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Abstract & Rationale: Mission-oriented Innovation Policy (MIP) has risen to prominence around the world. Within the European Union's *Horizon Europe* FP9 programme it forms Pillar2, addressing sustainability 'missions' around climate, energy, mobility, food, natural resources and the environment. And yet there has been limited academic research to-date on the question of *how* to translate MIP into the knowledge and skills needed by multi-stakeholder practitioners to effectively work within a mission-oriented policy framework. Our paper addresses this question through the prism of *Enquiry and Problem-Based Learning (EPBL)*. An iterative research study was undertaken comprising four elements. The first involved a literature review mapping the synergies between MIP and EPBL; the second piloted the use of EPBL for undergraduate modules related to sustainability challenges; the third involved external stakeholders in the co-creation of a postgraduate programme that brought together innovation and sustainability, with EPBL fundamental to the design and development; the fourth curated and comparatively analysed international cases of EPBL in the context of MIP, and sustainability challenges highlighting the versatility of EPBL and the importance of creativity in EPBL design and implementation. The paper makes both a scientific and practical contribution. In pedagogic scientific terms we show how EPBL can underpin the design of programmes to provide learners with the knowledge and skills to support organisations working effectively within a mission-orientated innovation policy addressing sustainability challenges. For practitioners we provide recommendations for educators seeking to embed EPBL within their curriculum. We conclude by calling for external stakeholders to proactively engage with educators to co-create programmes with context specific outcomes.

Purpose: To present theory, practice and original research findings to support the proposition that broad EPBL approaches provide an appropriate pedagogical lens for sustainability educators to develop the knowledge and skills needed to work effectively within MIP environments.

Methodology: The research study comprised four elements, each of which employed different research methods. The first element involved a literature review mapping the synergies between MIP and EPBL; the second element piloted the use of EPBL for undergraduate modules related to sustainability challenges; the third element involved external stakeholders in the co-creation of a postgraduate programme that brought together innovation and sustainability, with EPBL fundamental to the design and development; the fourth element curated and comparatively analysed international cases of EPBL in the context of MIP, and sustainability challenges in particular, highlighting the versatility of EPBL and the importance of creativity in EPBL design and implementation.

Findings: The systematic literature review reveals synergies between the key features of EPBL and defining characteristics of MIP, indicating the relevance of applying EPBL to support MIP. Two *in-situ* pilots generated 13 recommendations on the benefits and operational challenges of applying EPBL. These recommendations informed the design and development of a postgraduate programme, involving a transdisciplinary consultation process with key industrial and societal stakeholders. Comparative analysis of four international case studies describing EPBL applied in practice in different international settings show there is no 'one size fits all'. Instead, the application of EPBL to different

sustainability challenges and for different learner groups demonstrates the versatility of the pedagogical approach and the creativity of the sustainability educators.

Originality: A discourse around the appropriate pedagogical methods and teaching/learning practice to equip the current and future workforce with the knowledge and skills to respond to mission-oriented innovation policy and global sustainability challenges is nascent but emerging. Our paper makes a scientific and practical contribution to the discourse. We show how EPBL can underpin the design of programmes to provide learners with the knowledge and skills to support organisations working effectively within a MIP context, especially addressing sustainability challenges. We provide recommendations for educators seeking to embed EPBL within their curriculum and call for external stakeholders to proactively engage with educators to co-create programmes with context specific outcomes.

Key Words: Mission-oriented Innovation Policy (MIP); global sustainability challenges; Enquiry & Problem-Based Learning pedagogy (EPBL); teaching and learning practice

1.0 INTRODUCTION

Mission-oriented Innovation Policy (MIP) lies at the heart of the new European Union research and innovation framework programme (FP9) *Horizon Europe* (2021- 2027). Pillar 2 of *Horizon Europe* focuses on Global Challenges that address societal and sustainability 'missions' related to climate, energy, mobility, food, natural resources and the environment. Pillar 2 is forecast to receive more than half of the €97bn Horizon Europe budget (Interreg Europe Policy Learning Platform,2019)[1]. Many academics and policy advisors couple explicitly a mission-oriented approach with addressing a range of sustainability 'grand challenges' (Mazzucato 2018a, European Commission 2018a, Flink and Kaldewey 2018, The Royaumont Process Report 2021). This emphasis on grand challenges is mirrored around the world (European Commission 2018b).

And yet, a systematic discourse on the pedagogic implications of preparing workforces with the knowledge and skills to fully engage and participate in an MIP approach to address sustainability challenges has yet to bear fruit (Mazzucato 2018a, European Commission 2018a). Translating the top-down directionality of a missions-orientated innovation policy approach into the knowledge and skills needed for cross-disciplinary, cross-sectoral and cross-actor innovation requires sustainability educators to work with the full milieu of actors – businesses large and small, public authorities, scientists, social enterprises and civil society – to stimulate bottom-up experimentation (The Royaumont Process Report 2021, European Commission 2018b, Randles *et al* 2016).

Our paper aims to contribute to this discourse by pedagogical approach that can help train graduates and help organisations to thrive within such a policy environment. It reports on a systematic research and engagement study comprising four interactive elements. The authors participated in the four elements as an evolving creative process with reflective feed-back and feed-forward loops. The first element comprised a systematic literature review of the (limited) academic and policy literature on MIP to identify the defining characteristics of the policy approach. Alongside the MIP literature, a review of the more mature academic literature on Enquiry and Problem Based Learning (EPBL) was undertaken to identify the central pedagogic elements that define EPBL teaching and learning methodology. Juxtaposing the two enables the identification of synergies that connect MIP and EPBL, demonstrating the appropriateness of EPBL teaching and learning methods for developing the knowledge and skills of learners to operate effectively within an MIP policy framework.

[1] Accessed March 2020 https://www.interregeurope.eu/policylearning/news/5970/grand-challenges-the-new-mission-oriented-innovation-frontier/

In the second element, EPBL was applied *in-situ* within two contrasting undergraduate modules, both of which explored social and environmental sustainability from different disciplinary perspectives. This offered first-hand experience of the benefits and challenges for students and staff of applying EPBL in-practice. Drawing on the learning from the literature reviews and the *in-situ* practical examples, the research team reflexively produced a list of 13 recommendations for sustainability educators interested in the *practical* implications of applying EPBL in the classroom.

The researchers drew on the findings of the literature review, *in-situ* experiments and their own varied experience to design a new sustainability and innovation postgraduate programme built on an underlying EPBL pedagogy. This third element of the study involved industrial and societal stakeholders in the creation of the MSc programme through in-depth one-to-one consultation interviews and workshops. Representatives from multi-national corporations were interviewed, including a global engineering consultancy, a public utility, a pharmaceuticals multi-national and a major environmental non-governmental organisation. Further input was received from a wider group of stakeholders from business, academia, policy and civil-society organisations at a workshop held at the *International Triple Helix Conference* in 2018.

Finally, the fourth element of the study gathered and compared four international case studies of EPBL. The case studies demonstrate the wide variety of applications of EPBL applied in different international settings illustrating the scope for variety in the design and delivery of EPBL, tailored to local contexts, local problem-framing, different learner profiles, and reflecting the creativity of local sustainability educators.

