Investigating the impact of rich media resources on students' self-efficacy, statistics anxiety, and performance.

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Investigating the Impact of Rich Media Resources on Students' Self-Efficacy, Statistics Anxiety, and Performance

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Preface

This EdD dissertation represents more than just a piece of academic writing; it has been a transformative experience that has shaped me as an individual and a practitioner. Over the past six years, the process of researching and writing this thesis has taken me on a remarkable journey, one that has seen me through a pandemic and the birth of my child. Along the way, I have encountered new people and ideas that have left a lasting impression on me. Conducting scientific research demands careful attention to detail and can be incredibly time-consuming. However, I have come to appreciate that my work is but a small part of a larger, intricate puzzle. Numerous other elements, including articles, databases, and recording devices, have worked in concert with me to bring this project to fruition. I found myself woven into the fabric of an extensive sociomaterial network through which this dissertation took shape. This endeavour has allowed me to blend my past experiences with my current aspirations.

My academic journey began with a focus on mathematics and statistics, which I studied extensively from college through postgraduate studies. As I embarked on a teaching career, my scope of practice gradually expanded. Initially, my primary goal as an educator was to effectively convey mathematical and statistical concepts to my students. However, upon being introduced to sociomaterial perspectives and actor–network Theory (ANT), I found myself re-evaluating my own identity and practice. It was as if I had been handed a magnifying glass or a torch, illuminating previously unexplored areas of my life and work. The journey through my EdD programme has been a profound experience, one that I believe has made me a better person and educator. ANT, though unfamiliar to some readers and initially to myself, has become an essential component of my doctoral story. As the dissertation progresses, the concepts and their relevance to my EdD narrative will be increasingly evident. I hope that as you delve into this dissertation, you will not only gain an understanding of the research but also appreciate the personal and professional growth I have undergone throughout this transformative journey.

Abstract

This research study explores the relationship between students' statistics anxiety, their self-efficacy, and their use of rich media resources in the sphere of statistics education. The research posits the potential for digital tools to transform student experiences and enhance learning. Utilizing an emergent mixed-methods approach, the study combines quantitative techniques, such as MANOVA and independent T-tests, with qualitative methods like multimodal journaling, to record students' e-learning experiences and examine differences in their levels of statistical anxiety, efficacy, and performance when engaging with rich media resources. The study design recognizes that tacit modalities – subtle, often overlooked aspects of engagement – play a critical role in students' interactions with rich media resources, and these modalities are integral to creating sensorial, affective, and embodied meaning. This doctoral study is evolving in nature, welcoming emerging research questions, theoretical frameworks, and methodologies that emerged during the investigation. Guided by actor–network theory (ANT), this dynamic approach allows for diverse avenues of inquiry, engaging with various actors – both human and non-human. By employing ANT, I explore the complex relationships and interactions among students, technologies, and educational environments, shedding light on the role of each actor in shaping e-learning experiences.

This research dives into the complex relationships and interactions within the network comprising students, technologies, and educational environments. It provides insights into some of the conditions that could potentially foster an effective learning environment capable of mitigating statistics anxiety, enhancing self-efficacy, and promoting student engagement and perseverance in learning statistics. The research, however, refrains from making direct assertions about performance. It proposes that rich media resources can serve as a safety net, aiding students in their journey through learning statistics, thereby redefining traditional boundaries of learning.

Acknowledgements

I want to write acknowledgements for my own doctoral thesis. Firstly, I extend my sincere thanks to my supervisors, Dr Kate Pahl, Dr Michaela Harrison, and Dr Steph Ainsworth. Their ongoing support and patience have been invaluable during my research. It has been a privilege to learn from supervisors whose experience and positive attitude have made every session rewarding and enjoyable.

My heartfelt thanks also go out to my participants, my dear students, who placed their trust in me and shared their life stories so openly. Their experiences and trust were the bedrock upon which this study was built.

Abbreviations Used in the Thesis

ANT	Actor–Network Theory
MANOVA	Multivariate Analysis of Variance
MM	Multimodal Journaling
RMR	Rich Media Resources
SAS	Statistics Anxiety Scale (Questionnaire for Statistical Anxiety)
SESPS	Self-efficacy in Statistical Practices Scale (Questionnaire for Statistical self-efficacy)

1.1 Glossary of terms:

1) **Multimedia Learning:** Refers to the educational approach based on the Cognitive Theory of Multimedia Learning, which posits that learning is enhanced when information is presented using both visual and auditory formats, encouraging deeper processing and understanding.

2) **Rich Media Resources**: Rich Media Resources (RMR): Refers to the comprehensive online educational materials provided by the university, including key-concept videos, tutorial solutions, discussions, and lecture recordings, utilized throughout this dissertation.

3) **Tacit Modalities:** This term describes the implicit, often subconscious aspects of students' interactions with rich media resources (RMR). It includes the subtle cues and insights gained through various sensory channels (visual, auditory, tactile) and cognitive and emotional engagement, contributing to a deeper, embodied learning experience.

4) **Sociomaterial assemblages:** Refers to the interactive network of social and material elements within rich media resources (RMR) that facilitate learning. This

concept emphasizes the interconnectedness of resources, social dynamics, and personalized student engagement, leading to a unique integration of knowledge.

5) **Cognition:** This research delves into self-efficacy in statistics and statistics anxiety, concepts deeply rooted in cognitive theories. These theories explore the mental processes that govern how learners perceive and interact with statistical information. They provide a framework for understanding the internal cognitive mechanisms that influence a learner's belief in their abilities (self-efficacy) and their emotional responses to statistics (statistics anxiety).

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Chapter 1: Introduction

1.1 Background and context

For the past decade, I have taught statistics to Level 3 students at a university in the Northwest England. Alongside this, I hold a full-time position as a programme support tutor in the Computing and Mathematics department at my university. Every year, I teach an introductory statistics course, Numeracy and Data Analysis (NDA), to approximately 750 students with a variety of related degrees and academic backgrounds who enrol in the foundation degree programme. The foundation year at my university has a diverse student body, mainly attracting students who lack, or perceive themselves as lacking, the prerequisites to enrol directly onto an undergraduate programme with most of its students coming from a non-mathematical background and pursuing degrees in social care, psychology, and humanities. Owing to the modern demands of professions in the current job market, knowledge of applied statistics has become a necessary component of the foundation year programme. Therefore, teaching applied statistics to this group of students presents academic and behavioural challenges; the majority of students have not studied mathematics or statistics for many years and feel disassociated from studying such analytical and quantitative content. Students are expected to achieve pre-defined learning objectives in each course with the level of difficulty varying for each student owing to the wide-ranging differences in their starting knowledge of statistics. Many undergraduate students – particularly those from non-maths majors such as psychology, nursing, social work, and the social sciences – shudder at the mention of the word statistics and at the thought of enrolling on a statistics course (Chew and Dillon, 2014a), and while statistics and research methods are mandatory courses in these majors, many students tend to underperform in these subjects (Chew and Dillon, 2014b).

At the start of every academic year, numerous students exhibit anxiety and a lack of confidence in their ability to pass this course, which can keep them from progressing to their degree; however, the final tangible outcome, i.e. performance in an

assignment, does not always reflect the student's journey. Many students find it difficult to relate this course to their degrees or future interests; it becomes harder to engage, and learning becomes a significantly more difficult task. Statistics classes have been shown to be among the most anxiety-inducing for graduate students and non-maths-oriented student (MacArthur and Santo, 2022), and some students may be hesitant to take these classes or even postpone their enrolment due to high levels of anxiety and tension. Students with high anxiety levels have been reported to have low self-efficacy, which can affect their ability to grasp statistical concepts and to excel in these courses (McGrath et al., 2015).

1.2 Research purpose

My university recently started providing additional online resources to its foundation year students, including key-concept videos, video recordings of solutions or discussions related to tutorial questions, and lecture recordings, and all media resources provided by the university will be referred to in this study as rich media resources (RMR) throughout this dissertation. My research aims to explore how and why students use the (RMR) provided by my university, and to investigate the potential of these resources to influence self-efficacy, statistics anxiety, and performance among students enrolled in the foundation-year statistics course. This study will also examine the association between students' utilization of these resources and these three key constructs.

1.3 The prospects of digital media resources in enhancing learning outcomes

The potential and constraints of digital media resources regarding improving learning outcomes has been a topic of debate among educators with education researchers, for example, arguing that digital learning is valued by learners for its flexibility, interactivity, and self-pacing (Hromalik and Koszalka, 2018; Laufer et al., 2021). Studies have also demonstrated that educational technology and media resources can improve learning motivation and engagement (Jones, 2020), self-regulated learning (Broadbent et al., 2020), and knowledge transfer (Dohn et al., 2020), and, in addition to fostering learner satisfaction and cognitive skills,

technology has been shown to hold promise in terms of promoting critical thinking abilities, sociocultural learning, student engagement, and learner creativity (Bishop et al., 2020; Lu et al., 2021).

However, the correlation between educational technology and improved education outcomes remains inconclusive, implying that technology alone is insufficient to achieve a digital transformation of education (Castañeda and Selwyn, 2018). Greenhow et al. (2023) provide a compelling explanation for these inconclusive results, suggesting that the drastic shifts in the educational landscape, particularly accelerated by the COVID-19 pandemic, necessitate a reconceptualization of learning boundaries in the digital age. Today's technology-mediated environments, it is argued, extend our understanding of learning contexts, creating both continuities and tensions between learning and participation in diverse settings.

Successful implementation of technology in education enables learning to be continued across these diverse contexts, with various actors, settings, and experiences supporting the learner's ongoing participation and development of practice. However, realizing this seamless transition requires an in-depth understanding and acknowledgment of the dynamic boundaries of learning in the digital age. The COVID-19 pandemic has expedited the shift to digital teaching, propelling the rapid adoption of digital tools for instruction. This swift transition often leaves educational institutions with insufficient time to carefully design and implement these learning technologies effectively. This combination of rapid transition and the need for a comprehensive understanding of technology-mediated learning environments may contribute to the inconclusive correlation between educational technology use and improved outcomes, and my university has responded to this challenging context by providing additional online resources, such as rich media resources (RMR), to its foundation year students. Against this backdrop, the aim of my research is to investigate the impact of RMR on the self-efficacy, statistics anxiety, and performance of students enrolled in the foundation-year statistics course.

The primary goal of this EdD research is to fill this gap in the literature by examining the impact of rich media resources (RMR) on statistics education. In this context,

more specifically, this study aims to explore the impact of RMR on students' statistical anxiety, self-efficacy, and performance in an introductory statistics course at a university in the Northwest England. The study will use both quantitative and qualitative strands, including an analysis of student data and a focus on daily lived experiences to understand the influence of RMR on students' learning. By adopting a more holistic and nuanced approach, this study seeks to shed light on the complex interactions between students, digital tools, and the learning environment, providing valuable insights into how rich-media resources can be used to enhance the statistics education experience. To achieve this, my research will draw on the concept of 'digital practices' and use an emergent mixed-methods approach that incorporates quantitative instruments and qualitative methods to explore the experiences, study practices, and context of the students. I decided to answer my research questions in two distinct ways, one a quantitative study and the second a qualitative strand. The first strand, quantitative, not only seeks to make generalizations about the impact of RMR on students' statistical anxiety, self-efficacy, and performance but also provides a broad perspective, mapping trends and drawing out patterns of influence. These quantifiable data help establish baseline relationships and identify potential factors that can be explored in depth through the qualitative strand, which will be grounded in the daily lived experiences of students and explore how RMR influences their study patterns, self-efficacy, and statistics anxiety.

In this research, the primary focus lies on students' social practices, examining what students actually do, the interpretations they assign to those e-learning activities, and how they utilize RMR in the broadest sense to attain their learning objectives. A comprehensive understanding of this field relies on the recognition of social practice as a fundamental component. Therefore, my research strategy aims to employ a methodologically diverse approach to enhance the paradigmatic reflexivity necessary for investigating the diversity and depth of students' individual e-learning practices. Furthermore, it provides insights into how these practices are utilized to manage their anxieties, boost their self-efficacy, and enhance their performance. The study will adopt a materiality of lived experience approach,

examining how RMR influence students' daily experiences, with a particular emphasis on the tacit modalities of their interactions with digital resources. Tacit modalities are a way to describe and understand the subconscious, sensory, and emotive responses that individuals have towards objects and spaces in their environment, capturing the ways in which these (material) objects provoke the senses and stir memories and affect. This concept of tacit modalities helps to capture how students experience digital resources in the moment, as well as what these resources resurrect for them on embodied, sensory, and emotive levels (Rowsell and Abrams, 2021). It is not only about how these resources are utilized across time and spaces, but also how they are perceived and received in the instant, and the roles they play in the students' affective meaning-making processes (Pink, 2011; Hollett and Ehret, 2019).

1.4 Impact of RMR on self-efficacy, statistics anxiety, and performance: identifying literature gaps

In recent years, the integration of rich-media resources (RMR), such as video resources, lecture capture, and virtual learning environments, has become increasingly prominent in statistics higher education. This is due to an increasing expectation from both institutions and students for more engaging and interactive learning experiences (Lewin et al., 2018). As noted by Gillie et al. (2017), statistics education has evolved from a time when rich-media support in teaching was rare to a time when it is increasingly expected.

As I explain in my literature review the field of online statistics education has largely focused on comparing student performance across different modes of instruction, including online, face-to-face, and hybrid approaches. Some studies have reported better performance by face-to-face students (Scherrer, 2011; Sabbag and Frame, 2021), while others have found little difference in statistical literacy, reasoning, knowledge, or final grades across delivery methods (Shotwell and Apigian, 2015; Hahs-Vaughn et al., 2017). In addition to comparing student performance, other studies have explored how students' attitudes and fears regarding statistics impact their course outcomes and have compared attitudes across different education styles (Gundlach et al., 2015; Zimmerman and Austin,

2018). The results of these studies indicate that online students tend to have higher levels of test anxiety, which can have a greater impact on course achievement than experienced by face-to-face students (Zimmerman and Austin, 2018). Online and flipped sessions also tend to view statistics as more challenging and generate less positive attitudes towards statistics compared to traditional sections (Gundlach et al., 2015). Furthermore, Shotwell and Apigian (2015) found that online students rely more on the textbook and homework assignments, while face-to-face students primarily use in-class assignments and exams.

In recent years, the current research on lecture capture has focused on quantifiable metrics such as student achievement or physical attendance, using a positivist approach that views education and learning as observable, measurable, and quantifiable (Wahyuni, 2012; Luke, 2020). However, this approach fails to account for the complex nature of rich-media resources and their impact on students' statistical anxieties, self-efficacy, and performance.

1.5 The emotional impact of technology in education

Education is a deeply emotional and human activity. The use of technology in education has a deeply emotional and human effect on students, beyond the cognitive impacts of teaching and learning, and there is a growing consensus that all learning is entwined with our emotion (Immordino-Yang and Damasio, 2007). If students' experience in higher education is considered to be limited to 'gathering of expertise and verifiable ability' (Zeide, 2017), the emotional aspect of this experience becomes downplayed or overlooked. Moreover, technology shapes the tangible experiences of students within the educational setting, influencing their interactions and engagement. This focuses on technology's observable effects on student experiences without delving into the deeper, potentially unobservable cognitive or neurological impacts. In the context of my study, technology has been shown to influence not only the cognitive and emotional aspects of education but also the way students engage with educational content. This impact is evident in their cultural, affective, and emotional experiences. According to Bhatt (2014), e-learning consists of dynamic and intertwined relationships between how it is used in practice and how it is influenced by tools, cultural norms, historical patterns of

use and understanding. This point of view normalizes technology-assisted learning and recognizes it as a human endeavour shaped by core human qualities, with Castañeda and Selwyn (2018) suggesting that more emphasis on the interaction between students' emotions, feelings, and affect is necessary in order to explore the concept of digital technology use as a community endeavour rooted in social interactions. In keeping with this, they argue that the social-practice perspective on statistics e-learning shares similarities with the social-practice perspective on the statistics learning experience.

1.6 Introducing the constructs

The title of my study, *'Investigating the impact of rich media resources on students' self-efficacy, statistics anxiety, and performance',* outlines the focus of my research. This study will centre on exploring these three key constructs.

1.6.1 Statistics anxiety

Statistics anxiety is a well-documented issue in the field of statistics education research (Frey-Clark et al., 2019) with various definitions of statistics anxiety proposed by different authors, including Onwuegbuzie et al. (1997), who define it as 'a state-anxiety reaction to any situation in which a student is confronted with statistics in any form and at any time'. Zeidner (1991) defines statistics anxiety as the affective, cognitive, and physiological responses – such as worry, intrusive thoughts, mental disorganization, and tension – experienced when working with statistics. Cruise et al. (1985) describe it as the feelings of anxiety encountered when taking a statistics course or doing statistical analysis.

Studies have shown that high levels of statistics anxiety can have a negative impact on students' ability to learn the skills, information, and techniques needed to interpret and criticize research findings. Additionally, students with high levels of statistics anxiety may experience lower academic performance and face a higher likelihood of dropping out of their degrees or taking longer to graduate. This issue is particularly prevalent among social sciences students, with 80 percent of graduate students in this field reporting high levels of statistics anxiety (de Vink, 2017). According to Perepiczka et al. (2011), research in the field of statistics

education has also shown a relationship between the number of completed mathematics courses and statistics anxiety among social work students. Minimal prior maths experience, a late introduction to quantitative analysis, anti-quantitative bias, lack of appreciation for the significance of analytical models, and a lack of mental imagery were all identified as contributing factors to statistics anxiety (Perepiczka et al., 2011). Furthermore, multiple studies have found that a higher level of statistics anxiety is linked to lower exam performance (Keeley et al., 2008; Macher et al., 2015; de Vink, 2017). To address the negative effects of statistics anxiety, researchers have attempted to understand its multidimensional nature, and Cruise et al. (1985) has identified six components of statistics anxiety: (a) Worth of Statistics, (b) Interpretation Anxiety, (c) Test and Class Anxiety, (d) Computational Self-Concept, (e) Fear of Asking for Help, and (f) Fear of Statistics Teachers (Hsu et al., 2009).

Statistics anxiety can manifest differently for each person and is considered a persistent issue unless there is intervention in the environment or experience (Macher et al., 2015; Frey-Clark et al., 2019). According to Todd (2020), anxiety can limit an individual's comfort level when working with information, and this experience is unique to each person. Anxiety has a spatial, temporal, and relational aspect and is influenced by specific places, times, and materials and communication, and statistics anxiety can be a constant presence or only occur when studying statistics in a classroom setting. During this study I aim to focus on understanding the emotions and experiences associated with statistics anxiety, and how it affects students during their academic journey.

Statistics anxiety is not merely an emotional state that students bring to the statistical learning environment but an emergent phenomenon that is produced and reproduced in the intra-actions between students and their learning environments. It is influenced by a myriad of interconnected factors such as the complexity of statistical content, students' prior experiences with statistics, pedagogical practices, and the type and quality of available learning resources (Onwuegbuzie and Wilson, 2003). The view of statistics anxiety as an emergent phenomenon also has significant implications for how it can be addressed,

suggesting that strategies to reduce statistics anxiety need to be multifaceted and responsive to the unique set of conditions that produce anxiety for each student. For instance, the deployment of RMR as a pedagogical tool can alleviate anxiety by catering to diverse learning styles, simplifying complex statistical concepts, and offering opportunities for repetitive practice and self-paced learning (Chew and Dillon, 2014b; Frey-Clark et al., 2019). However, it is crucial to note that these resources are not intrinsically anxiety-reducing; their efficacy is contingent upon how they intra-act with students and the broader learning environment. The engagement of students with RMR and their impact on their anxiety will be explored through a sociomaterial lens. Quantitatively, this study explored the levels of anxiety among students who engaged with RMR compared to those who did not. By employing statistical methods, the research aimed to objectively measure and understand the variations in anxiety levels associated with the use of RMR, offering an insightful perspective into its potential effects on student anxiety.

1.6.2 Self-efficacy

My research examines the impact of digital resources with rich media on students' statistics self-efficacy. The self-efficacy of students is affected as they interact with these resources, which include visual, auditory, written, and textual elements, and with more options for sound, image, and language, there are greater opportunities for creating meaning. The material and social contexts that shape meaning into different modes are constantly present, and I aim to understand the association between the use of rich media resources and students' statistics self-efficacy. By analysing the relationship between these variables, the study seeks to explore whether and how engagement with RMR is linked to students' perceived self-efficacy in learning statistics.

Self-efficacy is a concept related to statistical anxiety and represents the second construct of my research. It refers to an individual's belief in their ability to achieve specific performance objectives in a particular environment, as defined by Bandura (1994) in the context of social cognitive theory, and statistics self-efficacy

specifically refers to an individual's confidence in their ability to complete statistics-related tasks. Finney and Schraw (2003) describe it as ‘confidence in one's abilities to solve specific tasks related to statistics’, while Bandura's (1997) understanding of self-efficacy is deeply entrenched in the social cognitive paradigm, a development that integrates elements from both cognitive and behavioural paradigms. This integration emphasizes the pivotal role of observational learning and the intricate interactions occurring between individuals and their surrounding social contexts (Bandura, 1997). At its core, self-efficacy is a profound cognitive construct. It not only signifies an individual's belief in their capability to perform specific tasks and reach desired outcomes but also influences their choices, the effort they exert, their persistence in the face of challenges, and their emotional responses to situations. Such beliefs or cognitions are instrumental in shaping an individual's behaviour, especially in the way they navigate challenges and demonstrate resilience when confronted with adversities (Bandura, 1997). In essence, the socio-cognitive paradigm underscores the symbiotic relationship between personal cognitions, actions, and the environment, painting a comprehensive picture of human behaviour and its determinants.

According to Pathirage and Pathirage (2015), students' statistical performance is positively related to their self-efficacy in performing these tasks, and that low self-efficacy can negatively impact performance, even if the individual has the necessary knowledge and skills. Additionally, there is evidence of a negative relationship between statistics self-efficacy and statistics anxiety, as well as a positive correlation between self-efficacy in learning statistics and attitudes toward statistics (Perepiczka et al., 2011; Cui et al., 2019). It has also been suggested that students' self-efficacy plays a role in determining their level of statistics anxiety (Perepiczka et al., 2011) with Kaufmann et al. (2022) emphasizing the importance of self-efficacy and its connections to other concepts such as anxiety, motivation, and academic performance. Similarly, Honicke and Broadbent (2016) note that a lack of self-efficacy can lead to a loss of motivation and difficulty persevering when faced with challenges. Students’ self-efficacy in statistical practices play a significant role in their performance in statistics-related tasks and is a variable

specific to the learning of statistics. Self-efficacy theory posits that individuals have varying beliefs in their abilities in specific contexts or tasks, rather than a generalized confidence across all areas. This means that one might feel highly capable in one area (like public speaking) but less so in another (like mathematics). The theory emphasizes not just the belief in one's ability to perform an action but also the ability to manage one's thoughts, motivations, and emotional and psychological well-being (Bandura, 1997: 36). Transitioning from a purely psychological perspective, it's interesting to also consider the insights from social anthropology. According to Pink (2015), the self is shaped by the individual's sensory learning experiences and interactions with their social, sensory, and material environment. Moreover, I believe that self-efficacy is unique to each individual and changes in response to their sensory experiences in their socially constructed environment. There is only limited research on students' statistics self-efficacy while e-learning statistics and how it is shaped by their socially constructed environment.

1.6.3 Performance

In this study, the impact of RMR on the performance of students on the Numeracy and Data Analysis (NDA) course will be examined with performance measured by the assessment marks in the course, which will be a numerical construct. The NDA course was taught in two blocks throughout the academic year, and the average of Block 3 and Block 4 NDA 1 and NDA 2 assessments will be taken. These assessments were designed by the teaching team to test the learning objectives, which covered basic introductory level statistics concepts and some numerical concepts as well. Each assignment was worth 100 marks, and students had to submit one assignment in each block. Therefore, the marks of the two assignments will be averaged to create a single performance variable, which will be a mark out of 100 that the student received at the end of the academic year. This approach will allow for a quantitative exploration of the associations between the use of RMR and students' performance in the NDA course. By analysing these relationships, the study aims to provide insights into how engagement with RMR correlates with performance outcomes, rather than making a definitive claim about its impact.

After exploring the key constructs – self-efficacy, statistics anxiety, and performance – it becomes evident how critical these elements are in the context of education. As technology, particularly rich media resources, continues to shape the educational terrain, it is essential to explore the potential associations between RMR use and these constructs. This study, therefore, emerges from an attempt to unravel the relationships between technology-driven educational resources and the pivotal constructs that define the student experience. It is not merely an academic pursuit but a deep-rooted aspiration to bridge the gaps in our current understanding. In my effort to better understand our evolving educational landscape, I have generated the following research questions to guide this study.

1.7 My research questions

1. Are there statistically significant differences between students that did and did not engage with rich media resources in terms of the students' statistical anxiety, statistical self-efficacy, and performance?
2. What is the potential appeal of rich media resources for students who are experiencing statistics anxiety?
3. How do students experience RMR and what do their embodied experiences of learning in this way tell us about the affordances of this mode of learning?
4. How do students and material things interact together to form a statistical e-learning experience?

1.8 Thesis outline

The thesis will be structured into nine chapters, beginning with the introduction in Chapter 1:, which establishes the research problem and the constructs being investigated. Chapter 2: will provide a comprehensive literature review of the study, tracing the journey from cognition to socially situated cognition, and ultimately settling on actor–network theory, which brings together both human and non-human entities. This chapter will also examine how the selected theory fits into the research context and serves as a theoretical framework for the study.

Chapter 1: will present the rationale for the heterogenous emergent approach, which emphasizes the importance of a flexible research design that can adapt to the changing needs of the study. It will also detail how the chosen approach can help address the research problem and research questions.

Chapter 4: will focus on the methods employed in the study, including the techniques, instruments, and procedures used in the research process, as well as providing a detailed account of the research design, data collection, and data analysis.

Chapter 5: and Chapter 6: will consist of two separate strands of the mixed methods design, qualitative and quantitative, and present the results of the study, followed by Chapters 7 and 8, in which I will present the data analysis and the discussion of the findings. These chapters will provide insights into the implications of the findings for the constructs under investigation.

In the final chapter (Chapter 9:), the conclusion, the overall findings will be presented and discussed. Firstly, the specific answers to the research questions will provide the concluding remarks of the study, drawing on the research questions, findings, and theoretical and empirical foundations established in the previous chapters. It will also discuss the contributions and limitations of this study and provide recommendations for future research.

The final part of this dissertation consists of a general discussion of the study as a whole. In this chapter, the overarching research question will be addressed by examining the complex dynamics of the three constructs (statistical anxiety, self-efficacy, and performance) in relation to engagement with rich media resources (RMR). The chapter also offers a critical reflection on the methodological strengths and limitations of the full research project. Throughout the unfolding research process, the study remains oriented towards the exploration of new ways of seeing and understanding, resulting in a methodologically heterogeneous research project. In this process, the value of the combination of separate strands, distinct theories, and ontologically different approaches becomes apparent for an

understanding of the impact of RMR on student statistical anxiety, self-efficacy, and performance.

Chapter 2: Literature Review

At the outset of this literature review, it's important to acknowledge the inherent challenge faced by the reader in navigating through diverse and complex theoretical frameworks. We are delving into realms that span cognitive processes and socially situated cognition, as well as sociomateriality and actor-network theory. These concepts, while not automatically interconnected, are brought together in this review to provide a comprehensive understanding. As a novice researcher and someone new to ANT, I initially struggled with reconciling the contradictions between the theories, such as social cognitive theory discussed in Section 2.1, and ANT. My first instinct was to find ways to eliminate these contradictions, as most people are uncomfortable with cognitive dissonance. As I continued to understand my project, I realized that when it comes to comprehending the impact of rich media resources on the anxiety and efficacy of students, it is important to consider not just the relations between the resources and other entities but also how the properties and spatial configurations of these resources give rise to emergent learning activity. I recognize that merging these apparently incommensurate ideas presents a unique intellectual challenge, and it is my intention to guide the reader through this intricate synthesis thoughtfully and coherently.

In my literature review chapter, I will explore the theories and ideas around how students interact with digital materials. Figure 1 shown below serves as a heuristic, helping to explain the foundation for my thought process on this project.

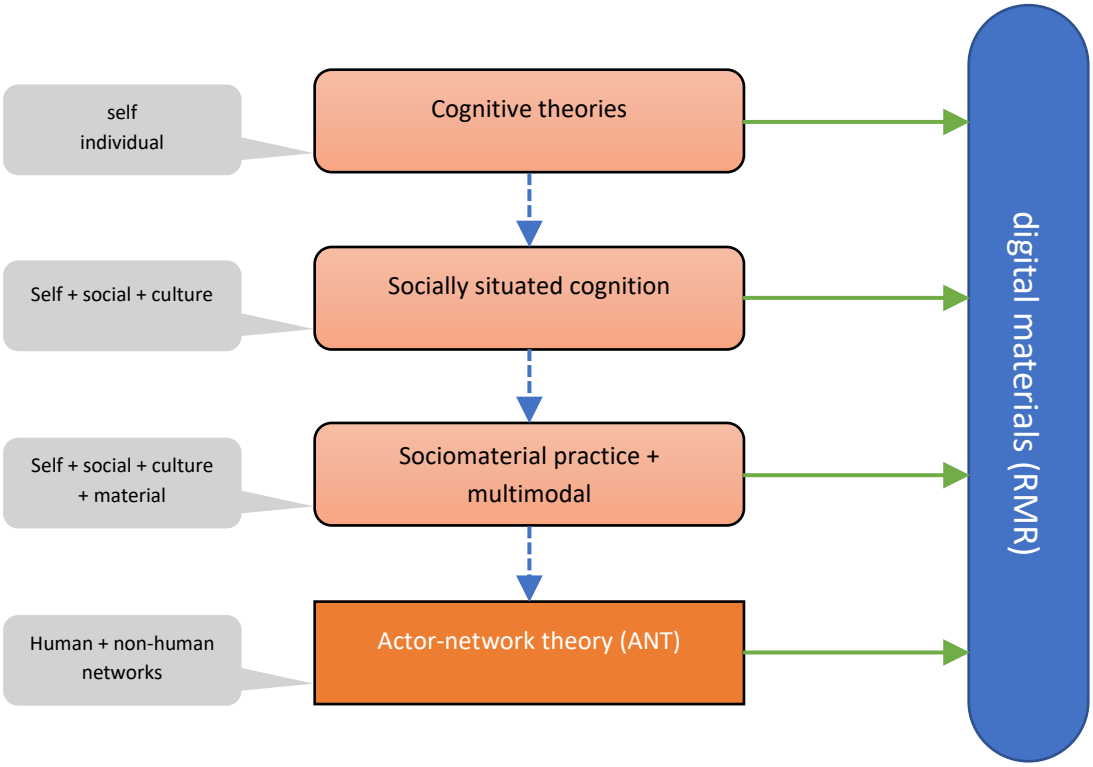

Figure 1: Heuristic for describing how I think

Starting with cognitive theories related to e-learning, it is essential to understand that self-efficacy is a component of social cognitive theory. Bandura (1997) asserts, 'Effects are not the characteristics of agentive acts; they are the consequences of them... Beliefs of personal efficacy constitute the key factor of human agency'. In this assertion, Bandura underscores the significance of the self in our actions, positing that our actions are not solely determined by their outcomes but, more importantly, by the intentions behind them. At the heart of this perspective is the belief in oneself: the conviction that we possess the power to take purposeful actions. It is this belief in our own efficacy that stands as the foundation of our ability to act autonomously.

Cognitive theories related to e-learning provide valuable insights into the mental processes underpinning interactions with digital resources and shine a light on the cognitive structures that help learners to understand and apply knowledge acquired from these resources. As we transition from focusing on individual

cognitive functions, we dive deeper into the realm of socially situated cognition, a stance that propounds that cognition is not a solitary affair but intricately woven into the socio-cultural fabric. Learning, therefore, emerges as a process deeply embedded in social contexts. Taking this further, I spotlight the utilization of RMR as a multifaceted, sociomaterial undertaking, a viewpoint that facilitates a profound appreciation of the intricate dynamics among learners, digital tools, and the encompassing sociomaterial ecosystems, emphasizing how each facet shapes the learning trajectory. Understanding cognitive processes and the arising social dynamics requires a holistic perspective. It is not only about isolated experiences but the interconnected web they form. Cognitive processes, emotions like anxiety, and beliefs such as self-efficacy are embedded within a larger network, where these elements are in constant flux, influenced by both tangible and intangible factors of the learning environment. This overview introduces a complex interplay of factors, which is explored in greater detail in the literature review, guiding the reader through each concept step by step. To truly grasp the association between RMR and students' statistical anxieties and self-efficacy, a holistic approach is paramount. This approach acknowledges the interplay of human and non-human entities within learning domains, understanding them as entities in constant evolution alongside their users. By tracing the intricate web of connections among physical objects, humans, space, time, and even more elusive elements like tacit modalities, a clearer picture emerges. This narrative paints how these diverse factors collaboratively impact students' emotions and proficiencies, and accentuates the essence of viewing learning as an intertwined network rather than the sum of isolated components. Lastly, I turn to actor–network theory (ANT), a robust framework that allows for the tracing of intricate relationships among both human and non-human actors in the educational setting (Latour, 2005). By incorporating ANT, I acknowledge the agential capacities of all actors – human and non-human alike – in the process of knowledge co-construction. Moreover, the structure of this literature review is designed to offer a sequential and integrative perspective on the multifaceted phenomena surrounding learning with digital materials in contemporary educational settings. Each section builds upon the last, resulting in a layered, comprehensive understanding of the subject at hand.

2.1 The evolving landscape of digital learning theories

The cognitive theory of multimedia learning (Schneider et al., 2022) is a central theory of learning with digital media, based on three assumptions: (1) information is processed via two cognitive channels; (2) working memory capacity is limited; and (3) learners need to actively process information to build coherent mental representations and models. CTML distinguishes between five cognitive processes during learning with digital materials: the selection of relevant words (1) and images (2), the organization of the selected words (3) and images (4), and the integration of the verbal and pictorial mental model with the learner's prior knowledge (5; i.e., the building of a coherent mental model) (Schneider et al., 2022). These processes repeat for each section of the multimedia message.

