, etc.
- Presentation of solutions: Examination of solutions and their feasibility, etc., and summarize proposals and how they can be actualized.
- Proposal evaluation: Evaluation as to whether proposals meet requirements or not.
- Improvements as required: Proposal improvement according to evaluation results.

3.3 Schedule

The overall schedule is shown in Table 1.

Table 1 Schedule.

Item	Overview	Details	2017			2018				
			Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Creation of CI (Logo) story										
	Survey/Workshop on corporate philosophy and its background									
	Clarification of CI (logo) story requirements									
	Proposal of basic design of the CI (logo) story as a potential solution									
	Evaluation of proposal and creation of beta version based on it									
Revision of current CI Manual										
	Clarification of objective	Clarify the purpose of the revision through discussions.								
	Determine usage situation	Through interviews and so forth, ask about current usage of the CI Manual, areas that are lacking, problem areas, etc.								
	Identifying problems	Elucidate problem areas through brainstorming sessions, etc.								
	Carification of requirements	Clarify requirements (goals) by looking at objective of the manual, it's aims, problem areas, etc.								
	Presentation of solutions	Examination of solutions and their feasibility, etc., and summarize proposals and how they can be actualized.								
	Proposal evaluation	Evaluation as to whether proposals meet requirements or not.								
	Improvements as required	Improvement proposals according to evaluation results.								

4 Promotion of Understanding of CI: Creation of Lead Statement through Workshop

As stated above, incorporating the thoughts of the founders at the time of the company's founding, thoughts employees have towards the company, the thinking behind AIRDO's CI and so on in a story explaining the CI (logotype and symbol mark) was considered.

4.1 Objectives behind creation of CI (logotype and symbol mark) story

The objectives behind the creation of a story about the company's CI (logotype and symbol mark) were as follows:

1. Convey the story behind the AIRDO company name in an easy-to-understand manner.
2. Convey the meaning behind and ideas embodied in the logotype and symbolmark/symbol color.
3. Explain not only the steps in the development of the actual design, but also the thoughts held by those involved at the time.
4. As a message from the company to its employees, convey the company's idea (vision) through the logotype and symbol mark/symbol color in an easy-to-understand manner.

4.2 Method of implementing the creation of the CI (logotype and symbol mark) story

A workshop involving AIRDO employees and students from the School of Design was held in order to obtain the information required to achieve the aforementioned objectives.

The background to the AIRDO logotype and symbol mark and the thoughts it encompasses were to be clarified. The workshop employed the 'doodle communication' method, currently in development by Naoki Wakabayashi (2017)[3], one of the authors of this study, and his team. Specifically, as shown in Figure 1 (left), the interviewer recorded the details heard from the interviewee in graphical form on the spot using figures, keywords, and so on, and collated these with the interviewee to be shared among participants by putting them all together as shown in Figure 1 (right). As a note, the drawings made during the 'Doodle

Communication' process are called 'Doodle graphics'. 'Doodle Communication' and 'Doodle Graphics' will be explained in detail in the next section.

The outline of the workshop is as follows:

- Date/Time: January 10, 2018, 16:00-17:10
- Location: AIRDO Headquarters (Chuo-ku, Sapporo)
- Participants:

AIRDO:	Representative from the CS Promotion Office, General Administration Department Director, and Representative from Corporate Safety Office (Total of 3 people)
School of Design:	3 students

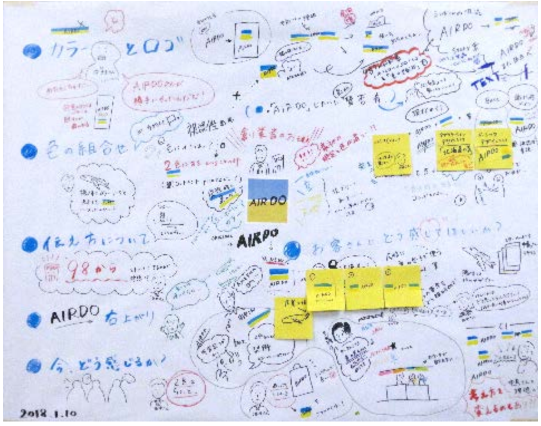



Figure 1. 'Doodle Graphics'. Taking down ideas (left) and the final outcome (right)

The most important consideration in the creation of the CI (logotype and symbol mark) story was that, rather than digging up the past, the story should be created anew; this was seen as a way of bringing out the views of current employees. At the same time, it was decided that a survey on corporate philosophy and its background and a workshop regarding this area would be held, CI (logotype and symbol mark) story requirements would be clarified, and a CI (logotype and symbol mark) story then put forward.

4.3 Doodle Communications/Doodle Graphics (Dialogue mediated by visual expression)

The process of 'Doodle Communication' is intended to allow an individual to freely draw what they experience in doodle form, objectifying these experiences in order to create concrete images to share with others.

By externalizing the memories based on one's own or others' experiences as a concrete image, it becomes possible to objectively accept these experiences as a tangible reality. In addition, through this drawing process, the experiences can be recalled and minor details confirmed. The images drawn in this process are what have been termed 'Doodle Graphics' and may be saved for later review or as a record of the experience.

The drawn representations ('Doodle Graphics') allow for the images and, in turn, the experiences they represent to be shared with others. By drawing an image while talking with people around oneself or other participants of what you and the other person experiences during such interaction, in addition to being able to confirm and recall the memory of what was discussed, it can be expected that additional information can be supplemented and confirmed through dialogue.

In addition, others that the dialogue is shared with may also participate in the drawing of the images; these images can then be turned into ‘Doodle Graphics’. Effects such as raising motivation to draw through dialogue and lowering the difficulty of the act of actually drawing can also be expected due to this.

Doodles drawn through such a process can also be used as drafts for presentations or drawing production, and this is a method that can be expected to have a positive effect on the approach of sharing images in the process of communication.

There are several visual recording methods utilizing illustrations and keywords that have been proposed, such as graphic recording at meetings and so on that combines illustrations and keywords[4], and graphic methods of facilitation that are shared with participants that illustrate the content of previous discussions and the direction those discussions have developed to promote the progress of the meeting[5].

On the other hand, ‘Doodle Communications’/’Doodle Graphics’ are techniques that can be powerful tools to develop discussions by means of visual expression-mediated dialogue generated while drawing illustrations and keywords during dialogues.

By “drawing what you talk about” (record), “draw what others have talked about” (confirm), and “leaving a trace of what steps the conversation took” (draw relationships) in a free manner that takes the form of doodling, the result may be utilized as a visual dialogue tool.