The last section concludes by drawing out the scientific and practical contributions of the paper. We show how EPBL can underpin the design of programmes to provide learners with the knowledge and skills to support organisations working effectively within a MIP context, especially with respect to addressing sustainability challenges. We provide recommendations for educators seeking to embed EPBL within their curriculum and call for external stakeholders to proactively engage with educators to co-create programmes with context specific outcomes.

2.0 LITERATURE REVIEW: ANALYSING THE SYNERGIES BETWEEN MIP AND EPBL

The first element of the study comprises a systematic literature review that aims to identify the defining characteristics of the latest generation of mission oriented innovation policy. Section 2.1 synthesises the knowledge and skills needed by organisations to operate collectively and effectively within an MIP environment. In section 2.2 we unpack the key pedagogical features of an enquiry and problem based learning approach, identifying an underlying framework for knowledge and skills

development. In section 2.3, we highlight synergies across MIP and EPBL, showing that EPBL provides an appropriate pedagogical response to the skills and capabilities needs of MIP.

2.*1 Key characteristics of sustainability related mission oriented innovation policy (MIP)*

Beyond the latest EU policy thrust, societal-challenge focussed initiatives have been taking place across the world, at different scales from national to regional and cities. A group of European agencies was commissioned to provide an inventory of the mission- or goal-oriented initiatives across EU member states, Australia, Brazil, India, Japan, Norway and Russia addressing the themes of climate change, energy transitions, circular economy, health, security, food and transport (European Commission 2018b). The authors of the inventory noted the importance of national, regional and local cultural and political factors influencing the societal goal-oriented practice in different locales *(ibid.)*. Successful mission-oriented research and innovation initiatives were designed, they concluded, to fit the specific purpose and contexts found locally *(ibid.)*. Similar context-contingent analysis features in Mazzucato's (2020) mission-oriented policy advice to the Italian government and was echoed in the findings of a recent foresight analysis of global challenges and research gaps (The Royaumont Process Report, 2021). The Royaumont Process Report finds that intellectual traditions and histories influence the agenda-setting and problem-framing processes, in turn influencing how and which actors can be mobilised to address local and national sustainability challenges. These initiatives emphasise that there is no 'one size fits all': successful projects are the result of effective local co-ordination and co-creativity. Among its key recommendations, the EC (2018b) report concludes that: i) new forms of governance are required to enable horizontal and vertical co-ordination of multiple stakeholders, and to break down silos; ii) public authorities play an important role in prioritising societal targets and creating favourable conditions for bottom-up solutions to emerge, co-evolve and compete; iii) citizen-engagement is a challenge for the mission-oriented initiatives observed, but remains of key importance; and iv) mission-oriented research and innovation initiatives must be reflexive, and flexible enough to be re-assessed and adapted to new developments.

Mission-oriented policy approaches are not new (Flink and Kaldewey 2018; Robinson and Mazzucato 2019). The current '3rd generation' mission-oriented policy (Kattel and Mazzucato 2018) can be differentiated from its antecedents by the emphasis placed on *directionality*, involving *system transformation,* and notably a discernible shift away from technology-push solutions, towards user-focussed, social and institutional innovation processes. In operational and implementation terms, these shifts in policy emphasise a fundamentally different role of the State. Public authorities, at all scales, are now tasked with creating the conditions to support a diverse portfolio of bottom-up, co-created experimental project responses requiring relational, intermediating and networking

capacities and capabilities. The role of the State is re-configured to be closer to the concept of the 'Entrepreneurial State', within which the full range of societal actors is invited to participate through modes of inclusive governance (Mazzucato 2015, European Commission 2018a, Kettel and Mazzucato 2018).

Unlike the approach of the US Obama administration in the 1990s which sought to 'harness science and technology to address the grand challenges of the 21st century' (Flink and Kaldewey 2018:17), the latest generation of mission approaches re-frame the linear, technology-push approach, to one that emphasises 'long term, large scale research goals determined by heterogeneous societal stakeholders' (Flink and Kaldewey 2018:17). Indeed, the authors of the European Commission Report (2018b) propose two types of mission-oriented policy: those policies which seek to accelerate science and technology solutions, *accelerators*, and those that seek to address societal challenges through transformative systems change, *transformers*. Robinson and Mazzucato (2019) similarly differentiate Type 1 missions where a single outcome is clearly defined, typically the 'man (sic) on the moon' mission, and Type 2 missions which they describe as needing to be 'enacted in a decentralised and distributed innovation system connecting broad, complex, and often contested challenges with concrete problems to be solved by innovation actors' (p946). It is these heterogenous, transformative Type 2 missions that characterise the challenges of the United Nations Sustainable Development Goals, requiring the translation of broad challenges and political orientations into 'doable' problems to be solved (Robinson and Mazzucato 2019).

Wanzenböck *et al.* (2020) place mission-oriented innovation problems on the divergent end of a spectrum of 'wickedness', a function of the (i) degree of contestation, ii) degree of complexity, and iii) degree of uncertainty. The divergent wicked problems will not be 'solved' through a single innovation pathway. Rather, they feature multiple, contested pathways potentially involving struggle between different competing actor coalitions. Mission-oriented challenges, such as the SDGs, are 'wicked' in the sense that they are complex, systemic, interconnected and urgent, requiring insights from many perspectives. For example, poverty cannot be solved without paying attention to the interconnectedness between nutrition, health, infrastructure and education', and not without bringing into the innovation process different public, private and non-profit actors who can experiment and learn over time (European Commission 2018b).

And yet there is an inherent paradox in the call of the MIP literature for system level learning capacity, which is itself written from a siloed stakeholder perspective. For example, whilst Kattel and Mazzucato (2018) helpfully list a set of dynamic capabilities needed to move from a 'support and measure' to a 'lead and learn' approach, they write exclusively from the perspective of new capabilities needed by

the public authorities. And whilst the Royaumont Process Report (2021) notes that "Reaching the Sustainable Development Goals (SDGs) approved in New York in 2015, by 2030, in the most appropriate, inclusive, and equitable way calls for deep transformations of societies (in order to) avoid silos … co-produce knowledge with users … (and)…promote iterative processes to deliver knowledge addressing the diversity of contexts, uncertainties and complexities" (Ibid. p3), their perspective is concerned with the training and capabilities needs of scientists and researchers, albeit with added attention to the need to refresh science/civil society relations in order to address the SDGs equitably and inclusively.