Looking at learning with media from a cognitive perspective, Hawley (2021) posits that metacognitive and affective processes are integral extensions to learning theories. The augmented cognitive load theory and the cognitive-affective theory of learning with media suggest that emotional and cognitive processes are intertwined in the learning process, and that metacognitive and affective factors mediate or moderate the process. These extensions emphasize that learning is not solely a cognitive process but also involves emotional, motivational, and metacognitive factors (Schneider et al., 2022). Engaging with digital educational content, particularly rich media resources, can evoke social experiences, making the relationship between a learner and a digital tool feel more social than merely technical. The subsequent sections will delve into the emergence of social dynamics within digital spaces and discuss how these theoretical insights inform and mould the direction of this project.

Digital technology interaction has a social component that involves the interaction of digital environments and human beings. The computers-as-social-actors framework, as described by Nass et al. (1994), suggests that computer-based interaction is primarily a social event that is based on social cues. The social cues within digital media environments, such as touch, voice, gaze, or gestures, prime a social activation schema that triggers social processes and scripts of human-to-human communication. Even if no other actual humans are present, learners can

interpret their interaction with technology as a social event (Xu and Lombard, 2016) as a result of implicit anthropomorphism, which is the tendency to attribute human characteristics to non-human objects, such as technology/gadgets. Simple cues, such as voices and touch, can create the sense of social presence and lead to social responses, and the computers-as-social-actors framework posits that multimedia environments can elicit social processes, leading students to perceive their interactions with technology as social events, which in turn can influence their learning experiences (Schneider et al., 2022). This notion is supported by socially situated cognition theory, which suggests that learning is not solely based on cognitive functions, but also on the interaction between behaviour, environmental resources, and other learners. (Schneider et al., 2022).

2.2 Socially situated cognition

Socially situated cognition theory suggests that learning is not just based on cognitive functions like attention and perception but also on the interaction between our behaviour, the behaviour of others, and environmental resources (Hawley, 2021), and it emphasizes that learning arises from a mutual adjustment of behaviours when individuals interact. Distributed and embodied cognition theories provide specific insights into learning processes, proposing that cognition is not confined to the individual but emerges through interactions with various elements distributed within a system, including the environment and tools at one's disposal. These theories illuminate how individuals leverage both internal and external resources to facilitate cognitive processes and learning. In this view, minds are not contained within brains or bodies but rather extended outwards, and artefacts play a significant role in reasoning processes. People's beliefs are rooted in their direct sensory interactions and experiences with objects and tools. According to Carvalho and Yeoman (2018), both cognition and perception work together to find alignment between our actions and our predictions about the environment. It is recognized that learning is situated in epistemological, physical, and social contexts, and they emphasize the social nature of knowledge through the concept of "networks". Networked learning accentuates collaboration and participation, which not only fosters co-creation but also bolsters people's engagement in knowledge-building

processes. Kittler (2004) argues that the university itself can be analysed as a network, wherein modes and media of communication carry meanings between streams and flows that make up the texture of the contemporary world. Therefore, a deeper comprehension of how students, media, and learning interconnect is required. Essentially, the way students engage with media and apply it to their learning is influenced by their specific circumstances and the educational environment they are part of (Gourlay, 2015).

Engagement with the RMR I have discussed earlier can generate social processes that affect students' cognitive abilities, including their emotions, self-efficacy, and anxiety related to specific subjects. However, when trying to envision this process, there appears to be a gap that neglects the materiality of the objects, space, timing, and tacit modalities. Typically, when people think of learning with rich media, while they acknowledge the significance of social elements and subtle, underemphasized factors in learning, they primarily concentrate on individual motivation and effort. The significance of the learning environment, and the material and temporal dimensions are often disregarded (Gourlay, 2015). This perspective is rooted in a strongly humanistic conception of education, which places the supposed agentive and free-floating human at the centre, relegating objects, resources, and devices to the status of mere “tools”. Spatial and temporal dimensions, while acknowledged as essential, are considered as mere ‘context’ or backdrops to human action and endeavour. As cited by Gourlay (2015: 407), Fenwick et al. (2011), have attempted to reframe education practices by highlighting the agency of non-human elements, such as material objects, physical artefacts, and settings.

> *Humans, and what they take to be their learning and social process, do not float, distinct, in container-like contexts of education, such a classrooms or community sites that can be conceptualised and dismissed as simply a wash of material stuff and spaces. The things that assemble these contexts, and incidentally the actions and bodies including human ones that are part of these assemblages, are continuously acting upon each other to bring forth and distribute, as well as to obscure and deny, knowledge.*
> *(Fenwick et al., 2011, vii)*

Cognitive processes and social events do not arise in a vacuum but are part of a broader network in which a student's anxiety and self-efficacy fluctuate. Therefore, to comprehend the impact of RMR on students' anxieties and self-efficacies, a framework is required that captures the entire network. I aim to offer a different approach to understanding and exploring the impact of rich media resources on students' statistics anxieties and self-efficacy in this section, which involves looking at the entanglement of human and non-human elements within learning spaces, which I believe is always changing and evolving with its inhabitants. By examining the flows and interconnectivity between different parts of the elements and their identities, we can better understand the non-subjective assemblage of physical objects, humans, time, space, and the intangible elements, including tacit modalities, and how they all work together to impact students' emotions and abilities. This perspective emphasizes the importance of considering the whole network of factors involved in learning, rather than just the individual student or resource in isolation.

2.3 Sociomaterial theoretical approach

The sociomaterial strand of theoretical work, as argued by Fenwick et al. (2011), challenges the traditional focus on human processes in learning and instead consider the materiality of learning, treating the material and the human equally to explain how entities, knowledge, and other actors converge in learning. Sociomaterial studies explore relations between entities through which activity occurs, rather than the individual entities themselves, tracing the ever-shifting web of interaction that holds these processes together. This sheds light on how increased connectivity and participation in networked structures leads to an increased dependence, driving the need to understand the relations between constituent parts. However, as Carvalho and Yeoman (2018) note, simply exploring these relations risks failing to explain how the parts relate to the whole and how they support valued learning activity. When it comes to understanding the impact of rich media resources on the anxiety and efficacy of students, it is important to consider not just the relations between the resources and other entities but also

how the properties and spatial configurations of these resources give rise to emergent learning activity.

The framework used in the upcoming literature review section is based on the notion of sociomateriality, which includes perspectives that are helpful in analysing how RMR and related technologies impact emotions, anxieties, and efficacy in education. It is important to recognize that education is not just about human cognition but also about material practices, nature, time, space, technologies, and objects. In other words, sociomaterial studies show that everything around us, including technology and objects, plays a significant role in shaping our learning experiences. Casting a light on the everyday dynamics in educational events and enhanced by the idea of tacit modalities, sociomaterial studies help us understand learning in a deeper way. Enriched by Rowsell and Abrams (2021) concept of 'tacit modalities' – the subtle ways our senses and experiences interact with the environment – sociomaterial studies shine a light on the everyday dynamics in educational events, and these nuanced interactions, often overlooked, are instrumental in shaping our learning and comprehension while offering a more comprehensive perspective on education. Rich media resources (RMR) and related technology is part of a larger system of actors and relationships that affect educational space and time. By analysing the sociomaterial dynamics of this system, we can better understand how RMR impact students' emotions, statistics-related anxieties, and self-efficacy.

2.4 Shifting perspectives: the importance of sociomateriality in understanding the impact of RMR

As mentioned by Howard (2022), there are numerous theories that can be applied to attempt to explain the various interventions or strategies designed to boost students' self-efficacy in learning mathematical content. One such theory addresses physiological and affective states, which can impact self-efficacy (Bandura, 1997; Usher and Pajares, (2008)), and anxiety in academic settings, often used as an indicator of these states, has been identified as a source of poor self-efficacy

(Bandura, 1997; Usher and Pajares, 2008), while other theories include experiential (Wenger, 1998) and emotional accounts (Beauchamp and Thomas, 2009). Relevant to this inquiry, however, is a poststructuralist, sociomaterial approach that acknowledges how students' self-efficacy and anxieties are shaped through social interactions and material practices (Mayer, 2020; Todd, 2020; Howard, 2022). These emotions and beliefs emerge from lived experiences and are influenced by narratives, which are in turn shaped by the normative assumptions that actors believe they should adhere to (Howard, 2021). As explained by Ebben and Murphy (2022), it is the variety of self-talk and emotions that play a crucial role in identity formation, which in turn influences self-efficacy and beliefs. Self-efficacy and anxieties are complex, relational, and constantly changing, and students must navigate various narratives and societal expectations while also considering the tangible and digital-material aspects of their experiences. The interaction between human and non-human elements can influence educational practices and shape identities, emotions, and anxieties (Stephen and Rockinson-Szapkiw, 2021). As students use technology in practice, it may result in significant changes to their workflows, relationships, power dynamics, and cognitive processes, which Huang and Mayer (2018) find can either threaten or reinforce their self-beliefs, depending on how they perceive the material agency of technology.

In the context of education, a sociomaterial perspective argues that matter is important, and a 'more-than-human' view of the world should be considered (Gourlay, 2014, 2015; Fenwick, 2015). According to Fenwick (2015: 84), materials and things that matter are often overlooked in accounts of learning and practice.

> *Materials—things that matter—are often missing from accounts of learning and practice. Materials tend to be ignored as part of the backdrop for human action, dismissed in a preoccupation with consciousness and cognition, or relegated to brute tools subordinated to human intention and design. This treatment still tends to privilege the human subject, which is assumed to be different or separate from the material: the material is the non-human… Today, however, it is fair to acknowledge a growing educational interest in understanding everyday material and social inter-*

relations: why matter matters, and how to unpick the abstractions that can blind us to the micro-dynamics that influence everyday practices.

Johri (2011) uses the expression ‘sociomaterial bricolage’ to capture the dynamic and habitualized learning practices that occur through learners successfully leveraging the tools and artefacts available to them (Bhatt, 2014). Building on the theoretical discussions from the previous sections, there is scope to explore the viewing of RMR practices through the same framing, in order to help explicate the relationship between technology and engagement with RMR practices. I have conceived the digital practices of statistics students as taking place within a sociomaterial system or 'assemblage'; that is, in conceptualizing them, I encompass both material and social considerations. This is a key tenet of a set of theoretical sensibilities that have come to be known as actor–network theory (ANT, outlined later in this chapter). Effective evaluation of engagement with RMR events in digital environments can be productively grounded in a robust theory that relates the potentials of technologies and artefacts in the practices of RMR engagement and how these are enacted over apparent time/space parameters. ANT provides a theory of this kind, and the following sections outline how I will draw upon its palette of theoretical resources in my research. This will be presented firstly with a discussion of 'sociomateriality' as a theoretical sensibility and ontology, followed by an exploration of multimodality and its relevance. Then, I will present ANT-inflected approaches and explain how I have applied this theory's methodological implications.

2.5 Sociomateriality

Sociomateriality is a theoretical framework that explores the entanglement of human and non-human resources in creating actions, objects, knowledge, and space. Initially developed to investigate the relationship between technology and work practices in organizations, the concept emphasizes the interdependent nature of human bodies, physical artefacts, technologies, and other agents that are woven together (Lamb and Ross, 2021). Sociomateriality focuses on the network of human and non-human discourses and phenomena that are involved in meaning-making processes, rather than solely relying on human interests and actions (Knox and

Bayne, 2013). In higher education, sociomaterial theory emphasizes the co-dependence of the lectern, laptop, and learning management system with human bodies in meaning-making practices (Lynn Thompson, 2012), offering a sensibility or way of thinking that is open to the full range of human and non-human resources and modes involved in educational practice, through the concepts of assemblage and relationality. This framework can help us understand how learning space and technology are related as a shifting continuum, alerting us to the unseen interests that shape these relationships (Lynn Thompson, 2012; Knox and Bayne, 2013).

The study of e-learning often presents a descriptive account of machines' capabilities and their potential advancements. By examining the properties and affordances of technology, as well as the digital learning practices that manifest these relational effects, we can better understand how things develop and how we can influence them. Sociomaterial assemblages are responsible for shaping ways of 'being' and 'doing' (Latour, 2005; Fenwick and Edwards, 2012), and actor–network theory (ANT) offers valuable techniques to explore digital learning practices and the sociomaterial assemblages in which they arise (Luke, 2020). Building on this sociomaterial foundation, the concept of multimodality further enriches our understanding of digital learning environments.

2.6 Multimodality

My research uses multimodal data collection methods that are attuned to the environment being researched to ensure that the holistic multimodal character of the artifacts – the digital resources like RMR and/or interaction – is recorded (as far as is possible). Modal affordances of RMR are connected to both a mode's material aspects and the social purposes that it has been used for in a specific context. Every interaction and communication with the material or human is mediated via modes. By multimodality, we mean a more mixed set of semiotic resources – or modes – used for meaning-making, and within multimodality, the objects and sequences of interaction are understood as meaningful signs – the outcome of a person's or people's actions, imbued with the maker's interests mediated through the environment in which the sign was produced or encountered (Kress, 2010).

Meaning is understood as a socially situated choice from a dynamic set of available resources, the affordances of which are shaped through their historical, cultural, and social usage and their materiality – all of which relate to and are shaped by technologies (Jewitt, 2020). Multimodality enables us to describe, categorize, and understand the material and social resources and affordances of digital resources, the principles that underpin them, and how they are shaped (Jewitt, 2020). Considering the use of RMR as a multimodal and sociomaterial practice helps shed light on the complex interplay between learners, digital materials, and their environments. This perspective underscores the importance of tacit modalities – those subtle, often unnoticed elements like sensory experiences, emotional responses, and embodied actions that shape learning and influence anxiety and self-efficacy (Rowsell and Abrams, 2021). When it comes to understanding the impact of RMR on the anxiety and efficacy of students, it is crucial to consider not only the relationships between the resources and other entities but also how the properties and spatial configurations of these resources give rise to emergent learning activities. Every emergent learning activity involves multiple modes that are in constant play, and in order to capture and understand how these modes function in everyday life, I attuned to the multimodal journaling method.

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2.7 Actor–network theory (ANT)

Actor–network theory (ANT) emerged in the 1980s from the field of science and technology studies, associated with the work of Michel Callon, Bruno Latour, and John Law (Heeks, 2013), seeking to understand how networks form, connecting

heterogeneous actors including humans, non-humans, and intangible entities (Latour, 1999). This perspective highlights the often-overlooked agency of non-humans, distributing agency across networks of humans and non-humans (Latour, 2005) with ANT providing an approach that allows us to track how things come together, operate, and become taken for granted or 'black-boxed' (Fenwick and Edwards, 2010).

Rather than seeing ANT as a theory, many scholars view it as a method, focusing on describing relationships at different sites of mundane, messy local practice (Law, 2009). Drawing on post-structuralist ideas and the concept of the 'rhizome' (Deleuze and Guattari, 1987, 2004), ANT has evolved into a family of theoretical resources that concentrate on the relational activities of sociomaterial networks or assemblages (Bhatt, 2014). By following actors and their connections, ANT helps understand relational activity in various contexts, such as e-learning events, and the transformations that occur within them (Bowker and Star, 1999; Latour, 1993).

The objective of ANT research is to examine the micropractices that occur in students' day-to-day lived experiences, focusing on how humans and non-humans continuously co-create and enact routine, emerging, and localized practices, such as students in my study engaging with rich media resources (RMR). ANT is centred around practice, emphasizing concrete practices, especially materiality, and practices, as Reich and Hager (2014) contend, are dynamic and emergent, as they are perceived as the interwoven combinations of humans and objects.

2.7.1 Exploring the dynamics of actor–network theory in rich media learning environments

In this section, I offer a concise overview of several ANT concepts that resonated strongly with this research project. Firstly, the notion of symmetry is central to ANT, suggesting that human and non-human actors are equally important and capable of influencing each other at the outset (Latour, 2005). Things possess agency as parts of networks, not individually, and ANT highlights how things in practice are connected to various other actors, both human and non-human. When a student begins viewing or engaging with RMR, a networked assemblage of people

and objects (e.g., computers, laptops, tablets, pens, paper) extends through time and space, and such a network, also known as an actor-network, can make other actors behave in specific ways (Law, 2009). Mol (2010) talks about the double aspect of actions, whereby an actor performs, creates change, and at the same time is influenced by other actors around it. Actors come into existence through activities happening 'here and now' (Mol, 2002: 33; Oosterhoff et al., 2021), and this distinctive view on the question of 'what exists' suggests that actors and practices, formed by a specific collection of actors, shape 'what is'. Groups of people and objects create reality, and because different objects are gathered and used in various locations, multiple realities arise (Mol, 1999). As a result, things are not fixed or stable entities; instead, they are constantly emerging and changing (Law and Singleton, 2005). Therefore, practices carried out by and through these assemblages of unstable, dynamic, and diverse actors are complex and fluid. The goal of studying the actions within networks is not to discover overarching explanations but rather to explore their unexpected impacts in everyday, localized practices. In line with this, students' engagement with RMR and the subsequent shifts in their self-efficacy and anxieties are not static or stable but continuously adapting and evolving.

While working on this research project, I learned that every student creates their own unique network of elements while studying statistics using Rich Media Resources (RMR). Within that network, their anxieties, self-efficacies, and various beliefs, emotions, and feelings are in a constant state of flux, and these assemblages of networks, enacted by and through these unstable, dynamic, heterogeneous actors, are fluid and complex. The objective of studying networks within students' learning practices is not to find overarching explanations but to unravel their surprising effects in everyday, local practice.

The qualitative strand's second phase, 'Dialogue with the unspoken: tacit modalities in a sociomaterial landscape', describes in detail how a network is formed when a student views RMR, simultaneously shaping and being shaped by local, situated e-learning practices through numerous connections and disconnections between locations, categories, gadgets, computers, artefacts,

stationery, and a multitude of other actors. ANT examines how fluctuations in students' self-efficacy and anxiety are distributed among people and things in constantly shifting alliances within e-learning practices.

Beginning my research with limited experience in Actor-Network Theory (ANT), I found it challenging to integrate the divergent viewpoints of various theories, such as the social cognitive theory mentioned in Section 2.1, with ANT. Initially, I sought to resolve these theoretical disparities, as it is natural for most individuals to seek harmony in their understanding. However, as the project progressed, I began to appreciate the value of these discrepancies. ANT encourages acknowledging contradictions as important aspects of practices rather than dismissing them (Oosterhoff et al., 2021). Consequently, I challenged myself to tolerate incommensurability (Lather, 1993: 679) and explore what it could bring to the project, as stepping out of one's comfort zone often leads to discovering beautiful things. Embracing these theoretical contradictions became a crucial part of the PhD project's methodologically diverse approach, which will be discussed in the next chapter.

2.8 Interweaving actor–network theory, multimodality, and tacit modalities in statistics education and e-learning: a new perspective on self-efficacy and statistics anxiety

Taking a step back to trace the threads of my exploration, I am led towards actor–network theory (ANT), which sees everything as interconnected – both the physical and the non-physical, the tangible and the intangible (Latour, 2005). This theory explains how everything is linked and constantly changing, connecting both human and non-human elements in a lively process. In this case, the context is statistics education and e-learning, and in this setting, a student's self-efficacy in their statistics skills is seen as an evolving relationship that forms from various interactions within the network, including learners, educators, statistical tools, learning materials, and more (Fenwick and Edwards, 2010). Therefore, a learner's self-belief is not simply a standalone psychological state but tied to their

interactions within their social and material environments. The facets of statistics anxiety find new light through this lens, as the network's many actors – ranging from the structure of the learning environment to the nature of the statistical tasks themselves – collectively contribute to the subjective experiences of the students (Johnson and Onwuegbuzie, 2004; Pan and Tang, 2005). This illuminates the understanding that statistics anxiety is not simply a manifestation of individual psychological processes but a phenomenon shaped by a myriad of human and non-human actors interplaying within the learning environment.

My perspective widened as I drew upon the concept of multimodality described by Rowsell (2013) as an orchestration of multiple modes to communicate, represent, and express meanings. These modes, in their multitude, embrace the visual, aural, embodied, and spatial aspects of communication, interweaving them into the tapestry of learning. Multimodality encapsulates the richness of learning experiences, drawing attention to the vast array of communicational forms contributing to meaning-making and representing the sensed, embodied, and non-representational aspects of learning, including feelings, emotions, and memories (Rowsell and Abrams, 2021).

These tacit modalities come alive, shaping the way we experience and engage with the world and influencing how we think and feel, deeply impacting our understanding of reality. It is in these experiences that what we cannot touch becomes real, the unspoken becomes spoken, and the unseen becomes seen, and this active engagement with the world, with all its unique and changing aspects, is described by Barad (2007) as 'dynamic specificity'.

Both self-efficacy and statistics anxiety serve as pertinent examples of these tacit modalities, and these constructs, while elusive and often silent, exert a palpable influence on learners. They might be challenging to articulate verbally, but their presence is unmistakable, deeply felt, and profoundly impactful. To further explore these tacit modalities and their roles in statistics education, particularly in relation to e-learning, I will employ multimodal journaling techniques in subsequent chapters (Gourlay and Oliver, 2016a). This novel approach, with its focus on capturing the richness and subtlety of learning experiences, sets the stage for my

contribution to the field. In summary, this exploration aims to highlight the importance of understanding how human and non-human actors interplay to shape our learning experiences, underlining the role of tacit modalities and multimodalities in these experiences. By shedding light on these complex, interwoven relationships, I aim to enhance my understanding of statistics education and e-learning. This perspective could potentially offer new pathways to transform these experiences, reducing statistics anxiety, and enhancing self-efficacy.

2.9 Literature review conclusion

To conclude this literature review, I have drawn upon a multi-dimensional theoretical landscape that acknowledges both cognitive and socially situated processes in the context of digital learning. The cognitive theories explored in the initial part of the review establish a foundational understanding of the individual learning processes that engage with digital materials. However, learning is not an isolated cognitive event, and this idea led to the incorporation of theories concerning socially situated cognition in recognition that learning is deeply intertwined with our social and cultural contexts. Considering the use of rich media resources as a multimodal and sociomaterial practice has helped shed light on the complex interplay between learners, digital materials, and their environments. This perspective underscores the importance of tacit modalities – those subtle, often unnoticed elements like sensory experiences, emotional responses, and embodied actions that shape learning. Finally, by leveraging the actor–network theory (ANT), I was able to trace the complex networks of relationships among human and non-human actors within educational settings, highlighting their shared agency in the learning process. The perspectives drawn upon in this literature review, while diverse, all contribute to a rich, multifaceted understanding of how learning with digital materials unfolds in contemporary educational contexts. They lay a solid groundwork for my subsequent research chapter, in which I embrace an emergent approach and apply a mixed methods design that is intended to capture the full complexity of student engagement with RMR and its effects on their statistical self-efficacy, anxiety, and performance. It is important to recognize that these

perspectives do not exist in isolation, but rather they interact and complement each other to create a comprehensive framework to guide this study.

Chapter 3: Emergent Approach

3.1 Embracing an emergent approach

In this chapter, I will outline the various factors that led me to adopt an open and emergent research approach from the beginning of this study and the reasons for maintaining this approach throughout the research process. There were multiple reasons behind adopting an open and emergent research approach at the outset of this study and maintaining this stance throughout the research process. Firstly, ethical and political considerations prompted the decision to adopt an open research question as the study focused on the experiences of students with rich media resources (RMR) and how e-learning impacted their self-confidence (self-efficacy) and performance, as well as how it altered their anxieties. Given the sensitive nature of these aspects of participant emotions, feelings, and beliefs regarding their own self, it was deemed inappropriate for yet another outsider to impose a specific theory on their anxieties and self-efficacies related to statistics as a subject.

Instead, it was more ethical to begin with the lived experiences of the student participants and provide them with an agentic role in the research, an approach that allowed the participants to contribute actively to the research rather than being passive subjects, thereby acknowledging their autonomy and inherent value. Ethical considerations have been paramount in shaping this research design, and these are comprehensively addressed in the 'Ethical considerations' section (5.2.3) of this thesis. This approach highlighted their experiences, the issues they faced, and the concerns they had, taking these as a starting point for further research. As Lincoln et al. (2018, p. 135) suggest, inviting research participants to take control – by nominating questions of interest, for example – represents a means of promoting emancipation, democracy, and community empowerment.

The second reason for maintaining an open research approach is rooted in Karen Barad's (2007) concept of intra-action, which suggests that all phenomena are connected and shaped by the mechanisms used to measure or collect data. Failing to have clarity regarding these mechanisms can result in normalizing certain

‘reality-making’ processes, while ignoring others, and concealing the moral and political implications of these decisions. Given that actor–network theory (ANT) research is contextually bound, interventionist, and productive, ambiguity and uncertainty are integral components of the ordering process rather than methodological restrictions (Law, 2004), which means that my research narratives and affects are mutually and recursively influenced by methodological choices. Wrestling with ambiguity throughout the research process can be challenging, especially when dealing with sensitive topics such as students' self-efficacy beliefs and anxieties. However, viewing research as an activity associated with uncertainty can help researchers embrace the unknown and recognize worry as an opportunity for deeper understanding. This approach aligns with the exploratory approach, which aims to work with the uncertainties and open-ended nature of a networked environment and the digital world, as opposed to imposing order through a specific research paradigm. Researchers can experiment with different methods to make things different and to produce new knowledge (Creswell, 2013), an approach recognizing with the messiness of social research, which seeks to produce a world in motion rather than uncovering a pre-existing reality. Sociomaterial theorists emphasize the importance of recognizing both human and non-human resources in the creation of meaning and action, and speculative methodology in digital education can be a valuable alternative to the pseudoscientific methodologies popularized by the ‘what works’ agenda (Biesta, 2009, 2020a).

The third reason emphasizes the importance of adopting a more humble scientific stance. As Law (2004) argues, the issue does not necessarily lie within the standard research methods themselves but in the normativities attached to them in method-related discourses (Oosterhoff et al., 2021). When realities appear definite and singular, it might be due to these realities being enacted and repeatedly re-enacted in certain hegemonic research practices. Science is done in practice, which includes the production of rules that must be followed. Therefore, Law (2004) finds it problematic when advocates of specific research methods make excessively general claims about their status. Methodological humility means understanding that while parts of reality can be captured through respondents' narratives,

ethnographic field notes, or statistics, none of the different ways of turning realities into scientific knowledge are more real than others. Moreover, no single method can capture the complexity, fluidity, and multiplicity of practice on its own. Law (2004: 6) contends that the need is for heterogeneity and variation, which a methodologically heterogeneous approach achieves.

By foregrounding multiple discourses in a single research project, it can be used to decentre the researcher as the master of truth (Lather, 1993: 680). Like Hultin (2019), I aim to inspire greater diversity in researchers' epistemological practices by discussing our methodologically heterogeneous work, acknowledging that there might be multiple, overlapping, and sometimes conflicting interpretations of the world. By decentring the researcher, the research process becomes more about engaging in dialogue, collaboration, and negotiation, rather than asserting a singular understanding or interpretation. The reference to the posthuman perspective offered by Thompson and Adams (2020) suggests that researchers are asked to adopt different, and potentially unfamiliar, ways of knowing and being. As a researcher, I am not only exploring the interplay of students' self-efficacy and anxieties with RMR but also continually reassessing my role and perspective within the research process. This necessitates flexibility, adaptability, and an openness to change and transformation. The emphasis on methodological heterogeneity and epistemological diversity urges researchers to embrace a more humble scientific stance, an approach that recognizes that no single method or perspective can fully capture the richness and complexity of human experiences and emotions. By acknowledging this, the researcher steps back from a position of authority and opens the space for more nuanced, comprehensive, and authentic accounts of students' experiences with RMR. It is through this humbler and more reflexive stance that the relevance and significance of my research into students' self-efficacy and anxieties when engaging with RMR become strikingly evident.

The important fourth reason for adopting an open, diverse, and emergent approach was to maximize opportunities for learning. Popa and Guillermin (2017) suggest that combining methods from different paradigms can facilitate transformative reflexivity, which purposefully engages with difference to learn from

it. According to St. Pierre et al. (2016), fostering transdisciplinary dialogue can enhance qualitative research. As Chang (2008) argues, ontological and epistemological differences can create space for dialogue and convergence. Throughout the project, it became clear that such dialogue was valuable for understanding the emotions, feelings, anxieties, and self-efficacy of my participants, as multiple forms of knowledge seemed to be in competition. To support this emerging methodologically heterogeneous approach, I will outline the benefits of combining methods from different paradigms in my EdD research process.

3.2 Methodological mosaic: crafting a holistic research approach through multifaceted paradigms

Researchers' beliefs and assumptions about ontology and epistemology, which are reflected in their chosen methodologies, guide their research actions and priorities (Hesse-Biber, 2010). While methodologies shape the researchers' choices of methods, the methods themselves are not bound to a particular methodology, but rather are shaped by the methodological framework in which they are used (Oosterhoff et al., 2020b). Paradigms are formed throughout researchers' professional lives, educational training, and research experiences, as they engage with different scholarly communities (Creswell, 2013; Denzin and Lincoln, 2018). For example, as Law (2004) explains, scientists have a culture with beliefs and practices that ultimately produce scientific knowledge and accounts of reality, and research communities also differ in their methodological scope, with some being narrowly focused on a particular approach, while others are more diverse and draw from multiple disciplines (Creswell, 2013).

The discourse on paradigms in research often presents a dichotomy between qualitative and quantitative approaches (Creswell, 2014), yet these categories are not mutually exclusive and may overlap (Landrum and Garza, 2015; Lincoln et al., 2018). Moreover, there are variations in philosophical assumptions within each approach (Lather, 2006; Tracy, 2010). While particular methodologies may prefer

certain methods, the choice of methods is not limited to a specific methodology (Oosterhoff et al., 2020a). Generally, qualitative and quantitative approaches differ in terms of data types, knowledge claims, and data-gathering and analysis methods (Hesse-Biber, 2010; Landrum and Garza, 2015), while mixed methods research seeks to integrate these two approaches in a complementary manner to offer a more comprehensive understanding of the complexity of the studied phenomenon (Morse and Chung, 2003; Creswell, 2014; Landrum and Garza, 2015). Triangulation is a widely cited rationale for using mixed methods, as it can improve the credibility and acceptability of research findings, although it is associated with different epistemological assumptions (Cho and Trent, 2006; Flick, 2018; Oosterhoff et al., 2020a).

My initial stance in combining multiple methodologies was greatly influenced by my background in quantitative analysis, predominantly within a statistics department. This contrasted sharply with my subsequent immersion in an education research department, where qualitative methodologies were more prevalent. This shift in academic environment played a pivotal role in shaping my approach, driving me to explore and appreciate the value of diverse research methodologies in a field dominated by qualitative perspectives. The incorporation of multiple methodologies in this study helped to make the conclusions of the first quantitative strand more acceptable to advocates of qualitative methods, the main value of using a range of research approaches evolved beyond the traditional conception of triangulation. Through the study, I adopted a way of thinking about method and methodology that was concerned with the theoretical assumptions and normative commitments underlying diverse research methodologies, including those that extend the boundaries of traditional concepts of qualitative research. Instead of striving for certainty or completeness, I aimed to describe the specific, contradictory, and fluid nature of reality, and to engage with difference in order to learn from it, an approach that allowed me to avoid one-sidedness and to promote transformative reflexivity. As Bryman (2016) suggests, tools, frameworks, and criteria are not value-free, and combining different paradigms in one research project can promote deeper understanding and address the complex nature of the

research context and the issue at hand. I embarked on a deeper journey of methodological reflection, exploring the diverse ways in which various research techniques might shed light on the complex issue of students' statistical anxieties, self-efficacies, and academic performance. Through the lens of methodological heterogeneity, I uncovered the unique value of combining different paradigms and approaches, pushing beyond conventional notions of quantitative and qualitative research.

As the project progressed, two distinct strands emerged (qualitative and quantitative), each based on its own unique ontological assumptions that contradicted the other. Throughout each strand, I remained true to the philosophical assumptions and traditions of the approach being used, relying on the rules, criteria, guidelines, and tools that had been developed over time within the respective research communities. Tracy's (2010) assertion that guidelines offer a path to expertise resonated with me, as did the argument regarding authority, which emphasized the importance of connecting with numerous allies accepted within diverse paradigms (Latour, 1987). Therefore, it was crucial that the research team, consisting of one EdD student (myself) and three supervisors with different areas of scientific expertise related to different paradigms, had an open paradigmatic attitude. Working under them was essential to the success of the project. Given that the research projects in the Computing and Mathematics department at a university in the North West of England had traditionally been rooted in quantitative-oriented research, I initially planned to conduct a denser quantitative-focused study. This led to the expansion of the research team with the addition of a co-supervisor from the Education department who was experienced in quantitative methods. However, after being introduced to qualitative approaches like actor–network theory (ANT) by my supervisory team, I decided to use a mixed methods emergent design that incorporated the ANT approach.

The subsequent two strands in my mixed methods study used different methods, gathered different types of data, aimed to meet different quality criteria, used different terms, and applied different writing styles. The differences between the two strands will be presented in detail in the following two chapters (5 and 6),

wherein the results of the two strands with multiple phases will be presented. I will embark on a journey to explore the transformative power of diverse research methods and their potential to revolutionize our understanding of student anxieties, self-efficacies, and performance.

Chapter 4: Methodology

In this chapter, I will provide an account of the conceptualization and implementation of the two-strand project. To set the stage for the methodologies employed in this study, it is essential to root them in the context of the research questions outlined in Section 1.7. The decision to utilize a quantitative strand for the first research question arose from the nature of the question, as I needed to determine any statistically significant differences in students' statistical anxiety, self-efficacy, and performance based on their use of rich media resources (RMR), and this method offers a straightforward, empirical approach suitable for such comparisons. By integrating these two methodologies, the aim was to present a comprehensive understanding of the topic, with the quantitative data providing the foundation, and the qualitative insights adding depth, to ensure the findings are both empirically strong and richly detailed. For the subsequent research questions, a more intricate understanding was necessary, and these questions explore the deeper experiences, feelings, and interactions students have with RMR. In addition, my qualitative strand was apt, allowing me to capture the detailed richness of students' experiences. Section 4.1 will provide a brief overview of the entire project, while Sections 4.3 and 4.4 will introduce the two strands – quantitative and qualitative – and provide a detailed description of each, including information on the corresponding data collection techniques, sampling processes, pilot studies, data analysis procedures, and ethical considerations. The project employs an emergent design, mixed-methods approach, and the integration of data from both strands will be discussed at the end of their respective sub-sections.