4.4 From creation of a CI (logotype and symbol mark) story to becoming a manual lead statement

The outcome of the workshop was summarized in what was described as the ‘AIRDO Logo Story Memo’. However, after discussions with AIRDO, rather than have this summary in a story form, it would become the lead statement in the revised CI Manual.

The workshop found that the way in which the logotype and symbol mark have been used to date differed from the usage rules established at the time the company was founded. Figure 2 shows the way in which the logotype and symbol mark are currently used. However, as Figure 3 shows, they were originally not meant to be overlaid but later, contrary to the designer’s intentions, this in fact took place.

Figure 2. Conventional logotype and Symbol mark

Figure 3. Conventional logotype and Symbol mark

The lead statement was amended to include words from Shobun Nakashima, the graphic designer who created the logotype and symbol mark: “The AIRDO symbol represents the clear blue Hokkaidō skies, and in addition to the color of the wide-open land covered with a blanket of flowers in full bloom, the yellow also expresses the clarity of mind found in those with an entrepreneurial spirit.” These are the very concepts embodied in the company name of AIRDO, which represents both the “*dō*” in “Hokkaidō” and the English verb “do” - a graphic expression of the feeling of flying to Hokkaidō.

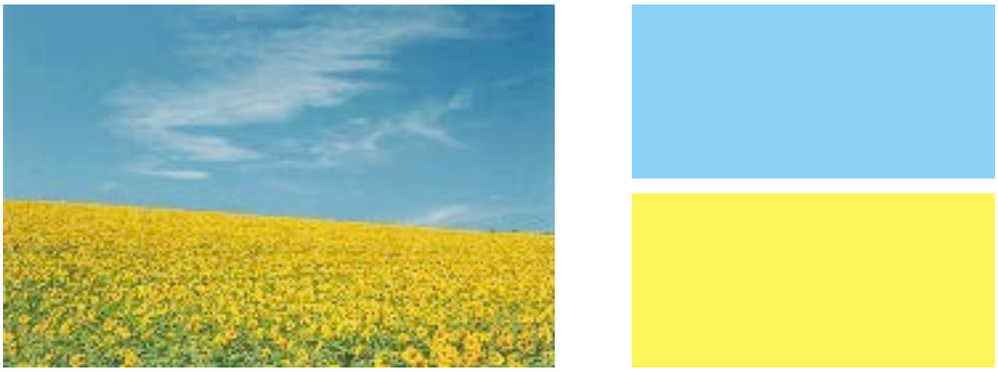


Figure 4. Motif of symbol mark: sky and earth in Hokkaido (left), symbolic mark (right)

Figure 4 (left) is a photo that shows this image of the Hokkaidō sky and the land covered with blooming flowers; the AIRDO symbol mark/symbol color (Figure 4 (right)) is an expression of this scene.

It was decided that the revised manual would exclude the design usage shown in Figure 2 and instead only include the correct usage stipulated at the time the company was founded.

5 CI Manual Revision

5.1 Usage Survey

The usage survey was primarily conducted in order to determine the way in which the CI Manual is used so that its revision would be in line with a human-centered design (HCD) philosophy. The survey was conducted for those accepting orders for the use of the CI and for those on the ordering side. An overview is provided below.

Objective: To determine current usage of the AIRDO CI Manual.

1. Determine usage of the CI Manual by parties receiving orders
2. Elucidate problem areas in the CI Manual from parties receiving orders
3. Determine usage of the CI Manual by parties submitting orders
4. Elucidate problem areas in the CI Manual from parties submitting orders

5.2 Method: Semi-structured Interviews

Semi-structured interviews were conducted with an advertising agency, a printing company, and a production company – typical examples of companies with which orders are placed by AIRDO.

Date/Time: November 9, 2017 (Thu) 17:30-19:30, December 5 (Tue) 17:30-19:30

Location: AIRDO Headquarters meeting room

Target: Parties receiving orders (advertising agencies, printing companies, production companies)

5.3 Outcomes

Outcome of Objective (1): Mainly refer to the Manual for use of the logotype. Relatively easy to deal with.

Outcome of Objective (2): They require more rigorous guidelines, such as logotype isolation rules and its relationship with backgrounds. Need rules to be stipulated.

Outcome of Objective (3): Parties with which orders were placed and how the CI Manual is used/its development chronology were understood.

Outcome of Objective (4): Difficult-to-use and problematic areas were identified, and requests, etc., in regards to the creation of a web-based manual were better understood through manuals created by other companies. In addition, an understanding on the restrictions on the use of the AIRDO mascot character, ‘Bear Do’, was gained.

Summarizing the above and organizing requested items formed the core of the proposal.

While there was the opinion that the logo was easy to use and the CI Manual was easy to understand, there was also a call for more examples of misuse and a shorter, “digest” version of the manual (detailed version).

Based on the above, the following CI Manual revision policy was adopted.

5.4 CI Manual Revision Policy

Narrow down to the minimum requirements
A staged development process was to be adopted to achieve this:

1. Digest version and explanation (detailed version)
2. Construction of CI Manual operational flow
3. Case studies (style book)
4. Web version (electronic version)

It was decided that for FY2017, only the first of the above processes would be completed.

6 Final Proposal

6.1 Summary of Final Proposal

Based on the above policy, the manuals shown in Figure 5 below were completed at the end of May 2018 after re-collating the minimum information required.

1. Manual for internal use: ‘CI Manual Ver. 3.0’
2. ‘CI Manual Digest Ver. 1.0’
3. Manual for external use: ‘CI Guidelines Ver. 1.0’

While the lead statement cannot cover the entire content of the manual, it encompasses the philosophy held by Shobun Nakashima, the person behind the design of the AIRDO logo and corporate colors, and accurately communicates the thinking behind the company’s CI at the time of its founding to an external audience.

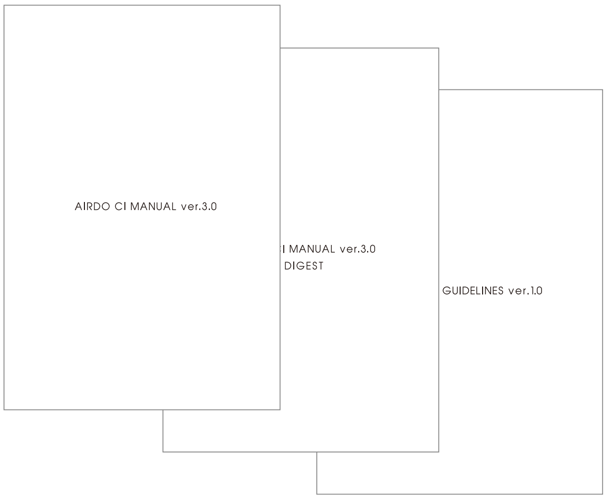


Figure 4. Cover of the proposed manuals

6.2 Evaluation of Final Proposal

Due to cost concerns, the revision of the usage items in the current CI (VI:Visual Identity) would not possible all in one go – it was therefore decided that it would be revised gradually. For this reason, since usage has not permeated to external contractors, an internal evaluation of the final proposed revisions would first take place. As there were only a few people involved with the CI Manual without the presence of external contractors, there was a limited number of people who took part in the survey. The evaluation primarily addressed the level of understanding of the lead statement (‘The AIRDO Logotype and Symbol mark’ section at the beginning) and the readability and simplicity of the CI Manual as a whole.