Notwithstanding this paradox, four key characteristics of an MIP approach can be summarised as:

- **Policy directionality provides the steering mechanism for system transformation:** Top-down policy directionality combines with bottom-up experimentation to generate a wide range of creative projects offering different routes to system transformation. The system must itself be a learning system capable of learning from bottom-up experimentation nurtured through dynamic feed-back loops. The transformative system perspective of MIP requires workforces capable of cross-disciplinary, cross-sectoral and cross-actor working to be effective.
- **Diversity and adaptation to local contexts and changing situations:** A diversity of mission- or goal-oriented initiatives are in evidence around the world, at different scales (national, regional and city-level) influenced by local histories and local cultural and political factors. The most successful MIP initiatives show a propensity to adapt to specific local conditions and contexts. Mission-oriented research and innovation initiatives must be flexible enough to be re-assessed and responsive to new developments.
- **Problem-solving within contested problem-solution spaces and with regard to alternative futures imaginaries:** Missions are enacted in decentralised and distributed innovation systems, connecting broad complex and often contested challenges with concrete problems to be solved by the whole spectrum of innovation actors. Alternative innovation pathways navigate 'wicked' problems in the sense that they are highly contested, complex and uncertain. Mission-oriented challenges operate within alternative futures imaginaries and narratives constructed in the present about alternative futures.
- **New forms of governance are needed to operate effectively:** Effective local co-ordination and co-creativity is important to successfully operate within a MIP approach. New forms of governance are required that enable horizontal and vertical co-ordination of multiple stakeholders, breaking down silos between them. Public authorities play a vital role in stating and prioritising societal targets and creating the conditions for effective bottom-up experimentation and solutions to

emerge. The role of the State is to create the enabling conditions for local creativity, requiring relational, intermediating, and networking capacities and capabilities fostered across all actors ('The Entrepreneurial State'). A 'lead and learn' approach replaces a 'support and measure' approach; Inclusive governance invites the full range of societal actors to participate and be heard; and citizen-engagement is a challenge, but remains important.

2.2 Key pedagogical features of Enquiry and Problem Based Learning (EPBL)

Missing thus far from the discourse on system-level capacity building to address sustainability related MIP is a supply side perspective on how the necessary knowledge and skills will be developed and delivered. The EC began consulting on a European Education Area, including a proposal for an initiative on education for environmental sustainability (https://education.ec.europa.eu). An 'Education for Climate Coalition' is being established, the aim of which is to mobilise education and training for climate neutrality and sustainable development. Moreover, the EC is planning to co-create with higher education institutions (HEIs) and research communities a higher education transformation agenda (see https://www.developmentaid.org/#!/news-stream/post/136186/environmental-sustainability-commission, last accessed January 2022). The central question is how to develop the knowledge and skills of all stakeholder groups, together and simultaneously. This requires systematic effort from educators, HEIs and research communities to translate mission-oriented innovation policy into system-level learning competencies. In turn it requires attention to the appropriate pedagogical approaches which explicitly enable different stakeholder groups to participate in the form of cross-disciplinary, cross-sectoral, and cross-actor learning that are central to MIP.

Enquiry and problem based learning is one such pedagogical approach. The academic literature on (EPBL) bears witness to a wide range of innovative EPBL programmes and modules. Aditomo et al's (2013) study of EPBL in Australian univeristies is a good example showing how EPBL is practiced at different levels (undergraduate and postgraduate), with different cohort sizes, in different types of universities (research intensive and teaching universities). Globally, a small number of universities stand out for the extent to which they embed EPBL pedagogy across the entire depth and breadth of the university. Aalborg University in Denmark and Maastricht University in the Netherlands are two such examples. This partly reflects a deep values-centred commitment to addressing societal challenges as a primary mission of these universities, coupled with the view that learning through EPBL approaches provides a better student experience, higher student achievements, accelerated and higher levels of programme completion, and offers graduates with the knowledge and skills favoured

by local employers. Barge (2010: 7)[2] reports on the six principles of problem and project based learning that constitute the 'Aalborg Model', namely Problem-orientation, Project organization, Integration of theory and practice, Participant direction, Team-based approach, and Collaborative feedback.

In simple terms, problem based learning (PBL) can be considered a learning pedagogy that uses a problem as a trigger for students to develop solutions in a student-centred problem-solution or practical 'task' based setting, whilst also learning from the process (Klegeris and Hurren, 2011). Enquiry based learning (EBL) takes a similarly inductive approach, but often uses a more abstract trigger and may start with a question rather than a problem (Prince and Felder 2016). In both enquiry and problem based learning, the tutor acts as a 'facilitator' of learning rather than an imparter of knowledge, and the learning process is characterised by a high degree of self- or team-directed learning. Typically, EPBL is operationalised through differently constituted (heterogeneous or homogeneous) student groups (Bell, 2010) and whilst some contexts may use particular types of EPBL (e.g. business education more often uses enactment of practice and role play), the approach can be applied at various levels and in different contexts. Indeed, it is characteristic of EPBL to creatively bring together different 'design elements' to adapt programmes to the local contexts that define missions, and different framings of problems.

It has been proposed that EPBL provides appropriate pedagogical approaches to develop skills and build capabilities to address sustainability challenges and goals (Corvers *et al* 2016; Leal *et al* 2019). EPBL can contribute to the development of both social skills (Kolmos, 1996) and context-specific new knowledge, and to transferable skills for direct professional application in a teams-focussed problem-solving workplace environment (Corvers *et al* 2016). EPBL provides a platform to explore the rich complexity of sustainable development and sustainability challenges through criticality and deep understanding (Sipos *et al*, 2008; Thomas, 2009). When EPBL projects with a focus on sustainable development are undertaken on a university campus, or other *in-situ* organisational settings, it has been demonstrated that they can support organisational learning towards sustainability change and transition (e.g. supporting an organisation's decarbonisation strategy) (Leal *et al* 2019). This ability to tailor EPBL to pressing, complex societal challenges, makes it stand out as a 'context-based learning' approach, where the context can span a continuum of real world events. In this sense, EPBL is an appropriate response to the 'wickedness' of innovation pathways in a mission-oriented problem-solution space, characterised by uncertainty, and more or less known and specified challenges.

[2] See also Malbeck et al (2017)

The key features of EPBL pedagogical methods can be summarised as:

- ***Problem/project based approach*****:** Combines a *problem-solution approach* beginning with an unstructured and open real-world problem or question which needs to be refined before it can be addressed, with a *project-based approach* involving the scheduling and management of tasks, with a clear end-product in mind (eg a collective student team report or presentation).
- ***Learner centred knowledge acquisition*****:** Combines *the acquisition of foundational theoretical and applied knowledge. S*elf-direction enables the acquisition of *experimentation and creative skills.* Feed-back loops and processes of 'cycling' taking account of new knowledge acquired along the way; interim peer and 'expert' evaluation, enables adaptation to new developments and *develops reflexive capabilities*.
- ***Interdisciplinary collaboration:*** *Working together* to *refine the problem, considering degrees and parameters of 'wickedness'*. Cross-disciplinary teams reflect (or simulate) the full range of actors' perspectives, and bring these viewpoints to the table, producing problem-solution outputs that reflect a wider range of stakeholder views and positions and develop skills and competences in cross-discipline, cross-sector, and cross-actor working. Evaluation (and assessment) of the final outputs probes for evidence of a *'lead and learn' approach*.
- ***Futures orientation*****:** Promotes consideration of the *alternative futures and future imaginaries and/or alternative pathways* to the same future, via tools and techniques such as gamification and scenarios.
- ***Transformation from the bottom-up to the systems level, and vice versa*****:** The collaborative teams translate the implications of mission-specific, context-specific, bottom-up problem framing, taking account of local, grassroots and cultural and political factors into a *system transformation mapping* identifying the *full range of actors* (public, private and non-profit) who are (or should be) participating in the system transformation process. Identifying structural rigidities and the harm caused by the status quo provides a critical perspective.