4.1 Brief overview of the entire project

Guided by the proposed research questions (RQs, see Section 1.7), the project aims to investigate whether and how the integration of technology into students' studies influences their statistical anxiety, self-efficacy, and academic performance. The research design was devised to contrast levels of statistical self-efficacy, statistical anxiety, and course performance (as evaluated by assessment scores) between two

sets of students within an introductory statistics course with the comparison made between students who utilize rich media resources (RMR) and those who abstain from their use. Beyond comparing students' quantitative performance across the two groups, multimodal journaling is utilized as a method of data collection, and this approach is intended to analyse how participants integrate RMR into their daily lives and how these practices influence their levels of statistical anxiety, self-efficacy, and performance.

4.2 Summary of the emergent research design

A defining feature of this project's research design, when considered as a whole, was its evolving character; there was a willingness to embrace emerging research questions, theoretical frameworks, and methodologies as they arose throughout the process. By being open to the project as it unfolded, intentional decisions as well as circumstances and opportunities that arose during the process guided the research direction (Oosterhoff, 2021). This openness allowed for several directions of inquiry to emerge, a focus on different actors, and the application of diverse methodological approaches and theories to answer questions that arose from the first strand of the study. As a result, a methodologically heterogeneous research project was developed. The full research project unfolded along the way and gradually developed into a collection of two distinct but related strands with multiple phases. Figure 2 below provides a visual depiction of the research design.

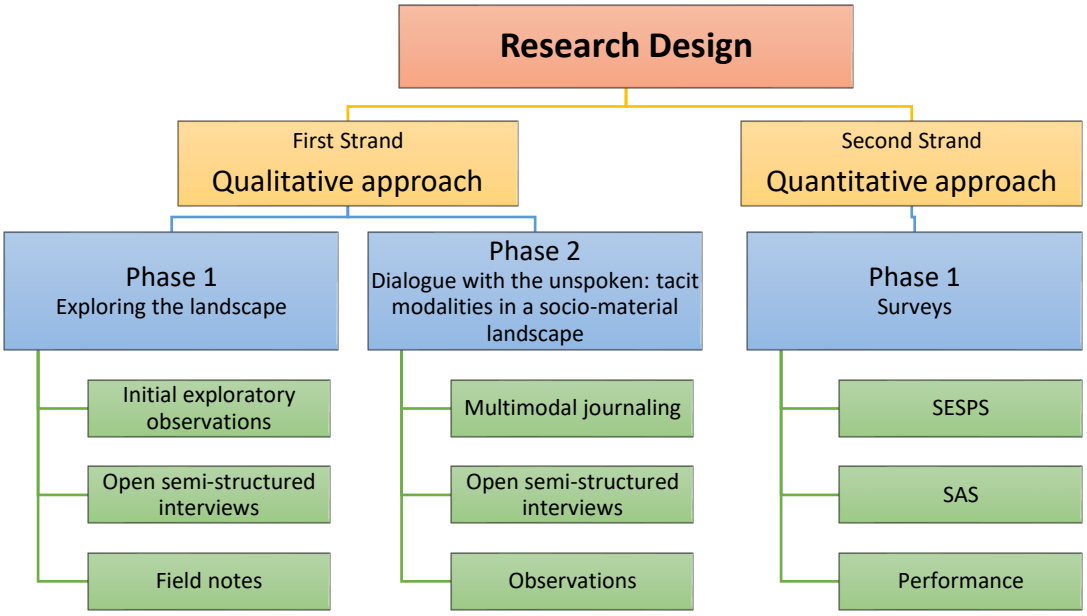

Figure 2. Research design

4.3 First strand: a qualitative approach

The first strand consisted of a **qualitative approach**, which was divided into two phases:

Phase 1: Exploring the landscape: This phase is primarily aimed at addressing the second research question: 'What is the potential appeal of rich media resources for students who are experiencing statistics anxiety?'. The methods employed in this phase, including initial exploratory observations, open semi-structured interviews, and field notes, are designed to gather insight into the students' initial reactions to and engagement with rich media resources.

Phase 2: Dialogue with the unspoken: tacit modalities in a sociomaterial landscape: This phase is designed to tackle the third and fourth research questions: 'How do students experience RMR and what do their embodied experiences of learning in this way tell us about the affordances of this mode of learning?' and 'How do students and material things interact together to form a statistical e-learning experience?' For this phase, multimodal (MM) journaling, open semi-structured interviews, and observations are used to gain an in-depth understanding

of the students' experiences and interactions with rich media resources in their everyday learning.

4.3.1 Phase 1: Exploring the landscape

The first phase of the landscape exploration consisted of getting to know my participants, engaging in informal conversations with them, making observations, and discussing my study goals through semi-structured interviews. This phase was essential for my data collection journey as it fostered a connection with my participants, and this connection made it easier to navigate emotionally charged topics in the later phases (Smith and McGannon, 2017). This phase, initiated around the early middle stage of the course (Block 3), offered students the opportunity to discuss their experiences with e-learning while enrolled in the introductory statistics course.

4.3.2 Phase 2: Dialogue with the unspoken: tacit modalities in a sociomaterial landscape

The title ‘Dialogue with the unspoken: tacit modalities in a sociomaterial landscape’ in Phase 2 underscores the agency of RMR in this intricate web of interactions, compelling us to consider their role within complex networks of individuals and objects and appreciate the collective labour these entities undertake (Adams and Thompson, 2016). The agency of RMRs, and associated ‘things’, is not merely expressed but it is also amplified when students interact with these resources, thereby initiating a dialogue with them. The term 'tacit' in the title refers to the implicit or unspoken elements of this dialogue. These elements encompass the subtle cues and insights students glean from their engagement with the RMRs, often without consciously realizing it. Meanwhile, 'modalities' refers to the various forms or modes through which this dialogue takes place, including visual, auditory, tactile, and other sensory modes, as well as cognitive and emotional modes of engagement.

Methods used in Phase 2 consisted of multimodal image-based journaling using handheld iPhone and Android Touch devices, as it provided an opportunity to gain insights into the students' engagements with technologies over time, based on their day-to-day practices as opposed to data at a more abstracted level, such as that generated by traditional interviews. Multimodal journaling is a unique style of journaling that focuses on the small-scale, emergent actions of everyday materials and embodied practice (Gourlay and Oliver, 2016b), and participants were encouraged to focus on messy microlevel, day-to-day lived action, networks, and the material aspects of practice. Because the data were multimodal, it was easier to get a sense of specific interactions or responses by focusing on images or videos of everyday things and processes. These images and other artefacts produced via MM journaling were used not only as objects for analysis but also as a starting point for more in-depth discussion of identities, challenges, and issues in the interviews (Appendix N: Phase 1 and 2 interview details). This led to a rich set of participant accounts of technology use. This method of journaling was also chosen to avoid relying on textual mediation (the process where experiences are interpreted solely through written text, potentially missing out on the depth and nuance of the experiences), which can lead to a shift away from the material; instead, the focus was explicitly on the visual, with an emphasis on objects, embodied material practices, and visual methodologies (Gourlay and Oliver, 2016b). Multi-modal journaling also provided an invaluable way of gaining access to participants' hidden worlds and the unfolding of personal experiences over time (Braun et al., 2017). During the second phase of the qualitative strand, each participant was interviewed at least once (Figure 5. Distribution of participants by phase and academic year Appendix I: Phase 2 Participants), while for some participants, shorter interviews occurred on multiple occasions during and after their journaling period. The multimodal journal assemblages served as the foundation for these interviews and observations (Gourlay and Oliver, 2016b), and the data provided specific ideas about how to effectively use RMR to improve students' statistical anxiety, self-efficacy, and performance. By incorporating an ethnographic lens into my research approach, one of my primary objectives was to identify the unique challenges, concerns, and learning experiences faced by the participants during their

engagement with RMR, and these methods also helped highlight and address potential issues that the participants might not have recognized themselves (Moschkovich and Zahner, 2018). An ethnographic approach allowed me to view students' activity with RMR as part of their everyday learning routines, wherein they employ social and cognitive resources to understand complex situations.

4.4 Second strand: a quantitative approach

The second strand of my research project took a quantitative approach in order to directly address my first and second research questions. Before diving into the emotional intricacies and nuanced experiences of my students, it was paramount that a foundational understanding was lain down through quantitative means. The intention behind this dual-layered approach was not just my liking for quantitative methods as a statistics lecturer. It stemmed from a belief that a quantitative lens offers a structured, consistent, and often generalizable way to identify broad patterns, setting the stage for a more microscopic investigation later.

The research aimed to ascertain if there were statistically significant differences in students' statistical anxiety, self-efficacy, and performance based on their engagement with rich media resources (RMR). Data collection for this strand took place in the first week of April 2022, before the end-of-term assessments were due, and involved three surveys: a short questionnaire aimed at understanding students' perceptions of and experiences with rich media resources (relating to research question 2); the self-efficacy in statistical practices scale (SESPS), which measured students' belief in their ability to perform statistics-related tasks (addressing research question 1); and the statistics anxiety scale (SAS), which quantified their anxiety levels related to statistical tasks (also relevant to research question 1).

Additionally, students' scores on the end-of-term assignment for the statistics unit Numeracy and Data Analysis were used as a measure of their performance (an element of research question 1). With these data, I utilized descriptive statistics to explore the relationship between anxiety, self-efficacy, and performance, calculating the arithmetic mean and standard deviation for each. Subsequently, a multivariate analysis of variance (MANOVA) was used to examine whether

students' statistical task-related self-efficacy and statistics anxiety varied based on their engagement with RMR. Essentially, MANOVA is a statistical procedure used to assess the differences between groups on multiple dependent variables simultaneously, accounting for the correlation between the variables, after which an independent T-test was conducted. The T-test is a statistical method used to determine if there is a significant difference between the means of two groups, which might be related to certain features, and in this context, it was used to identify significant differences in performance between students who did or did not engage with the RMR, thereby addressing research question 1. For these analyses, the statistical software SPSS was the tool of choice before the results were visually depicted through charts and tables, which I generated using Microsoft Excel.

Chapter 5: Data Collection Process (Qualitative Strand)

This chapter on data collection sheds light on the central procedures of gathering data. Drawing from my initial engagement with participants, I will detail the specificities of my sample used for both phases of this strand, describe the sequential steps of data collection, address the guiding ethical considerations, and discuss the methods chosen. This structured approach in data collection forms the bedrock for the analysis to follow. I will navigate through this process, emphasizing the methodical precision at each stage.

5.1 Phase 1: Exploring the landscape

The initial step in the landscape investigation was to become familiar with my participants through casual conversations, observations, semi-structured interviews, and preparing for the next phase, which was crucial to my data gathering process as it helped me establish a connection with my participants, thereby facilitating open discussions of sensitive topics in subsequent phases and stages. During this phase, I gathered insights into the students' experiences of e-learning on an introductory statistics course. An open, interested and encouraging but non-judgemental listening attitude was sought.

The data gathered during this phase contributed towards addressing research questions 2 and 3, which will be discussed in the later chapters.

5.1.1 Sample

In this stage of the research, 13 students who were enrolled in the Numeracy and Data Analysis course and willing to participate in my study were selected as participants. The selection criteria for participation were based on the students' previous interactions with me, their difficulty in understanding course material, and their willingness to receive extra support. The participants came from various educational backgrounds and degree programmes, as shown in the chart below, allowing for a diverse range of data to be collected on how the RMR were being

used by the students in their statistics learning. Each participant was provided with a second version (2.2) of the participant information sheet, which explained the purpose of the research, and throughout the research, all participants were treated with kindness and confidentiality, which will be discussed in more detail in the Ethics section. Pseudonyms for the participants were used. (Refer to Appendix J:

5.1.2 Procedure and timeline for Phase 1

Phase 1	**Procedure and Timeline**
1	Getting to know my potential participants through informal conversations (observing and taking field notes) and formally inviting them to participate (via email or face-to-face) including sharing the Participant Information Sheet (PIS) version 2.2
2	Building connections: engaging in initial dialogues and interactions with participants to foster trust and rapport, which aids in creating an open and receptive environment for data collection
3	Selection of interview sites
4	Conducting first informal semi-structured interview (lasting approx. 8–47 minutes)
5	Transcribing audio recorded interviews using VEED.io transcription software
6	Entering unprocessed information from informal conversations, notes, observations, and semi-structured interviews into separate Word files, labelling each file with the participant's name and storing it in an encrypted data folder accessible only by me
7	Inputting raw data into Quirkos software for Phase 1 thematic analysis using codes

5.1.3 Ethical considerations

This study has received ethical approval and is in alignment with the ethical guidelines and processes of my university. Throughout the study period participants' well-being was of utmost importance, which I protected by preventing conflicts and maintaining strict confidentiality. Recognizing the significance of ethical responsibility in research, all students were provided with detailed Participant Information Sheets (PIS version 2.2) prior to participation, which elucidated the aims and objectives of the study. Understanding my position as a lecturer grants me a certain level of authority, and I emphasized that there was no obligation for students to participate. Instead, I reassured them that their decision

to participate or abstain will not impact their academic results or standing in the foundation year, and this assurance was verbally reiterated when explaining the PIS for the students' comfort. The data collected and this research are intended to assist my university in enhancing its services for future students.

All participating students were assured of their right to withdraw at any point and that they could convey their decision by sending a written email or letter to the principal investigator. Upon receipt, all related data for that participant will be deleted, and they will be informed of the same. Confidentiality is paramount in this study, and all collected personal data will remain strictly confidential. They would be pseudonymized, with identifiable data stored separately in a securely encrypted format, and only the research team would have access to this data, which were stored online in password-protected locations. If participants had given consent, anonymous direct quotes might be used when publishing the results, but no personal data will be disclosed outside the supervisory team, and no identifiable personal information will be included in the published results of the study. Recognizing the inherent power dynamics present when a lecturer researches their own students, deliberate steps were taken to minimize potential undue influence, which not only involved clear communication regarding participation but also frequent check-ins and feedback sessions, ensuring students felt comfortable with their involvement. Such power dynamics are not just about ensuring unbiased data but also about ensuring the psychological and emotional well-being of the participants in a study setting where the researcher holds an authoritative role.

Furthermore, the broader ethical framework of this research was grounded in the understanding that academic research has the potential to impact not just the immediate participants but also the larger academic community and society at large. Upholding stringent ethical standards ensures the credibility of the research, respects the autonomy and dignity of participants, and aligns with the university's commitment to socially responsible research practices.

5.1.4 Connecting with the participants'

In this study, where I was aiming to explore students' personal experiences, developing a rapport with them was crucial, since it paved the way for me as the researcher to gain the participants' trust and cooperation. If the respondent is at ease, they may be more forthcoming with information, increasing the reliability of the data, and connecting with participants is an additional step in conducting an ethical study that values the wellbeing of its participants. My understanding of the participants' cultural backgrounds, historical context, and personal experiences helped to alleviate any reluctance they may have had in sharing their e-learning practices, frustrations, and other related information, thereby allowing for a more accurate and complete representation of the data collected, and I will use interview transcripts, observation notes, and my own memories to describe the relationship that formed between some of my participants and myself. This connection was strengthened by our shared cultural background, past experiences, and personal choices, even though they were not directly related to the research topic.

5.1.5 Selection of site for interviews and observations

To conduct the semi-structured interviews and observations, I offered the participants a choice of three locations as sites for the interviews, based on their preferences: my shared office space; the lecture theatre after the conclusion of the lessons; and online via MS Teams. Initially, I had intended to conduct all the interviews in my office, but discussions with participants necessitated additional options to cater to their comfort levels and preferences. In this phase, I agreed to work with the participants' preferred locations and methods of interviewing.

The following vignettes, occurring at distinct points within the study's timeline, illustrate the students' proactive roles in selecting their interview settings and methods. The vignette mentioned below was written up immediately following the interview to capture the nuances of each interaction, and students were given an opportunity to review and reflect upon the vignettes.

I had arranged an informal interview with one of my participants following our lesson. Observing her nervous demeanour as the lesson concluded, I enquired about her comfortability with proceeding to my office for the interview. The presence of colleagues in my shared office space led us to opt for the empty classroom instead. My participant, uncomfortable with being recorded, chose to communicate her thoughts and feelings in a more informal, unrecorded setting post-lesson. From this, I learned the importance of considering each participant's comfort level and creating an environment conducive to open conversation.

5.1.6 Observations and field notes

Observations, Phase 1: In the initial phase of my research, I embraced a methodical approach to observations, conscientiously writing them in an Excel file (named PHD data) located within the 'DATA' folder on my password-protected OneDrive. This systematic documentation commenced post-consent, ensuring that each participant had agreed to partake and had provided a signed consent form. During Phase 1, I conducted 13 observation sessions, capturing the essence of the interactions with precision and attentiveness to detail.

Field notes, Phase 1: The field notes, numbering seven in total, were gathered during interviews or any communicative exchanges concerning our study sessions and meticulously scribed in my personal notepad, a dedicated repository for my thoughts and observations. My narrative was crafted in vivid detail, chronicling events, behaviours, and interactions, while always anchoring them within the relevant context and background.

Immediately transcribing the observations ensured the preservation of their freshness and accuracy. In addition, multilingual notation was employed, with entries in both Urdu and English, intertwining observed facts with reflective commentary to construct a comprehensive account of the research encounter. To safeguard the confidentiality of my handwritten notes (see Appendix M: Field notes diary), I stored them in a secure, locked drawer. Upon completion, I meticulously redacted any personal identifiers, replacing them with pseudonyms or anonymizing

them through careful overwriting with a black pen, thus preserving participant anonymity. These organized and categorized notes were then ready to serve as a cornerstone for subsequent analysis and synthesis during the research process.

5.1.7 Semi-structured interviews Phase 1

Semi-structured interview questions (Appendix G: Phase 1: Semi-Structured Interview Questions) were designed to elicit participants' subjective experiences and perspectives on engagement with rich media resources (RMR) and to assess whether the RMR were identified by students as being effective in reducing their statistical anxiety and increasing statistical self-efficacy.

A Participant Information Sheet (PIS) version 2.2 (Appendix B: Participant Information Sheet) was provided to each participant, which not only outlined the research's purpose but also detailed the nature and scope of the participants' involvement, potential risks, confidentiality measures, and their rights as participants, ensuring they had a comprehensive understanding of the study before giving their consent. Throughout my analysis, I treated all participants with kindness and confidentiality and made sure to double-check responses from the participants to fairly represent their perspectives. Interview questions were open-ended and formulated to discuss various aspects which may be linked to their statistical anxiety and self-efficacy, representing a way for the researcher (myself) to discuss topics like changes in students' levels of anxiety and self-confidence. The leading questions in the interviews were derived from these topics with some examples included below:

- Which forms of rich media did students find most engaging, and why?
- How much did the resources improve the students' ability to learn? Did they feel anxious or experience any sort of emotional stress while using these resources?
- How did students make use of multimedia resources?
- How effective were the rich media materials as a learning tool? And how did they compare to traditional lectures?

The participants had the option to conduct their interviews either online or in-person, with most choosing to do so before or after their scheduled study sessions in my office. Thirteen semi-structured interviews took place during phase 1 with the interview length varying, lasting between 8 and 47 minutes (Appendix N:). Some participants did not want their interviews to be audio recorded, and I took notes during those instances. The audio-recorded interviews were transcribed using the free version of VEED.io's transcription feature, and I then saved the relevant sections of the data in a Word document and placed it in an encrypted, password-protected folder called 'Data'. During the interviews, I strived to maintain a balance between being involved and maintaining distance in order to establish a trusting relationship with the participants and make them feel comfortable

discussing potentially emotionally charged subjects. I also shared the transcription texts and my hand-written field notes with each participant during a follow-up meeting, which typically happened after the taught lessons, to verify interpretations and clarify any ambiguities. These transcribed texts were based solely on the interview transcriptions and observations made during the study sessions. The interpretations were presented using quotations from the participants in their original, colloquial language but with some corrections and omissions for clarity, and all participants agreed that the transcribed texts accurately represented their viewpoints.

5.1.8 Transcription and analysis of the Phase 1 data

The data gathered during Phase 1 were analysed using thematic analysis, which is a flexible research tool that can provide a detailed and complex account of data (Braun and Clarke, 2006), with the focus on the topics of statistics anxiety, self-efficacy, beliefs, feelings, memories, and RMR/e-learning practices. It was conducted using all data from the interviews, informal chats, and study session observations. Using the Quirkos 2.5.2 qualitative data analysis software, the primary issues, statements, or incidents related to the research topics were noted and collected in an initial coding process. Quirkos allows for a more interactive and visual way of working with qualitative data by using a process called 'concept mapping', which allows users to create an interconnected web of ideas and themes from the data.

The three basic components of this thematic analysis model – noticing, collecting and thinking about the data – were applied in an iterative process, and initial codes (referred to on Quirkos as Quirks) were combined to form broader themes of interest. In the subsequent phase, these themes were checked for patterns and for variability and consistency across the entire dataset. An important aim was to explore if and how differences in respondents' engagement with the RMR affected their statistical anxieties and self-efficacies, and the research questions and related topics guided the analytic process and evolved as the analysis progressed, leading to the formulation of more specific interview questions. In the second phase, the

data were analysed by combining similar codes in Quirkos under common themes (see

Appendix L: Phase 1 & 2 Quirkos Themes) and interpreting the themes by reading and re-reading while also referring to relevant literature (Creswell, 2013). The process was supported by grouping similar codes together in the Quirkos software.

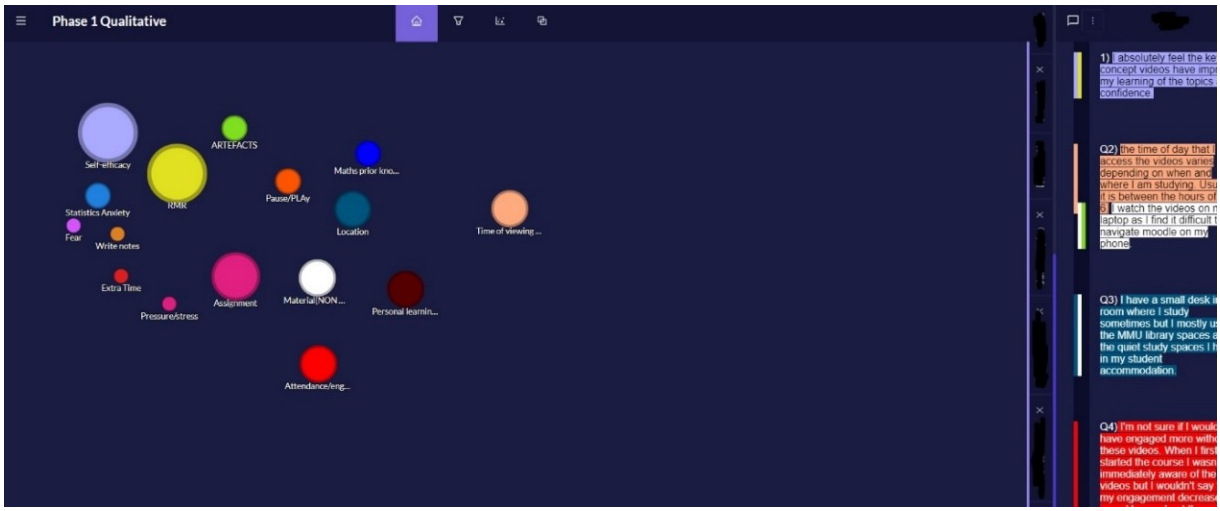

Figure 3. Data analysis process using Quirkos

5.2 Phase 2: Dialogue with the unspoken: tacit modalities in a sociomaterial landscape

5.2.1 Explaining multimodal journaling to the participants

Some of the participants in this exploratory phase asked me to clarify the concept of the multimodal journaling which was used to gather data in Phase 2 with one participant even presenting me with an example of their own handwritten journal (Figure 4), which they had created based on their own understanding of what I was looking for in the later stages of the study. To address this, I created a PDF document that explained what multimodal journaling means in lay terms along with some examples (Appendix D: Multimodal Journaling Information):

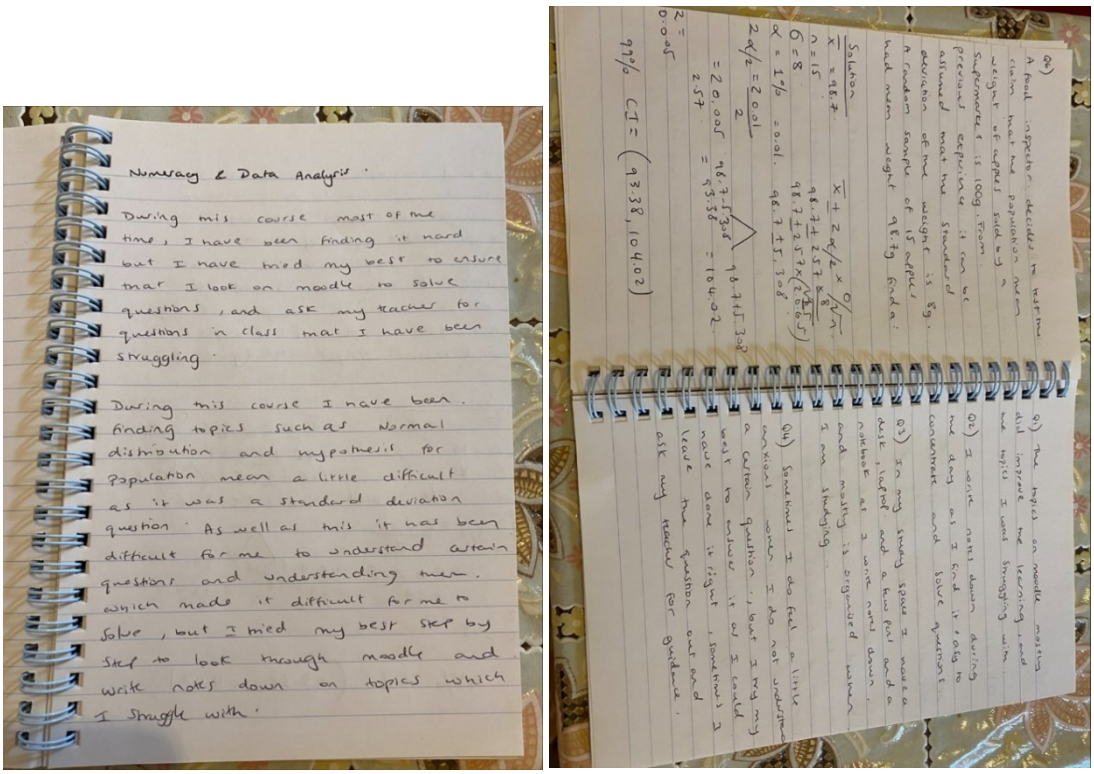

Figure 4. A participant's handwritten journal

The qualitative phase, termed 'Dialogue with the unspoken: tacit modalities in a sociomaterial landscape', served as a crucial instrument in addressing Research Questions 3 and 4.

RQ3) How do students experience RMR and what do their embodied experiences of learning in this way tell us about the affordances of this mode of learning?

RQ4) How do students and material things interact together to form a statistical e-learning experience?

In educational environments, rich media resources (RMR) emerge as operative entities, or 'things', taking a myriad of forms, which include video content, Moodle systems, graphical representations, audio over images, narrated slides, lecture recordings, and more. Conventionally, we perceive these 'things' from a human-centric perspective, considering them as tools employed to serve human objectives. In doing so, we recognize these things as catalysts that can alter student experiences, anxieties, and self-efficacies when they engage in e-learning activities. Actor–network theory (Law, 2004) proponents challenge this view, asserting that these 'things' themselves possess agency by acting and inducing behaviours in both

human and non-human actors (Mol, 2002; Latour, 2005; Law, 2004). What's critical here is the notion that neither things nor humans act in isolation. Instead, they act through interplay with a multitude of other humans and non-humans.

The title ‘Dialogue with the unspoken: tacit modalities in a sociomaterial landscape’ in Phase 2 underscores the agency of RMR in this intricate web of interactions, compelling us to consider their role within complex networks of individuals and objects and appreciate the collective labour these entities undertake (Adams and Thompson, 2016). The agency of RMR, and associated ‘things’, is not merely expressed but also amplified when students interact with these resources, thereby initiating a dialogue with them. The term 'tacit' in the title refers to the implicit or unspoken elements of this dialogue, which encompass the subtle cues and insights students glean from their engagement with the RMR, often without consciously realizing it. Meanwhile, 'modalities' refers to the various forms or modes through which this dialogue takes place, including visual, auditory, tactile, and other sensory modes, as well as cognitive and emotional modes of engagement. Interactions with rich media resources (RMR) can be perceived as a complex dance of sensory and cognitive engagement, abundant with embodied interactions and relational dynamics.

Further extending this discussion, Bhatt et al. (2015) advocate a 'deep dive' approach in educational research associated with students e-learning practices, entailing multi-faceted data capture and analysis. They consider educational research to be multi-layered and unbounded, in which students engage in a complex set of socially situated practices that are increasingly being mediated through a variety of semiotic resources and multimodal contexts (Gourlay, 2015). This draws attention to digital objects as non-human actors in evolving networks, interacting in conjunction with humans, and the comprehensive understanding of these practices and interactions necessitates examining the intricate relationship between students, their physical spaces, the technological tools they use, and the subsequent choices and preferences they make.

5.2.2 Embracing ethnographic approach

According to a study by MacLeod et al. (2019), using an ethnographic approach is considered an effective method for investigating sociomaterial phenomena. Ethnography seeks to provide detailed descriptions of ‘undisturbed’ natural settings and compile accounts by attempting to obtain an ‘insider's view’ into the studied phenomenon. As Price et al. (2022) states, this goes beyond 'ways of seeing' to include 'ways of feeling', and in this context, research data are connected across different spaces and times rather than focused on a single site where it may be assumed to be a bounded entity (Luke, 2020). According to Kien (2009), devices are not ‘dead props’ but dynamic actors that work with human actors to ‘create and maintain the world we live in’, while Berg (2022) redirects our understanding towards how digital technologies act as participants in everyday life, adding excitement and meaning to people's experiences. In doing so, Berg (2022) positions technologies, rather than human actors, as agents at the centre, aiming to pay attention to the contexts from which the digital technology emerged, and by utilizing multimodal journaling as a research method, I can delve into the usage of specific digital technologies in day-to-day scenarios and explore their potential influences on human interactions. As highlighted by Gourlay and Oliver (2016)a, multimodal journaling serves as a window into the participants' routine lives and settings with researchers able to uncover invisible aspects of people’s spoken and performative experiences when using these digital actors (Pink, 2021).

5.2.3 What is multimodal journaling?

The multimodal journaling is a unique style of journaling focused on the small-scale, emergent actions of everyday material and embodied practice (Gourlay and Oliver, 2016a). Participants are encouraged to note their experiences within the 'messy' intricacies of everyday life, particularly as these experiences relate to their engagement with rich media resources (RMR) in their statistics studies, and this approach underscores the importance of the temporal and spatial aspects that anchor these everyday practices. By paying attention to objects and processes in a very detailed way, this focus is meant to uncover these networks. Stand-alone interviews can leave out important parts of the data and everyday life; therefore,

to capture these details, 17 participants (see Appendix I: Phase 2 Participants) were asked to document their day-to-day practices and interactions with RMR for their statistics course in a variety of natural settings using their own devices. Next, they were instructed to compile and discuss the documented details in one-on-one interviews with the researcher (me). The participants were introduced to the concept of multimodal journaling (Appendix D: Multimodal Journaling Information) and shown how they could use it to create images, videos, and textual notes that enrich the journaling of their learning as the unfolding event. The participants were encouraged to concentrate on any emergent, microlevel detail in the day-to-day lived experiences and draw attention to non-human contributors in their sociomaterial entanglement when interacting with RMR. This detailed focus was intended to reveal the material, spatial, and temporal elements that were embedded in their actor-networks in everyday practices as data collected by interviews alone can obscure this level of detail by relying on self-reporting under recall bias. Students then had approximately four to six weeks to complete preliminary work, which included creating 'journals' of their practice using a variety of multimodal data. My 17 participants were able to share their home/study environments by including pictures and notes about them, including physical artefacts such as books, notebooks, pens, favourite drinks, devices, etc., and they employed diverse methods to compose their journals. For instance, Ayesha utilized her phone camera to capture images of her work environment and then documented her reflections in a Word document, pairing each image with the corresponding sentiments. Meanwhile, Siddiq preferred to send his images through Teams, sharing his thoughts directly in the chat window with me. Further details on the timelines and methodologies are outlined in the subsequent sections.

5.2.4 Why multimodal journaling?

Multimodal journaling provides researchers with a mostly undisturbed view of the sociomaterial entanglement of each participating student. By using multimodal journaling, participating students can generate an ‘insider's perspective’, capturing extensive descriptions of their natural learning environment with the help of text, images, videos, screen recordings, and other modes. This insider's perspective may

encompass the anxiety felt by the student when confronted with digital technology – a feeling that might not otherwise be associated with their environment at that time. In an interview environment, the participating student is devoid of their personal learning environment and choice of moments, which does not then encapsulate rich-media-based learning. An integral aspect of this methodology is that it captures tacit knowledge or 'episodic shimmerings' by incorporating sketches, photographs, or notes about physical sensations, allowing for the expression of experiences that may otherwise remain inexpressible (Rowsell and Abrams, 2021).

Requiring research participants to jot down their thoughts or record their experiences through journaling that includes nonverbal media like photos, videos, or drawings can make the task more interesting, expressive, and less time-consuming than writing a text-based account. Escott and Pahl (2019) draw attention to these central, often overlooked, dimensions of research that emerge from a researcher's participation in coproduction, having studied data generated by short films made by a group of young people (aged 9–10) in Northern England and exploring their understanding of spelling through a lens focused on the materials used to create narratives. Attending to the material and non-human features of the children's data allowed them to gain a better understanding of their emotive reactions to and embodied understandings of spelling. As highlighted by Banzato and Coin (2019), multimodal journaling relieves some of the pressure from the verbal or language skills needed to adequately express the feelings and environment that a student is experiencing, especially in the context of foreign language interviews. Students can capture information at the original source in any language-independent medium and require much less verbosity to express themselves fully. Banzato and Coin (2019) further argues that by allowing students to use multimodal means, they not only produce richer content, but their perception becomes wider, more vivid, and broader. Jewitt (2020) uses a holistic concept of sociotechnical imagination to explore students' emergent desires, concerns, and expectations and how these connect to their present and past. Implementing the proposition to use this multimodal lens, Jewitt (2020) creates a

discursive space that moves between reality and imagination, absorbing the essence of both, and presenting it in terms of students' narratives of continuity and change and arguing that this enabled their research to connect people's hopes and desires for the future, and their passion and sense of self with their present, which incorporates their past achievements.