The evaluation schedule and outline were as follows:

- Period conducted: January 9-15, 2019
- Location: AIRDO office. Based on the original draft created by the School of Design, AIRDO employees responded to the questionnaire form created by the AIRDO CSR department.
- Respondents: 17 individuals at AIRDO involved with CI manual.
- Main question details:

1. Status of use of the CI Manual within respective departments
2. Lead Statement.
   2.1. I understood the origins behind the logotype and symbol mark after reading this Lead Statement.
   2.2. I felt more of a sense of placing importance on the use of the company’s logotype and symbol mark after reading this Lead Statement.

2.3. After reading this lead statement, I now feel a greater sense of affinity to the company (AIRDO)
2.4. Please state any opinions you may have on the Lead Statement (free answer).
3. Readability, etc., of the CI Manual
3.1. The page layout was easier on the eye than in the previous manual.
3.2. The new structure made it easier to understand than the previous manual.
3.3. The contents were better organized than in the previous manual.
3.4. It was easier to use than the previous manual.
3.5. Please state any opinions you may have on the CI Manual (free answer).

Questions 2.1 to 2.3 and 3.1 to 3.4 were on a five-point scale, with ‘1’ being ‘Strongly disagree’ and ‘5’ being ‘Strongly agree’.

Table 2. Questionnaire Results

No.	2.1	2.2	2.3	3.1	3.2	3.3	3.4
Question	I understood the origins behind the logotype and symbol after reading this Lead Statement.	I felt more of a sense of placing importance on the logotype and symbol after reading this Lead Statement.	After reading this lead statement, I now feel a greater sense of affinity to the company (AIRDO)	The page layout was easier on the eye than in the previous manual.	The new structure made it easier to understand than the previous manual.	The contents were better organized than in the previous manual.	It was easier to use than the previous manual.
Average	4.0	4.2	3.5	4.2	4.1	4.1	4.0
Standard deviation (SD)	0.77	0.98	0.92	0.62	0.73	0.76	0.69

The results are as shown in Table 2. These were most favorable, with almost all being a ‘4’ or above. There was a discrepancy in the results for Question 2.2 ("I felt more of a sense of placing importance on the logotype and symbol mark") and while the results were positive, it is difficult to say consensus was found on this point. It was hoped that the most positive effect would be shown in Question 2.3 (“After reading this lead statement, I now feel a greater sense of affinity to the company (AIRDO)”), but the results were somewhat disappointing for this question. However, as Question 3.1 (“The new structure made it easier to understand than the previous manual.”) had consistent, favorable results, it is thought that manual layout had become easier to read.

6.3 Improvement of final proposal

At the time of writing this paper, the “Proposal improvement according to evaluation results”, as stated at the end of ‘3.2 Revision of the Current CI Manual’ above, has yet to be implemented. The questionnaire showed poor results for 2.3 “After reading this lead statement, I now feel a greater sense of affinity to the company (AIRDO)”. To improve this situation, it was surmised that the CI Manual be used in conjunction with other internal communication methods.

Furthermore, the free answer sections included opinions such as, “There are too many paragraphs in the Lead Statement” and “The sentences are too long.” There is room for improvement in the writing style and doing so in a way that keeps the main gist of the Lead Statement.

7 Conclusions and Future Work

7.1 Observations

Revision of the parts of the manual concerning use of the logotype and symbol mark was put aside for the time being, and as it was decided that recreating these parts would be undertaken based on the new manual, large-scale revision of signboards and stationary and the like will not be made yet. Therefore, while things are not yet at the stage where the concepts have penetrated deeply among the workforce, the results of ‘6.2 Evaluation of Final Proposal’ above at least indicate that they are starting to understand the enthusiasm the company’s founders had when they established AIRDO and the underlying intentions behind the logotype and symbol mark. In addition, employees reported that the final proposed revised manual was easier to read and understand than the original.

7.2 Conclusions

Although contained in the CI Manual’s Lead Statement, the philosophies present at the company’s beginning were clearly laid out and it could be shown that, from the company’s point of view, the CI should be maintained in-line with these and the fact that the intention behind the CI Manual could be demonstrated was one important outcome. We also believe that the CI Manual was able to be revised based on the usage survey and that we could again show the use of the logotype and symbol mark as originally intended.

As described above, there were two study objectives:

Objective 1: Propose ways to promote understanding of CI. Have the company’s CI understood both internally and externally.

Objective 2: Revise the CI Manual. Transform the current CI Manual to be simpler and easier to understand.

By returning to the basics on the company’s 20th anniversary and revising the manual after clarifying the positioning of the CI itself, we believe that the two original objectives were fully achieved.

7.3 Findings from this research

1. Effectiveness of the ‘Doodle Graphics’ method
   The ‘Doodle Graphics’ method used in this study enabled employees to express their thoughts about the company. It also proved to be effective by allowing us to discover the sequence of events behind the creation of the logotype and symbol mark/symbol color at the time of the company’s founding. ‘Doodle Graphics’ has traditionally been used primarily by places such as zoos and aquariums and aimed at children or younger students – there has been no case to date where it has been used by a company in this field. This study showed that the ‘Doodle Communication’ method may also be of use in certain corporate activities and it can be said that its range of application has been expanded.
2. Internal communication
   “3.1 Method of Promoting Understanding of AIRDO CI" demonstrated the importance of communication within the company. This study attempted to develop greater internal communication by way of the CI Manual Lead Statement. There were, no doubt, many employees who were not fully familiar with the meaning of the company logotype and symbol mark, developed 20 years ago. It is assumed that at the very least, an understanding of these was furthered thanks to the Lead Statement.
3. External communication
   The results of the questionnaire showed that, compared to the previous version, employees felt that the updated manual was easier to read and understand, more readily navigable, and the contents better organized. While the investigation did not extend to external vendors and the like, a similar positive outcome could be expected

with those users. In terms of external communication, it can be assumed that the CI Manual revision was effective.