2.3 Connecting Mission-oriented innovation policy (MIP) and EPBL pedagogy.

In Table 1, we draw this section to a close with an analysis of the key characteristics of sustainability related MIP and key features of EPBL pedagogical methodology, demonstrating how the latter can contribute to the development of workforce knowledge and skills in the context of the former.

Table 1: Synergies across MIP and EPBL approaches

Key Characteristics of Mission-oriented Innovation Policy	**Key Features of EPBL pedagogical methodology, applied to MIP.**
MIP is anchored within a transformative systems perspective where broad top-down missions (e.g., UN SDG targets) provide the framework for defining problem-solution spaces where problems are interconnected, open, uncertain and 'wicked'.	Open systems and system inter-connectedness provide a starting point for learners to identify a range of options for problem/project framing and specification to address the mission. Levels of contestation and uncertainty according to different options can be explored.
Top-down directionality in the setting of broad mission-oriented goals and targets is coupled with bottom-up experimentation and co-creation to support a range of problem-solution projects aimed together at achieving system transformation.	Learner-centred construction and interpretation of the 'system', and how and what needs to be 'transformed' forms the first stage of the enquiry. Learner-centred approaches stimulate and encourage local experimentation, critical thinking, creativity and the integration of theory and practice.
Problem-framing and problem-specification become part of the collaborative project-identification task.	Learners participate in the problem-framing phase of the enquiry.
Emphasis on the inclusive participation and collaboration of all actor groups in society: Business, public authorities, academia, and civil society.	Stakeholder mapping analysis enables an understanding of the problem (including problem framing) from multiple (potentially contested) perspectives.
Actor constellations – involving a mix of public, private, and non-profit actors – collaborate across geographies to define projects contributing to the mission-goals, appreciating that different political, cultural and institutional contexts will influence priorities and the defining of the problem-solution space.	Learners work in (cross-disciplinary) teams. Experiential and peer-learning raises awareness to political, cultural and institutional differences and contexts.
Knowledge is constructed and potentially contested. Different actor priorities and	'Constructivist ontology explores the evidence base and status of knowledge, including points

perspectives may give rise to conflict. Different competing solutions may be advanced by different co-existing actor coalitions.	of contestation. Knowledge is captured through analysis of different actor perspectives. Use of simulation and role-play reveals different actor perspectives.
Workforces must be capable of cross-disciplinary, cross-sectoral, and cross-actor working and learning.	Learners frame and address problems by working in, or simulating the perspectives of, different industrial and societal actors.
Assumption of open and unpredictable futures.	Curriculum design includes foresight and anticipation tools and techniques, which are applied and built into EPBL projects.
Assumption of innovation as processual and adaptive, learning through reflexive feedbacks.	Project-based learning follows a series of sequential tasks, through rounds of refining and addressing the problem-solutions, incorporating cycles of decision making, reflexive feedback and adaptation before concluding with sets of concrete recommendations, and project outputs (such as a team report and/or presentation to a panel of simulated and real 'experts').
Evaluation of project success goes beyond 'support and measure' to 'lead and learn'	Evaluation and assessment of group outputs includes peer-evaluation, panel evaluation by facilitators and mentors representing different actor groups and actor perspectives, looking for evidence of a 'lead and learn' approach.

3.0 Methodology

The research study proceeded in four elements, employing different research methods. The output of element 1 underlines the synergy between MIP and EPBL. Table 1 became a set of 'design elements' that provided the building-blocks of good-practice to be incorporated into the design and implementation of *in-situ* classroom-based 'tests' in undergraduate modules in the second element of the study. These were situated within two modules: *Professional Geographer (PG*) in the Faculty of Science and Engineering (FSE), and *Business Ethics and Sustainability (BES)* in the Faculty of Business and Law (FBL) at Manchester Metropolitan University in the UK. Experiential feedback was gathered at an internal workshop of the research team which considered input received from students, module

evaluations and staff reflections. Textual coding of the feedback was undertaken using Nvivo, revealing top level themes. Early insights were presented – and further reflections gathered - at an interactive workshop attended by over 40 staff and students from across Manchester Metropolitan University, joined by external participants from industry, social enterprises and academics from other universities. The output of the second element of the study was a series of recommendations based on the practical experience of implementing EPBL in practice. These recommendations are shown in Table 2.

Outputs from elements 1 and 2 informed the co-development of a full (eight module), cross-faculty MSc programme on sustainability and innovation, built on EPBL foundations and involving input from industrial and societal stakeholders. Element 3 involved a stakeholder consultation exercise involving in-depth interviews and a practitioner workshop. Five consultation interviews were held with large employer organisations on the design, development and implementation of a new MSc programme[3]. The interactive practitioner workshop was undertaken at the International Triple Helix Conference in 2018 bringing together 30 international participants from across industry, academia, government and civil society sectors. At the workshop the programme's theoretical foundations, learning objectives in terms of knowledge and skills, and methods of teaching and learning were presented. The output from element 3 was a further set of recommendations for the development of postgraduate EPBL programmes for MIP. These are reported in Table 3.