5.2.5 Sample

During this phase of the qualitative strand, I enlisted the participation of 17 students enrolled in the Numeracy and Data Analysis course who were enthusiastic about contributing to my study. The participant selection was based on two main criteria: the students' willingness to partake in Phase 2 by creating MM journals, and their engagement with the rich media resources (RMR) for their statistics studies. The participants were drawn from a variety of educational trajectories and degree programmes, as detailed in the subsequent chart, which ensured a diverse dataset representing the distinct ways students engage with RMR to augment their statistics learning. I supplied each participant with the 2.2 version of the Participant Information Sheet, detailing the research objectives, and maintained a high standard of ethical conduct throughout the research, treating each participant with respect and safeguarding their privacy – a topic that has been elaborated upon in the previous Ethics section. See Appendix I: Phase 2 Participants for a summary of the participant characteristics.

5.2.6 Procedure and timeline for Phase 2

	Procedure and Instruments for Phase 2
1	Selection of the 17 participants who agreed to co-produce data through multimodal journaling
2	Participants creating their multimodal journals using their own devices, capturing data in various forms like images, drawings, videos, and text notes

	Procedure and Instruments for Phase 2
3	Allowing participants a month for preliminary work and the creation of their multimodal journals, focusing on their engagement with rich media resources Students could choose any method to share their journal (via email, handwritten, via Teams call, or chat).
4	Conducting short semi-structured interviews to discuss the data participants created in their multimodal journals, with each interview lasting between 12 to 43 minutes Interviews took place in person and online via Teams.
5	Some interviews were audio-recorded with consent for transcription purposes. Transcription of the audio-recorded interviews was done using the free version of VEED.io transcription software.
6	Participants using visuals and artefacts from their multimodal journals as a catalyst for reflection during their interviews, enabling the exploration of students' statistics anxiety and self-efficacy beliefs.
7	Conducting a thematic analysis on the transcribed data to derive common themes
8	Incorporating additional data sources (like observation notes during the interviews) to build conceptual frameworks supporting the study
9	Analysing the multimodal dataset thematically using visual methodologies to further interpret images

5.2.7 Timeline for multimodal journaling

Participants were allotted four to six weeks to engage in preliminary work, leading to the creation of multimodal journals (MM journals) based on their interactions with the RMR, and my involvement in the data collection for this phase spanned 1

March 2022 to June 2023, a period that allowed for an in-depth exploration of the participants' experiences. The participants collected a variety of data in these journals, presenting their experiences and engagement in a creative manner. Following this, participants were invited to informal semi-structured interviews to discuss the content of their journals, which helped illuminate their experiences and feelings regarding the engagement with technology and its influence on their statistics anxiety and self-efficacy beliefs. Throughout this phase, each of the 17 participants (see Appendix H) navigated the journaling process at their own pace. (For instance, Mandy was actively engaged from March 2023 until the end of April 2023.) Such individualized timelines were integral to the process, as they facilitated the collection of genuine and spontaneous inputs. In striving to capture the most authentic expressions of their experiences, I consciously refrained from imposing stringent deadlines on the MM journaling activity, an approach that was designed to respect each student's unique process and to ensure that the data collected were a true reflection of their unfiltered interactions with the media resources provided.

In Phase 2 of the study, the cohort consisted of the same 12 students who participated in Phase 1, all from the academic year 2022, with five new students from the academic year 2023 joining this subsequent phase, providing an opportunity to broaden the scope of the research. I conducted semi-structured interviews with these students to delve deeper into their experiences. However,

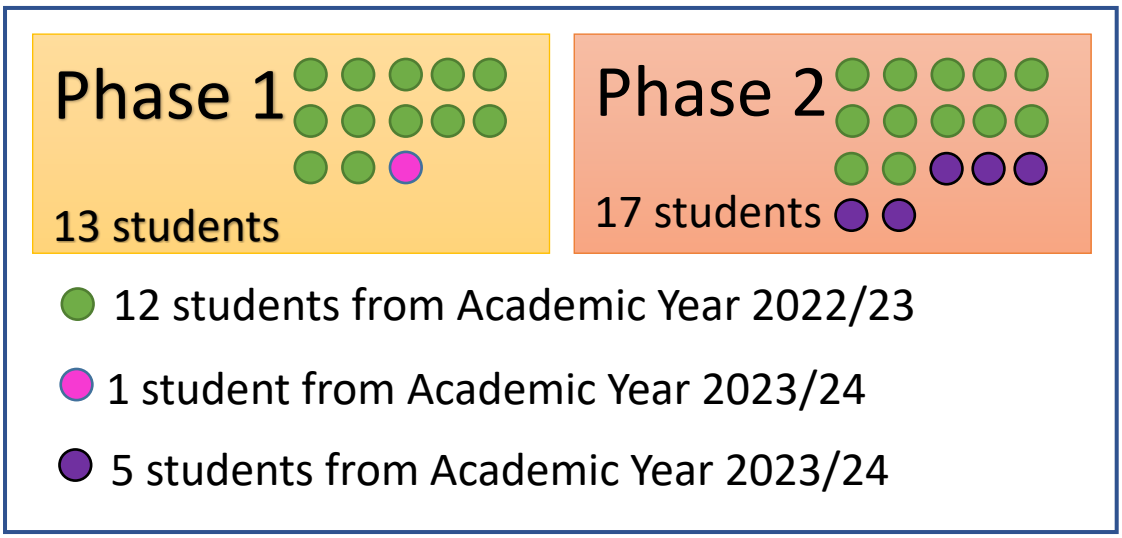

Figure 5. Distribution of participants by phase and academic year

the insights gleaned from these interviews were not incorporated into the findings of Phase 1, titled ‘Exploring the landscape’. Figure 5 illustrates the distribution of participants engaged in each phase of the study, categorized by their academic year.

5.2.8 Analytical approach and strategy in Phase 2 of multimodal journaling research

In Phase 2, the gathered data underwent a thorough thematic analysis, an adaptable method providing a rich and comprehensive understanding of the data (Braun and Clarke, 2006), focusing on areas including statistics anxiety, self-efficacy, beliefs, emotions, past experiences, and practices related to RMR/e-learning. For Phase 1, I employed Quirkos to facilitate the thematic analysis, a critical step in synthesizing the diverse data collected, and following the acquisition of additional data from this phase, I integrated the contents of semi-structured interviews and textual entries from the journals into Quirkos. Key issues, comments, and occurrences related to the research topics were identified and collected during the initial coding process, thereby laying the foundation for an interconnected web of ideas and themes. The three core components of the thematic analysis model – recognizing, collecting, and reflecting on the data – were employed in a cyclical process, before initial codes were merged to form broader themes of interest (Braun & Clarke, 2006). These themes were then assessed for patterns, variability, and consistency across the entire dataset, with an emphasis on exploring the impact of RMR engagement on students' statistical anxieties and self-efficacies.

Additional data sources, like observation notes (Section 5.1.6) added to Excel during Phase 2, were incorporated, which allowed the building of conceptual frameworks to support my arguments in subsequent stages of the work. It is important to note that Quirkos' capabilities do not extend to the management of images, photos, or physical artefacts; therefore, the utility of this software was confined to textual analysis. The specific themes that emerged are detailed in Appendix Y.

To analyse the multimodal (MM) journals, I adopted a more manual, yet meticulous, approach, allowing for an in-depth examination of the non-textual components that Quirkos could not process. In Phase 2, I prioritized the use of manual coding over software-based methods – a conscious decision driven by the unique nature of MM journaling, which, as undertaken in this study, is characterized by emergent, deeply emotional, and human-centric nuances. Such subtleties demand an intimate understanding and a close, human touch that is not entirely possible through standardized software tools. As Saldaña (2021) emphasizes, while software can assist, it cannot replace the depth and nuance that human coders bring to qualitative data analysis. While the software utilized in Phase 1 was sufficient for the more surface-level data it processed, it felt inadequately equipped to handle the depth and richness of MM journaling data. Paulus and Lester (2023) discuss the range of digital tools available for qualitative research, weighing their advantages against the richness of manual analysis, echoing a sentiment that resonates strongly with my methodological choices. However, the essence of MM journaling lies in its ability to capture human emotions, experiences, and intricate subtleties which, I believe, are best deciphered and understood by the human mind. As highlighted by Jackson and Bazeley (2013), while software tools can assist in organizing and managing data, the interpretative depth remains a distinctly human domain. Introducing artificial platforms or software into this delicate equation could risk diluting or missing out on some of these rich subtleties, and while I acknowledge the efficiency and systematic nature of coding software, for this specific phase, I felt the need to prioritize depth, sensitivity, and understanding intrinsically human qualities. Throughout the phase, preliminary findings and ideas for further study were communicated to research groups through supervision meetings and conference presentations. This step, important in gauging the data's credibility and validity, enabled a wide dialogue, inviting ideas and feedback and helping to build a robust argument based on the received inputs. This collective wisdom was incorporated into the analysis, leading to more nuanced and credible findings.

Chapter 6: Data Collection Process (Quantitative Strand)

6.1 Design and research purpose

The goal of the project was to investigate how students' statistical anxiety, self-efficacy, and performance changed after they used technology in their studies. The quantitative research design was developed to answer the first two research questions.

6.2 Instrumentation (questionnaires for data collection)

A short questionnaire, one self-efficacy measure, one statistical anxiety scale, and a course performance assessment were used in this strand of the research study.

The instruments used were as follows:

1. **A short multiple-choice survey** designed to gather information about students' multimedia usage, English proficiency, mathematical education, and demographic data
2. **The self-efficacy in statistical practices scale (SESPS) questionnaire**, utilized to measure students' self-efficacy in statistical practices
3. **The statistics anxiety scale (SAS) questionnaire**, implemented to evaluate students' anxiety in relation to statistical tasks
4. **Assessment scores**, specifically the average scores from the Numeracy and Data Analysis unit assessments (NDA1 and NDA2). Each student's performance score was derived from these assessments, which comprised of a combination of numerical and statistical questions, and was marked out of 100.

The next sections go through each of these instruments in detail.

6.2.1 A short questionnaire

A short questionnaire was designed to gather information about students' use of multimedia resources and their proficiency in English as a second language. Understanding students' English proficiency is vital as language competency can significantly influence comprehension and engagement with course material, particularly for those who are using English as their second language (Bo et al.,

2022). Participants in the study were asked to provide their student IDs, which, with their consent, allowed the researcher to retrieve demographic data such as age, gender, and degree programme from the university's Presto and QLS systems. Participants were informed that their demographic information would be used solely for research purposes and would be strictly confidential and anonymized, and I collected this information to create a detailed participant profile, which would help to characterize our sample group. Additionally, the questionnaire aimed to assess students' prior knowledge of mathematics. For complete transparency and reference, a copy of the questionnaire has been included in the Appendix section. The security and anonymity of participants' personal data were prioritized and maintained throughout the study, reinforcing my commitment to ethical research practices.

6.2.2 The self-efficacy in statistical practices scale (SESPS)

The second tool for collecting quantitative data is the abbreviated version of the self-efficacy in statistical practices scale (SESPS; Walpitage, 2016). This questionnaire was used to assess the students' self-efficacy regarding statistics and their perceived confidence in this subject. Self-efficacy refers to an individual's belief in their ability to perform a specific task or achieve a certain goal, and in the context of statistics, self-efficacy in statistical practices refers to an individual's confidence in their ability to understand, apply, and perform statistical tasks effectively. The SESPS was created by Pathirage and Pathirage in 2015 to assess students' self-efficacy in statistics, and adopts a Likert-type scale, consisting of a set of statements that the individual must rate on a scale of 1 to 7, with 1 indicating ‘not at all confident’ and 7 indicating ‘very confident’. The statements in the SESPS questionnaire assess the individual's confidence in various aspects of statistics, such as understanding statistical concepts, using statistical software, and interpreting statistical results.

The SESPS has demonstrated consistent reliability and validity as a measure of self-efficacy in statistical practices with numerous studies, including those cited in Pathirage and Pathirage (2015), employing the SESPS to assess the impact of diverse instructional strategies on students' self-efficacy in statistics. For instance,

the SESPS was used to differentiate between ‘self-efficacy in conducting statistical procedures’ (with 37 items) and ‘self-efficacy in utilizing computer software for statistical procedures’ (with 6 items). Findings from Pathirage and Pathirage's (2015) study revealed significant differences in students' self-efficacy based on gender, degree major, year of study, and the number of previously taken statistics courses, particularly in the utilization of computer software for statistical procedures. For example, male students and STEM majors displayed higher self-efficacy than their counterparts, and those with more exposure to statistics courses showed increased confidence in using software tools for statistical analysis (Pathirage and Pathirage, 2015).

Therefore, the SESPS was used in this study to provide an accurate measure of self-efficacy related to statistical practices, as by measuring an individual's self-efficacy in statistical practices, researchers can gain a better understanding of the factors that contribute to their success in statistics and identify areas for improvement.

In the present study, I adopted Dammika Akmal's abbreviated version of the SESPS to evaluate the self-efficacy of the student participants (Walpitage, 2016). This condensed form comprises 20 items, a substantial reduction from the original 41-item version, which makes it more efficient without compromising its effectiveness. This shorter version of SESPS showed evidence of acceptable levels of reliability and validity.

Validity is a numerical measure of how well an instrument measures what it is intended to measure, and it contributes to the credibility and integrity of the study, also helping to determine the generalizability of the findings. Reliability, on the other hand, refers to the consistency of results produced by a research tool or technique. A tool's reliability is often demonstrated by a coefficient of 0.7 or above, such as the Cronbach's alpha score, which is indicative of robust test–retest reliability, and the truncated SESPS showcased an impressive internal consistency reliability with a Cronbach's alpha of 0.96, illustrating its high dependability (Walpitage, 2016). The convergent validity of the abbreviated version was demonstrated by the Pearson correlation coefficient with the statistical anxiety

scale (SAS), which was -0.32 with $p<0.001$. This shows that the truncated SESPS was a suitable instrument for measuring self-efficacy in statistical practices .

6.2.3 Statistical anxiety scale (SAS)

The statistical anxiety scale (SAS) is a Spanish-language instrument specifically designed to measure statistics anxiety, which consists of three subscales, each with eight items, including examination anxiety, anxiety related to seeking help, and interpretation anxiety. The 24 items are rated on a five-point Likert scale, ranging from 1 (No Anxiety) to 5 (Extreme Anxiety). A high score on examination anxiety indicates that the student experiences significant anxiety when taking statistics exams, while a high score for anxiety related to seeking help implies that the student feels extremely anxious when asking for help from teachers, classmates, or tutors. Meanwhile, a high score for interpretation anxiety indicates that the student experiences anxiety when interpreting data and understanding statistical calculations.

Vigil-Colet et al. (2008) conducted a component analysis with 159 participants, finding evidence of construct-related validity for the SAS in Spanish. (The article was also published in English by the authors using the back translation procedure.) The data show a correlation between the three components, indicating that they represent linked subscales of statistical anxiety. In addition, the study also reveals high Cronbach's alpha values for the overall scale ($\alpha = .91$), the examination anxiety subscale ($\alpha = .87$), the seeking help anxiety subscale ($\alpha = .92$), and the interpretation anxiety subscale ($\alpha = .82$), indicating strong internal consistency.

The SAS questionnaire was used in this thesis to examine whether the three distinct aspects of statistical anxiety might manifest in the same way for students who viewed rich media resources (RMR), with the aim that the results will provide insight into how viewing multimedia resources might impact students' anxiety related to statistics.

6.2.4 Course performance measures

Each student's performance score was derived from the average of two unit assessments for the Numeracy and Data Analysis course (NDA1 and NDA2), and

these assessments, designed and moderated by the course instructors, included a mix of numerical and statistical questions. Over the span of 12 weeks, the course unit was divided into two blocks with students studying concepts from NDA1 in the first half, and then, during the latter half, covering topics related to NDA2. Students were then given a four-week period to complete each assignment, submitted at the end of each respective block. Both scores (NDA1 and NDA2) ranged from 0 to 100, with each assignment accounting for 100 percent of the final unit grade within the course context. The unit lecturer marked the assessments. The detailed content of these assessments, demonstrating their alignment with the course objectives and learning outcomes, is included in the Appendix. However, it is important to note that these assessments are not standardized but were crafted specifically for this course, ensuring a tailored evaluation of the students' comprehension and application of the course content. While using non-standardized measures like NDA1 and NDA2 assignments might present certain limitations, such as using researcher-generated measures tends to generate over-inflated effect sizes and may not be generalisable, they offer the advantage of being tailored specifically to the curriculum of this course, which ensures that the assessments directly evaluate students' mastery of the material they were taught. Furthermore, the design and moderation by course instructors guarantee that these measures are contextually relevant and aligned with the course's unique learning objectives. Despite the inherent challenges of non-standardized measures, their bespoke nature in this context ensures that the data collected offer a nuanced and accurate representation of students' grasp on the course content.

6.3 Sample for the quantitative strand

When designing a study, one of the critical aspects to consider is the sample size in that the chosen sample size must have adequate statistical power to detect effect sizes that are of relevance to the research (Lakens et al., 2016). In statistical terms, 'statistical power' pertains to the likelihood of a test revealing a statistically significant result, provided there exists an effect of a certain magnitude. It is influenced by effect size, sample size, and the alpha level (the probability threshold

for rejecting the null hypothesis, often set at .05). It is typical to set the power at .80, implying that given a true effect, the null hypothesis would be rejected 80 percent of the time, leading to a 'Type II error' or a false negative in the remaining 20 percent of cases (Cohen et al., 2013).

Linking these concepts to the specifics of the study, it is imperative to calculate an appropriate sample size, taking into account the specific analyses planned. For the purpose of this study, which involves utilizing various regression algorithms to analyse the data, a power calculator was used to compute the required sample size. This calculator is readily available online (Soper, 2023) and is based on Cohen's statistical power analysis (Cohen et al., 2013). Based on the anticipated effect size of 0.15, a statistical power of 0.8, three predictors, and a probability level of 0.05, the power calculator recommended a sample size of 76 participants. Thus, the study included 84 foundation year students from all linked degrees mentioned in Appendix E: Linked Degrees. The chosen effect size of 0.15 is based on Soper (2023), which pertains to the anticipated differences in statistics anxiety (SAS score), statistics self-efficacy (SESPS), and performance (NDA assessment scores) when comparing students who have been exposed to RMR against those who have not. In essence, the 'effect' seeks to quantify the magnitude of difference in these outcome measures, attributing it to the influence of media exposure. The rationale behind utilizing an effect size of 0.15 is to capture even subtle yet potentially impactful variations in student outcomes that RMR might bring about. Data collection for the quantitative component took place during a single week in April 2022, where all participating classes or groups I taught were given the opportunity to partake in the study. During these timetabled NDA sessions, students completed the questionnaires and provided their consent via consent forms, with printed participant information sheets made available to them (all of which are attached in the Appendix for reference). As for the NDA2 assessment results, these became available for analysis in August 2022.

6.4 Participants

The participants in this study were foundation year students registered for the Numeracy and Data Analysis module, taught at my university across Blocks 3 and 4. Each block constitutes a six-week teaching period and duration of a typical semester, albeit with twice the number of weekly lessons.

The students registered for this module are enrolled in various linked degrees (a detailed breakdown is provided in Appendix E: Linked Degrees), affording a diversity of disciplinary backgrounds among the participants. Out of an approximate total 630 students registered for this module, 90 agreed to participate in the research study. After addressing outliers and missing data (see below), the final sample for quantitative data analysis comprised 84 participants, which exceeded the minimum sample size of 76 suggested by the relevant power calculations for multiple regression, (assuming an anticipated effect size = 0.15, statistical power=0.8, number of predictors = 3, and a probability level = 0.05).

Furthermore, a subset of these participants, comprising 43 students, chose to engage with the rich media resources (RMR) provided as part of the study. This group's data were particularly pertinent to addressing the research questions concerning the impact and appeal of rich media on students' statistical anxiety, self-efficacy, and performance.

6.4.1 Characteristics of participants

To ensure confidentiality, an Excel spreadsheet was established containing participant IDs and their corresponding original responses with each participant receiving a unique code number, which was stored separately from the data that were later analysed. With the aid of the student IDs, I was able to discern the degree programme of each participant, as well as their performance marks. A short questionnaire additionally aided me in understanding their previous mathematics knowledge, mode of transportation (as students who have longer or more inconvenient commutes may, in an effort to save on the cost or effort of travel rely more heavily on RMR for their academic needs) and frequency of utilization of RMR on a weekly basis.

Of the 84 participants, 43 students engaged with RMR, while the other 41 students did not. It is worth mentioning that frequency of engagement with RMR varied among students who interacted with these resources, with 36 students reporting viewing RMR at least twice a week. In addition, it is essential to note that when students reported their engagement with RMR, some might have watched a single video multiple times, which means that the total number of views could be higher than the number of individual students who accessed the RMR. In terms of prior mathematical education, the majority of the students, 65 (77 percent), had completed a GCSE level mathematics unit, while a smaller group, 24 (27 percent), indicated that they had not studied mathematics after secondary school.

Participation in this study was entirely voluntary, and no incentives were offered to students. This aspect supports the authenticity of the data collected, as they are less likely to be influenced by external motivational factors.

6.5 Ethical responsibility and data screening

Ethics played a pivotal role in the conduct of this study. All participants were treated with respect, kindness, and assurance of confidentiality, a principle that was applied consistently throughout all phases of the study, and students wishing to participate were required to provide informed consent, which included granting permission for the researcher to access their demographic information and assessment scores from the university's QLS, Moodle, and Presto systems for the Numeracy and Data Analysis module. The participants' personal data and responses were maintained confidentially, and participants were informed that they had the right to withdraw their consent at any point, leading to the removal of their data from the study. Participants' responses were gathered and reviewed for the presence of signed informed consent forms and completion of both measurement instruments – the self-efficacy in statistical practices scale (SESPS) and the statistical anxiety scale (SAS) – and the data were then entered into a Microsoft Excel spreadsheet for organization and further analysis. In addition to the procedural ethics outlined above, it was imperative to acknowledge the broader

ethical dimensions associated with this research. As mentioned in Section 5.1.3, given my position as the lecturer and the inherent authority that comes with it, special care was taken to ensure participation was voluntary. Emphasizing the significance of ethical responsibility, students were thoroughly informed about the research's aims and reassured about the non-obligatory nature of participation alongside the clear distinction that their academic standing would remain unaffected by their decision to participate or not. These broader ethical considerations, especially the emphasis on participant wellbeing and the management of potential conflicts, provided the foundation upon which the specific ethical actions in this part of the study were built (see Section 5.1.3 for a detailed discussion on these broader issues).

6.5.1 Pre-analysis data cleaning and exploration

Eligibility for participation was tied to the signing of the consent form, and individuals who failed to provide this were excluded from the study. Furthermore, those who withdrew from the course had their data omitted from the study. Instances of missing data in the questionnaires were addressed using list-wise deletion in SPSS, a common approach when handling missing data (Roth, 1994). To ensure the robustness of the data, bootstrapping, a statistical method that resamples a dataset to estimate the distribution of a metric (such as its variance or bias), was performed on all analyses, which enhances the reliability of the results by assessing their stability across multiple samples. A scatter plot analysis was also conducted to identify and manage potential outliers that could skew the results of the multivariate analysis of variance (MANOVA) and independent samples t-test (Tabachnick and Fidell, 2007). Details and visuals of these plots will be discussed in the subsequent section.

6.6 Data analysis plan for the quantitative strand

To analyse the quantitative data collected, I used two software programs. Firstly, I used Excel to compile the raw data into a concise form, and later used it to calculate the averages for each instrument (survey). Secondly, I used IBM's SPSS

program to generate descriptive statistics, enabling me to summarize and present the data in a more meaningful format. The raw data were divided into two groups based on whether participants had viewed rich media resources (RMR) or not, which became the independent variable. The study aimed to determine whether the two groups differed in their statistics anxiety (gathered via SAS questionnaire score), statistics self-efficacy (gathered via SESPS), and performance (average marks in assessments), which were the three dependent variables studied.

A multivariate analysis of variance (MANOVA) was conducted to investigate whether there were any differences across the three dependent variables between those students who engaged with the RMR and those that did not. The independent variable here was a categorical one with two alternatives – namely, whether the RMR was viewed or not. Before diving into the analysis, it was crucial to examine whether the data met the assumptions needed for a MANOVA, which include sample size, normality, outliers, linearity, and multicollinearity and singularity (Tabachnick and Fidell, 2007). The correlation assumption for the MANOVA test requires a significant correlation between the dependent variables, and upon examining the cross-correlations in a subsequent table, it was observed that the performance variable exhibited weak and non-statistically significant correlations with the other dependent variables. As such, this variable did not meet the correlation requirement for inclusion in the MANOVA test. Consequently, the performance variable was analysed separately using the independent t-test, while the MANOVA test was used to examine the effects of RMR on two dependent variables only – statistics anxiety and self-efficacy scores. Furthermore, individual one-way ANOVA was conducted for each dependent variable to examine their individual effects more closely.

Chapter 7: Data Analysis (Quantitative Strand)

This section presents the data collected from the assessment scores and questionnaires distributed among foundation year students enrolled in the Numeracy and Data Analysis course, subsequently explaining the outcome of each analytical step taken. This chapter will begin with a summary of the results, followed by a more detailed demonstration of the data analysis, MANOVA and hypothesis testing process.

Results summary

The quantitative research design was developed to answer the first two research questions:

RQ1) Are there statistically significant differences between students that did and did not engage with rich media resources in terms of the students' statistical anxiety, self-efficacy, and performance?

RQ2) What is the potential appeal of rich media resources for students who are experiencing statistics anxiety?

The objective of this strand was not to establish a cause–effect relationship between RMR usage and students' statistical self-efficacy, statistical anxiety, and performance. Instead, its aim was to discern any significant differences in these variables between the group of students who engaged with RMR and those who did not with the RMR, including resources like lecture recordings, short key-concept videos, and online tutorial recordings. My interest in exploring the potential association between Rich Media Resources (RMR) and students' statistical anxiety and self-efficacy stemmed from a desire to understand if RMR could play a beneficial role in these areas. The first critical step was to ascertain whether there were quantifiable differences between groups regarding these factors. This quantitative analysis served as a foundational step, setting the stage for a deeper dive into qualitative methods to gain a more nuanced understanding. The analysis revealed that students engaging with RMR had significantly lower scores in statistical self-efficacy (SESPS) and significantly higher scores in statistical anxiety

(SAS) compared to those who did not use the RMR. This indicates a significant difference in statistical anxiety and self-efficacy levels between students who engaged with RMR and those who did not. Additionally, there was a small but significant inverse correlation between SAS and SESPS. However, no significant difference in performance was observed between students who engaged with RMR and those who did not.

In conclusion, while significant differences between students who did and did not engage with RMR were found in the statistical anxiety and self-efficacy levels, no such differences were observed in their performance. Based on these findings, I speculate that RMR may act as a safety net, aiding students in their journey of learning statistics, thereby redefining traditional boundaries of learning. This evidence hints at the potential appeal of RMR for students experiencing statistics anxiety, which aligns with the aim of our second research question, and in the subsequent sections, I delve into a more in-depth presentation of the data analysis and results, including further interpretation of these findings

Section A: Data analysis quantitative strand

The following section of the data analysis aims to provide insights into Research Question 1, which investigates whether statistically significant differences exist between students who engaged with rich media resources and those who did not in terms of statistical anxiety, statistical self-efficacy, and performance.

7.1 Descriptive presentation of quantitative data

Key to understanding the SPSS analysis

SPSS Label	Interpretation
SeenVideo	RMR engagement
SAS score	Statistics anxiety score
SESPS score	Statistics self-efficacy score
Marks	Statistics performance score

Presented below, Table 1 offers a detailed display of the descriptive statistics for all variables evaluated in this study. In the table, a value of **0** for the 'SeenVideo' variable indicates that students did not engage with RMR, while a value of **1** signifies those students viewed one or multiple rich media resources (RMR).

Table 1. Descriptive statistics for SAS score, SESPS score and marks

	Seen Video	Mean	SD	N
SAS score	0	2.1820	.47709	41
	1	3.2295	.72837	43
	Total	2.7182	.80972	84
SESPS score	0	.6247	.12694	41
	1	.4080	.21524	43
	Total	.5138	.20755	84
Marks	0	79.488	16.3602	41
	1	80.430	14.0053	43
	Total	79.970	15.1153	84

Descriptive scores' for student students who engaged with RMR and those who did not*. The mean and standard deviation of statistical anxiety score, statistical self-efficacy, and performance (marks) are presented in relation to whether or not students viewed rich media resources (RMR).*

Presented above, Table 1 presents descriptive statistics for the three variables: statistics anxiety (SAS score), statistics self-efficacy (SESPS score), and performance marks, and the variable 'RMR engagement' refers to whether the participant

watched rich media resources (RMR) or not, with a score of 0 indicating that they did not watch RMR and a score of 1 indicating that they did.

Comparing the means of the two groups (0 and 1) in the 'RMR engagement' variable, I can see that participants who watched RMR had higher mean scores for SAS (3.2295) and lower mean scores for SESPS (.4080) compared to those who did not watch RMR (SAS: 2.1820, SESPS: .6247). However, the mean performance score for those who watched RMR (80.430) was only slightly higher than those who did not (79.488). Overall, the results suggest that there may be a relationship between watching RMR and higher SAS and lower SESPS scores, but the relationship with performance marks is less clear.

7.1.1 The inverse relationship between statistics self-efficacy and statistics anxiety: exploring the instruments

In this study, two separate instruments were used to examine the relationship between statistics self-efficacy and statistics anxiety: the SESPS (statistics self-efficacy measure), and the SAS (statistics anxiety measure). As expected and in line with findings from prior studies (Perepiczka et al., 2011, Chew and Dillon, 2014a), results showed a statistically significant inverse correlation between these two measures. This moderate, statistically significant Pearson's correlation coefficient (-0.316, p=0.003), implies that students who reported lower self-efficacy in statistics tended to experience a higher degree of statistics anxiety. These findings offer further support for the relationship between students' beliefs about their own abilities and their level of anxiety in statistics, which has been observed in other populations (Perepiczka et al., 2011; Chew and Dillon, 2014a; Dart, 2022).

Interestingly, no significant relationship was found between performance and either statistics anxiety or self-efficacy, as reflected in Table 2 – a result that diverges from some earlier studies (Yokoyama, 2018), which had found a correlation between these factors. Theoretically, one might expect a relationship between these variables because heightened statistics anxiety can hinder comprehension and retention, while a higher sense of self-efficacy typically boosts confidence and, potentially, performance in academic tasks. The lack of correlation

in this study could be attributed to limitations in the performance measures used, sample size, or other contextual factors specific to this study (such as study environment and the mode of instruction). Therefore, further research is required to elucidate this relationship in greater detail and to determine if these findings are consistent across other samples and settings.

Table 2. Cross correlations

		RMR engagement	SAS score	SESPS score	Marks
RMR engagement	Pearson correlation	1	.653**	-.525**	.034
	Sig. (2-tailed)		<.001	<.001	.756
	N	90	90	88	86
SAS score	Pearson correlation	.653**	1	-.316**	-.079
	Sig. (2-tailed)	<.001		.003	.468
	N	90	90	88	86
SESPS score	Pearson correlation	-.525**	-.316**	1	-.097
	Sig. (2-tailed)	<.001	.003		.379
	N	88	88	88	84
Performance	Pearson correlation	.034	-.079	-.097	1
	Sig. (2-tailed)	.756	.468	.379	
	N	86	86	84	86

** Correlation is significant at the 0.01 level (2-tailed).

The focus of this study extends beyond merely establishing these relationships. It dives further into the potential role of RMR in relation to these variables, which constitutes the novel contribution of this research. Specifically, the qualitative component of this study will deepen our understanding by examining why students might choose to use RMR and the benefits they derive from such engagement, thereby providing a richer and more comprehensive perspective that complements the quantitative findings.

7.2 MANOVA

In this section, I will provide a detailed presentation of the multivariate analysis of variance (MANOVA) and the assumptions that needed to be considered before

performing this data analysis technique. Subsequently, I will present the results obtained from the MANOVA analysis.

7.2.1 Hypothesis testing using MANOVA

Research question: *RQ1) Are there statistically significant differences between students that did and did not engage with rich media resources in terms of the students' statistical anxiety, statistical self-efficacy, and performance?*

H_0: Students who viewed the rich media resources did not significantly differ from those who did not view the rich media resources in terms of statistical anxiety, self-efficacy, and performance.

*Hypothesis testing rationale: In simpler terms, the null hypothesis **H_0** suggests that there is no observable effect or difference in the three variables — statistical anxiety, self-efficacy, and performance — based on whether or not students engaged with the rich media resources. It represents a starting point in hypothesis testing, whereby the aim is to either reject this assumption (based on evidence) or fail to reject it. The rationale behind hypothesis testing, like the null hypothesis **H_0**, lies in providing a systematic method to draw conclusions about populations based on samples, and the process begins with an assumption (the null hypothesis) that there is no effect or difference. We then use sample data to test this assumption.*

Statistical tests compute the probability (p-value) of observing the sample data (or something more extreme) were the null hypothesis true. A small p-value indicates that the observed sample is unlikely under the assumption of the null hypothesis, leading us to reject the null hypothesis in favour of the alternative, and this method is trusted because it provides a structured, consistent approach to inferential statistics and decision-making. By setting a significance level (often 0.05), researchers can control the risk of making incorrect conclusions. However, it is crucial to complement hypothesis testing with other analytical methods and domain knowledge, as p-values only provide a measure of evidence against a specific hypothesis and don't quantify the size or importance of an effect.