7.4 Role of this study in a design context

As mentioned above, the study provided an example where the ‘Doodle Communication’ method was used in a setting close to a company’s business and that it could be used effectively as a corporate activity.

The Lead Statement showed that internal communication can be promoted by telling the story behind the creation of the logotype and symbol mark/symbol color at the time of the company’s founding. It is envisaged that by again presenting the company’s founding philosophies and the reasons for it’s inception in future CI development and in CI Manual creation/revisions and so on to employees can contribute to the promotion of internal communication.

Needless to say, by taking a human-centered design approach to determine the usage situation, clarify requirements, create design-focused solution proposals, and verify if requirements are being met, it is expected that construction/revision of an easy-to-understand manual is possible.

7.5 ’Doodle Communication’ as an Exercise in Design Thinking

It goes without saying that most projects that involve designers are based on design thinking.

In ‘Doodle Communication’, the interviewer engages in a conversation with those being surveyed or project participants and writes down notes or draws figures as they go. This action corresponds to observation and empathy. ‘Doodle Communication’ itself creates an empathetic environment; the ‘Doodle Graphics’ are the tools used to express that empathy.

While writing down words and figures, the interviewer develops a story. The definitions of this are the problems that are identified and the summary of issues that arise out of this process. In this exercise, words and figures have a creative role – ‘Doodle Communication’ promotes ideas and their conceptualization.

Words and diagrams relating to a certain direction or aiming towards a particular direction almost simultaneously take on the definition of a prototype. Additionally, the process prompts those participating to give their evaluation on the spot, test ideas, and have improvements made based on a particular judgement.

It is thought that these design thinking processes are carried out almost simultaneously in parallel. The design thinking approach found in ‘Doodle Communication’ requires a trial and error process as a way of pursuing further analysis and determining methodology in future; it may prove to be an important method to be incorporated in the design process and for designers.

7.6 Future work

As requests from employees arose during the work on revising the CI Manual, efforts are currently underway to create specifications for a revised web-based version of the manual. With the development of these specifications, the process of going back to examine CI-related brand identity and visual identity has also begun.

It is hoped that efforts to revise the CI Manual will ensure that AIRDO’s CI will be understood not only by employees and the various parties involved in producing company materials, but also by those who fly with the airline.

References

1. Hamada, T. (1999). *Zero kara idonda kokugaisha*. Tokyo: Wave.
2. Shobun Nakashima: Profile (2019, January 3) Retrieved from URL http://shobun-nakashima.com/profile/
3. N. Wakabayashi *et al*., Comparative analysis of dialogue by graffiti participants of workshop with impression thermometer, PROCEEDINGS OF THE ANNUAL CONFERENCE OF JSSD, 2017 Volume 64 B9-04
4. Shimizu, J. (2017). *Graphic Recorder - Textbook for graphic recording which visualizes discussion*. Tokyo: BNN.
5. Debiddo Shi Bet (2013). *Visual Meeting Yoso Gai No Idea to Seika Wo Umu "Team Kaigi" Jutsu.* Tokyo: Asahi Shimbun Publishing.

About the Authors:

ANZAI, Toshinori: Ph.D., Professor, School of Design, Sapporo City University; Graduated Master's Course at Graduate School of Engineering, Chiba University (1982); Part-time lecturer at Design Dept, Chiba University (2004); Ph.D. (Engineering) Chiba Institute of Technology (2014); Sapporo City University (2015)

WAKABAYASHI, Naoki: Ph.D., Professor, School of Design, Sapporo City University; Kanazawa College of Art (1981); Graduated Master's Course at Graduate School of Art, Tsukuba University (1984); Lecturer at School of Design, Okayama Prefectural University (1994); Ph.D. (Kansei) Tsukuba University (2006); Sapporo City University (2017)

IASDR 2019

International Association of Societies of
Design Research Conference 2019
DESIGN REVOLUTIONS

Manchester School of Art
Manchester Metropolitan University
02-05 September 2019

The use of design thinking in non-design contexts – a journey and experience

Burns, Kathryn*[a]; Carter, Claudia[b]; Ahmed, Zuby[c], Sisay, Susan[d]

[a] School of Fashion and Textiles, Birmingham City University, Birmingham, England, UK
[b] School of Engineering and Built Environment, Birmingham City University, Birmingham, England, UK
[c] New Technology Institute, Birmingham City University, Birmingham, England, UK
[d] Business School, Birmingham City University, Birmingham, England, UK
* kathryn.burns@bcu.ac.uk

Design thinking is gaining momentum for developing solutions to issues in many areas, eg, health, education and business management. It is seen as a tool for improving creativity, addressing complex or wicked problems and a method for promoting interdisciplinary working among students and professionals. In this paper, we focus on the experiences of four academics on their design thinking journey as part of a European project. This aimed to share design thinking skills and processes for peer training and application with non-design student cohorts. Important is the fact that none of the participants are trained designers. The four have been participants, facilitators and teachers and been subject to and used design thinking tools and techniques in a variety of contexts, together and individually. By reflecting on these experiences and drawing out lessons learned the paper argues that design thinking is useful in a non-design context and has become well enough defined to be applied by people whose background is not design. The paper concludes with some key factors in delivering design thinking workshops for the future as well as identifying areas for further research.

Keywords: design thinking, interdisciplinary working, divergent, convergent

1 Introduction

This paper is based on the experiences of four people who have been involved in a pan European project, 'DT.UNI – Design thinking approach for an interdisciplinary university'. The project is part-funded by the Erasmus+ programme and is led by the University Maria Curie Sklodowska, in Lublin, Poland with partners from seven other European countries: Bratislava, Germany, Iceland, Italy, the Netherlands, Portugal and the UK (see www.umcs.pl/en/about-the-project,13514.htm). Throughout this paper, the project is referred to as DT:Uni.

The main aim of the project is the stimulation of interdisciplinary work in higher education (HE) institutions. This is considered as a means of equipping the next generation of workers with problem solving skills whereby they become the producers, not just consumers, of knowledge.

DT:Uni is proposing to achieve its aim by instilling design thinking methods in three interlinked HE groups: academics; HE managers and students. This will be achieved through a number of international workshops held across Europe, as well as the development of workbooks and case studies relating to the implementation of design thinking in HE. The project suggests that design thinking will enhance the level of interdisciplinarity among participants by improving their abilities to think in a divergent, creative and designerly way. It should also develop their abilities to introduce the design thinking approach into the teaching and learning environment of 'non-design' courses. In the project, design thinking focuses on and is empathetic with the user as well as enabling divergent and convergent thinking. It is viewed as a method for solving complex or 'wicked' problems. In short, the DT:Uni project is about facilitating processes, experiences, experiments and reflective practice with a focus on design thinking methods rather than designerly thinking skills.