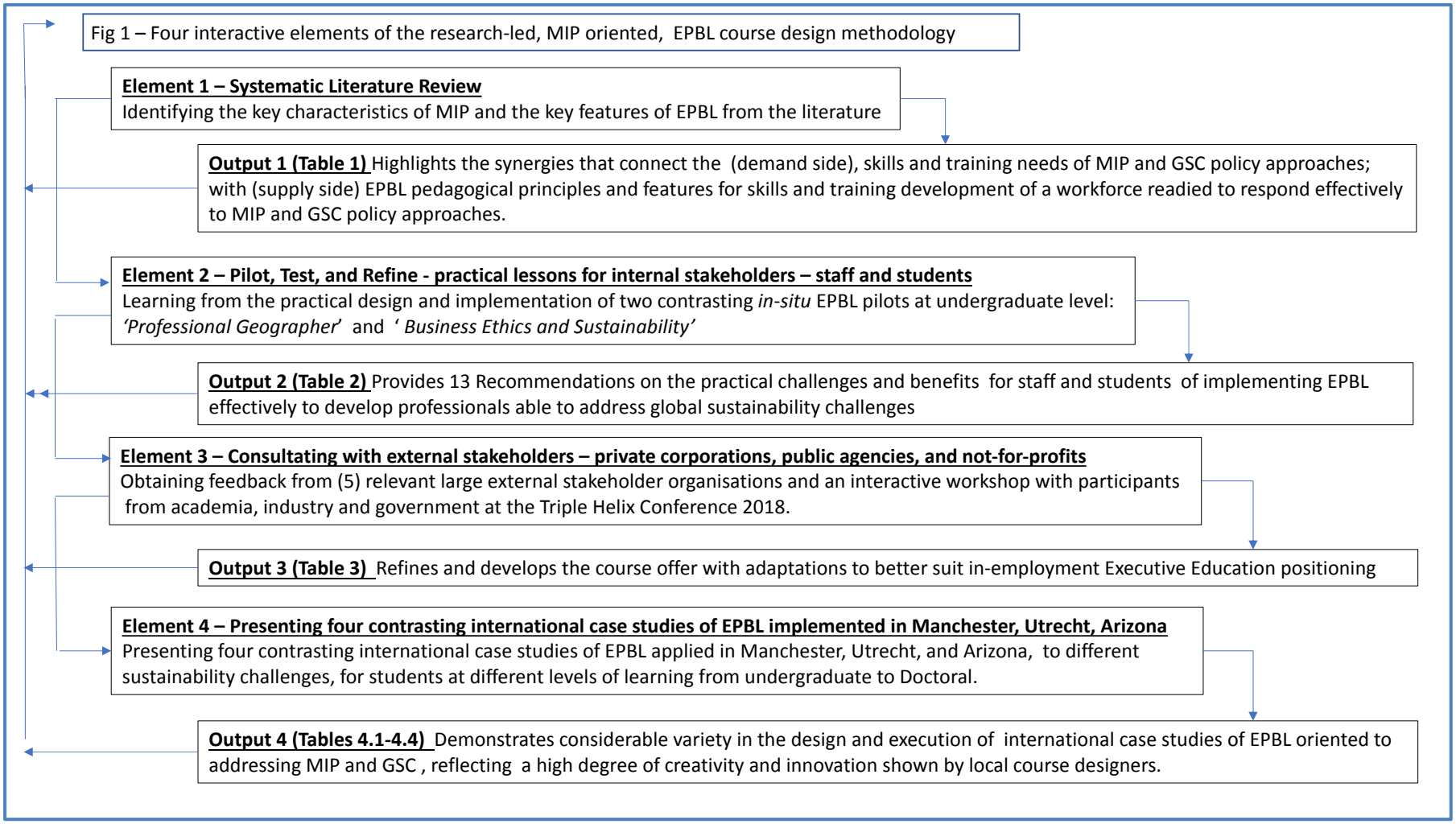
The fourth and final element of the research method was an international comparison of EPBL case studies which shows the versatility of the pedagogical approach applied to different sustainability challenges and various student cohorts. The output of element 4 was a series of case studies distilled into four 'vignettes', summarised in Boxes 4.1 to 4.4 below.

The four elements of the research study are shown in Figure 1 below[4].

[3] Interviews included a global engineering consultancy with specialisms in energy, water, transport, urban infrastructure; a nationwide energy planning and regulatory consultancy; a regional electricity utility; an international environment and conservation NGO; and a global pharmaceutical multi-national, conducted in 2018 and 2019.

[4] All co-authors were involved in one or more of the four elements. For further information on any of the elements, in the first instance please contact the corresponding author.

Figure 1: Four interactive elements of the research-led, MIP oriented, EPBL course design methodology



4. Findings

4.1. Element 2: Pilot, test and refine EPBL

Element 2 enabled the team to learn from the direct experience of implementing EPBL into two contrasting undergraduate course modules at Manchester Metropolitan University. This took the form of a 'live experiment' in the translation of EPBL philosophy into teaching and learning practice. The experiment raised questions about how to fulfil the pre-defined learning outcomes of the module; how to integrate module-specific theory alongside EPBL pedagogy and techniques; how to incorporate guest lectures to reflect different interpretations of a 'problem'; how to design and implement appropriate assignments and assessment; and practical concerns relating to logistical organisation and management such as room layout and resourcing.

Business Ethics and Sustainability (BES) is a longstanding final-year undergraduate elective module chosen by about 160 students from programmes across the Faculty of Business and Law (FBL) at Manchester Metropolitan University. The module aims to explore cross disciplinary universal themes drawing on the knowledge and skills of staff as well as making extensive use of films and fiction. The module was already adopting elements of EPBL, and the pilot was an opportunity to do so more explicitly.

In contrast to BES, the *Professional Geographer (PG)* was a new, core, first year module, taken by around 120 students on cross-disciplinary programmes across the Faculty of Science and Engineering (FSE). *Professional Geographer* effectively straddles the boundaries between the multidisciplinary nature of geographical thinking and global sustainability challenges, and the development of graduate skills within a future-facing outlook as global citizens. The intended module learning outcomes centre around collaborative enquiry, critical thinking, data handling, communication, and professional development planning. These are achieved through mixed discipline team-based enquiry focusing on a contemporary global geographical challenge within the framework of the Sustainable Development Goals.

Feedback on the pilots was gathered from students and staff and discussed at an internal workshop involving wider academics and students. Analysis of these two *in-situ* experiments produced remarkably similar findings and identified the primary advantage of EPBL as its capacity to develop deeper understanding of the complexities and systems nature of given sustainability contexts and goals (consistent with Nicholson and Vargas, 2021). The output from the analysis led to the recommendations in Table 2 below. There were two stand-out findings.

First, a key anticipated challenge was that the level of prior skills and knowledge in first year might not be sufficient for the learning challenges posed. Student co-design input, module evaluation and staff reflections highlighted several strategies to mitigate this effect (linked recommendations in parentheses):

- Potential knowledge and skills gaps need to be identified and acknowledged [**Recommendation 5, 7**];
- Embedding self-reflection can help reinforce the learning that has taken place [**Recommendation 12**];
- The nature of EPBL needs to be clearly articulated to both students and staff, including managing expectations around prior skills and knowledge [**Recommendation 12, 13**];
- Some knowledge and skills gaps can be filled through supporting resources, peer learning, and interactive online learning. [**Recommendation 6, 11**];
- Tutor facilitation and scaffolding learner autonomy can promote independent study. [**Recommendation 4**];
- Certain tutors can be identified as subject 'experts' to provide specialist input as appropriate. [**Recommendation 7**]; and
- Draw on students' pre-existing motivations and interests to promote enquiry [**Recommendation 10**].

Second, cohort size was important. Both BES and PG involved cohorts of more than 100 students drawn from different programmes. Managing EPBL through such large cohorts proved challenging (consistent with Klegeris and Hurren 2011), not just from a logistical viewpoint, but also psychological. In BES for example, there was some reporting of raised levels of anxiety among students when asked to engage with independent and team-based learning activities within large cohorts. This highlights the need for appropriate staff development training (consistent with Murray and Savin-Baden 2000) that will raise awareness of potential impacts and equip staff to provide students with the necessary support [**Recommendation 3, 4, 13**]. Potential strategies include proactively and regularly encouraging students to seek help and support – making this 'the norm', signposting to supporting resources online, a clearly articulated framework of support and the nature of EPBL, and establishing ground rules for effective teamwork [**Recommendation 2,9,11,12**]. Table 2 presents the recommendations from the MMU pilots.