MANOVA assumptions testing

Correlation: Prior to conducting the MANOVA, a series of Pearson cross-correlations were calculated between all of the dependent variables in order to test the MANOVA assumption that the dependent variables would be correlated with each other in the moderate range (i.e., Pearson's correlation co-efficient r is between .20 and .60; (Cohen, 1988)). As can be seen in Table 2, a meaningful pattern of correlations was observed amongst most of the dependent variables, suggesting the appropriateness of a MANOVA. Appendix O: Statistical Figures (Figure 23) demonstrates the meaningful pattern of correlations between two of the dependent variables, SAS and SESPS, suggesting the appropriateness of inputting statistics anxiety (SAS) and self-efficacy (SESPS) into the MANOVA.

The performance variable (assessment score) was not correlated with SAS (r = -0.079) or SESPS (r = -0.097), which means that it fails to meet one of the assumptions required for MANOVA analysis. A separate hypothesis test is therefore conducted for the performance variable. Since the performance variable will be analysed separately from the other two dependent variables, I divide my null hypothesis into two parts.

7.2.2 Split hypothesis H_0 into two parts

Splitting of H_0 into H_{01} and H_{02}.

MANOVA H_{01}: Students who viewed the rich media resources did not significantly differ from those who did not view the rich media resources in terms of statistical anxiety and self-efficacy.

Independent samples t-test H_{02}: Students who viewed the rich media resources did not significantly differ from those who did not view the rich media resources in terms of statistics performance.

7.2.2.1 Testing H_{01} using MANOVA

A one-way multivariate analysis of variance (MANOVA) was conducted to investigate if there was a significant difference in students' statistical self-efficacy and statistics anxiety based on their engagement with the rich media resources (viewed or did not view).

7.2.2.2 Preliminary Assumption Testing for MANOVA Analysis

In addition to testing the assumption around the extent to which the dependent variables were correlated, it was also necessary to check the validity of the MANOVA analysis, and preliminary assumption testing was conducted. Univariate outliers were examined using boxplots (Appendix O: Statistical Figures - Figure 24), and no outliers were identified. for either dependent variable (SAS or SESPS score).

The normality assumption was examined using Shapiro-Wilk tests, and the results showed that the assumption of normality was met for both levels of the independent variable and both dependent variables (P>0.05). However, for the group that viewed the video on SESPS variable, the p-value was 0.019, which is slightly below the conventional significance level of 0.05. Nevertheless, the MANOVA is reasonably robust to modest violations of normality when the sample size was at least 20 in each cell (Tabachnick and Fidell, 2007: 25).

Additionally, the Mahalanobis distance was used to assess multivariate outliers, and the results showed that the critical value of 13.82 for two variables was not exceeded (maximum value=8.046), indicating that the assumption of no multivariate outliers was tenable. The assumption of linearity was assessed by examining scatterplots (see Appendix O: Statistical Figures **Error! Reference source not found.**), and it was found to be satisfactory. In the analysis below (Appendix P: SPSS MANOVA Full Results), the dependent variable SESPS did not meet the assumption of homogeneity of variance, as revealed by the Levene's Test, and to address this violation, a log transformation, Log SESPS, was performed. Using a logarithmic transformation is a common technique to stabilize variances.

Table 3. MANOVA – Multivariate Tests

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[c]
Intercept	Pillai's Trace	.992	5452.229[b]	2.000	85.000	<.001	.992	10904.459	1.000
	Wilks' Lambda	.008	5452.229[b]	2.000	85.000	<.001	.992	10904.459	1.000
	Hotelling's Trace	128.288	5452.229[b]	2.000	85.000	<.001	.992	10904.459	1.000

	Roy's Largest Root	128.288	5452.229[b]	2.000	85.000	<.001	.992	10904.459	1.000
RMR Engage-ment (Q3)	Pillai's Trace	.529	47.729[b]	2.000	85.000	<.001	.529	95.458	1.000
	Wilks' Lambda	.471	47.729[b]	2.000	85.000	<.001	.529	95.458	1.000
	Hotelling's Trace	1.123	47.729[b]	2.000	85.000	<.001	.529	95.458	1.000
	Roy's Largest Root	1.123	47.729[b]	2.000	85.000	<.001	.529	95.458	1.000

a. Design: Intercept + Q3
b. Exact statistic
c. Computed using alpha = .05

Descriptive statistics were computed for the two dependent variables – the SAS score and the newly created Log SESPS score – and are presented in Appendix P: SPSS MANOVA Full Results (Descriptive statistics). Mean and standard deviation were reported for each group (viewed and not viewed).

Table 4. MANOVA – Box's Test of Equality of Covariance Matrices

Box's M	7.463
F	2.425
df1	3
df2	1331280.000
Sig.	.064

Tests the null hypothesis that the observed covariance matrices of the dependent variables are equal across groups.

a. Design: Intercept + Q3

Box's M was conducted to examine whether the observed covariance matrices of the dependent variables were equal across groups, with the results indicating that the null hypothesis was not rejected (M = 4.463, p=0.064).

In conclusion, the preliminary assumption testing for the MANOVA analysis indicated that the assumptions of no univariate or multivariate outliers, normality, and linearity were met, and the Box's M test indicated that the assumption of equal

covariance matrices was tenable. Therefore, the results of the subsequent MANOVA analysis can be considered reliable and valid.

7.2.3 Assessing differences: MANOVA results on rich media resource viewing

Results of the MANOVA yielded that there was a statistically significant difference between the two groups, viewed and not viewed (rich media resources), in terms of the combined dependent variables, statistical self-efficacy and statistical anxiety: Wilks A=0.471, F (2,85) =47.729, p<0.001, partial ɲ^2=0.529, observed power=1.00. Based on these results, evidence was sufficient to reject the null hypothesis, as the effect size was large. Using MANOVA allows for the consideration of multiple dependent variables simultaneously and tests whether groups differ on a combination of these variables, thereby providing a more holistic view of the group differences on the set of dependent variables. However, it doesn't pinpoint which specific dependent variable(s) the groups differ on. This is where follow-up ANOVAs come in, conducted to determine between which individual dependent variables the significant differences lie. This two-step approach – first using MANOVA and then ANOVA – ensures a comprehensive analysis of group differences across combined and individual metrics (Tabachnick and Fidell, 2007). Follow-up ANOVA were conducted in the section below.

H_{01_A}: Students who viewed the rich media resources did not significantly differ from those who did not view the rich media resources in terms of statistical anxiety.

H_{01_B}: Students who viewed the rich media resources did not significantly differ from those who did not view the rich media resources in terms of statistical self-efficacy.

Using the Bonferroni method, each ANOVA was tested at a 0.025 (0.05/2) alpha level, and results demonstrated that there was sufficient evidence to reject the sub null hypothesis H_{01_A} of statistical anxiety and H_{01_B} statistical self-efficacy null hypothesis: F (1,86) =61.280, p<0.001, partial =$ɲ^2$=0.416, observed power=1.00 and

F (1,86) =29.699, p<0.001, partial =η^2=0.257, observed power=1.00. The effect size was large for both ANOVAs, and the relationship between the viewing of RMR and statistical anxiety was strong, with the type of group accounting for 41.6 percent of the variance in the dependent variable. Similarly, the relationship between watching rich media and statistical self-efficacy scores was robust, with the type of group explaining 25.7 percent of the variance in the dependent variable. An observed power of approximate 1.00 (0.99999) indicates an approximate 100-percent confidence level in the results, suggesting that the findings are statistically significant for both analyses. Students who engaged with RMR exhibited significant differences in statistical anxiety and self-efficacy compared to those who did not interact with these resources.

7.3 Testing H_{02} using independent samples t-test

H_{02}: Students who viewed the rich media resources (RMR) did not significantly differ from those who did not view the RMRs in terms of **performance.**

To test this hypothesis, an independent samples t-test was conducted. Table 5 presents the performance group statistics for the two groups (viewed and not viewed).

Table 5. Performance group statistics

	RMR-engagement	N	Mean	Std. Deviation	Std. Error Mean
Marks	0	41	79.488	16.3602	2.5550
	1	45	80.500	13.7931	2.0562

Levene's test for equality of variances was conducted, and the results (F=0.686, p=0.410) indicate that the variances of the two populations are assumed to be approximately equal. Therefore, the assumption for a standard t-test was satisfied, and the standard t-test was used to compare the means.

The results of the independent samples t-test showed that there was no statistically significant difference between the mean performance scores of

students who did not view the RMR (n=41, M=79.48, SD=16.36) and those who viewed them (n=45, M=80.50, SD=13.79): t(84)=3.11, p=0.76.

Appendix P: SPSS MANOVA Full Results Table 7 presents the results of the independent sample tests, including the 95-percent confidence interval of the difference in means, ranging from -7.4824 to 5.4580. These results suggest that there was no significant difference between the performance of students who viewed the RMR and those who did not. Therefore, I fail to reject the null hypothesis that there is no significant difference in performance between the two groups.

7.4 Results from hypothesis testing: the relationship between students' statistical self-efficacy, statistical anxiety, performance, and rich media use

The purpose of this study was to investigate the potential relationship between students' use of rich media resources (RMR), such as lecture recordings, short key-concept videos, and online tutorial recordings, and their statistical self-efficacy, statistical anxiety, and performance. The data analysis conducted thus far revealed that students who engaged with the RMR scored significantly lower on the statistical self-efficacy measure (SESPS) compared to those who did not use the R

MR (M=91.19, SD=12.58; M=87.21, SD=12.54;): t(248)=2.48, p=.014, two-tailed Table 1. Additionally, students who viewed and engaged with the RMR scored significantly higher on the statistical anxiety measure (SAS) than those who did not use the RMR (M=91.19, SD=12.58; M=87.21, SD=12.54;): t(248)=2.48, p=.014, two-tailed Table 1. Moreover, Table 2 shows a low level of inverse correlation (-0.316) with significance, p=0.003, between SAS and SESPS.

Students who viewed and engaged with the RMR did not show any significant difference in terms of performance than those who did not use the RMR. Possible interpretations of these findings will be explored in section 9.1.1. First, we will explore report the analysis for the second research question.

7.5 Section B: Data analysis quantitative strand

This next part of my data analysis focuses on Research Question 2, whereby I dig deeper into students' feelings about their own experiences with statistical anxiety. I also explore the possible role of rich media resources (RMR) in easing this anxiety.

Research Question 2: *RQ2) What is the potential appeal of rich media resources for students who are experiencing statistics anxiety?*

7.5.1 Zooming in on different types of statistical anxiety (SAS questionnaire)

As highlighted in the review of existing research, statistics classes can sometimes feel competitive and unwelcoming, which can lead to increased levels of anxiety among students (Chew and Dillon, 2014a; McGrath et al., 2015; Cui et al., 2019). To get a sense of how anxious students might feel in a foundation-level statistics course, I used a tool called the statistical anxiety scale (SAS) questionnaire (Vigil-Colet et al., 2008). As detailed in section 6.2.3, this questionnaire measures three specific types of statistical anxiety:

Examination anxiety: This measures how anxious students feel when they take statistics exams. A high score here means that a student feels highly anxious during these situations.

Asking for help anxiety: This reflects the anxiety students feel when they need to ask for help with statistics from their course instructor, classmates, or private tutors.

Interpretation anxiety: This measures how anxious students feel when they have to interpret statistical data or understand statistical formulas.

Bar chart comparison of examination anxiety subscale scores for students who viewed and did not view rich media resources

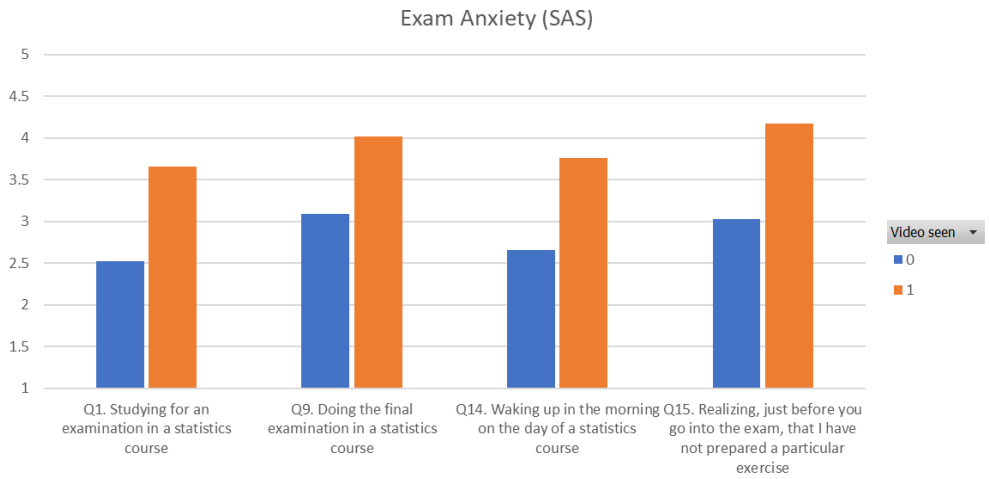

Figure 6. Breakdown by question and comparison of examination anxiety subscale

Figure 6 presents a bar chart that breaks down and compares the examination anxiety subscale questions for students who viewed and did not view RMR. The chart displays the mean scores for each of the four questions, with the y-axis representing the score range from 1 to 5, and the x-axis representing the four questions being compared. The blue bars represent the mean scores for students who did not view RMR, while the orange bars represent the mean scores for students who did.

The chart above indicates that those students who viewed RMR scored higher on all four questions related to the examination anxiety subscale, indicating higher levels of anxiety. Specifically, the mean score for students who viewed RMR was higher for questions related to fear of examinations, fear of failing, fear of being evaluated, and fear of forgetting key concepts.

This result supports the conclusion that students who use RMR may do so as a coping mechanism to reduce their anxiety levels. Additionally, it suggests that students with higher levels of exam anxiety are more likely to seek out resources like rich media to alleviate it. These findings may have implications for instructors and course designers, highlighting the need for additional resources and support for students experiencing exam anxiety.

7.5.2 Relationship between rich media resources and asking for help anxiety

The presented breakdown of the asking for help anxiety subscale in figure 7 shows a similar trend to the examination anxiety subscale discussed earlier. Students who viewed RMR reported higher scores on the anxiety scale for each question in the asking for help subscale. However, it should be noted that these results are based on a standard questionnaire and do not establish a causal relationship between the primary variable of viewing RMR and increased anxiety.

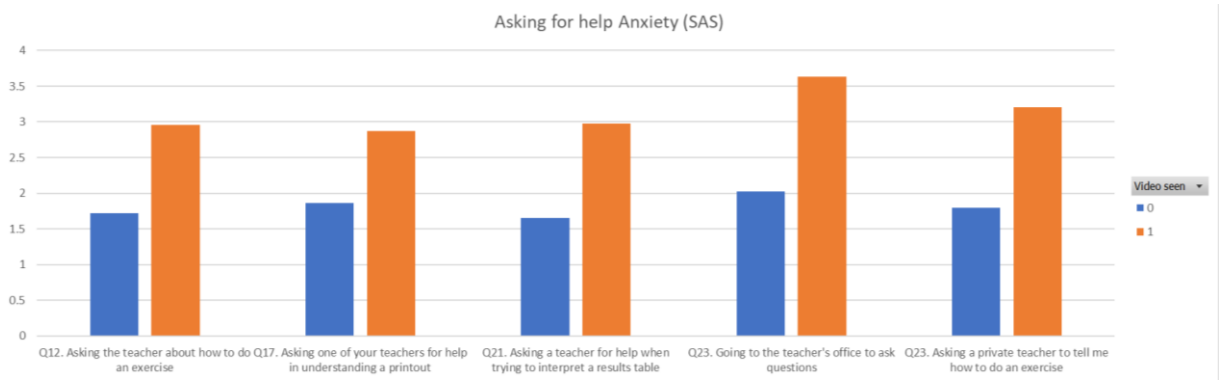

Figure 7. Breakdown by question and comparison of asking for help anxiety subscale

Analysing each question in Figure 7, it can be inferred that students who experience higher levels of anxiety when seeking help from their instructors or peers were more likely to view RMR, and these findings suggest that students may use RMR as a way to cope with anxiety when seeking help from others.

Further analysis (

Appendix K: Further analysis on SAS) revealed a noticeable correlation between the utilization of RMR and higher reported levels of both examination anxiety and anxiety related to asking for help. This finding was based on the significantly higher mean scores for students who engaged with RMR as compared to those who did not. For instance, the mean score for exam anxiety among RMR users was 3.8820 (SD=0.85200), while non-users reported a mean score of 2.8864 (SD=0.93732). A similar trend was observed in the asking for help anxiety subscale, with a mean score of 2.9876 (SD=1.10813) for RMR users and 1.7662 (SD=0.73044) for non-users. These outcomes suggest that RMR might be sought as a coping strategy by students already experiencing elevated levels of statistics-related anxiety. This

leads us to further probe the implications of RMR usage on students' consciousness of their embodied reactions to statistics-related texts and its influence on forming a comprehensive statistical e-learning experience, subjects that I will investigate in more depth in Research Questions 3 and 4.

7.5.3 Conclusion Section B: Data analysis quantitative strand

The findings detailed above indicate that students who engaged with RMR were more likely to experience anxiety about statistics and have lower levels of self-efficacy. While the design of this study does not allow for causal inferences, it is possible to speculate that students with less confidence in their statistics abilities might seek out RMR for additional support. This hypothesis aligns with the intuitive notion that students might turn to RMR to bolster their understanding and, in turn, reduce their anxiety. However, it's also conceivable that the association could operate in the opposite direction, where RMR use exacerbates students' anxiety. Yet, this possibility does not seem to be supported by the qualitative data collected. As will be explored in the next chapter, students reported positive experiences of engaging with RMR. The qualitative findings imply that RMR usage is perceived positively by students, potentially aiding in improved confidence and managed levels of exam anxiety, particularly when used as part of their examination preparation.

Exam anxiety manifests differently among individuals. For some, it can create a feeling of butterflies in the stomach, while others may experience difficulties in concentrating during the exam. This anxiety is nearly universal, with most students experiencing it to some extent, and a small amount of pre-exam anxiety can even serve as a catalyst for motivation, making students more mentally alert and prepared for the challenges that lie ahead (Yerkes and Dodson, 1908). However, when a student's stress levels exceed their coping threshold, this excessive anxiety can impair their performance in the exam (Cherry, 2023). Indeed, some students may possess the necessary skills and knowledge to perform well on exams, but excessive anxiety can become a debilitating barrier (Zeidner, 1998; Macher et al., 2015; McGrath et al., 2015; Frey-Clark et al., 2019; Dart, 2022).

Based on the Yerkes-Dodson law, the relationship between performance and arousal suggests that increased arousal levels can improve exam performance up to a certain point. Beyond that point, high levels of anxiety can cause undue stress, impairing performance (Cherry, 2023). Therefore, achieving a balance between mental alertness, motivation, and the potential negative consequence of excessive anxiety is crucial for optimal exam performance, and there are numerous strategies available for students to alleviate their anxiety, one of which is engaging with RMR. These findings suggest that students experiencing statistics anxiety are more likely to engage with RMR, indicating that these resources may serve as an important channel for educators to support students who are lacking confidence in this area (Macher et al., 2015; Dart, 2022). It must be noted, however, that these results do not imply the effectiveness of RMR in reducing anxiety but rather suggest an inclination among anxious students to utilize such resources. Building upon these insights, the qualitative strand of this study aims to delve deeper into understanding why students might be motivated to use RMR and what they gain from such engagement, adding nuance and depth to the findings of the quantitative strand.

Chapter 8: Data Analysis Qualitative Strand

8.1 Qualitative analysis: exploring the use and impact of rich media resources through the lens of Phase 1

While the quantitative strand of my investigation provided essential insights into the relationships between statistics anxiety, statistical self-efficacy, and the potential appeal of RMR, it also prompted curiosity about the students' individual experiences, motivations, and behaviours. To address this, I turned to the qualitative data gathered during Phase 1 of my qualitative research strand, aptly titled 'Exploring the landscape'.

In this phase, through casual conversations, observations, and semi-structured interviews, I sought to familiarize myself with my participants (who were enrolled in the Numeracy and Data Analysis course) and understand their experiences with e-learning on an introductory statistics course. This qualitative exploration aligns with Research Question 2, investigating the potential appeal and utilization of RMR for students experiencing statistics anxiety, and the insights gathered during this phase enriched my understanding of the data from the quantitative strand and provided a more holistic picture of the students' interactions with, benefits from, and perceptions of RMR in managing their statistics anxiety and supporting their learning. In the section that follows I will summarise some of the insights that came out of these preliminary discussions (which I refer to as phase 1), which provide a connection between the initial quantitative findings presented in chapter 7 and the in-depth exploration of students' experiences of RMR reported later in this chapter (phase 2).

8.1.1 Phase 1 Discussions: Exploring the Landscape

During our discussions, several participants across all data collection points positively linked the RMR to flexible and individualized learning enabling them to tailor teaching and learning practices to fit their own needs, preferences and capabilities.

Aly exhibits his planned reliance on RMR as providing assurance that he will have satisfactory alternatives available even if he misses lectures in class:

I will not fail this course just because I am stupid; I simply need to devote more time to it... I can't leave things till the last moment. I know I would panic... I admit that I don't attend the sessions regularly, but I do my best to catch up, and whatever I miss, I tell myself that I will view the lecture recording, which assures me that I will not fail.

He further explains his circumstances and shows that one reason for relying on RMR for this course is flexibility and how easily he can fit study around his work and personal life:

Okay, so, I had a lot going on both at work and in my personal life, and as a result, I was unable to devote as much time as I would have liked to the stats assignment... Then again, I didn't realise how much time was really required. I now solely depend on the online lectures to catch up on things that I missed.

Considering Aly's response, it could be argued that RMR serve an important function, providing information for students who otherwise would have missed out. In some cases, students who missed the lectures did not know how to study without the guidance the lectures provide and they were hesitant to seek any support (Q23 in Figure 7). People often feel uncomfortable when they ask for help because it means giving up control to someone else (Chester et al., 2011), and the responses from students during interviews highlighted factors such as 'losing control', 'fear that people will think they are weak' and 'don't want to look like [I] don't know what [I'm] doing [when asking the teacher for help]'. This anxiety about others' judgement is not limited to seeking individual help but within classrooms too, as depicted by Harper:

When I'm talking with you [teacher] and [during the discussion] … when I realise that I answered a question incorrectly, it makes my nervousness a little bit worse. I'm sitting there thinking, 'Oh wow, I bet the person sitting next to me thinks I'm an idiot'.

Conversely, I also noticed students doubted themselves in lectures or could not keep up with the pace during live lessons yet were anxious of raising their

questions or concerns. Hazel highlighted how RMR allow her to attend lectures in a productive way despite the anxiety about asking questions in class:

> *In earlier lecture sessions [before I had properly discovered the videos] I felt very anxious [in the live session] and asking questions felt… as if I was slowing the rest of the class down. After watching these videos before lectures… I at least had some groundwork to build on.*

Maggy's experience resonates with Hazel's in that she tends to refrain from asking questions. However, she goes on to discuss the advantages of feeling at ease with the RMR, which she believes allow her to absorb the material at her pace of understanding.

> *I am more comfortable in spotting my mistakes... I'd rather not go see my teacher. At times I doubt my ability to solve the questions and I usually check over them multiple times by playing the lecture videos… as I often make small mistakes that I worry about, because I believe they might affect the overall answer and make me lose marks.*

From the narratives of participants like Maggy, it becomes evident that RMR plays a pivotal role in the learning process, especially in foundation-year-level statistics courses. Several participants reported how RMR contributed significantly to their academic well-being, crediting these resources with the potential to reduce statistics anxiety and boost their statistics self-efficacy, and enhance their overall satisfaction with the course. The advantage of RMR does not just come from catering to varied learning paces but also in accommodating different learning styles and needs, and this inclusivity ensures that students from diverse backgrounds or with varying challenges find a supportive learning tool in RMR, making the course content more accessible and manageable. The flexibility of RMR – being able to pause, rewind, and review – allows students to engage deeply and overcome specific challenges, thus creating a more inclusive learning environment. As highlighted by numerous student testimonies, the reasons for accessing RMR varied greatly. Students were found to engage with RMR not only to compensate for missed classes but also for examination revision, revisiting complex material,

and studying at their own pace, which suggests that students may be using RMR to complement as well as replace traditional lectures.

As I further delve into the exploration of how students interact with RMR, I turn to Phase 2 of my qualitative research.

Reminder of Phase 2 methodological approach

This phase adopted multimodal image-based journaling using handheld devices, which offered the opportunity for more nuanced understandings of the students' engagements with technology over time, rooted in their everyday practices rather than abstracted accounts obtained through traditional interviews. Using this unique journaling method, I focused on the small-scale, emergent actions of everyday materials and embodied practice (Gourlay and Oliver, 2016a), which provided me with a more comprehensive and intimate window into the participants' hidden worlds and experiences over time (Braun et al., 2017). The multimodal journal entries, which emphasized visual methodologies and material practices, served not only as objects for analysis but also as a springboard for more in-depth discussions during subsequent interviews. Next, in the upcoming section I adopted an ethnomethodological lens to explore the relationship between digital learning tools like rich media resources (RMR) and students' embodied reactions – an intersection of minds, bodies, and emotions – and I was intrigued to unpack *RQ3*: *'How do students experience RMR and what do their embodied experiences of learning in this way tell us about the affordances of this mode of learning?'* This process of becoming aware of one's holistic responses offers a unique window into the self-perception of students and their understanding of their learning process, and the insights gained from this might hold the potential to redefine my approach towards easing statistics anxiety and increasing self-efficacy. Another part of my inquiry will focus on the symbiosis between students and their learning materials, addressing *RQ4: 'How do students and material things interact together to form a statistical e-learning experience?'* This question prompts us to ponder on the role of materiality in e-learning, the intertwining of physical and digital realms, and the everyday practices so entrenched in our routines that they often elude our conscious recognition. In this way, my journey as a doctoral student/researcher continues as I

venture further into the multi-layered impacts of RMR on the student experience in statistics courses and decipher the subtle ways in which students interact with their learning materials in the digital era.

8.2 Qualitative analysis Phase 2 – Dialogue with the unspoken: tacit modalities in a sociomaterial landscape

The quantitative analysis conducted in the preceding chapter yielded valuable insights into students' statistics anxiety, perceived efficacy, and their performance during their engagement with the RMR. By design, this cross-sectional study captures data at a specific moment in time, and while the quantitative portion of this study bolsters its validity and provides information about how students perceive and quantify their statistics-related anxieties and self-efficacies, the qualitative aspect complements and extends this view. It aids in examining the unique emotional and cognitive journey that each student embarks upon within their personalized learning environment with Bhatt et al. (2015) suggesting that some digital practices are essentially inaccessible, undetectable, or impossible to analyse using conventional research techniques. This research attempts to delve into students' practices *while* engaging with digital media resources in the rapid unfolding of their digitally mediated practices. To do so, it brings into focus ‘tacit modalities’, which capture how students’ experiences matter in the moment and on the embodied, sensory, and emotive levels (Rowsell and Abrams, 2021). These tacit modalities are crucial in shaping students' immediate experiences and the creation of affective meanings as they interact with a variety of elements, including artefacts, memories, hopes, feelings, and spatial contexts over time (Rowsell and Abrams, 2021), and this theoretical construct of tacit modalities within a sociomaterial landscape not only embodies the sensory, emotional, and physical aspects of their experiences, but also acknowledges the dynamic interplay between the mind, body, and text (Barad, 2007).

To accurately examine the complex nature of student statistical anxiety and self-efficacy, and the corresponding tacit modalities that contribute to these experiences when interacting with technologies, multimodal journaling (Gourlay

and Oliver, 2016a) played a crucial role. This approach allowed for the documentation of practices that emerged from a wide array of modalities – including but not limited to digital and paper texts, talk, audio, and images – while students engaged with video resources. An integral part of understanding these dynamics was acknowledging the fluctuating nature of students' statistics anxiety and self-efficacy within their daily experiences, as recognizing that these feelings originate and fluctuate within their everyday experiences and digital practices provides a more profound and comprehensive understanding. Students' everyday experiences, interests, and knowledge are essential and valuable resources that, when appropriately activated during e-learning, can significantly aid educators in fostering meaningful learning experiences (Silseth and Erstad, 2022), so that when it comes to studying for a statistics course, students may draw upon a vast array of resources. The diversity in resource utilization sets statistical learning via RMR apart from traditional learning modalities, and by exploring this intersection, this phase aims to delve deeper into the effects of RMR on students' cognition, emotions, and efficacy.

8.3 Multimodal analysis of student-produced data

The analysis of multimodal data highlights the connections between students and the multimodal elements in their individual environments as the process of learning using RMR unfolds. Students' interviews about their experiences and multimodal journals filled in the gaps in their multimodal journals about connected elements and the students' connections with these elements. Each student made their own integrations and connections with RMR in the presence of their environment and surrounding actors. Moreover, speaking with students about their 'felt embeddedness' shifted my focus away from how a student recalls feelings and toward how those feelings and negotiations resulted in a more complex understanding of the non-human actors, their positionalities, and their situatedness in relation to the student and the learning process. The integration of multimodal journals and semi-structured interviews enabled me to perform a

multilevel analysis, affording the ability to ‘zoom in’ on particular interactions and an array of tacit modalities which appear during students’ engagement with RMR for their statistics course. Following the data collection, a thematic analysis was performed with the three core components of the thematic analysis model – recognizing, collecting, and reflecting on the data –employed in a cyclical process (Braun & Clarke, 2006). Initial codes were then merged to form broader themes of interest (

Appendix L: Phase 1 & 2 Quirkos Themes). In the upcoming sections, I will explore some research project data that illustrates how the use of rich media resources (RMR) can reconfigure statistics education.

8.4 Emergent themes

8.4.1 Media resources and spatiotemporal (re)configurations

Timing and space

Pedagogically, in a traditional classroom setting, the sociomaterial positioning of bodies creates a scenario where many students are bound in an intercorporeal process, competing for the teacher's attention within a controlled and rigid space and time (Hawley, 2021). RMR acts as a replacement that is flexible and fluid in the organisation of space and time, providing students with an additional virtual space to practice and develop their cognitive capabilities. In addition, Lynn Thompson (2012) finds that hybrid spaces, which are characterized by a fusion of physical and virtual spaces that are mediated by various actors, were at the centre of the practices involving rich media artefacts. For example, when one RMR is viewed in multiple different places, it will have a different sociomaterial construction each time. Therefore, it is important to tease out the specificities of entanglements between people and technologies in particular practices.

Technologies used to access RMR make it possible for people to move easily between different actor-network configurations, meaning that teaching and learning are not limited to closed settings. Rich media allow students to study in their safe spaces at their chosen times, which has the potential to alleviate anxiety, increase comfort, and boost confidence, and as suggested by (Gourlay, 2014), technology allows students to be ‘less bound by place’ and ‘serves to constitute the spaces’ in which students feel most productive when learning. Students might say that the RMR provided to them enables them to study ‘everywhere or even being nowhere’ (Gourlay, 2014: 115), implying complete spatial independence, but, implicitly, these resources free them from the spatiotemporal bounds of the classrooms, allowing them different kinds of ‘moorings’ and enabling them to

choose the spaces in which connect with learning – the spatiotemporal configurations where they may feel safest and most comfortable. In most cases researched in this study, these are the configurations wherein students have the autonomy to add or remove non-human actors that reduce their perception of comfort, increase levels of anxiety, or cause distractions. Students tend to fill the 'personal spaces' around them with actors that connect in a soothing and enhancing way, often including stress relief mechanisms within the networks in a way that is not possible in a classroom or uncontrolled spatiotemporal configuration. Within these comfort zones, the technology used to access RMR in this study allowed students to adopt more comfortable postures to control physical tiredness, including factors like on-demand external resources (access to the internet and search engines, access to other individuals or notes), physical objects of comfort (a cup of tea or a bottle of water, a blanket, a comfy chair), choice of postures (reclining on a sofa, sitting on a bed, standing up) and other soothing ambient actors (such as a soft or colourful ambient light or the calming presence of a pet).

Ayesha (Participant 1) explains some of the spatiotemporal configurations of her RMR practices' in the following vignette in her journal, highlighting the minute details of actors in the configuration. She highlights personal comfort and access to various items, which acts as a support mechanism to reduce anxiety and disruptions while she studies in order to build understanding and increase efficacy:

> *This is my favourite way of performing work at home, in my bedroom, as I believe having a comfortable space when studying is important. My study space often involves a laptop to access* resources *online, my pencil case, my university note pad, a workbook and key note papers alongside a water bottle. Having a technological item in my workspace is vital as I can easily access the online materials given by tutors but also for note taking, and I find that it is very useful when practising questions. Whilst studying at home or in university, I do sometimes feel a sense of anxiety due to feeling tense about certain topics I may not understand or be able to do by myself;*

however, in my opinion, the feeling of anxiety is natural and common in a studying environment.

Similarly, Ben (Participant 2), who states that his environment incorporates a dedicated anxiety relief actor (a console), which he could not have in a classroom environment, is seemingly able to mitigate his anxiety through self-management:

My study space is one set corner of my room, where all the technology is kept. A computer with two monitors at a near-90 degree angle from each other where each monitor is dedicated to specific tasks where needed. A console is sat next to one of the monitors as a quick escape/relief mechanism if stress builds swiftly, and a mobile stand where my tablet, used for audio recording, sits as an additional device for any work in the event the computer is occupied with tasks at the present moment.

The rich media resources available to the students can extend the spatiality of the original lecture event into new spatiotemporal environments and help assemble and translate new actor-network configurations (Luke, 2020), and the following quotes extracted from the MM journals illustrate how RMR enable students to make new preferred connections with spatial and temporal configurations.