The project comprises international workshops that train academics and managers in design thinking techniques and tools. Participants are then obliged to hold local multiplier events, where they train their colleagues in a similar fashion. The project also includes local workshops and innovation bootcamps for students. Winners from the local bootcamps will attend an international bootcamp for students to be held in Poland towards the end of the project.

The workshops are supported by the development of various materials such as handouts, programme guidelines for trainers and task descriptions based on real-life challenges. There will also be an e-book of case studies to demonstrate best practice in design thinking and interdisciplinarity as well as teaching materials. It is intended that these materials are tested through the workshops.

Thus, the overall rationale of the project is to 'train' people in design thinking who then take the principles back to their institutions to implement for groups of students, academics and management staff. The first international workshop was held in Dresden in April 2018 and organised by Technische Universität Dresden. This paper considers four people who took part in that workshop and explores their individual and joint experiences post the workshop. The participants had different levels of design thinking experience from expert to novice and a range of backgrounds encompassing environmental studies, game design, entrepreneurship, business studies and project management.

2 Literature review

To help us contextualise our own experiences and findings, our review concentrates on recent work that relates to using design thinking in the HE context. While still a relatively new and evolving field, the benefits of using creative thinking approaches in HE seem to be supported by evidence from action research and pedagogic studies (eg, Bennett et al.,2015; Blanco et al., 2017; Wrigley & Straker, 2017; Mosely et al., 2018; Pohl et al., 2018; Tu et al., 2018). Design thinking has also captured interest in secondary level education (eg, Aflatoony et al., 2017; Cook & Bush, 2018) and teacher training with the need for educators to be innovative and creative in their facilitation of learning (eg, Norton & Hathaway, 2015; Henriksen et al., 2017).

The study by Mosely et al. (2018) is probably closest to our own focus. Their research built on work conducted as part of two Masters projects, with case studies in Brisbane (Australia) and Utrecht (The Netherlands) where one-off 2-2.5 hour informal design thinking workshops were held for undergraduate students. The authors focus on critically appraising how the level of design knowledge and experience by facilitators/tutors impacts on teaching design thinking to students from a range of non-design based disciplines with a view to establishing "what level of design expertise facilitators require to educate non-design students" (Moseley et al., 2018: 177). They also considered the complexity of the 'problem', or design challenge, and how this may have to be adjusted to the level of familiarity by students with design thinking type approaches and their willingness or ease to 'change' the mindset from 'traditional' (linear) towards creative thinking.

While a relatively small sample, the research found that designerly thinking by design-based tutors pitched the delivery and analysis of design thinking processes and outcomes at a 'higher' level compared to facilitators who were classified as design thinking novices. Reflections and comments of the latter focused mainly on design thinking methods and processes, whereas facilitators trained in design paid attention to how design thinking approaches will coach students in designerly thinking and mindset change – moving from a discussion-based approach to a more creative, experimental and innovative thinking approach. Limitations of the study were the very short design thinking 'educational' sessions and it was felt retrospectively that a half or full day workshop would be ideal.

The distinction between design thinking (or design science) and designerly thinking (or design as a discipline) has been made clearly (eg, Cross, 2001; Mosely et al., 2018). While designerly thinking is firmly rooted in the design profession and courses, design thinking has evolved for and within non-design based contexts. Importantly, there appears to be a further contrast between the two, namely design thinking being explicitly group based and usually interdisciplinary whereas designerly thinking tends to be largely focused on the individual. We found this an almost hidden part of many papers and this element proved of particular interest and relevance in our own research. For example, Tu et al. (2018: 2649) highlight "the purpose of interdisciplinary collaboration" and worked with groups of 3-4 students. Similarly, Henriksen et al. (2017: 150) emphasise the importance of viewing the challenge from "multiple perspectives".

Attention is paid in various case studies and by a range of authors to what extent designerly thinking is something that can be acquired 'quickly' and outside design practice and studies. It appears that the popularity of design thinking has shifted attention away from 'designerly thinking' as a 'trait' and that it should be more usefully understood as a habit of mind or approach (Cropley, 2016; Baaki et al., 2017; Henriksen et al., 2017). Stables (2008), for example, argues that educators should facilitate the development of design capabilities (which could be argued to include doing, thinking, experimenting) at all levels of education (rather than being the sole domain of 'designers'). This then highlights the need to probe more into the 'robustness' of approaches and integrity of design thinking processes rather than simply jumping on a bandwagon.

Different models of and guidance for design thinking exist. For example, the Stanford guide (Doorley et al., 2018) and IDEO's Design Thinking for Educators' Toolkit (IDEO, 2013) in North America and the Design Commission (2011) in the UK. The DT:Uni consortium also will publish an online design thinking manual. In our research we draw on five stages (define challenge, explore, create/ideate, prototype, evaluate) as part of a double-diamond approach emphasising the need for phases of opening up (diverging) and closing down (converging) as part of the design thinking process (see, eg, Shapira et al., 2017). The importance of opening up and closing down has also been made in other fields such as participatory processes as part of deliberative democracy (Stirling, 2008). With the emphasis of design thinking to address 21st century complex social, economic and environmental challenges, the connection to social-ecological literature beyond design seems also very relevant and is reflected in the range of fields of design thinking applications (eg, Cahn et al., 2016; Eckman et al., 2016; Mummah et al., 2016; McGann et al., 2018; McLaughlan & Lodge, 2019).

3 Methodology

Our analysis is based on reflective practice of the workshops we attended and/or organised. All workshops were based on the same model of design thinking and used a set of prescribed tools. Although not stressed during delivery, divergent and convergent processes were used within each phase. For example, we tended to use a form of brainstorming as an idea generator (divergence) and clustering and dot voting to filter ideas (convergence). Where possible, progress was summarised and the adopted design thinking methods reviewed at the end of each day using various participatory and reflective tools. Prototyping was based on various materials including paper, cardboard, Lego and the ability to wireframe. The following provides more details.

3.1 International workshop for academics

The international workshop for academics was held in Dresden over five days in April 2018. Attended by representatives of all DT:Uni partners, each day covered a different phase of design thinking: defining the challenge; explore; create; prototype and evaluate. Participants worked in groups of five to six and were introduced to various tools and techniques as summarised in Figure 1. During the prototyping stage all groups developed, unprompted, a video of their solution. The authors of this paper all attended this workshop.