Table 2 – Recommendations for effective design and implementation of EPBL

Philosophy	**#1-Benefit students**	Use EPBL pedagogies to help improve academic achievement, development of intrinsic motivation and transferable skills (e.g. critical thinking, creativity, teamwork, systems thinking, conceptual understanding), and knowledge retention in the long term.
	#2-Recognise plural values and their significance	Different values orientations need to be **respected**. Staff and students will bring a **plurality of values** to their engagement in Enquiry and Problem Based Learning. These may be **convergent or contested** but will materially influence the way problems and decisions are understood, framed and tackled. Surfacing them in a **participative**, **open** and **reflexive** way helps raise awareness of the diversity of values held, and their **implications and significance** in learning processes seeking sustainability and responsible innovation solutions.
Staff development	**#3-Develop teaching teams**	Teaching teams who wish to implement EPBL require to build **good communication**, reflexive practice, **preparation**, **organisation**, **flexibility** and being willing to learn.
	#4-Encourage staff development	Develop and implement a staff development plan that suits the needs of the teaching team. Staff development for EPBL is likely to be required in terms of flexibility, managing student expectations, **confidence in letting go of control** and traditional power dynamics between staff and students, **digital competence and awareness.**
Curriculum development	**# 5-Tailor according to cohort**	Tailor teaching methods, guidance and supporting resources to take account of different cohort characteristics (e.g. **size**, **discipline**, **year of study**). Plan well in advance to cater for the **logistical challenges** of large cohorts (e.g. multimedia, breakout groups).
	#6- Design technology enhanced learning strategies	Design strategies for the use of **technology to address certain challenges** associated with implementing EPBL. Both blended and online modes of EPBL can be achieved, particularly to aid **communication** and **collaboration**. Use of technology should **enhance and not distract** from the main purpose of the approach.

	#7-Address knowledge gaps	When facilitating knowledge acquisition through EPBL ensure **knowledge gaps are addressed** appropriately. This can be done through expert guest lectures, the use of online learning and other pedagogies.
	#8-Develop appropriate assessment	Facilitate **fairness** in group assessment by including an element of **peer assessment**. Provide resources to support training students in the process and practice of peer assessment, and use this to promote full engagement, **critical thinking**, **professionalism** and **self-regulation**.
	#9-Prepare room layout	Prepare the room for a **'cabaret style' layout** if the room has flexible layout. Alternatively prepare in advance strategies for structured student engagement. EPBL requires room layouts that help **students to interact in groups**. Lecture theatres in rows are unlikely to be a good fit for EPBL.
	#10-Encourage student engagement	Encourage student engagement through the **use of triggers** such as **popular culture, object based learning and multimedia**. However, **ensure the relevance** of the triggers is clearly articulated and linked to students' interests.
	#11-Support groupwork	Agree with teaching team the approach to group membership. Provide student training in **effective groupwork** and **conflict management**. Discuss **group dynamics** and establishment of ground rules, and agree on processes to manage practicalities (e.g. contributions, information management and sharing). Raise awareness of **diversity** to maximise participation and **inclusion**.
	#12-Manage student expectations	Implement strategies to manage student expectations. For instance, **emphasise relevance** of knowledge, skills and EPBL approach, **establish ground rules** for team work, and **promote reflective learning**.

Transitions	**#13-Support staff and student transition**	Manage student expectations (**recommendation #12**), address knowledge gaps (**recommendation #7**), address team building issues within teaching teams (**recommendation #3**) to provide a coherent message to students, address staff development needs (**recommendation #4**) to support the **uncertainties and challenges** associated to EPBL that students will perceive.

4.2. Element 3: Transdisciplinary co-development of an EPBL MSc programme on sustainability and innovation

Building on the insights from the literature (element 1) and pilots (element 2), element 3 required the research team to look beyond the institution to capture the perspectives of industrial and societal stakeholders and to involve them in the co-design of a cross faculty (Faculties of Business and Law and Science and Engineering) MSc programme on sustainability and innovation. The MSc programme on Sustainability, Technology and Innovation Management was designed to provide underpinning knowledge on innovation dynamics, sustainability, governance and change agency across four, first semester modules. The intention was that these modules would offer enquiry and problem based learning opportunities related to challenges suggested by industrial and societal stakeholders. Four second semester modules would be anchored in the following sustainability challenges: circular economy, biodiversity, mobility and energy. Working in cross-disciplinary teams, students would collaboratively agree on a 'doable' problem within a mission-oriented context. In addition to critical enquiry, input would be received both from cross-faculty academics and industrial and societal stakeholders. Both internal and external experts would be involved in the assessment. The programme also includes a research-based dissertation. The dissertation would mobilise the learning from across the programme to address a concrete sustainability problem, relevant to the student's employer or other industrial or societal organisation.

Input on the design and development of the programme involved consultations including both one-to-one meetings and an interactive workshop at the Triple Helix conference. The consultation process led to recommendations about the design and development of a post graduate programme targeting learning in a MIP context. These recommendations are shown in Table 3.

Table 3 – Recommendations from multi-stakeholder consultations

Structure and positioning of course	Place greater emphasis on part-time and shorter Executive Education options with flexibility to accommodate the needs of in-work employees.
Engagement with employer organisations	Place greater emphasis on working closely with employer organisations and other stakeholders to jointly develop the content of placements, team projects and dissertations to orientate the problem-framing and problem-based learning to the sustainability challenges actually faced by 'client' organisations.
Cross-disciplinarity	Retain the cross-disciplinary element, in particular combining business and management with science and engineering within the structure of teams working on problem and project-based learning activities, as this is an important (and often missing) element of existing courses and programmes
Develop 'clusters' of organisations as 'clients'	Develop and work with clusters or networks of organisations, eg a cluster of Small and Medium Enterprises (SMEs) co-located on a science and enterprise park, network of community organisations, or mixed multi-stakeholder group.
Certification	Certify the course through a business-recognised authority.

4.3. Element 4: International comparative analysis of EPBL case studies

The fourth element involved an international comparative analysis of case studies where EPBL has been applied to modules situated within an MIP (especially sustainability) context. Each case is presented for the purpose of this paper as a short 'vignette' and to enable their comparative analysis they have been prepared and presented to a common template (Boxes 1-4 below). Each is explicitly linked to addressing one or more the UN Sustainable Development Goal(s). The four cases cover very different programme aims and contrasting ways of organising student learning, curricular content, scheduling, and levels of learning (undergraduate, post-graduate and PhD, and Executive Education short course), illustrating once again how EPBL emerges as an educational creative response to (different and specific) local contexts**.** It is also noteworthy that different normative premises sit behind the different course provisions. For example, the ASU case on wastewater systems (Box 3) is

explicitly critical of technology-centric innovation pathways as the assumed route to addressing sustainability challenges; whilst the Manchester Met example of Executive Education short course is, in contrast, oriented to helping SMEs identify and develop technology-based product and service innovations related to (hydrogen) fuel cell technologies**.** The different case studies also feature different models of funding. Notably, all involve supplemented funding.