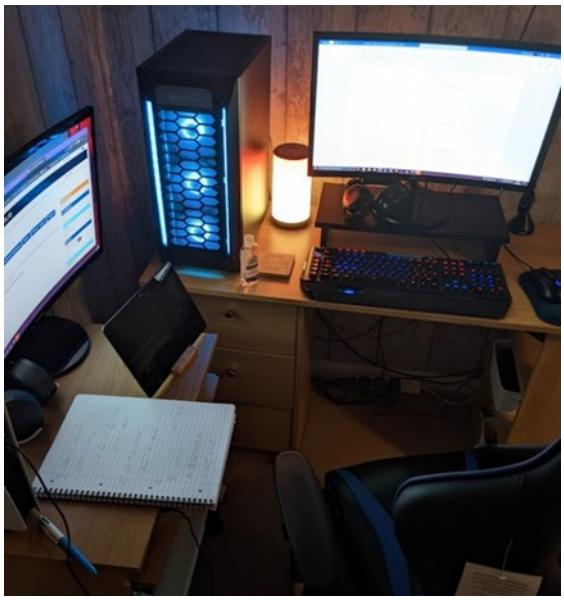

Figure 8. Ben's personal study space

Alexa (Participant 3) mentions in her journal:

> *I love to study early in the morning and late at night with a cuppa by the side. I take a lot of screenshots during lectures and it has helped me a lot when I'm reading. I also like watching the recorded lecture uploads as it gives me better understanding on that very topic. Below is a picture of my study desk.*
>
> *Today, I got up at half past six. I always have my coffee in the morning, and I usually start doing my university work at that time. It's a sign for me… that I work hard.*

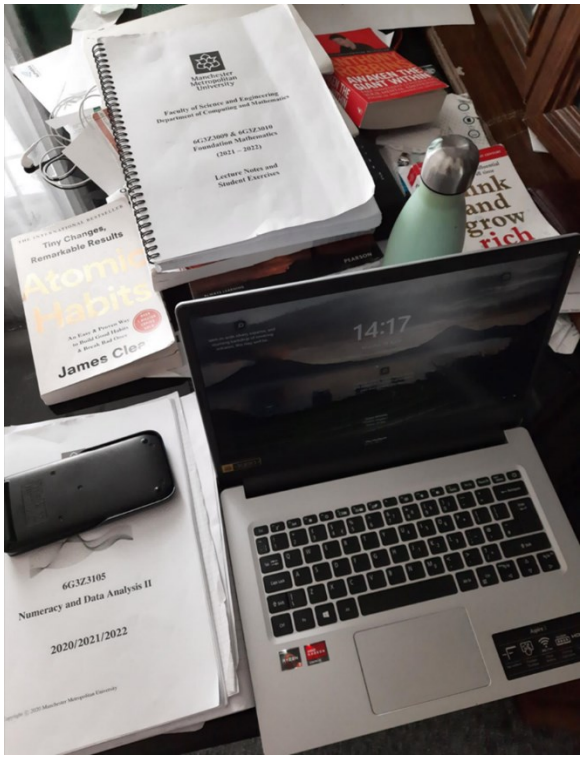

Figure 9. Alexa (Participant 3) study space

Alexa (Participant 3) highlighted a useful yet uncommon attribute in the form of visceral and discursive reflexivity by clearly identifying to herself that her actions show to herself that she is working hard, describing her selection of study time as a feedback mechanism to boost the perception of hard work, which she takes pride in when writing in her journal. As students' bodies interact with the surface of objects, feelings are registered 'viscerally' (Archer, 2000, as cited by Hawley, 2021 pg 7). The interaction with RMR appears to affect her innate impulses, sense of self,

and this reflexivity of hers was also part of the sociomaterial entanglement as she interacted with the RMR.

For Hazel (Participant 4), utilising her interruption-free time is also important, as illustrated by her writing in her MM journal:

> *My work area is usually either sat on the couch or floor, surrounded by paper and with laptop on my knee, or at the kitchen table. I'm lucky to be able to have peace and quiet (for the most part) when I work.*

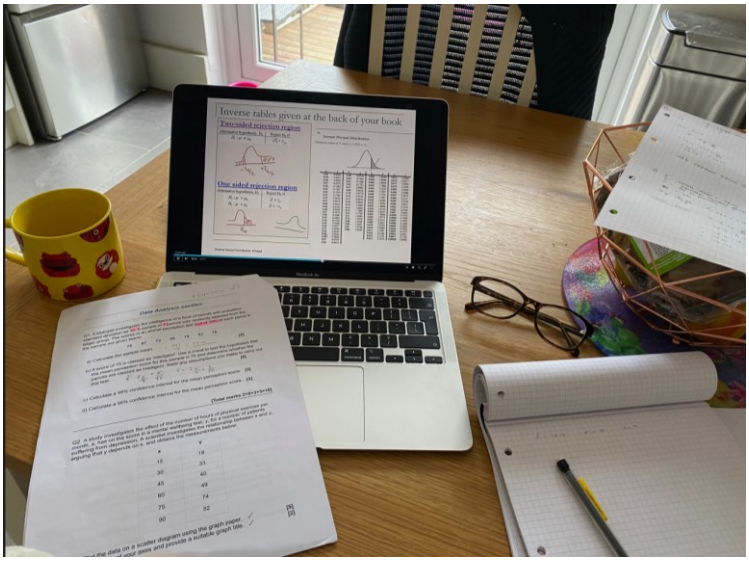

Figure 10. Hazel (Participant 4) study space

Both students have highlighted the importance of the temporal situatedness of their study configuration. Alexa (Participant 3) prefers the early morning and late evening, times when she does not have to interact with other people around her. In her interview, Hazel (Participant 4), a mature student and parent, mentions that she prefers to use her most-frequently-used space, the kitchen area, when she has complete control over it during the day. Both students cherish the peace and quiet they find at their chosen times in the comfort and predictability of their preferred locations.

All of the above students support the view that the on-demand RMR provided to students for their statistics course operate within and across hybrid spaces, and that the unfolding event of learning is not confined to enclosed or externally-controlled spaces for example lecture halls or labs. The availability of these

resources extends them to different physical environments, e.g., libraries, cafes, and bedrooms with each interaction between a student and a learning resource occurring in a unique spatiotemporal configuration. However, all of the above quotes taken from MM journals highlight that despite the availability of online learning resources at all times, students are sensitive to location, and the construction of their study configuration requires effort and attention. The students highlighted the use of pre-constructed study routines whereby the RMR for statistics become part of their own familiar spatiotemporal environments, improving their perception of learning, comfort, ability to learn, and control over the learning resources, leading to a reduction in triggers or anxiety when learning statistics.

This study uses a sociomaterial approach to spatial research to interrogate the interactions, tensions, and experiences of spatial-social relationships. As mentioned by Acton (2017), a sociomaterial approach allows attention to be focused on embodied learning and teaching; people's spaces; possibilities to design, construct, and interact with the resources in those spaces; and the experienced realities of the people who inhabit those spaces in practice.

8.4.2 Sociomaterial assemblages

In this study, the spatiotemporal allowances presented bespoke variations in sociomaterial assemblages for every student. When students access RMR in their personal spaces, the common constants from the classroom environment are no longer present in their individualized sociomaterial assemblages. Instead, students customize their sociomaterial assemblages in expectation of a variety of effects from the material components that surround them. For example, when students solve a statistical problem, they use ideas from the wider class, school, and 'home' communities. They also use ideas from the larger underlying discourses, such as political or sociocultural factors that shape their thoughts regarding the task and statistical activity. De Freitas and Sinclair (2014) talk about how 'thought' spreads across both social and physical environments. Moreover, similar to Meyer's (2015) suggestion, RMR offers a sociomaterial bricolage for learning wherein interconnected systems provide resource interaction, building a notion of socially

distributed knowledge. Students control the inclusion or exclusion of materials in this assembly and access these resources in particular and personalized ways, and the resulting process is not just the accumulation of the various 'bits', but also a new mesh of social and material elements (Calder and Murphy, 2018).

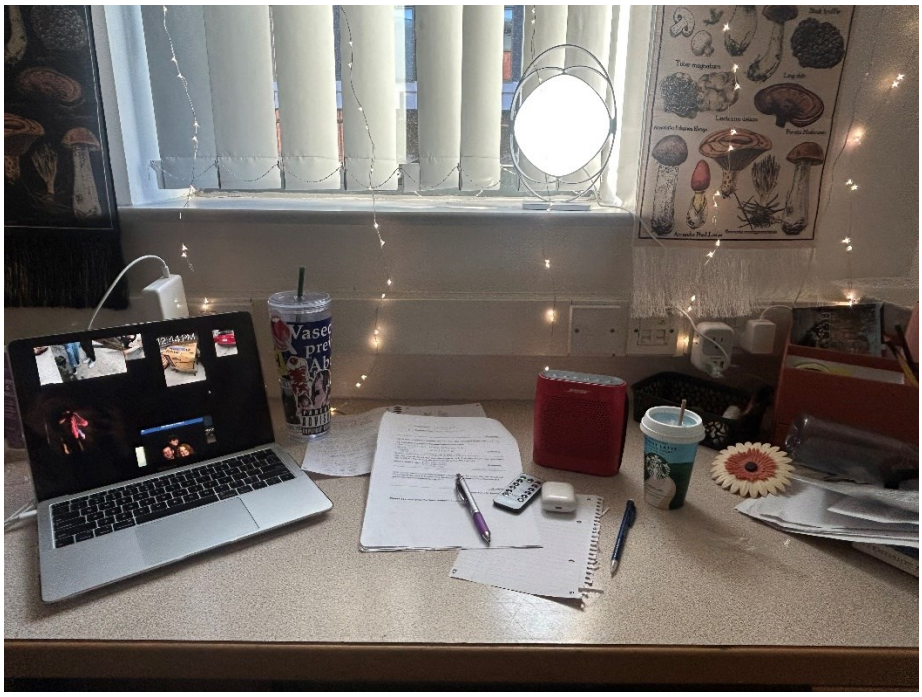

Figure 11. Participant Olivia's study space

Extract from Participant Olivia's MM journal:

> *I have several necessities while I'm studying. For starters, I like to sit at my desk with my fairy lights turned on and sometimes my SAD lamp. I also spray my room with some sort of air freshener. I make sure I have water and sometimes a coffee. I either use my air pods or my speaker depending on what time I'm studying. I like to listen to a playlist of songs I don't really know. Sometimes I play chill music in another language so I don't get distracted by the lyrics.*
>
> *I only like using my purple pen unless it's maths and I need to erase a lot. I use my laptop and the notes I took in class to help me find the information I need. When I'm using my laptop, I start by going to Moodle to read through the notes before I search on Google.*

Sometimes I have a hard time focusing for long periods of time. When that happens, I allow myself to have a little break. In that time, I'll go make something to eat or just scroll through social media.

The inclusion of sociomaterial assemblages provides a nuanced understanding of how students like Olivia cultivate atmospheres in their MM journals that serve their specific learning needs, particularly in managing anxieties and enhancing self-efficacy in the study of statistics. In Olivia's case, her thoughtful arrangement of fairy lights, SAD lamps, and specific playlists, combined with her tactical use of Moodle and Google, serve as a rich tapestry of sociomaterial elements that create a specific atmosphere conducive to learning. This assemblage of elements resonates with Bille's (2014) research on how lighting impacts the atmosphere in homes, Shaw's (2014) exploration of darkness in domestic settings, and Pink et al. (2015) focus on the role of digital media in shaping the home environment. Like the atmospheres described by Bille and Shaw, Olivia's study space is not merely functional; it is also affective and sensory, designed to manage her statistical anxiety and boost her self-efficacy.

The interplay between these materialities and the digital environment is aligned with Pink's notion of 'presence bleed' between work and leisure (Gregg, 2011), reflected in Olivia's 'ambient study' practices that incorporate both work and leisurely elements like social media and food preparation into a seamless routine. Such a routine goes beyond the mere juxtaposition of work and leisure, instead forming a sociomaterial assemblage that enhances her emotional and intellectual wellbeing.

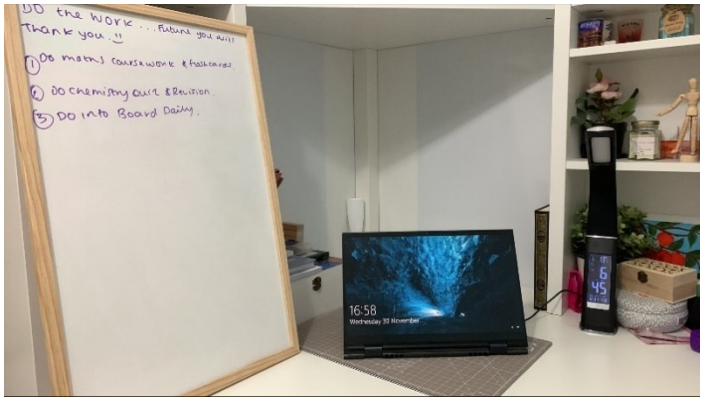

Figure 12. Participant (Siddiq)'s personal space

Participant Siddiq shared his multimodal assemblage, which included a touch screen laptop, a lamp featuring a digital clock, some books, and a whiteboard. He also mentioned that his smartphone with a calculator and social media access was also part of this assemblage, but it is not in the photo because he was using it to take the photo. Siddiq explained that he gets guidance from the RMR and controls the flow of media to use the whiteboard for exercises or working out a solution himself, as in the video. RMR provides multimodal, multisensory input to students, which allows them to reconstruct a semblance of the classroom environment and connect it to their personal study environment. The multimodal material assemblage shown in Siddiq's study space shows fluid interactions bespoke to him, allowing him to bring in an element (whiteboard) that isn't commonly accessible to students in a classroom and might not be a preferred choice for others in their own private spaces.

Figure 14 shows a participant making yellow lined paper to make notes as a preference. She expressed this preference during an interview by mentioning she makes quick access notes on yellow lined paper, and if she does not do that, she does not feel she has understood the topic. Figure 13 depicts a participant's assemblage, including a calculator, water bottle, pen, notepad for solving practice questions, and the laptop as a rich resource to access their emails, MS Team messages, Moodle (location of some RMR) and the text book to physically be on the same page as the teacher. Figure 15 shows an example of a participant using their assemblage, which includes access to the tutor via email over the Internet, using a technological device, and sharing their notes with me (their lecturer) to confirm their method, virtually including the tutor (or guide) in their assemblage. While using RMR, students can carefully construct their sociomaterial assemblages to prime their learning and make interactions between multimodal materials and take charge of their personalized learning. Even though these resemble reconstructions of their classroom environment, their own assemblages go far

beyond the limitations of the classroom, especially in terms of the larger impact of non-human actors within students' study spaces.

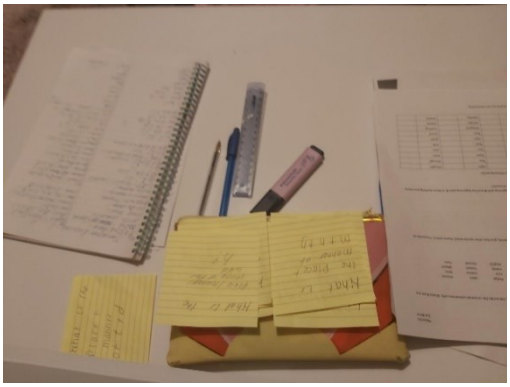

Figure 14. Quick access notes made in a simpler environment

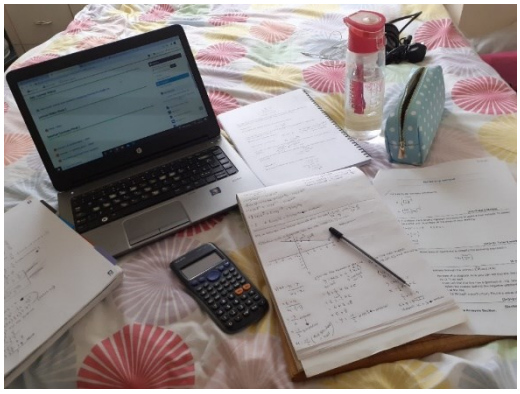

Figure 13. Note-taking while interacting with various non-human actors in a personal space

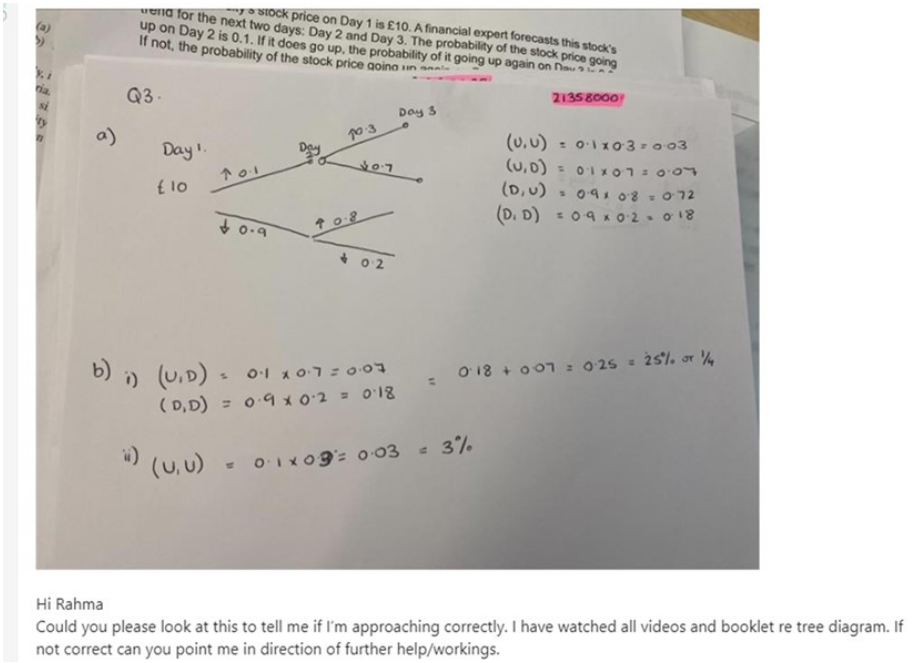

Figure 15. Notes with annotation by a student seeking lecturer's support

8.4.2.1 Personalized learning and note-taking

According to Calder and Murphy (2018), in order to provide personalized experiences and learning support, the teacher must pay close attention to each student's individual knowledge and skills. Leadbetter (2005) assumes students will be more in charge of their individualized learning but asks teachers to create an environment in which students are informed and empowered to make personal choices that result in individualized learning. Rich media resources (RMR) enable differentiation in the learning experience to best facilitate statistical learning for the student.

Providing resources that encourage individual student choice is intended to engage and motivate students by instilling a sense of ownership in their learning, allowing them to be more receptive to statistics learning, which enhances their self-efficacy. Making handwritten notes, or taking notes, is an informative and transformative process in which students mimic the teacher's content and then personalize it, making it more accessible and tailored for their own understanding.

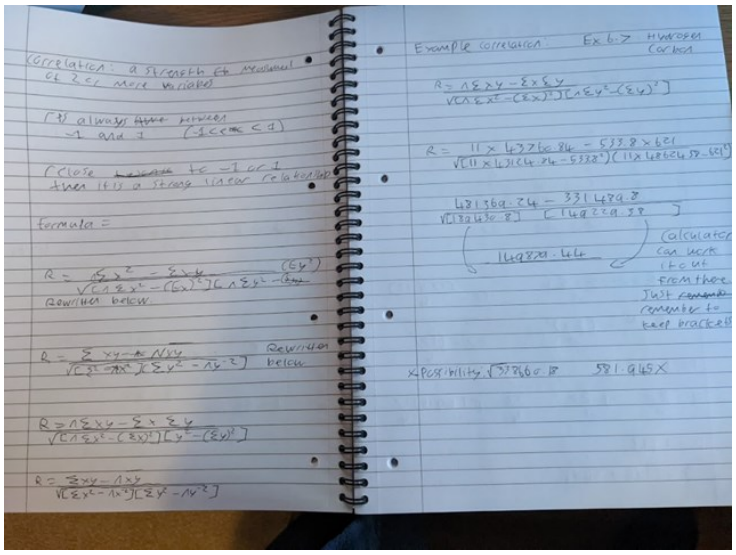

Figure 16. Solving exercise questions while note-taking

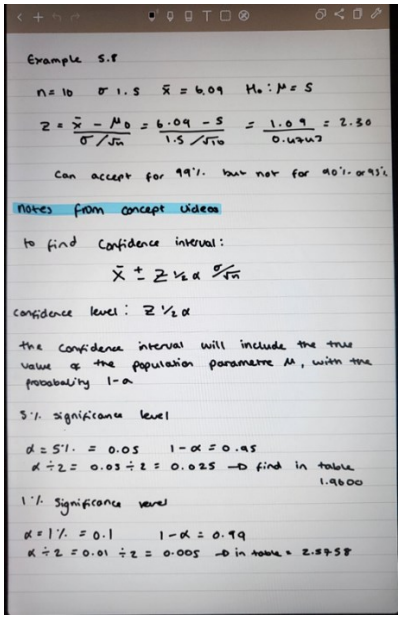

Figure 17. Digital note-taking using touch screen and electronic pen

Based on the data collected from journals and student interviews, it was observed that the provision of RMR significantly influenced note-taking activity. The following excerpt from Harper's (Participant 5) online multimodal (MM) journal encapsulates the substantial impact that the availability of RMR had on her, particularly in terms of note-taking:

> *Every time I come in for a lecture, even on the days when I've had a fantastic day, I have this sinking feeling of 'dread in the pit of my stomach'. Regardless of the amount of support I've had from the instructor, the amount of work I put into taking notes, or the amount of enthusiasm I feel, this intense psychological uneasiness continues to dominate everything that I do. It mirrors my actions. One of the ways that worry manifests itself in my life is through the recurring ideas that instruct me on how to arrange my calculator and book on the table in the optimal way. However, the recent discovery that I have lecture recordings of what has just been spoken (taught) helps me feel much more at ease.*

Note-taking during a class-based lecture is an overwhelming task for students that can induce a high level of anxiety. In the absence of handwritten notes, students worry about what materials they take away from a traditional classroom lecture, which is sometimes only lecture slides and their course textbook. Students' own

handwritten notes provide them with invaluable supporting material when they later need to recall the concepts from the lectures. Although a means to reduce anxiety, note-taking creates a high cognitive load, requiring the ability to multitask, and students with high levels of anxiety struggle to manage and distribute their attention effectively, struggling to multitask, which leads to more anxiety-inducing moments. Note-taking requires students to iterate through a two-phase process, constantly switching back and forth. First, students have to pay attention to the lecturer and process the multimodal information, such as the lecturer's speech, writing on a board, slideshows, or animation; then, almost immediately, students have to identify the important information and salient features and transcribe them onto a notebook or device. The task of note-taking creates a complex network of actors with almost simultaneous input and output with a fear of misunderstanding something when writing, having too little time to annotate or write, and not being able to recall or recreate the moment once the lecturer moves on or the lecture concludes.

Harper (Participant 5) also makes a comparison when she does not have access to rich media resources:

> *Because once you take away* [lecture recordings*], all you really have is some very basic notes that you are able to take while you are attending the lecture. Since all you have is a couple of A4 sheets of notes from the lecture and a* [statistics] *course handbook, I believe that it will be important for me to be able to reflect back on those things when it comes time to revise, and I also believe that this will have an impact on my grade.*

Harper (Participant 5) presents herself as well informed and aware of her intrapersonal state of anxiety and its triggers, and she actively attempts to alleviate anxiety in her studies. Overlapping with the previous theme of socio-temporal configurations, RMR allows students like Harper to eliminate various anxiety-inducing factors, such as other students or noise, and start their study time from a lower, more manageable anxiety state. As a result, a larger proportion of the limited resource that is attention is dedicated to cognitive function. Students are able to navigate swiftly through the fluctuations in attention and anxiety when they

are in charge of the pace at which the resources are played back, and the fear of not being able to recall is alleviated with this control. Elliott and Neal (2016) and Nordmann et al. (2018) have also observed that this capability leads to extensive note-taking. Building on the concept of note-taking and control over resource playback, a critical tool emerges in the e-learning landscape that further empowers students: the 'pause and play' functionality, and this simple yet transformative feature of RMR videos not only complements the note-taking process but also grants students a deeper level of autonomy and engagement with the content, ensuring they dictate the rhythm of their learning.

8.4.2.2 Pause and Play Icon

It is standard for digital playback resources to incorporate a standard play-and-pause button as well as a timeline that allows scrolling back and forth through the resource without any restriction. The RMR provided to students included the following buttons and a seek bar (the university's blackboard website, shown in Figure 18) and when the pause icon is interacted with and clicked, the button's state changes to play (Figure 18). The play/pause button communicates with other actors via digital codes, and when activated, it is an assemblage and a complex arrangement of hardware, software, commands, semiotic signs, networks, and codes that work invisibly (Luke, 2020).

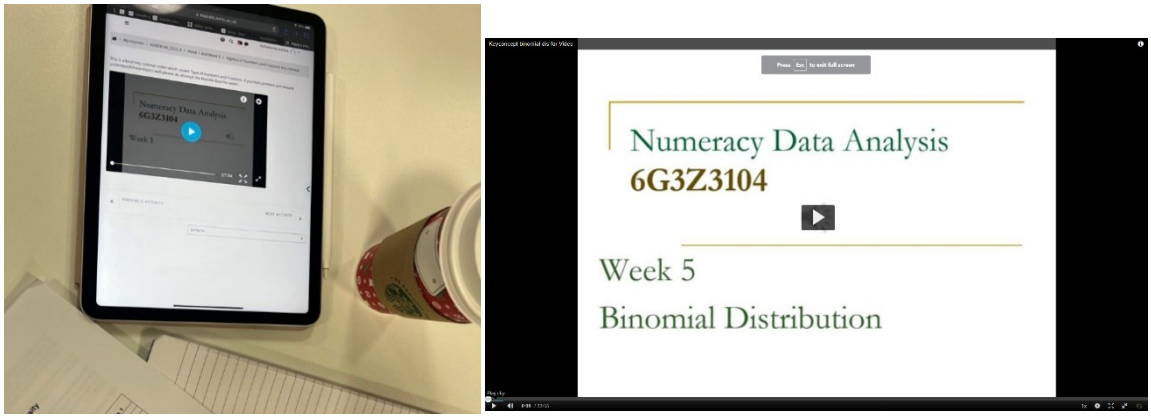

Figure 18. Rich media playback controls

Almost all participants, through their multimodal journal entries and interviews, confirmed the frequent use of the pause-and-play buttons while engaging with RMR. A prevalent theme that surfaces in the following four vignettes is that the

pause, play, and seek functionalities allow students to regulate the pace at which they consume and process information, including when carrying out tasks such as taking notes, understanding meaning, and networking with other actors.

This recurring theme alludes to the analogy of a funnel representing the students' cognitive processing capabilities. The funnel's wider end represents the intake of new information, while the narrower end denotes the processing and assimilation of this information. Each student's funnel differs in size, symbolizing their capacity to hold information at any given moment, while the flow speed through the funnel mirrors a student's processing speed – the rate at which they can thoroughly understand and retain information, thereby making room for new input. If new information is fed into the funnel faster than it can be processed, the funnel risks overflowing, which can manifest as classroom anxiety, inhibiting meaningful learning (Luke, 2020).

The ability to pause the video allows students to manage the information flow, thereby avoiding overflow-induced anxiety and establishing effective flow control. During the interview, Oliver (Participant 6) explains (below) that students utilize this functionality to buy themselves additional time throughout the lecture, which provides them with an opportunity to process information at their own pace, an advantage they believe is absent during a live lecture.

> *The button helps as I don't feel any time pressure that is usually the case in lectures and some students including me may need some more time that cannot always be given during lectures as we would be going fast over some topics.*

Bella (Participant 7) complements Oliver (Participant 6) by demonstrating the calming effects of the pause-and-play button by refraining from answering questions in front of the class:

> *The fact that I can pause and play the video is great. It means I can go back over what has been said and demonstrated in the video without feeling as though I'm annoying other students or taking up too much time. Asking*

questions in class is a massive anxiety point for me so the videos can be really helpful for my own study.

Harper (Participant 5) further illustrates the enhanced utilization of RMR, employing pause–play and seek functionalities to supplement her learning while solving coursework questions. By synchronizing her own work with step-by-step solved examples, she considerably enhances her learning process. Initially, she draws attention to her highly anxious state in the classroom:

I do find myself getting stressed out or nervous whenever I start my assignment. I feel less sure of my ability to cope with the task at hand. My wrists are tingling, and a strange sensation is permeating my body as I type this. I couldn't wrap my head around today's live session. Along with these physical reactions, I am thinking, 'I should be understanding this' or 'I have a coursework submission coming up, why can't I focus?'

She then explains how she uses the resources to alleviate the anxiety:

Watching the teacher solve questions that are very similar to those that I have been asked [on a loop] *does help reduce the amount of stress I feel and makes me feel more capable. If I have confidence that I am capable of doing it, I will eventually acquire the skills necessary to carry it out, even if I do not initially possess those capabilities.*

Pausing and playing the video does help because it allows me to catch up and take notes. It also helps because I usually attempt the coursework at the same time as a similar question is being demonstrated in the video. So, I have to pause for that.

However, Bens (Participant 2) explains in his vignette that, although this functionality allows him to control over flow of new information, it does not itself relieve the mental tensions related to learning.

The pause button primarily offers its assistance in stopping the flow of information from becoming too much and being able to write down the information being taught without anything else being added on. So, in

terms of offering control, yes, it helps in that regard but it does not help to alleviate any mental tensions offered from attempting to learn this course and taking more time to try and understand what's being said/presented.

Bens (Participant 2) goes on to explain that they used this functionality to introduce constructive interference from other sources, such as course textbook, internet searches, and emailing the lecturer for more help. This networking with other actors allowed Bens (Participant 2) to relive the anxiety of understanding the concepts of statistics being presented to him. Meanwhile, Hazel (Participant 4) further extends this position where she puts herself in a place of advantage during live lectures by consuming the RMR in advance at a pace of her choice:

I loved that I could pause the videos and stop them when needed without feeling like I was annoying the more competent students. Often in class I would feel like others had completed exercises whilst I was still struggling to start, but with the videos at home I could take my time and ensure I knew what I was doing and why. Now I watch a key concept video on Moodle before attending the lectures. They have built my confidence and helped me immensely.

Not only does Hazel (Participant 4) reduce her anxiety around understanding statistics content, she also prepares herself to be an involved actor in the classroom without being anxious about being a hurdle in terms of the class's pace.

The ability to pause, play and seek empowers students to take charge of their learning, and the above examples of narratives exhibit how students have used it for constructive interference, expanding or contracting their actor network, supplementing their perception of learning and self-efficacy, and soothing their anxiety. In contrast to a classroom, a self-constructed configuration can contain a much larger number of actors of conflicting interference; interruptions such as social media pop-up messages, a conversing flatmate or sibling, television in the background, or a WhatsApp message notification can all lead to oscillating between presence and absence. In fact, if a student does not adhere to restraint, learning can be interrupted by the student's own behaviour without external interruptions,

e.g., picking up the phone to call a friend or scrolling through the Instagram feed. Regardless, it is comforting to know that the pause–play and seek functionalities give students control over their own oscillation between presence and absence in the learning environment. As a result, they can synchronize the flow of information when they are attentive and stop it when they are not.

8.4.2.3 Elements and dynamics of everyday life

Unexpected sights and sounds triggered further evocative collections during online studying. Students were not only entangled with the virtual environment, but also with household members who could be heard in the background and occasionally interrupted the study session.

Participant Alishbah describes her cat jumping on her lap while she watches the video resources and another occasion when a little fluffy head popped into the frame and grabbed her finger (Figure 19). I notice their larger lives coming in, siblings, dogs, cats, and interruptions from their family intruding on their study space. Similarly, the student's own activities at home entered the online learning experience.

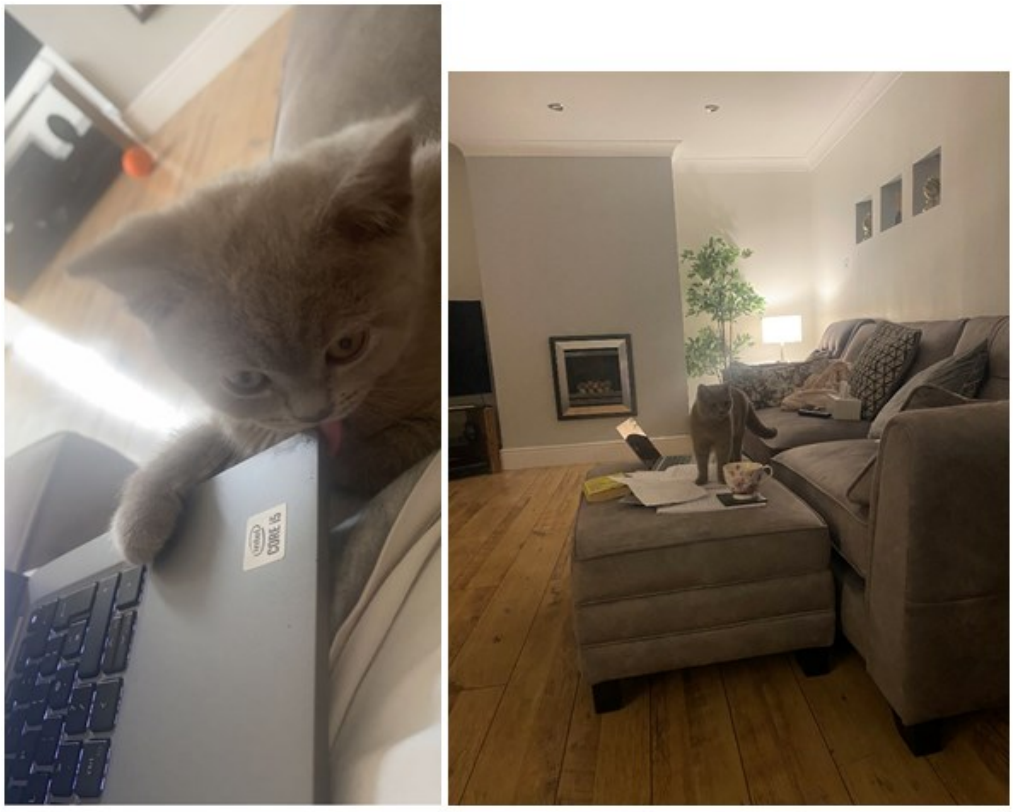

Figure 19. Participant Alishbah's personal environment

Asynchronous teaching develops further entanglements such as these, which raise questions about how best to bring together the meanings and connections of inclusion from different worlds.