Prior to the workshop, all participants completed a questionnaire that asked about their level of design thinking knowledge as well as for three challenges in their daily work. The latter were used as the basis for defining the challenge on the first day. These mainly covered motivating students and finding time to do research.

3.2 International workshop for HE managers

This workshop for university managers was held in Birmingham, UK in November 2018. It followed the same format as the Dresden workshop, using the tools and techniques as given in Figure 1.

Again, all participants completed a questionnaire that asked about their level of design thinking knowledge as well as for typical challenges in their daily work. Here concerns included attracting overseas students and developing lifelong learning.

3.3 Local workshop

Through discussions with the local project team, including the authors, the multiplier workshop condensed the five day process into a single day. To accommodate the reduced time span the participants were provided with a predefined challenge: ‘how can you motivate students to engage within the teaching & learning experience?’. This was supplemented with four identified student personas drawing on those developed during the Dresden workshop. The tools used for each stage are also shown in Figure 1.

	Form and define	Explore	Create	Prototype	Evaluate
DRESDEN - academics	• Icebreaker • Brainstorm challenges • Storyboard – who, what, how, why	• Warm up • Topic vote • Interviews • Persona • How might we? • Evaluation	• Warm up • Brainstorm (evil, nice, quick, realistic ideas) • Brainwriting • Write a postcard to explain the solution – goal, who, how • Evaluation	• Warm up • Build a prototype solution • Evaluation	• Robot warm up • Evaluation of the week individually, teams, whole group
BIRMINGHAM - managers	• Icebreaker • Present challenges • Select your preferred challenge	• Team forming • Explain to a stranger (museum) • Mindreading • Persona • Analogies – perspectives • Stakeholder mapping • How might we?	• Lean Café • Design brief • Brainstorm • Brainwriting • Idea communication sheet	• Introduction to prototyping (included make a phone holder) • Rapid prototyping sheet • Build a prototype • Pitch the solution (videoed)	• 'Show and tell' of prototypes (peer review) • Evaluation of the week individually, teams, whole group • Next steps
BIRMINGHAM – one day multiplier for academics	• Challenge and groups predefined	• Persona (based on examples) • Customer journey	• Brainstorm • Brainwriting	• Introduction to prototyping • Build a prototype • Peer review	• Post workshop evaluation by email

Figure 1.Phases and tools used during the workshops

3.4 Other activities

As well as attending and facilitating workshops all authors have used design thinking methods in other areas since the Dresden workshop. These include teaching, work with external organisations and research. These have been captured in individual questionnaires that the two lead authors put together to stimulate reflection and capturing experiences and which were completed by all four authors.

4 Results and discussion

The following presents the major findings from the pre and post questionnaires for the workshops. These are supplemented by reflections of the four academics arising from observations during planning, participating in and facilitating DT:Uni workshops, or teaching experiences in a design thinking context.

Feedback from the wider participants of the workshops has been very positive. The vast majority of participants have enjoyed the design thinking process and felt enthused as a result.

The findings have been grouped to cover opportunities, challenges and benefits of the design thinking process as experienced during the DT:Uni project, as these seemed to be the dominant categories within the individual and group-based reflection tasks.

4.1 Opportunities

4.1.1 Group working

A major part of the design thinking process as used in the DT:Uni project has been the formation of interdisciplinary cross-institutional groups to find solutions. Due to the range and type of tools used various positive effects have been observed. These include:

- Many design thinking methods, such as, brainstorming and brainwriting, encourage interdisciplinary working and allow all group members to present their ideas.
- In a similar vein, groups have not been hierarchical and trust has formed in groups relatively quickly.
- The process also promotes peer review as part of working groups, so that ideas are discussed and assumptions challenged and/or tested in a relatively safe environment.
- In developing solutions, group members felt that they would not have arrived at such effective solutions individually.

As reported by one facilitator at the academic one day workshop: “all groups seemed to develop quite good interdisciplinary communication and collaborative group dynamics”, even though one group initially had some character frictions but this issue seems to have disappeared by the start of the prototyping phase.

However, the positive aspects of group working may result from the people involved not working together on a daily basis and where new working relationships are temporarily formed and no ‘history’ (good or bad) dominating group dynamics. If the group includes participants with persisting relational tensions, the challenging nature of the design thinking may block ideas and stifle creativity. We also encountered situations where the attempt to use design thinking internally was resisted and seemed to be seen as a threat to decision-making power and ‘preferred’ ideas or trajectories.

4.1.2 Prototypes of solutions – testing ideas

All workshops have included building a prototype as a means of hands-on shaping and testing of ideas. The longer workshops have also resulted in the production of videos or pitches where the prototype is used as the basis of an explanation to help sell the idea through the institution, particularly levels of senior management. In all instances the prototyping activity seemed to flow very smoothly and was easily delivered within the allocated time; and this efficiency and ease impressed several participants.

Prototyping also allowed thinking time for participants to consider how to use design thinking methods and create innovative solutions in their own area of work. A physical artefact, constructed from Lego, paper, cardboard and other materials, allowed peer review of proposed solutions and an opportunity to discuss, share and get useful and relevant feedback from colleagues and/or potential users.

Furthermore, the model also provided an opportunity for storyboarding the user experience of the solution. This provided opportunities to visualise the results and record videos or similar to promote the benefits of the proposal in a time efficient and resource effective manner. While the artefacts were dismantled at the end of the prototyping session, the videos produced are still accessible.

4.1.3 Different methods and tools provide versatility

Reflection on using design thinking with students has highlighted that the different tools and techniques clearly map on to different types of learners and learning styles. Also, the design thinking techniques such as personas, empathy map, test grid and customer/user journey maps can be combined with more traditional management tools to develop new materials for small business management students.

4.2 Challenges

4.2.1 Choosing the right tools

As evidenced in a number of design thinking toolkits (eg, Fraser, 2012; Lewrick et al., 2018) there is a plethora of tools and techniques available. Also, underlying the DT:Uni toolkit, there seems to be an assumption that the sequence of ‘define the challenge, explore, create, prototype and evaluate solution(s)’ is the best way of applying the design thinking process. This leads to a number of issues including:

- In defining the initial challenge and workshop format, we had a number of debates on how prescriptive versus how flexible the process should be. How much should this stage be guided by existing design thinking templates or own preferences?
- When facilitating workshops, we found that sometimes the overall process or a particular tool were not well explained. Instructions need to be clear and easy to understand and ideally appeal to different learning styles, eg, oral and visual.
- In moving onwards, it is easy to forget to check back on how well a proposed solution addresses the initial challenge and meets user needs.
- Through the experiences, it became clear that reflection on the effectiveness of methods as well as own and shared learning needs to be built into the process at regular intervals.