Three key points emerge from the comparative analysis of the international cases. First, the four EPBL cases display a high level of variety reflecting adaptation to local political, institutional and cultural contexts and specific sustainability challenges. Second, the international cases reviewed show that EPBL can be effectively applied at all levels of learning, from undergraduate, to post-graduate, to executive education (though cohort numbers across all four cases are relatively small). Third, whilst all four share common features such as cross-disciplinary, cross-sectoral and team-based learning, the four cases also exhibit a high level of versatility and variety in the way EPBL is applied 'on the ground' in terms of the detailed design and delivery of programmes, highlighting the scope for bottom-up creativity in applied EPBL by academics around the world.

Figure 2: Case Studies

Box: 1

Course: Smart Sustainable Cities Minor

Host University: HU University of Applied Sciences, (Utrecht, Netherlands) in partnership with TUAS (Turku, Finland), UPV (Valencia, Spain), MMU (Manchester, United Kingdom), HAW (Hamburg, Germany)

UN SDG Addressed: 11 – **Sustainable Cities and Communities** (interconnected with other SDGs)

Programme Level: Undergraduate

Duration: One semester

Number of students: around 30 per year (one third international; one third drawn from University of Applied Sciences, Utrecht, and one third from other universities in the Netherlands);

Funding: ERASMUS+ project ESSENCE: European Sustainable Solutions for Existing and New City Environments.

Rationale: Through a cross-disciplinary approach, the course teaches students to design viable solutions for the complex challenges we face to make urban living environments more sustainable and healthy. Contributing to the achievement of the SDG 11 is considered its main mission: to make cities inclusive safe, resilient and sustainable.

Description: The emphasis in the course is on learning how to apply theories methods and tools for analyzing and designing smart sustainable cities. These include for example: design thinking, future probing, behavioural change models, building blocks for social design, canvas business modelling, entrepreneurial skills, energy analysis, carbon foot-printing, circular material flow mapping, and value sensitive design. The application of these knowledge and skills is practiced in several projects for enquiry-based learning during the programme. Theories, methods and tools are first trained in a small structured task, then practised in small guided project and finally applied in an independent student-led project. Both the small guided project and the independent student-led projects feature extensive collaboration with local municipalities and companies, providing real-life assignments for students. The problem-based learning approach is the dominant type of learning that characterises the student team projects in the programme. The students are actively involved in the framing and specification of the problem at hand. This requires a good mapping of the stakeholders involved, a thorough triple bottom line investigation for analysing people, planet and profit aspects of the problem and a good inquiry of the main target group.

There is no specific academic background or discipline required for participation in the programme. It is open to all 3rd year undergraduate students that are interested in sustainability issues, that are eager to learn, and willing to share their own knowledge and skills. This facilitates a full cross-disciplinary approach to problem solving in teams, a breeding ground for peer to peer learning, and international exchanges of experiences.

The processual learning among students is enabled through the formative and summative feedback sessions during the project. These include for example the drafting of a research plan, the presentation of it, mid-term progress reporting, the writing up the results of the research, and a final presentation to the client and the teachers. The programme also pays attention to professional development of the individual students; the participants have to draft an individual learning plan, work on development of new competencies, and reflect on the achieved learnings.

Box: 2

Course: Training Programme of the Sustainable Consumption Institute (SCI) Centre for Doctoral Training (CDT)

Host University: University of Manchester

UN SDG Addressed: 12 – Responsible Consumption and Production (interconnected with eg **SDG 13 – Climate Action**)

Programme Level: Doctoral

Duration: One day per week 'CDT Mondays'. Throughout the first three years of the PhD, the SCI Doctoral scholars came together to undertake inter-disciplinary group activities. They spent 20% of their time on SCI-DTC tasks and activities in Year 1, reducing to 10% in subsequent years.

Number of students: Over 40 scholarship-standard PhDs were 'hot-housed', over six year duration of the programme (2008-2014), in annual cohorts averaging 10 PhDs per annum, registered and hosted through a collaborative arrangement which brought together all four faculties of the University of Manchester: the Alliance Manchester Business School and Social Sciences within Humanities; Science and Engineering; Life-Sciences and Medical. Typically, the PhD's supervisors were located in two different schools, facilitating cross-disciplinary supervision.

Funding: Doctoral students of the SCI-CDT were holders of competitive scholarships funded by Tesco PLC. Tesco also funded the overheads of the CDT. By establishing the SCI within the University of Manchester, Tesco aimed to consolidate its position at the forefront of research on sustainable consumption and production in order to inform its own sustainability strategy and encourage improved sustainability outcomes across the retail sector.

Rationale: The SCI-CDT established an inter-disciplinary PhD community by creating an environment where the scholars stepped outside of their immediate research specialism and came together each week to follow a shared programme of collaborative problem and enquiry-based learning tasks, workshops and activities, in differently constituted groups. Enquiry-based learning (guided enquiry, feedback, iteration and reflexive development) formed the basis of the training philosophy that underpinned individual tasks. Together, the SCI-CDT community developed capabilities to communicate confidently and engage with a range of stakeholder audiences including policy, public, NGO and corporate audiences. By instigating a programme of EPBL learning *'beyond the Doctoral thesis'* the programme embedded *within* the doctoral experience, skills and experiences not typically encountered until post-doctoral employment. For example the requirement of research funders and a range of employers and stakeholders, for researchers to demonstrate concrete societal impact by engaging a range of 'user' communities and beneficiaries.

Description: Some examples of the SCI-CDT 'tasks' included:

Co-authorship Task: Students were formed into multi-disciplinary teams to produce co-authored discussion papers on how a key concept – eg Sustainable Consumption - is differently understood by different disciplines, then applied the findings to analyse a case-study of choice.

Teaching Task: Students were formed into teams to conceptualise, design, develop, gain approval for and deliver to hundreds of undergraduate students across campus, a foundational course on climate change awareness.

Policy Engagement Task: Students were formed into teams and engaged with a policy actor such as a Manchester municipal authority, to address a problem on a specific area of policy, for example aviation emissions, producing key findings and a set of policy recommendations as the output of the task.

Corporate Communication Task: Students worked with peer-learners from Tesco, at Tesco 'away days' where they presented and discussed their research, in formats (eg posters) and styles (eg short summary hand-outs) in order to communicate and discuss the implications of the content, relevance and key messages of their research for a corporate audience.

Public and Community Engagement Task: Students worked in the full-cohort group of 10+, to conceive, design and deliver a 'themed' day of family engagement activities, hosted by a local Manchester museum. A representative from the museum acted as project advisor, facilitator and client. E.g 'The Lost Sock' day traced issues of textiles production, consumption, retail and waste through a series of family-friendly activity tables.

Green Gown Award: In 2012 the SCI-CDT training programme was nationally recognised, winning a prestigious *Green Gown Award*, of the Environmental Association of Universities and Colleges (EAUC) for UK and Ireland. The judges said the SCI-CDT was *'An outstanding example of an imaginative, holistic approach to sustainability in post-graduate teaching, with curricular benefits back to the undergraduate curriculum, onwards to employment, and to local and green communities'* https://www.eauc.org.uk/green_gown_awards_2012_winners

Box: 3

Course: ASU School for the Future of Innovation in Society (SFIS). A workshop format was used to design an enquiry into the future of wastewater sensing (WWS) using participatory scenario construction methodology (Wythycombe-Keeler *et al,* 2019)

Host University: Arizona State University, USA

UN SDGs Addressed: Critical engagement at the intersection of SDG 11 – Sustainable Cities and Communities; SDG 3 – Good Health and Wellbeing and SDG 9 – Industry, Innovation and Infrastructure.