Elements and dynamics of everyday life – the worlds outside the virtual frame, the barking dog, the mail delivery, the ice cream purchase – assert their agency and signal the complex materialities that reconfigure the self through their intra-actions (Ebben and Murphy, 2022). Recognising the agency of materiality and the new relationships it forges, particularly within the sphere of virtual teaching, prompts an evolution in the consciousness of students. They find themselves operating within an intricate interface of household demands, distractions, and the teaching moment – a complex interplay that changes their learning landscape. Such a shift inevitably impacts their focus and attention, presenting unique challenges and opportunities, and this dynamic interaction aligns with the concept of 'learning lives' (Erstad, 2012), as delineated by Silseth and Erstad (2022), bringing into focus the fluid learning activities transpiring within and beyond the confines of academic environments. Drawing from its roots in a UK study that emphasized adult learners reflecting on their educational experiences across their lifespan (Goodson et al., 2010), the 'learning lives' concept captures the lived experiences of education, underscoring how educational practices for teachers and students alike are not isolated events but part of an ongoing narrative woven into their life trajectories.

Within this complex interplay, the tacit modalities come into effect, adding another dimension to the learning experience (Rowsell and Abrams, 2021). These modalities, as part of the everyday experiences, add depth to the students' journeys, as they weave through the intricacies of statistics anxiety, self-efficacy, and e-learning, and their silent presence, unspoken yet understood, becomes an integral part of the learning process. As I navigated through the data collection

journey, the tacit modalities and the concept of 'learning lives' become part of a greater narrative that continues to shape our understanding of education.

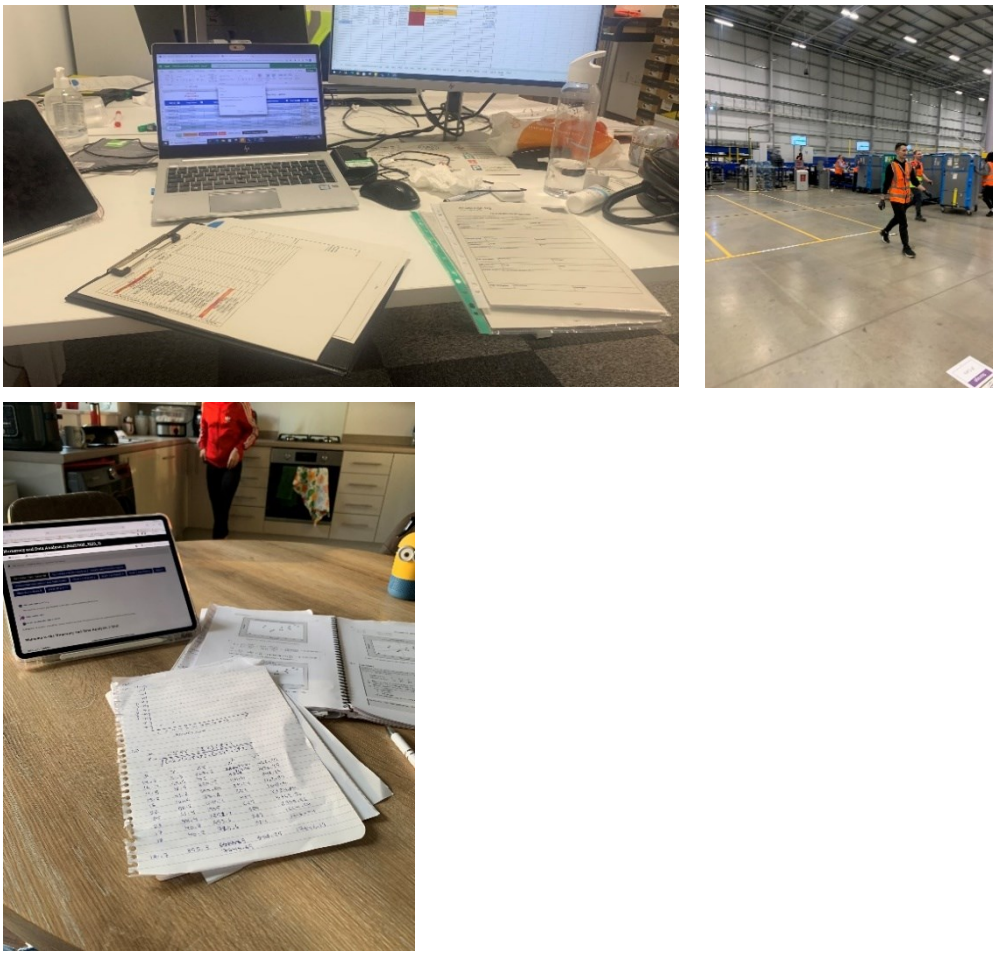

Figure 20. Mandy's snapshot

Above is Figure 20, a snapshot from my Participant Mandy's MM journal. Mandy was a dynamic participant in my study, whose life embodies the intricate dance of roles and responsibilities. She is a young woman and the mother of an 11-year-old daughter, and, balancing motherhood, studies and a part-time job, she works the night shift at an Amazon warehouse, overseeing delivery schedules. Her life is an intricate web of shifting contexts and roles, all captured in these three images. The bottom image reveals Mandy in her kitchen, a space where multiple dimensions of her life converge. It is a study spot, a mothering area, a kitchen – a dynamic, fluid space encapsulating her multifaceted identity. Mandy describes this photo as a manifestation of her struggle to balance motherhood with her other roles. As she is engaged with rich media resources to study statistics, her daughter interrupts her,

seeking guidance on heating Bao buns, and this incident, a symbol of her constant role shifting, exemplifies how Mandy's learning process is not limited to specific times or places but rather interweaves with her daily life. The second image provides another facet of Mandy's life, depicting her workspace in the Amazon warehouse, as from behind her glass office door, Mandy overlooks delivery schedules, embodying her professional identity. Despite the demanding workload, she manages to find moments of tranquillity post-midnight, where she returns to her learning journey, immersing herself in a multitude of media resources for her studies. As Turkle (2007) points out, viewing lives through an artefactual lens allows us to explore modalities that often go unnoticed, reminding us that stories about objects, like these images, often serve as markers of relationship and emotional connection, revealing multifocal and fluid life roles. These three images become more than snapshots of Mandy's life; they transform into vignettes capturing the intricate dance between her identities as a mother, a student, and a professional. The spaces she occupies – the kitchen and the warehouse – metamorphose into learning arenas, reflecting the complex dynamics of her everyday life. According to Tisha Lewis (2016: 513), ‘Although the artifacts (images) in these stories started as objects for digital story topics, they ultimately came to symbolize emotional tales of struggle, mourning, and everyday practices that opened up more equitable learning and meaning-making spaces’.

By scrutinizing these tacit modalities, we can deepen our understanding of students' lives, thereby catalysing transformation in pedagogical approaches and crafting agentive spaces for students within and beyond digital environments. In Mandy's case, her photographs bear testimony to her daily struggle to juggle work, motherhood, and learning. Acknowledging the emotional tales encapsulated in these artefacts is paramount, as it can foster more equitable learning and meaning-making spaces, with Mandy's journey, especially her experience of concurrently navigating motherhood and scholarship, exemplifying the dynamics of 'mothering/scholaring' (Rice and Dallacqua, 2022). This concept integrates an -ing suffix to emphasize the continuous process of being and doing mothering and scholarship simultaneously, and this perspective, informed by posthuman ways of

thinking, views motherhood not merely as a role but as an inherent identity that cannot be switched off or set aside (Lapayese, 2012). This concept serves as a 'conceptual practice', as defined by St. Pierre (2015), providing a lens to comprehend complex phenomena and the interactions between people and objects involved. In narrating Mandy's story, I aim to grasp her experiences from a diffractive perspective (Vasalou et al., 2020), shedding light on Mandy's experiences of balancing motherhood and scholarship, alongside her digital representation in these roles (Rice and Dallacqua, 2022).

In Mandy's world, she operates within constraints. Her agency, or ability to act, is deeply intertwined with other agencies that involve both human and non-human actors (Barad, 2007), and this interplay of agencies constructs a complex entanglement where the simultaneous demands of motherhood, work, and study limit her range of choices, generating a sense of push and pull and viewing these connections not as isolated entities but as intertwined nodes in a rhizomatic process. It manifests a tapestry of being and doing 'mothering/scholaring' that confronts the binaries of mother/scholar and digital/non-digital (Rice and Dallacqua, 2022).

8.4.2.4 Equality of the student learning experience

Disability and mature students

While not the central focus of this thesis, it is important to acknowledge the increasing role of digital technologies in enriching the learning experience, particularly for young people with learning disabilities, and recognizing these digital activities as pivotal for enhancing their digital involvement (Weber et al., 2022). Building on this, in a recent case study report published by the Quality Assurance Agency for Higher Education in 2022, students with learning disabilities were seen to benefit from recorded lectures compared to live lectures alone as the former reduced their feeling of being 'stressed out'. Rich media resources go further and enable students to reconstruct the lecture environment in the comfort of their personal spatiotemporal configuration, running at their own pace, enabling more support actors (e.g., sign language or colour filter transparency) than available in a live classroom environment. While supporting students with disabilities, I often

experience students having difficulty taking notes during lectures. Students can use note-taking facilities (having someone else take their notes), sign language interpreters (where available), or study guides to prepare for exams, but these services are usually separate from the live classroom environment. The reassurance of having these resources available has also turned around the experience of a live classroom for one of my participants who has a personal learning plan (PLP), and recognized dyslexia and partial hearing loss, as mentioned during the live interviews here:

> *During NDA* [Numeracy and Data Analysis unit]*, the concept videos helped a lot with understanding the material and being able to use most of it in a way that made sense. The key concept videos feel as though they go over topics at a reasonable slower pace. With my dyslexia and hearing loss, knowing that it was recorded gives me peace of mind that if I get confused or don't quite hear the lecturer, it's okay. I don't have to panic during the lecture, easing out the overwhelming data dump feeling during some lectures where there's little time to process the information or even digest it so you end up with either half-written notes or information you look back on and go 'What? Where did the X squared come from?'*

In a live classroom setting, the student faces a significant challenge due to dyslexia and hearing loss, as well as the fear and serious consequences of missing visual or audible information. He explains in the interview that due to his disabilities, live lectures necessitate additional preparation for each lecture, such as arriving on time to occupy the most suitable seat and, at times, using another student's notes. This causes fatigue and distraction. However, the provision of rich media resources has reassured him that he will not miss out, which helps manage his anxiety in the classroom and allows better focus on the cognitive process. This improved cognitive opportunity and the reduced sensory burden lead to a 'perception of a reasonable slower pace' when he is using the rich media resources. In reality, these resources tend to cover content at the same pace as class lectures. Asking questions of the same PLP student later revealed that his perception of a slower pace is unrelated to his ability to pause and rewind, an effect which can be

associated with the decrease in non-human actors in his personal configuration of comfort. Students with disabilities often hesitate to repeatedly ask for support during live lectures and take the blame for slowing others down.

A similar hesitation and feeling of self-blame can build up in mature students. Hazel (Participant 4), a mature student who is also a full-time parent, highlights this during her interview:

> *I found that when I first started the Numeracy and Data modules I felt out of my depth and as if I was holding other students back. The difference in our ages and length of time since I had last studied felt massive and sometimes like a gap too big to conquer.*

Hazel was delighted to find RMR available to her, enabling her to reconstruct the classroom within the confines of her comfortable space, her kitchen (see Figure 10), at the time of her choosing, when the kids were away, in the ambience of her choosing, in peace and quiet. Perhaps her feeling of out of depth was rooted in the high cognitive load in classrooms where she is not in control, an unusual situation outside her day-to-day happenings. Rich media resources pass the control back to her by placing the learning environment in the 'home turf' configuration where she eliminates the feeling of being 'out of depth' and instead feels empowered.

Chapter 9: Conclusion

There will come a time when you believe everything is finished; that will be the beginning.

- Louis L'Amour

In this final chapter, I am going to tie together the findings of my research, initiating the discussion with my research questions (see below) and shedding light on the ways in which my results, and by extension, my doctorate degree, have substantially contributed to my understanding in this field, and facilitated the production of novel knowledge. From my days as a statistics lecturer to now, a shift has taken place within me that can only be described as transformational. Initially, I was in the realm of figures, percentages, and probabilities. However, now I've evolved into an educator who values the human elements in teaching – love, connection, and affirmation of life.

This doctoral thesis initially embarked on its journey with the perspective of a statistics lecturer (myself) who envisioned exploring this topic through a predominantly quantitative lens. The primary aim was to delve into students' emotions, self-efficacy, and anxieties related to statistics, and given this purpose, tools like STARS (statistics teaching anxiety rating scale), SAS (statistical anxiety scale) and SESPS (self-efficacy in statistical practices scale) were contemplated as potential instruments to quantitatively gauge statistics anxiety and self-efficacy (Pathirage and Pathirage, 2015). These tools are aimed at providing a numeric representation of students' emotions and apprehensions. However, during the early phases of my research, I became acutely aware that the complexities of students' emotional landscapes as related to statistics would not be wholly captured by one-off surveys or purely quantitative metrics.

Introduced to the ‘social practice’ approach by my supervisor (Bhatt and MacKenzie, 2019), I realized the need to transcend beyond numbers. Thus, this doctoral thesis provides an argument for intertwining the fields of multimodality, sociomateriality, and post-humanism into the e-learning landscape of statistics education. By intertwining these influential domains, it opens new avenues for

examining the complexities of online learning environments, contributing to a richer, more nuanced understanding of statistics education.

To echo the wisdom of Palmer (2017), there is a certain kind of knowledge that frees us that is not only facts and figures but the knowledge that is deeply rooted in love, one that intertwines us in the intricate web of life. It invites compassion, instilling a sense of awe-inspiring responsibility while also fostering pure joy. This type of knowledge calls for participation, a sense of togetherness, and the understanding that we're accountable for one another. As an educator now, I strive to cultivate this understanding within my teaching and my classroom. It is more than just teaching statistics; it is about fostering connections, nurturing lives, and most importantly, **teaching from the heart**. Before beginning this chapter, I took a moment to look back and realize how much I've been anticipating reaching this final part of my thesis. But now, as I start to write, it doesn't feel like an end. Instead, it feels like a new beginning. It is the start of my ongoing contribution to this field.

9.1 Summary and discussion of key findings

Building on this foundational understanding, it is crucial to first address the surface-level patterns within the quantitative data. Before delving deep into the intricacies of students' emotional landscapes, there was a need to identify if, at a foundational level, engagement with rich media resources (RMR) manifested any discernible effects on students' statistical anxiety, self-efficacy, and performance. As a statistics lecturer, my inclination towards quantitative methods was not merely out of habit or training; it was driven by the conviction that such an approach provides a structured, consistent, and sometimes generalizable way to uncover patterns in larger datasets. Establishing these broad patterns was essential as a starting point, as it offered a macroscopic view of the landscape before I zoomed in on the nuanced experiences of students. Hence, my first research question emerged from this quantitative lens, focusing on discerning any statistical differences based on engagement with RMR.

9.1.1 Research Question 1

Are there statistically significant differences in students' statistical anxiety, statistical self-efficacy, and performance, between students that did and did not engage with rich media resources?

My first research question sought to determine whether there were significant differences in students' statistical anxiety, statistical self-efficacy, and performance based on their engagement with rich media resources (RMR). To do so, I conducted a multivariate analysis of variance (MANOVA) with the two dependent variables – the self-efficacy score (SESPS), and statistics anxiety score (SAS) – and a hypothesis t-test with the performance variable. The primary independent variable was the engagement with RMR, which was measured as a categorical variable with two possibilities – yes (engaged with RMR) and no (did not engage with RMR).

The analysis of the data indicated a significant relationship between engagement with RMR and the dependent variables of statistical self-efficacy and statistical anxiety. Specifically, students who utilized RMR showed significantly lower scores in statistical self-efficacy and notably higher scores in statistical anxiety compared to students who did not engage with RMR. The initial step of my analysis involved examining the differences between the two distinct groups – students who engaged with RMR and those who did not – and the findings from this analysis suggested a significant difference between the two groups with respect to students' statistical anxiety and self-efficacy levels. In particular, those who engaged with RMR exhibited higher levels of statistical anxiety and lower levels of self-efficacy, and these findings underscore the significant role that RMR can play in shaping students' attitudes and beliefs about statistics. As highlighted in chapter 7, this cross-sectional quantitative analysis only allows us to identify that there is an association between RMR use and statistics anxiety and self-efficacy, but it does not tell us about the direction of this association. In other words, it is impossible to tell from the quantitative data alone whether the use of RMR is a consequence of a lack of confidence with statistics or whether using RMR might actually be adding to students' feelings of anxiety and diminished self-efficacy. However as discussed in chapter 8 (and below) the qualitative data suggests that students the former

interpretation of this association is most likely. The students spoke of how RMR provided a valuable tool for them to tackle the anxiety that they often experienced during more formal statistics learning experiences and the flexibility to take things at their own pace, while working in a 'safe' space. This revelation highlights the potential appeal and influence of RMR on students' learning experiences, shaping their perspective towards statistics.

However, the influence of RMR on student performance presented a different picture. No significant difference in performance was observed between students who engaged with RMR and those who did not, and while this finding may initially seem counterintuitive, it highlights the complex nature of learning and performance. Further research is necessary to unpack the nuances of this relationship and explore other factors that could potentially mediate the impact of RMR engagement on performance. Despite this, the results of this study illuminate the profound influence of RMR on the learning experiences of students in statistics, setting the stage for further exploration into this critical aspect of education.

9.1.2 Research Question 2

What is the potential appeal of rich media resources for students who are experiencing statistics anxiety?

My second research question looks into the potential appeal of RMR for students grappling with statistics anxiety. The insights derived from my quantitative and qualitative strands paint a compelling picture of RMR's role in facilitating flexible, individualized, and supportive learning experiences, particularly for students facing challenges with the statistics subject. In exploring the attraction of RMR for students experiencing statistics anxiety, my research journey led me to a tapestry of human stories, of courage, perseverance, and discovery. From the practical necessity of Aly, who found assurance in RMR, saying *'I will not fail this course just because I am stupid; I simply need to devote more time to it... whatever I miss, I tell myself that I will view the lecture recording, which ensures me that I will not fail',* to Hazel's transformational learning experience, which led her to confess that *'after watching these videos before lectures… I at least had a groundwork to build on',*

RMR emerged as a trusted ally in their personal academic battles. Students like Hazel and Aly, as depicted in the data analysis section, embraced RMR as reliable safety nets, offering reassurance and confidence that they could catch up on missed lectures and continue progressing along their learning journey. For them, RMR wasn't merely an additional resource; it was a critical tool that allowed them to align their learning with their personal circumstances and constraints.

Moreover, I discovered the unique role RMR played in alleviating social anxiety related to learning statistics. Students often grapple with fear and embarrassment when they lack understanding or are unable to keep pace with live lectures. This fear sometimes leads to hesitation in seeking help, further exacerbating their anxiety. However, RMR emerged as a comforting ally for these students, enabling them to revisit complex material, review their understanding, and learn at their pace without the fear of judgment. The narratives shared in my data analysis section illuminated the critical role of RMR in creating a learning environment that was not just flexible and individualized, but also kind, patient, and non-judgmental. It gave students like Maggy the room to make mistakes, spot them, and correct them at their own pace, without the fear of being judged. As Maggy recounts her experience, ‘I am more comfortable in spotting my mistakes... I’d rather not go see my teacher. At times I doubt my ability to solve the questions and I usually check over them multiple times by playing the lecture videos…’. These powerful insights into the lived experiences of our students offer a more profound understanding of RMR's impact. While statistically significant differences in anxiety and self-efficacy were observed between those students who utilized RMR and those who didn't, these differences did not translate into noticeable disparities in academic performance, and this revelation raises compelling questions about the traditional link between anxiety, self-efficacy, and performance. The essence of my findings points towards the idea that rich media resources (RMR) might be acting as an 'academic comfort blanket' for students, helping to mitigate the negative impacts of anxiety and lower self-efficacy on academic performance. This echoes Dart's (2022) proposition that online class formats have the capacity to alleviate statistical anxiety, providing an empathetic and engaging substitute to traditional teaching

methods. Some elements contributing directly to statistical anxiety encompass time pressure (Kinkead et al., 2016) and apprehension about seeking assistance, especially from instructors (Hamid and Sulaiman, 2014), and videos, a component of RMR, can address these issues as they function as a self-help resource, permitting students to learn at their individual pace. Furthermore, research suggests that students in blended and online learning environments are less hesitant to ask for help compared to those in traditional learning scenarios (Kitsantas and Chow, 2007).

In conclusion, the powerful voices of our Statistics Level 3 students resonate through my research, amplifying the vital role of RMR in the statistical learning journey. RMR transcends its role as an educational tool, transforming into a comforting companion that students can rely on as they navigate the tumultuous seas of statistics anxiety. While this study opens new vistas of understanding, it also prompts us to delve deeper into the intricate relationship between RMR usage, self-efficacy, and academic performance. Ultimately, this research highlights the transformative potential of RMR in creating a more compassionate, flexible, and empowering learning environment, capable of nurturing academic resilience and success in the face of statistics anxiety. The human stories behind the data underscore the essence of my conclusion: the inclusion of RMR in our educational fabric is not merely a pedagogical decision, but a compassionate one, touching the hearts of our students and helping them conquer their academic anxieties.

9.1.3 Research Question 3

How do students experience RMR and what do their embodied experiences of learning in this way tell us about the affordances of this mode of learning?

The implementation of RMR in my university's foundation-year statistics classroom has indeed provided a transformative learning experience for our students. These resources have notably enhanced the students' understanding of complex statistical concepts, acting as a visual aid that helps bridge the gap between abstract theories and concrete comprehension. In addition, in moments where

students recounted having a clearer grasp of statistical ideas after an engagement with rich media resources, there was evidence of stronger embodied reactions – a sense of relaxation replacing tension, excitement kindling in the place of indifference. The immediate and tangible embodiment of learning through these resources has been profound. One student reported a sense of relief washing over her as she finally grasped the concept of standard deviation through a well-illustrated key-concept video on Moodle, while another shared, during the qualitative strand Phase 1 data collection process, her thrill of finally understanding a tricky probability tree diagram question after rewatching the relevant section of a lecture capture. These reactions, underlining the physical sensations accompanying their cognitive breakthroughs, reveal the immense potential of RMR to facilitate embodied learning. The students, rather than being passive recipients of knowledge, became actively engaged, with the interactive nature of RMR fostering a deeper, more personal connection to the material. Extending Pink et al.'s (2018) concept of 'ambient atmospheres', my study provides empirical evidence of how RMR contribute to the crafting of a specific learning environment or 'atmosphere', particularly in the realm of statistics education. While Pink et al. focus on the sensory and emotionally rich atmospheres crafted through digital play, my research takes this discussion into the academic setting, and I propose the concept of 'ambient study' environments, which demonstrates how students like Olivia and Ben consciously create atmospheres that mitigate statistical anxieties and improve self-efficacy (Pink et al., 2018).

A noteworthy shift in students' emotional responses was also observed. Instead of students viewing statistics as an intimidating subject, the accessibility and diversity of learning methods offered by rich media resources fostered a more positive outlook. Considering actor–network theory, the classroom dynamics transformed, with these resources becoming a pivotal actor in the network, mediating the relationships between teachers, students, and the subject matter. From a sociomaterial perspective, the intertwining of the material aspects of these resources (like personal gadgets, a comfy chair, calculators, and a notebook) with the social elements (such as teacher narration and interaction with other living

beings, i.e. pets or family members, including children) greatly influenced the embodied reactions of students towards learning statistics. Consequently, these resources have not only improved cognitive understanding but have also influenced students' physical and emotional responses towards the subject, making learning more interactive, inclusive, and effective. Yet, we must note that the alterations in statistical self-efficacy of these resources may vary depending on individual learning styles and preferences.

In conclusion, the implementation of RMR in my university's foundation-year stats classroom has substantially transformed the learning experience. These digital resources (RMR) have not only enhanced cognitive understanding but also heightened students' awareness of their embodied reactions when engaging with statistical texts. They bridge the gap between the 'disembodied' digital perceptions and the actual 'embodied' experiences (Gourlay, 2021), validating Acton's claim that there has been a growing recognition of sociomateriality and awareness of embodiment in education (Fenwick et al., 2011; Gourlay, 2015; Acton, 2017) and revealing the entanglement between social elements like teacher narration and the material aspects of resources, like personal gadgets or furniture, which greatly influence the embodied reactions of students towards learning statistics.

As Santiago de Roock (2019: 200) and his cited literature argue, the digital or virtual should be understood as 'embedded, embodied, and everyday', and my study's findings show that these digital resources are no less 'real or consequential' than traditional learning methods (Leonardi, 2010; Santiago de Roock, 2019). They have become pivotal actors in the actor–network theory framework, mediating relationships between teachers, students, and the subject matter, consistent with the perspectives on sociomateriality and human and non-human agency in education (Acton, 2017).

Future research could focus on adapting these resources to diverse learning needs, thereby further enriching the embodied statistics learning experience. Therefore, the study results emphasize the potential of RMR for making students more conscious of their embodied reactions to statistical texts, thereby enriching their overall learning experience.

9.1.4 Research Question 4

How do students and material things interact together to form a statistical e-learning experience?

The immersive nature of rich media resources has engendered an everyday statistical e-learning experience that is interactive and adaptive, catering to the individual requirements of students. A pivotal point in this e-learning journey is the synergistic relationship between the students and the material artefacts around them, both physical and digital. My students have exhibited considerable adaptability in integrating these resources into their daily routines, thus blending their learning into their lived experiences.

For instance, one of our mature students, a mother, shared how she felt empowered by studying in her kitchen while simultaneously managing her domestic duties. This space, which she had mostly associated with her domestic life, turned into a site of academic growth as she navigated through statistics videos and lecture captures on Moodle. The pause-and-play button on these resources granted her control over her learning pace, allowing her to switch between being a student and a mother, and this dynamic mirrors the findings of Pahl and Rowsell (2010) and Lewis (2016), who highlight the significance of home digital artefacts and the fluid boundaries between formal and informal learning environments. These instances underscore how students and material things interact, crafting personalized e-learning experiences that challenge traditional educational confines.

Similarly, another student mother could multitask – watching the videos, pausing to help her 11-year-old daughter heat bao buns in the heating device, and then returning to her study. The ability to do other chores while learning not only increased her efficiency but also reduced her anxiety, ultimately enhancing her self-efficacy, and these instances highlight the critical role of material things – the pause/play button, the kitchen, the bun-heating device – in shaping the learning experience. Their interactions with these elements enacted a unique, personalized e-learning environment.

The use of material things extends to other physical objects like calculators, books, pens, and even whiteboards. These artefacts not only supplement the learning process but also become an essential part of the interactive learning network, co-producing knowledge along with the students and the digital resources. Interestingly, even distractions, like pets demanding attention, become a part of this network, adding an element of spontaneity and unpredictability to the learning experience, making it more human and relatable.

This dynamic, multi-dimensional learning environment brought forth by RMR opens a wealth of opportunities for educational practitioners as the insights garnered from an actor–network theory (ANT) perspective underline the importance of creating an educational ecosystem that is attentive to this complexity. The mutable and adaptive nature of this ecosystem is key to fostering a conducive learning environment, whether it is through enabling the temporal control offered by a play/pause button or through expanding the spatiality of the learning experience beyond the confines of a traditional classroom. The intricate interplay between the students and material things is crucial in shaping their learning experience. From a sociomaterial perspective, the embodied, situated practices of learners and the agency of material things are intertwined, resulting in the formation of 'hybrid' educational actors (Luke, 2020). These insights suggest that the teaching and learning process is transformed significantly when its constituent elements change, thus underscoring the need for holistic understanding and incorporation of these emergent practices in designing future learning environments.

During my research, I grasped the significance of accommodating students' thought processes and understanding, including what they believe, value, and assume, as they go through these complex networks of learning. Both mental factors (like thoughts and beliefs) and material factors (like physical objects) play a role in influencing how people behave. Things like beliefs, values, and what they assume can play a big role in how they act, as with the actual materials they are using, as Latour's actor–network theory (Latour, 2005) suggests. Therefore, it is crucial to find a balance between these mental and material factors when we try to evaluate how well someone is learning and the results they achieve from their learning

experience. The *integration of rich media resources has the potential to revolutionize the e-learning experience*, and as a researcher deeply invested in the wellbeing and academic success of students, I am inspired by the transformative possibilities these resources offer. However, it is essential to acknowledge that this journey does not end with the implementation of these tools or in exploring their impact. Instead, it presents an opportunity for me as a researcher and educator to embark on a parallel journey of growth and learning alongside my students.

9.2 Contributions to the field

This thesis offers significant contributions to the specialized fields of statistics education and digital learning practices. By examining the impact of rich media resources on students' self-efficacy, statistics anxiety, and performance, this research illuminates the potential of these resources as pedagogical tools in statistics education, enhancing understanding of how technology and digital materials can be used to improve student outcomes and learning experiences. Moreover, the adoption of a sociomaterial perspective in this study provides a unique lens through which to examine the interplay between students, technology, and the learning environment, contributing to a growing body of literature in the realm of digital learning practices. This resonates with Gourlay and Oliver's (2016a) observations about the complexity of students' study practices, emphasizing how they rely on a multifaceted network of digital and traditional resources. The intricate relationship between students, technology, and the learning environment is further amplified through a sociomaterial perspective, aligning with the ideas of Santiago de Roock (2019) about objects serving as co-participants in social interactions. By integrating the physical and digital sites of study, the research echoes findings from Gourlay and Oliver's (2016a) work, underscoring that spaces are neither simply found nor just containers for practice but are dynamically constructed by students. In a parallel vein, drawing inspiration from Hand et al. (2022), this thesis acknowledges the experiential blurriness between analogue and digital spaces, emphasizing the dynamic complexity of physical and virtual modalities of understanding.

More than just theoretical observations, the insights from this study possess pragmatic implications. They can guide educators, curriculum architects, and policymakers in devising efficacious pedagogical strategies and resources in statistics education. By spotlighting and addressing statistics anxiety, the research also broadens the discourse on the emotive facets of learning, suggesting a more comprehensive and compassionate educational approach. The interplay of these elements, grounded in the studies of Gourlay and Oliver (2016a), Santiago de Roock (2019), and Hand et al. (2022), signals a transformative shift in statistics education and digital learning practices, advocating for a holistic and adaptive understanding of the evolving learning landscapes.

The insights garnered from this study can serve as valuable reference points for educators, curriculum designers, and policymakers, aiding them in the development of effective pedagogical strategies and resources in statistics education. Furthermore, by recognizing and addressing the issue of statistics anxiety, this thesis also contributes to ongoing discussions about the emotional aspects of learning, thus paving the way for more holistic and empathetic approaches to education. As we move into an era where artificial intelligence and digital technology increasingly permeate our lives, it becomes crucial to nurture the human attributes that computers cannot emulate, which include emotional intelligence, self-confidence, resilience, and the capacity to overcome personal anxieties. This study's focus on the role of RMR in enhancing students' self-efficacy and reducing statistics anxiety is therefore not only timely, but also essential.

The insights gathered from this research emphasize the value of technological tools in fostering a supportive educational environment where students feel empowered and less anxious. These findings contribute to the broader pedagogical discourse on leveraging technology to cultivate emotional wellbeing, self-belief, and resilience in learners, particularly when faced with challenging subjects like statistics.

Moving forward, it becomes imperative to focus on preparing educators and professionals to engage in rich, meaningful dialogues that bridge diverse areas of knowledge. Additionally, universities need to rethink how they view and engage with their community. Drawing inspiration from Pahl and Evans (2018), it is clear to

me that universities should shift their focus, giving more attention to understanding young people's real-life experiences. This is more than a change in perspective – it calls for tangible action. My work aligns with the idea of placing young people's voices at the heart of education, seeing them as active contributors. Future research, teacher training, and leadership initiatives should prioritize building essential skills, as by doing so, I believe we can better equip teachers, leaders, and students to collaborate effectively in the complex educational landscape of our time. An attitude of methodological humility: an acknowledgment that all knowledge production takes place within sociomaterial practices situated in time and place, and an acceptance that there is no superior way of knowing. I advocate, as Oosterhoff (2021) did, for the inclusion of a wider range of stakeholders in research and reflection processes, thus extending the transformative objectives of methodologically heterogeneous research beyond the field of science into professional practice.

In the educational context, this calls for a deliberate creation of an environment that allows a meeting of ontologies, seeking ways to generate forms of transdisciplinary research teams that integrate the expertise of all stakeholders. The goal would be to cultivate practices of collective inquiry in evaluating educational quality, and embracing the notion of the partiality and fluidity of truth, which as argued by Lincoln et al. (2018), could potentially replace the assumptions of a single objective reality. This approach, while not likely to resolve all controversies, serves as a solid foundation for transdisciplinary dialogue and collaborative knowledge creation in the years ahead.

From conducting research on statistics anxiety and efficacy, I have come to conclude that a conceptual framework that compartmentalizes the learning experience into tidy segments may not accurately reflect the lived experiences and the multifaceted realities of learners grappling with statistical concepts and procedures.

Building on the foundation laid out by my principal supervisor, Kate Pahl (2023), I propose a shift in our methodological orientation within the realm of statistics education. As Pahl (2023) eloquently conveyed in her work on literacy and

language, participatory methodologies, in harmony with an ethnographic perspective, can glean insights from participants that can reshape our understanding of what statistical literacy is and could be. In the context of statistics education, this means co-constructing the concepts, ideas, and research thinking on statistical literacy with the participants, focusing on their lived experiences and the ontological categories that form in the process. It may also require us to acknowledge the complex mathematical heritages, potentially unwritten or undocumented, that our students bring with them into the learning environment.

In essence, my proposed research in statistics education is a speculative enterprise, one that navigates the murky waters of 'not yet' explored possibilities. I advocate for a speculative, affective perspective – one that is hopeful and attuned to the everyday possibilities within statistics education. Similar to the advancement in literacy and language research driven by Pahl (2023), we may uncover spaces and practices that have not yet been written about in the field of statistics education. As such, this approach encourages a more dynamic, shared, and co-constructed understanding of statistical literacy.

9.3 Limitations of the study

My research study has several potential limitations that should be acknowledged. Firstly, the sample of the study was drawn from a single institution. As such, the findings of the study may not be readily generalizable to all student populations or across different educational contexts, which limits the applicability of the results beyond the specific environment and group of students investigated in this study. Secondly, the reliance on self-reported measures in order to understand students' self-efficacy and statistics anxiety might introduce bias, as the nature of these measures depends on students' abilities to accurately recall their experiences and feelings, which can sometimes be skewed or misrepresented. Thirdly, the study was conducted over a specific, relatively short timeframe. Therefore, it may not have sufficiently captured the long-term effects of the use of RMR on students' self-efficacy and their anxiety regarding statistics. Finally, while the focus of this study

was on the impact of RMR, there are numerous other educational resources or teaching styles that have not been investigated and which might also significantly affect students' self-efficacy and statistics anxiety.