4.2.2 Group dynamics and facilitation

At times in our journey, groups did not work together effectively. Tensions arose from outspoken and dominant members, people not listening and confusion and mini-conflicts regarding instructions. The design thinking process is intense, with strictly time-bound tasks, and some people did not respond well to the pressure. In our experience, these disruptions could mostly be smoothed over with good facilitation, but group dynamics do need to be monitored to ensure effective delivery.

Related to this is the level and style of facilitation. Some groups (eg, undergraduate students and participants not previously exposed to such a creative working environment) may prefer a degree of direct facilitation and a sounding board to check that they are on the right path.

In workshops, we found that groups tend to focus on finding a solution rather than the process of design thinking. In future we will focus on encouraging participants to better understand the various techniques and how to adapt and implement them for own use.

4.2.3 Design thinking expert versus a design thinking novice

We observed, on occasions, friction arising when design thinking experts and novices are trying to work together. Here the expert tends to want to control the process and define how it should be done rather than embracing the benefits of organic development. This can be compounded with language issues – different words are used to describe the same thing, eg, the phases of the process, or a different amount of emphasis was given to a task, or the keeping or killing of specific ideas. This is not always simple to resolve and can result in a direct (more linear rather than creative), task-focused approach to find the shortest route which may not provide the best solution.

4.3 Benefits

Our work to date has identified four major benefits of design thinking:

- A solution developed jointly is better than one developed individually, in all instances the sum (developed prototype) seemed more than its parts. The group nature and focus of design thinking supports buy-in of the solution and can almost be evangelical.
- The process is output-directed – developing a prototype takes the focus from the problem and allows consideration of how the solution is going to be used and the context of its application.
- Using design thinking tools changes mindsets and ways of working. It encourages learning to be negative/positive (kill/keep ideas) as well as helping people to leave their comfort zone.
- Finally, by fostering the notion that the result does not need to be perfect, it promotes faster working.

4.4 Discussion

In this paper we are exploring the value of design thinking in a higher education context. Throughout, as academics, we have been part of a learning process, as well as trying to teach other academics and students about the process. Importantly, the academics and students involved are engaged in non-design courses.

We have embraced the design thinking tools experientially in a ‘learning by doing’ context with very little theoretical background being provided to help ground the principles. While the importance of the user has been highlighted and tools introduced and employed to build empathy, there has been little explanation or emphasis on the notion of divergent and convergent thinking. Further, the concept of designerly thinking, has not been part of the experience at all and only emerged as a focus of discussion through working on this paper and deeper reflection on the design thinking approach and applications. In this sense, we did not engage with designing as an individual activity but our experience centred on working in groups, coming to joint solutions using design thinking tools and techniques.

This prompts a consideration of who might be a design thinking expert. In our work, we found that the more a person knows of the design thinking methods, the less flexible they seemed to become in their approach. This can shut off many of the benefits we have perceived on our design thinking journeys to date. We believe a major advantage of design thinking is the generation of many ideas, with the user at the centre, which are then filtered in a rational manner leading to a solution that meets with the user's approval as well as the constraints of the environment. It requires a change of mindset that is not always easy and demands that participants go with the flow and not be too fixated on instructions. This can make it difficult to use with students where there is a need for clear instructions and a definite outcome. This is as observed in previous work, for example Mosely et al. (2018).

With the DT:Uni project focus being on the design thinking approach and methods, the true value of designerly thinking has only become apparent through our recent reading of the pertinent literature. As described in Section 3, the underpinning theoretical grounding and complexity of designerly thinking was not covered in the workshops. However, through being part of a practical experience and undertaking the workshop in that way, the understanding of some of the values of design thinking have come to the fore. These include an appreciation of its divergent – convergent nature, moving out of one's comfort zone and feeling safe to challenge and question, particularly in relation to assumptions. In this way a solution arises from the consideration of an array of ideas and ways of combining ideas and experiences that is more than just one idea on its own, with the user (rather than the designer/idea creators) firmly at the centre of thinking throughout the process.

5 Conclusions and further work

In the DT:Uni project we are being tasked with passing on design thinking techniques and principles. While there are many books listing the techniques (eg, Fraser, 2012; Lewrick et al., 2018), there are few examples of how to run the process and instil the process into other people, ie, how this knowledge may be transferred.

Also, the perception that design thinking can be taught in short workshops led by non-designers may result in its value being diluted. However, the feedback we have received contradicts this perception and our experience was that actually it worked amazingly well and was empowering with interest in the process and its 'grounding' rather than just as a business formula for innovation. We thus found that it spreads awareness and knowledge of the value of design to a much wider audience.

Undoubtedly the project has made a difference – participants gained confidence with the design thinking approach through a realistic experience of the techniques and using them in a practical way. Being part of a week-long workshop gave participants time to absorb the techniques and the impetus to consider implementation of design thinking methods in teaching and research.

So in response to the question posed by the IASDR2019 call "is it [design thinking] still a valuable proposition?", we conclude that design thinking is not dead. It is thriving and having an impact in many areas through facilitating interdisciplinary working and changing mindsets. But, as yet, it is not clear how much designerly thinking can be taught in a short time-frame and a non-design environment.

In future work we would like to test the change in people's experience, confidence, learning from doing and mindset change, as a result of being part of the workshops. We would also like to explore what else they have managed to achieve in trying to transfer their knowledge to other higher education groups.

6 References

Aflatoony, L., Wakkary, R., & Neustaedter, C. (2018). Becoming a design thinker: Assessing the learning process of students in a secondary level design thinking course. International Journal of Art & Design Education, 37(3), 438-453. doi:10.1111/jade.12139

Baaki, J., Tracey, M. W., & Hutchinson, A. (2017). Give us something to react to and make it rich: Designers reflecting-in-action with external representations. International Journal of Technology and Design Education, 27(4), 667-682. doi:10.1007/s10798-016-9371-2

Bennett, S., Agostinho, S., & Lockyer, L. (2015). Technology tools to support learning design: Implications derived from an investigation of university teachers' design practices. Computers & Education, 81, 211-220. doi:10.1016/j.compedu.2014.10.016

Blanco, T., López-Forniés, I., & Zarazaga-Soria, F. J. (2017). Deconstructing the tower of babel: A design method to improve empathy and teamwork competences of informatics students. International Journal of Technology and Design Education, 27(2), 307-328. doi:10.1007/s10798-015-9348-6

Cahn, P. S., Bzowyckyj, A., Collins, L., Dow, A., Goodell, K., Johnson, A. F., Zierler, B. K. (2016). A design thinking approach to evaluating interprofessional education. Journal of Interprofessional Care, 30(3), 378-380. doi:10.3109/13561820.2015.1122582

Cook, K. L., & Bush, S. B. (2018). Design thinking in integrated STEAM learning: Surveying the landscape and exploring exemplars in elementary grades. School Science and Mathematics, 118(3-4), 93-103. doi:10.1111/ssm.12268

Cropley, A. (2016). The myths of heaven-sent creativity: Toward a perhaps less democratic but more down-to-Earth understanding. Creativity Research Journal, 28(3), 238–246.