Programme Level: All levels: a critical enquiry was undertaken collaboratively with students and scholars from ASU School for the Future of Innovation in Society; ASU engineering students and scholars; legal students and scholars; and multiple municipal and security authorities.

Duration: The workshop on futures of WWS was held in November 2015 in Tempe, Arizona USA, It formed part of a series of futures-oriented workshops looking at different substantive topics to

critically highlight the implications of dominant innovation discourses, which, by narrating the future, shape the present.

Participants : Social Science and Science, Technology and Society (STS) scholars and students from ASU SFIS, engaged with students and scholars from the ASU Centre for Environmental Security and LC Nano; and legal scholars, municipal water providers, military personnel, and local and federal law enforcement officers.

Rationale: The project sought to advance sustainability science by redressing the lack of attention to holistic visions of the future, whilst generating and dissecting such visions, to reveal the values and vested interests undergirding them. The strongly critical stance opened to question, three fundamental innovation governance 'quandaries' a) Why pursue innovation? (orientation) ii) Who to involve in the innovation process and why? (legitimacy) and iii) How to manage innovation to achieve desired (including contested) goals. The case uses participatory scenarios construction methodology to develop a strong critique on contemporary dominant innovation discourses, in particular associated with technological determinism, where narratives of technological development are functionally linear and unquestioningly assumed to go hand in hand with societal betterment. The four scenarios generated revealed to participants how different visions of the future bring into being different innovation pathways and coalitions of actors in the present. Siren early warnings for the present, associated with each scenario were generated, as well as unearthing the incumbency that structures and holds in place vested interests, incentive systems and motivations.

Description. A theoretical diagnostic framework brought together the key tenets of responsible research and innovation and sustainability science, highlighting some additional dimensions from sustainability science. For example that it aims to advance intergenerational equity, justice and socio-ecological integrity. A problem-solving approach within sustainability science centralises i) Systems thinking ii)Values thinking iii)Futures thinking iv) Strategic thinking v) Collaborative competence. These competences were proactively developed in the workshops, to influence and inform the content of the scenarios generated and enable critical reflection on their implications including consequences arising from decisions taken 'along the way' associated with particular innovation pathways.

Box: 4

Course: The Manchester Fuel Cell Innovation Centre (MFCIC) training programme to encourage innovation in small and medium enterprises (SMEs)

Host University: Manchester Metropolitan University

UN SDG Addressed: SDG7 – Clean and affordable energy (intersected with SDG 9 – Industry, Innovation and Infrastructure and SDF8- Decent Work and Economic Growth)

Programme Level: Executive Education

Number of students and duration: The project has engaged with and supported 77 Greater Manchester based SMEs between 2018 and 2021. The MFCIC project was delivered to cohorts of ten to twelve SME's through a series of knowledge exchange workshops and additional 1-2-1 support.

Funding: European Regional Development Fund (ERDF)

Rationale: The purpose of the project was to introduce the SME's to Hydrogen and Fuel Cell Technology and to support those that identified a market opportunity to iterate new products and services. A key aspect to this project has been researching and understanding academic theory and turning this into processes and practical actions that can be undertaken by SME's. An important element of this is supporting businesses through the discovery phase of innovation when SME's identify whether they think there is an opportunity to pursue.

Description:. First, the 'enquiry' dimension of MFCIC involves SMEs in self-directed learning, seeking to match opportunities for product and service development (which at the beginning of the training is clearly ambiguous, uncertain and underspecified); with market opportunities which are equally emergent and uncertain. Second, whilst innovation is vital for SME's to thrive in a changing market, many SME's do not have a process to manage the innovation process.

Only three of seventy-seven SME's that were supported through the MFCIC project already had a defined process to manage innovation. The project therefore provided a structured framework to guide the SMEs innovation journey, to enable the SMEs ideate a product/service and to develop a business model whilst simultaneously evaluating and keeping under review the changing market. Third, to understand critical technical criteria, for example to meet the sustainability drivers in the market, an example would be that the technology must not emit any pollution at point of use, or be able to operate off-grid, helping businesses understand the technology was key. Therefore the project was supported by the Faculty of Science and Engineering with scientists delivering the technical and scientific aspects of the project. This element of delivery introduced the SME's to the technology, the science, and examples of practical applications so that they had the knowledge to evaluate if the technology could provide the solutions. Finally the importance of networks cannot

be overlooked. The MFCIC project has worked hard to develop a community of businesses, agencies and stakeholders interested in eco-innovation and delivers its workshops to groups of businesses. This included inviting in external stakeholders, such as the gas infrastructure organisation *Cadent,* to introduce and explain their involvement in the development of the Hydrogen Economy and answer questions from the SME's. The development of a network has facilitated additional knowledge sharing between organisations and has directly resulted in SME's collaborating on innovations.

5. Conclusions

The *'Decade of Action'* of the United Nations Sustainable Development Goals coincides with new and significant focus on Mission-oriented Innovation Policy (MIP). It is imperative and urgent that Universities and Higher and Further Education Institutions re-double and up-scale efforts to prepare workforces with the knowledge and skills and competencies needed to operate within a MIP – especially related to sustainability - context.

Our paper contributes to this discussion by proposing that broad enquiry and problem based learning (EPBL) approaches can facilitate this transition in a way that traditional, didactic teaching and learning cannot. We make a scientific contribution to the literature by highlighting the synergies between EPBL and MIP. Our analysis reveals parallels between a missions-oriented innovation policy approach and EPBL. MIP encourages and facilitates bottom-up experimentation within the broad steering of missions- and sustainability goals setting. EPBL show-cases high levels of local variety and pedagogic innovation as educators respond creatively to specific and different local contexts, engage with actor-led strategies which frame problems differently, and become similarly involved in conversations about what successful learning outcomes might look like, and how to evaluate them. Despite an emerging discourse in the literature and wealth of experience and expertise within a broad EPBL community, the bridge between EPBL and new mission-oriented innovation policy has not been built. The potential consequences are an on-going mismatch between the ambitions of national and international agencies charged with chartering a pathway toward MIP and society's ability to realise that ambition. In this paper, we start a conversation about the challenges and opportunities of conjoining MIP with appropriate pedagogic and teaching and learning responses as a practical measure to develop a future workforce capable of responding to MIP.

Our paper also makes a practical contribution. By sharing learning from initiatives to embed EPBL in modules – and whole programmes – that address sustainability challenges in the MIP context, we

invite practitioners to validate, refine, expand our recommendations. We call on sustainability educators to trial EPBL and showcase international examples of the versatility of EPBL and the room for creative manoeuvre. This creativity is inherent in both MIP and EPBL. We also call on industrial and societal stakeholders to proactively engage in the co-design and co-development of EPBL programmes that enhance learners' knowledge and skills to work effectively in a MIP context.

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