Cross, N. (2001). Designerly ways of knowing: Design discipline versus design science. Design Issues, 17(3), 49–55.

Design Commission (2011). Restarting Britain: Design education and growth. London: Design Commission, Policy Connect. https://www.policyconnect.org.uk/sites/site_pc/files/report/490/fieldreportdownload/designcommission-restartingbritain1.pdf [last accessed 14 April 2019].

Doorley, S., Holcomb, S., Klebahn, P., Segovia, K. & Utl, J. (2018) Design Thinking Bootleg. D.school at Stanford University. https://dschool.stanford.edu/resources/design-thinking-bootleg

Eckman, M., Gorski, I., & Mehta, K. (2016). Leveraging design thinking to build sustainable mobile health systems. Journal of Medical Engineering & Technology, 40(7-8), 422-430. doi:10.1080/03091902.2016.1218560

Fraser, H. M. (2012). Design works: How to tackle your toughest innovation challenges through business design. University of Toronto Press.

Henriksen, D., Richardson, C., & Mehta, R. (2017). Design thinking: A creative approach to educational problems of practice. Thinking Skills and Creativity, 26, 140-153. doi:10.1016/j.tsc.2017.10.001

IDEO (2013). Design Thinking for Educators' Toolkit, version 2. https://designthinkingforeducators.com/ [last accessed 14 April 2019].

Lewrick, M., Link, P., & Leifer, L. (2018). The design thinking playbook: Mindful digital transformation of teams, products, services, businesses and ecosystems. John Wiley & Sons.

McGann, M., Blomkamp, E., & Lewis, J. M. (2018). The rise of public sector innovation labs: Experiments in design thinking for policy. Policy Sciences, 51(3), 249-267. doi:10.1007/s11077-018-9315-7

McLaughlan, R., & Lodge, J. M. (2019). Facilitating epistemic fluency through design thinking: A strategy for the broader application of studio pedagogy within higher education. Teaching in Higher Education, 24(1), 81-97. doi:10.1080/13562517.2018.1461621

Mosely, G., Wright, N., & Wrigley, C. (2018). Facilitating design thinking: A comparison of design expertise. Thinking Skills and Creativity, 27, 177-189. doi:10.1016/j.tsc.2018.02.004

Mummah, S. A., Robinson, T. N., King, A. C., Gardner, C. D., & Sutton, S. (2016). IDEAS (integrate, design, assess, and share): A framework and toolkit of strategies for the development of more effective digital interventions to change health behavior. Journal of Medical Internet Research, 18(12), e317. doi:10.2196/jmir.5927

Norton, P., & Hathaway, D. (2015). In search of a teacher education curriculum: appropriating a design lens to solve problems of practice. Educational Technology, 55(6), 3-14.

Pohl, C., Krütli, P., & Stauffacher, M. (2018). Teaching transdisciplinarity appropriately for students' education level. GAIA - Ecological Perspectives for Science and Society, 27(2), 250-252. doi:10.14512/gaia.27.2.14

Shapira, H., Ketchie, A., Nehe, M. (2017). The integration of design thinking and strategic sustainable development. Journal of Cleaner Production, 140(Part 1), 277-287. doi:10.1016/j.jclepro.2015.10.092
Stables, K. (2008). Designing matters, designing minds: The importance of nurturing the designerly in young people. Design and Technology Education: An International Journal, 13(3), 8-18.
Stirling, A. (2008) “Opening Up” and “Closing Down”: Power, participation, and pluralism in the social appraisal of technology, Science, Technology & Human Values, 33(2), 262-294.
Tu, J., Liu, L., & Wu, K. (2018). Study on the learning effectiveness of Stanford design thinking in integrated design education. Sustainability, 10(8), 2649. doi:10.3390/su10082649
Wrigley, C., & Straker, K. (2017). Design thinking pedagogy: The educational design ladder. Innovations in Education and Teaching International, 54(4), 374-385. doi:10.1080/14703297.2015.1108214.

About the authors:

Kathryn Burns: Associate Professor working in creative business management. She has led several significant projects linking design with industry. These total over £6.5m and connections with nearly 500 businesses. Research interests include knowledge exchange, the impact of design research and the elements of design knowledge.

Claudia Carter: Associate Professor in environmental governance and planning. With substantial teaching and applied research experience, she has over 60 peer-reviewed publications. Her research relates to climate change and sustainability adopting social-ecological systems thinking and approaches. She is also an Associate Editor of *Environmental Values*.

Zuby Ahmed: Associate Professor and programme director of MSc Video Game Enterprise & Production. Previously, Zuby worked as a freelance writer and for a number of leading game design companies. His research interests include effective pedagogy within vocational courses and entrepreneurship in the digital sector.

Susan Sissay: Lecturer in business studies including entrepreneurship and small business management. Following a law career, Susan moved to the UK to study management at MA and PhD levels. Research interests include international entrepreneurship; opportunity recognition and development; entrepreneurial education and BAME SMEs and entrepreneurs.

Acknowledgement: Thanks to the lead partner University Maria Curie Sklodowska, Lublin, Poland for Its very effective management of the ‘DT.UNI – Design thinking approach for an interdisciplinary university’ project. This is part-funded by the Erasmus+ programme. Also thanks to Charmaine Stint from Birmingham City University for giving the authors a chance to be part of the DT:Uni project.

IASDR 2019 Author Index

Alphabetical order by family name – First Name Family Name, **Volume**(Page)

INTERNATIONAL ASSOCIATION OF SOCIETIES OF DESIGN RESEARCH

MANCHESTER, UK 02-05 SEPTEMBER 2019

IASDR 2019 CONFERENCE PROCEEDINGS | **VOLUME 4**

01 CHANGE

02 LEARNING

03 LIVING

04 MAKING

05 PEOPLE

06 TECHNOLOGY

07 THINKING

08 VALUE

09 VOICES

10 OPEN

ISBN 978-1-910029-62-6

Manchester Metropolitan University

MANCHESTER SCHOOL OF ART