This study, while constructed with diligent consideration, carries certain inherent limitations that merit acknowledgment. The deployment of a methodologically heterogeneous approach, designed to promote a well-rounded perspective, has the potential to instil a degree of ambiguity in the drawn conclusions, which may be challenging for individuals seeking resolute outcomes. Moreover, the utilization of a diverse array of research methods amplified the demands placed on my capacity as a researcher (Oosterhoff, 2021). This complexity hints at the potential for unforeseen errors or oversights, inherent in the daunting task of mastering the suite of methodologies employed in this study. Furthermore, the vast scope of this approach, while encompassing a wide range of perspectives, might not find resonance with every stakeholder, and its potential unsuitability for certain research contexts could pose a limitation to its widespread acceptance and generalizability within some academic spheres. Ultimately, due to the intricate nature of this study and its sweeping scope of inquiry, attaining a comprehensive and definitive overview of all the variables in play proved unachievable. This reveals the importance of a focused research in certain areas to ensure a more comprehensive understanding of the topic at hand.

9.4 Future considerations

In terms of future research, there are several noteworthy considerations. It would be beneficial for future studies to extend the scope of the investigation to understand the impact of a variety of educational resources or teaching methodologies on students' self-efficacy, anxiety, and performance in statistics as this would provide a more comprehensive picture of the various factors influencing student learning outcomes. In addition, conducting longitudinal studies could provide deeper insight into the long-term effects of using RMR in statistics education. By following students over an extended period, researchers could track

changes in self-efficacy and anxiety over time. Moreover, to enhance the generalizability of the findings, future research could consider recruiting a more diverse sample of students. This could involve multiple institutions, students from different age groups, varying cultural backgrounds, and different levels of prior knowledge in statistics. Lastly, an in-depth exploration of the perspectives of all those involved in the creation and distribution of RMR is important, including technicians, teachers, and other educational staff who play a crucial role in delivering these resources. Using qualitative methods, such as interviews or focus groups, can shed light on their experiences and viewpoints, providing a more nuanced understanding of the factors that influence the effectiveness of rich media in educational contexts. Their insights, combined with those of the students, can create a holistic view of the use and impact of RMR in education, leading to more effective strategies and practices in the future.

9.5 My transformational journey

In this section of my doctoral thesis conclusion, I am reflecting on a journey that has been nothing short of transformative. It began with a methodological intention to encapsulate the lived experiences of students, but along the way I unknowingly began living with them. The moment when this transition occurred is still elusive to me. However, what I discern clearly is the profound impact this journey has had on my perspective on education.

During my exploration of this journey, I came to understand that the foundation of bravery in education genuinely springs from the heart – a conception that echoes the sentiments expressed by Palmer (2017), elaborating on teaching as an intricate interplay of commitment, connection, and relationship among students, subjects, and the world that links them. This interplay aligns well with transformative pedagogy, which is echoed in the work of theorists like Biesta (2020a), who presents a multi-dimensional view of education encompassing qualification, socialisation, and subjectification (van Balen et al., 2022). Qualification and socialisation respectively relate to the acquisition of knowledge and skills and the

internalization of cultural norms and practices. However, it is the domain of subjectification – the process of becoming a subject of one's own life rather than an 'object of educational interventions' – that resonates with the core of transformative pedagogy (Biesta, 2020a: 92). It represents the students' freedom to make choices, to say 'yes' or 'no', to do 'this' or 'that' (van Balen et al., 2022). In essence, the pursuit of authentic education – a dynamic space where living and learning coalesce. By introducing students to the freedom inherent in subjectification and guiding them towards its mature usage, educators can ensure their contributions to living well, both individually and collectively. This journey is towards transformative education, wherein we dare to venture into the heart of teaching, embracing the complexities, challenges, and changes that lie within.

I find immense resonance in the idea of 'circles of trust', an environment in which individuals can freely express their deepest hopes, concerns, and fears, and genuinely respond to those of one another. In this sacred space, our variances are not points of contention but acknowledgments that pave the path for collective growth towards broader, emergent truths. However, I feel that knowledge, in its traditional sense, is not the ultimate emancipator. Instead, I propose a different kind of knowledge – a kind that emanates from love, nurtures connections, and affirms life. This form of knowledge envelops both the learner and the object of learning in a blanket of compassion, sparking a bond of profound responsibility and transformative joy. It invites engagement, mutual respect, and accountability.

9.5.1 Self-knowledge living the experience: a voyage of self-discovery

Throughout the course of this thesis, I have found myself not merely an observer of the lived experiences of my students but an active participant. The power of teaching goes beyond the simple transference of knowledge; it sparks a transformation within oneself. Effective teaching stems from a deep self-understanding – an understanding forged through reflective engagement with our own experiences. In today's digital era, these formative encounters are often mediated by technology. As Neil Selwyn (2014, 2016) emphasizes, the everyday use of digital technologies in education can significantly shape teaching and learning experiences. Moreover, digital pedagogies offer a novel dimension to these

encounters, embedding technology in the teaching and learning process, and the work of Bhatt (2017) further supports this, illustrating how digital tools and literacy practices influence learning environments. As Palmer (2017) profoundly states,

> *Teaching, like any truly human activity, emerges from one's inwardness, for better or worse. As I teach, I project the condition of my soul onto my students, my subject, and our way of being together. The entanglements I experience in the classroom are often no more or less than the convolutions of my inner life. Viewed from this angle, teaching holds a mirror to the soul. If I am willing to look in that mirror and not run from what I see, I have a chance to gain self-knowledge—and knowing myself is as crucial to good teaching as knowing my students and my subject.*

My experience as a statistics lecturer for foundation level students has been a remarkable endeavour marked by numerous illuminating discoveries, and these revelations are so plentiful that an attempt to enumerate them would inevitably surpass our word limit. Nonetheless, this journey of self-discovery, underpinned by digital pedagogies, offers a transformative perspective on teaching and learning in the digital age.

One of the most significant discoveries came during my doctoral education, where I encountered actor–network theory and sociomaterial qualitative methods (Latour, 1987; Law, 2004). This introduced me to a completely new way of understanding (Callon, 1986; Hennion, 2007), and the experience was analogous to Alice stepping into Wonderland – a vibrant, colourful world, completely different from what I was accustomed to, eliciting both shock and surprise. In addition to academic discoveries, my teaching journey has been enriched by the diverse lives of my students. Each day, they walk into the classroom with a different story, a different mood, a different vibe. Underneath their masks of composure, there are often deep struggles, but these struggles never deter them from attending lessons and pursuing their educational journey. I have come to realize how profoundly they value my acknowledgement of their emotions and my genuine care for them. In return, they are prepared to put their **utmost effort into not letting me down,**

highlighting the reciprocal nature of our relationship. One of my participants mentioned,

> *When my teachers know me, like really know me, it pushes me to do better in class. It's like, if I bump into Rahma in the hallway, I want to be able to say, 'I've done the work'. I don't want to let her down, you know? It's this personal bond that makes me feel extra responsible, like I owe it to her, and myself, to do my best.*

Another student expressed, *'That one-on-one at the start of the semester? Yeah, it was scary at first. But it grew into a relationship that made me braver in class, knowing she's* [Rahma] *got my back'* (observation notes). I had an epiphany that in this classroom, we are not merely involved in a traditional teaching–learning dynamic. Instead, we are jointly constructing our knowledge. It reminded me of why I teach – not only to impart knowledge but also to live, feel and learn through their experiences. During my EdD, focusing on students' statistics anxieties and self-efficacy, I was not merely imparting knowledge. Instead, I was engaging in a mutually enriching process of knowledge co-creation.

9.5.2 Students (yes, you) are a priority

Relational trust is the bedrock of effective education, and it largely hinges on an educator's ability to explore their own 'inner landscape'. This refers to the personal and emotional dimensions of a teacher's life, including their values and motivations, and the emotional skills that shape their interactions with students. This trust is foundational for impactful education, and within the context of the EdD, it underscores the importance of an educator's exploration of their 'inner landscape'. This inner realm captures the personal and emotional dimensions of an educator's life, including their values, motivations, and the emotional aptitudes that inform their interactions with students.

In a society where trust can often be eroded, making space for this inner work is crucial. Not only does it fortify educators personally, but it also has a profound impact on their teaching practices and ultimately on their students' learning experiences. By reflecting upon the complexities of teaching, we can better

understand and navigate its challenges with more grace, which not only preserves our own spirit but also enriches our service to our students. This exploration of our inner landscape rejuvenates us and allows us to re-enter our teaching lives with renewed passion and purpose. When teachers love their work this deeply, the way out of any challenges is to venture further in, and this journey of inner exploration and self-discovery, in turn, helps create a more empathetic, supportive, and effective educational environment.

As I began to perceive this shift in my thinking, I noticed a corresponding change in the way my students interacted with me. Previously, I had believed that being an effective teacher meant instilling concepts, maintaining discipline, and ensuring students' obedience. However, I have come to appreciate the power of building genuine connections with my students, caring for them both inside and outside of the university setting. This newfound understanding has led to a more organic and beautiful process of learning and cooperation from my students, as evidenced by the significant changes I have witnessed in our interactions.

I began teaching Mollie numeracy and data analysis in Semester Two. Although he sat at the front of the class, he remained quiet. During our first break, I approached him to ensure everything was alright and Mollie shared that he had a personal learning plan (PLP) and struggled with mathematics. I noticed his laptop displayed the slides I was teaching on the board.

In our second week, Mollie hesitantly asked if any additional support was available for these sessions. I enthusiastically informed him that I could provide one-to-one instruction during my office hours and that we could tailor his learning experience according to his pace and preferred learning style. Surprised, Mollie mentioned that he assumed lecturers were too busy for such individualized support. I reassured him with a smile that I am never too busy for my students. In our following session, Mollie stayed after class to express that I was very different from his previous experiences with educators. He recounted a painful memory of his past math teacher who bullied and punished him, even expelling him from the class for asking what the teacher deemed to be 'stupid questions'. As he shared this story, tears began to flow.

Empathizing with Mollie, I encouraged him to let go of this painful past and not allow it to haunt his future, emphasizing the importance of overcoming these barriers in order to move forward in his educational journey. The following day, Mollie visited my office, and we engaged in an hour-long tutoring session, tailored to his preferred pace. I crafted questions on the fly, considering his prior knowledge and skills. After the session, he asked me a candid question: 'What's your background?' I provided him with a standard response, as if in an interview: 'I completed my BSc in Mathematics, followed by a Biostatistics Master's degree from the University of Manchester, and I am currently pursuing a Doctor of Education'. Intrigued, Mollie inquired about the focus of my doctorate. I explained that it revolved around statistics anxiety, self-efficacy, and technology. He exclaimed*, 'Ahh, now it makes sense! Then I would be a very good "subject" for you.'*

Without hesitation, I instantly replied**, 'Oh, no. I would never treat my students as subjects.'**

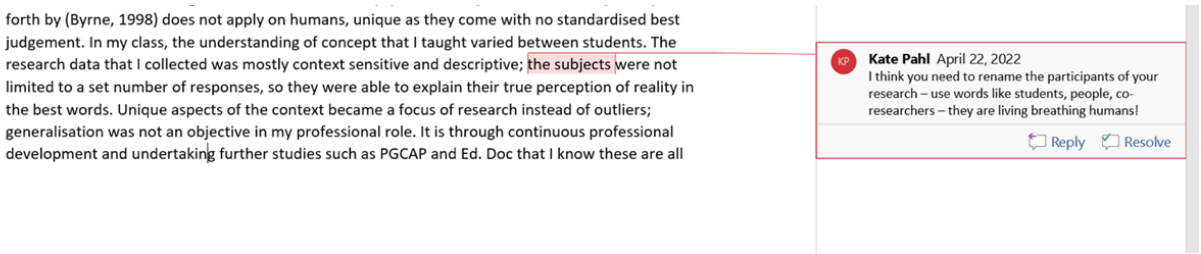

Figure 21: Screenshot of supervisor comments

Only after this incident I realized the significance of this feedback by my supervisor on my first draft (see above Figure 21), **its true meaning** and valuable insights that have contributed to my growth and development as both an educator and researcher. This experience has reinforced the importance of continuous improvement and the pursuit of excellence in my professional journey.

According to bell hooks (2010), the journey of knowledge is not merely a cognitive exercise, but rather one that is intertwined with our emotions and lived experiences. The act of education is not about amassing facts, but about developing a 'love of learning' that is grounded in our pursuit of truth and the

betterment of our collective existence, and this type of education cultivates a sense of compassion between the learner and the subject of learning, engendering a deep sense of responsibility and joy that transcends the conventional teacher-student dynamic. It fosters engagement, mutual respect, and a sense of shared responsibility. As I have come to internalize hooks' philosophy, I have developed a profound appreciation for the interconnectedness of teaching, learning, and the human spirit. Concluding my doctoral thesis, I understand that I have not merely been a researcher in this journey. I have evolved into a fellow traveller, living, experiencing, and learning with the students. While I end one chapter, I realize this is only the beginning of my contribution to the field of education, and I carry with me the profound lessons learned and the unwavering commitment to continue this transformative journey.

9.6 The extended reach: personal growth as an integral contribution

But the contribution of this thesis extends beyond its academic discourse. It narrates a deeply personal journey of transformation – my transformation as an educator. I have come to understand the profound impact that empathy, emotional intelligence, and a student-centred approach can have on the learning experience. It is not just about imparting knowledge; it is about tuning in to students' emotions, acknowledging their anxieties, and supporting them through their challenges.

As I carry these insights with me into each new academic year, the impact of this research continues. With each student I engage with, the ripple effect of this thesis expands, and every lecture, every conversation, every word of encouragement is imbued with the understanding and wisdom gleaned from this journey. **The heart of this thesis beats in the everyday practice of my teaching**. It breathes life into every interaction with my students, creating a nurturing environment that encourages not just academic achievement but personal growth too. As I continue to evolve as an educator, I will remain committed to fostering a space where students' emotional wellbeing and self-efficacy are valued and nurtured.

This ongoing embodiment of the research is the true contribution of this thesis. It lives in my classroom, in my interactions, in the lives of the students I am privileged to teach. It is a testament to the enduring power of compassion, empathy, and dedication in education – a contribution that will resonate in my students' lives, in my classroom, and in my heart, for years to come.

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Appendix A: Consent Form

CONSENT FORM (Interview)

Title of Study: **Investigating the impact of rich media resources on students' self-efficacy, statistics anxiety and performance.**

Name of Researcher: **Rahma Jawad, School of Computing, Mathematics and Digital Technology, XXXX University.**

Participant Identification Number: _____

Please initial all boxes

1. I confirm that I have read and understand the information sheet dated 28/01/2022 (version 2.2) for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason, without my foundation year programme being affected. ☐

3. I give permission for my data to be used as part of this study and I understand that I can withdraw at any time and my data will be destroyed before any further use. ☐

4. I give my permission for anonimised direct quotes from my interview(s) to be used as part of this study. ☐

5. I agree to take part in this study. ☐

6. I wish to receive the results via email.
   Email: _____ ☐

Name of Participant	Date	Signature
Name of Person taking consent.	Date	Signature

CONSENT FORM (survey)

Title of Study: **Investigating the impact of rich media resources on students' self-efficacy, statistics anxiety and performance.**

Name of Researcher: **Rahma Jawad, School of Computing, Mathematics and Digital Technology, XXX University.**

Participant Identification Number: _____

Purpose: **Consenting to fill in questionnaires for this study.**

Please initial all boxes

7. I confirm that I have read and understand the information sheet dated 28/01/2022 (version 2.2) for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐

8. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason, without my foundation year programme being affected. ☐

9. I give permission for my data (including assessment marks) to be used as part of this study and I understand that I can withdraw at any time and my data will be destroyed before any further use. ☐

10. I agree to take part in this study. ☐

11. I wish to receive the results via email. ☐
    Email:_____

_____	_____	_____
Name of Participant	Date	Signature
_____	_____	_____
Name of Person	Date	Signature

Appendix B: Participant Information Sheet

Version:2.2 Date: 28/01/2022

Ethical approval number (EthOS): 8272

Participant Information Sheet

Title: Investigating the impact of rich media resources on students' self-efficacy, statistics anxiety and performance

1. Invitation to research

Dear Student

I am currently researching the effects of support videos on students' attitude towards statistics and performance. I am trying to find out if rich media resources such as systematic recording of all Data analysis lectures, explanatory videos covering key topics, videos of examples being solved and summarising revision videos play a significant role towards students learning journey. You will be asked to fill in some questionnaires and might be invited to take part in short one to one interview/s with me so that I can hear your views. The interviews will be around half an hour long and will take place within the University premises. Online interviews via MS teams can also be arranged based on your preference. All participant information will be kept strictly confidential.

Before you decide if you would like to take part in this study as a participant, it is essential for you to understand, why I am conducting this research and what it involves. Please take time to read this attached information sheet carefully and discuss it with others if you wish. This information covers the most asked questions, but feel free to ask anything that is not clear or if you would like more information.

There is a consent form for you to complete if you wish to take part.

2. Why have I been invited?

You have been invited to take part as you are currently enrolled in the Numeracy and Data Analysis (NDA 1 &2) unit at XXX University). All students studying statistics during Foundation year at XXX university are eligible to take part in this study. I want to gain an understanding of how support videos affect students learning of statistics.

3. Do I have to take part?

It is up to you to decide. We will describe the study and go through the information sheet, which we will give to you. We will then ask you to sign a consent form to show you agreed to take part. You are free to withdraw at any time, without giving a reason.

Your participation or withdrawal will not affect your grades or student experience at XXX university.

4. What will I be asked to do?

If you agree to take part, you will be requested to fill three surveys.

. 1) Statistics Anxiety Scale (SAS) which contains 24 likert scale style questions.

2) Self-efficacy in statistical practices scale (SESPS) (shorter version) which contains 20 rating scale questions.

3) A demographic questionnaire which would also ask some basic questions for example "do you watch the support videos provided for this unit"?

Those surveys will ask questions regarding your attitude towards statistics and choice of learning strategies that you may employ to gain a conceptual understanding of statistics. I may invite the participants for some short one-to-one interview/s regarding video resources based on statistics. It will last no more than half an hour. Anonymised quotes from the interview may be quoted as part of results; however, if you do not want anonymised quotes from your interview to be published as part of results, you tick the box in the consent form (v2.2). Some of the interviews will be audio recorded for transcription only. Once the audio recording has been transcribed, it will be deleted permanently from our system. No audio recording will be published or released. Any personal information mentioned in the interviews will be transcribed using codes that will only be identifiable to the researcher.

5. Are there any risks if I participate?

There are no additional risks associated with this study.

6. Are there any advantages if I participate?

There is no direct reward or advantage for participation. However, the results of the study might help the University and staff to improve the services we provide to you as students. The aim is to make the learning experience meaningful one and

help students relate more to this course with their degrees or future interests. Your views and experience will make a valuable contribution.

8. What will happen with the data I provide?

When you agree to participate in this research, we will collect from you personally-identifiable information.

The ('the University') is the Data Controller in respect of this research and any personal data that you provide as a research participant.

The University is registered with the Information Commissioner's Office (ICO) and manages personal data in accordance with the General Data Protection Regulation (GDPR) and the University's Data Protection Policy.

We collect personal data as part of this research (such as name, University ID, Foundation year course). As a public authority acting in the public interest, we rely upon the 'public task' lawful basis. When we collect special category data (such as medical information or ethnicity), we rely upon the research and archiving purposes in the public interest lawful basis.

Your rights to access, change or move your information are limited, as we need to manage your information in specific ways in order for the research to be reliable and accurate. If you withdraw from the study, we will keep the information about you that we have already obtained.

We will not share your personal data collected in this form with any third parties.

If your data is shared, this will be under the terms of a Research Collaboration Agreement which defines use and agrees on confidentiality and information security provisions. It is the University's policy to only publish anonymised data unless you have given your explicit written consent to be identified in the research. **The University never sells personal data to third parties.**

Any personal data that is collected about you through the course of this study will be kept strictly confidential. Collected data will be pseudonymised and identifiable data will be stored separately in an encrypted manner, to which only the researchers on the project will have access. When the results are published, if you have consented, direct quotes from the focus groups or interviews may be used anonymously.

We will only retain your personal data for as long as is necessary to achieve the research purpose. When the study concludes, all collected data will be archived and retained for a further five years before it is permanently deleted.

For further information about use of your personal data and your data protection rights, please see the University's Data Protection Pages.

What will happen to the results of the research study?

The results of this study will be disseminated through my dissertation. If you wish to know the findings of this study please tick the box in the consent form that states that you wish to receive the results of the study once it is completed. Some of the results of this study may also be disseminated through a talk in a conference, piece of writing (article in a journal) and any website as piece of work under the researcher's name.

Who has reviewed this research project?

Three supervisors and the ethics committee will review the project.

Who do I contact if I have concerns about this study or I wish to complain?

If you would like to contact someone other than the researcher about anything relating to the study you may contact:

My supervisors

1) Prof Kate Pahl k.pahl@xxx.ac.uk +44 (0)161 247 2351
2) Dr Michaela Harrison m.j.harrison@xxx.ac.uk +44 (0)161 247 2069
3) Dr Steph Ainsworth s.ainsworth@xxx.ac.uk +44 (0)161 247 2344

Research Ethics and Governance Manager xxx

Ramona Statache R.Statache@xxx.ac.uk +44(0)161 247 2853

If you have any concerns regarding the personal data collected from you, our Data Protection Officer can be contacted using legal@xxx.ac.uk e-mail address, by calling 0161 247 XXX or in writing to Data Protection Officer, Legal Services at XXXX. You also have a right to lodge a complaint in respect of the processing of your personal data with the Information Commissioner's Office as the supervisory authority. Please see: https://ico.org.uk/global/contact-us/

THANK YOU FOR CONSIDERING PARTICIPATING IN THIS PROJECT

Appendix C: Short Questionnaire (quantitative strand)

Demographic Questionnaire

Directions: For each question, please select/write the response(s) that best describes you. The information that you are providing will be **confidential and used anonymously**.

Student ID: _____

1) Have you studied Mathematics content previously during your college/A levels?

☐ Yes ☐ No

2) How useful do you find the lecture captures and support videos on Moodle?

☐ Not useful ☐ Quite Useful ☐ Very Useful ☐ Extremely Useful

3) How many times do you access it in a week?

☐ None ☐ Once ☐ Twice ☐ Three or more times

4) I use Lecture captures & Video support materials to… (Please Tick)
   a) Review Complex topics
   b) Revisit sections I missed during the Live lecture
   c) Make more detailed notes
   d) Take control over learning particularly through self-pacing.

5) Do you commute to University for Live lectures?

☐ Yes ☐ No

6) Is English your second language?

☐ Yes ☐ No

7) I prefer

☐ Full Lecture recordings ☐ Weekly Key-concept Videos ☐ Topic-wise videos

Appendix D: Multimodal Journaling Information

Study Title:

Investigating the impact of rich media resources on students' self-efficacy, statistics anxiety and performance.

Multimodal Journaling

Q) What is Multimodal Journaling?

The multimodal journaling is a unique style of journaling. This method focuses on the small-scale, emergent actions of everyday material and embodied practise.

Individuals doing multimodal journaling will generate data such as images, drawings, videos, and text notes. For this you can use your own device (phone or laptop) and you can also use your hands to make drawings pictures to describe what you feel and sense in that moment. You can also bring artefacts for me such as "an empty costa cup" which you used to drink coffee in when you were studying for this unit. Or a picture of your favourite study space/snack which you have when studying for this unit.

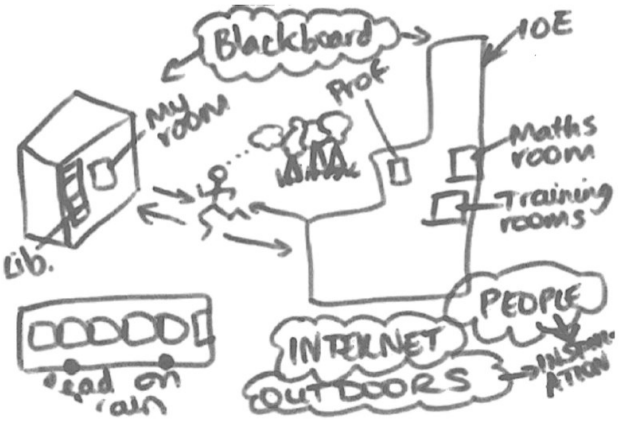
Participants are requested to pay attention to "messy," small-scale, day-to-day living activities. This focus was meant to show the networks that made up practise, including the material, spatial, and temporal elements that kept every day practises grounded. By paying attention to objects and processes in a very detailed way, this focus is meant to show these networks. Because stand-alone interviews can leave out important parts of the data and everyday life.

Examples of Multimodal Journaling are:

Notes: "*My favourite way of studying something is sitting down with a book and … a pen and some yellow paper and taking notes … And then I will use the technological side as well, because … Yes, I like combining the two, but I also like to be … the demarcation lines between them, you know, if I, if I have a reading to do then I can, then I almost, I invariably print it off and highlight." (Student056 Interview 1)*

I think they (the technologies) control me as well, because I can't really do anything without them. (Student Note 1).I don't feel I'm kind of like I'm really up to date with computers compared to a lot of people, but I feel like you just have to kept moving otherwise you will get left behind. (Student2 Note 1)

Figure 15.1A student's map of their study practices



Diagrams/drawings:

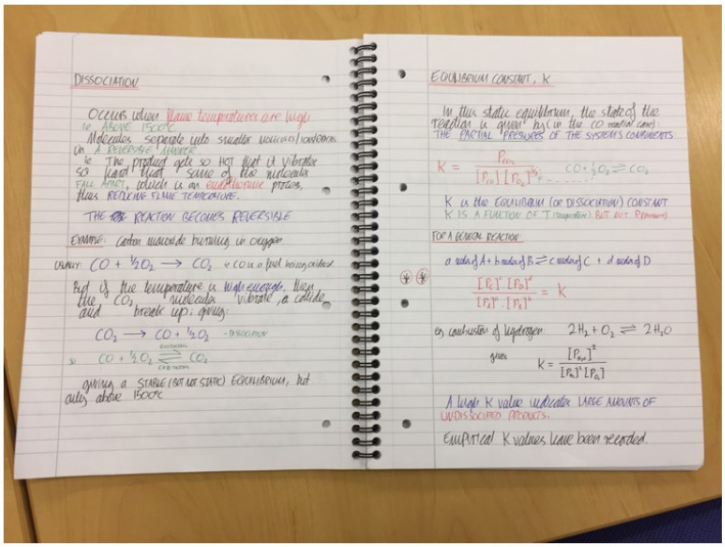


Figure 7. Example of notes taken by student participant 2.

Pictures/images:

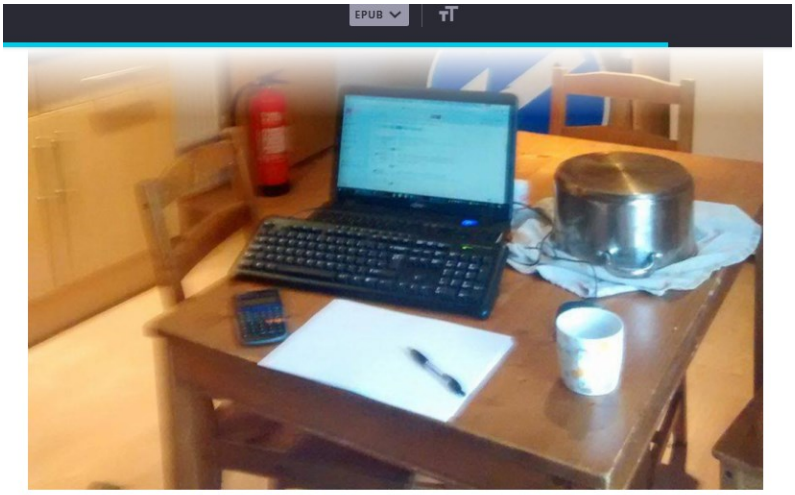
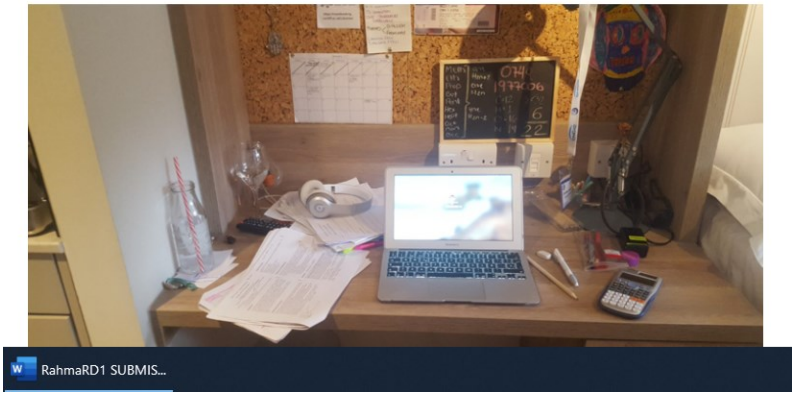


Figure 8. Photograph of study environment, provided by student participant 1.



Appendix E: Linked Degrees

Department of Engineering

BEng (Hons) Mechanical Engineering

BEng (Hons) Electrical & Electronic Engineering

BSc (Hons) Design Engineering

BEng (Hons) Biomedical Engineering

Department of Computing & Mathematics

BSc (Hons) Computer Forensics and Security

BSc (Hons) Computer Science

BSc (Hons) Software Engineering

BSc (Hons) Computing

BSc (Hons) Computer Games Technology

BSc (Hons) Computer Animation & Visual Effects

BSc (Hons) Mathematics

Department of Natural Sciences

BSc (Hons) Chemistry

BSc (Hons) Chemistry with Study Overseas

BSc (Hons) Pharmaceutical Chemistry

BSc (Hons) Medicinal & Biological Chemistry

Biology Sub-category

BSc (Hons) Animal Behaviour

BSc (Hons) Biology/ BSc (Hons) Biology with Study in North America

BSc (Hons) Microbiology and Molecular Biology

BSc (Hons) Wildlife Biology/ BSc (Hons) Zoology

Environmental Science Sub-category

BSc (Hons) Environmental Science

Geography Sub-category

BSc (Hons) Geography

BSc (Hons) Human Geography

BSc (Hons) Physical Geography

Department of Life Sciences

BSc (Hons) Biomedical Science

BSc (Hons) Human Biosciences

BSc (Hons) Human Physiology

Department of Sport & Exercise Science

BSc (Hons) Health & Exercise Science

BSc (Hons) Sport Coaching & Development

BSc (Hons) Sport & Exercise Science

Department of Health Professions (HPSC)

BSc (Hons) Physiotherapy

BSc (Hons) Speech & Language Therapy

Department of Psychology

BSc (Hons) Psychology

BSc (Hons) Psychology with Study Overseas

Department of Social Care & Social Work

BA (Hons) Integrated Health & Social Care

Appendix F: Assignment samples NDA1 and NDA 2

University

Science and Engineering

Foundation Year 2021– 2022

6G3Z3104: Numeracy and Data Analysis 1

Unit code:	**6G3Z3104 Numeracy and Data Analysis 1**
Assignment set by:	**Rahma Jawad**
Assignment type:	**Individual**
Date handed out:	**1st Feb**
Date handed in (the deadline):	**10th March before 9pm**
Percentage weighting towards total unit mark:	**100%**

Criteria for Assignment

- Apply algebraic rules, simplify equations and interpret functions.
- Analysis, graphical representation and summary of simple data set.
- Calculation of simple probability models.
- Application of probabilistic reasoning.

Guidelines:
1) Answer all of the following questions. You must clearly show all your working and formulas to gain full marks. Part marks are shown in square brackets.

2) Write the name of your lecturer and group number on the front cover page of your assignment so that we can sort out the scripts easily.

3) You can type the solutions or submit a properly scanned neat handwritten work.

4) Make sure all assignment pages have been numbered. Once complete, scan all the pages. Save all the scanned pages as a single Pdf file and submit this file online via Moodle.

5) You should be aware that evidence of copying will be severely penalized and dealt as a serious disciplinary matter in accordance with the University regulations.

You are advised to save a copy of your assignment or to ensure you have the means of re-creating it.
Please don't leave your submission to the last minute as you run the risk of it being recorded as a late submission. You should receive an e-mail receipt confirming your submission. For online submissions this is normally sent immediately.

If you are having problems submitting an assignment online, you should contact the IT Helpline on 0161

This coursework contains two sections: Numeracy (30 marks) and Data Analysis (70 marks). Total marks: 100.
Feel free to contact your tutor if you need any guidance regarding this work.

Section 1: Numeracy

Q1. Explain the distinction between:

i) $-x^2$ ***and*** $(-x)^2$
ii) $(xyz)^3$ ***and*** xyz^3
iii) $\sum x^2$ ***and*** $(\sum x)^2$

[3 marks]

Q2. Calculate the area of a rectangle with a length of $3\frac{2}{5}$ *m* and width of $1\frac{1}{10}$ *m*. Express your answer in **cm²**.

[2 marks]

Q3. Write the following number in the form 3^a, hence find the value of a.

$$\left(\sqrt{3}\right)^5 \div \left(\sqrt{27}\right)^{-2}$$

[3 marks]

Q4. The temperature of a liquid is reduced from 39.5°C to 35.5°C. Calculate the percentage change in temperature.

[2 marks]

Q5. A number, x is increased by 20% to form a new number y. y is then decreased by 20% to form a third number z. Express z in terms of x.

[3 marks]

Q6. Solve this expressing using BODMAS/BIDMAS rule. Show all the steps to gain full marks Should be (approx. 9 steps).

$$36 - 3(20 + 12 \div 2 \times 4 - 2 \times 2) + 7$$

[3 marks]

Q7. Answer the following:

a) The circumference of the planet Mars is about 21,000,000 m. What is this quantity expressed in scientific form (standard form) in meters?

b) Put the numbers below into scientific notation:

i. 0.000098742

ii. 750000002758

[3 marks]

Q8. A sum of £36000 is divided between Alex, Bill and Claire in the ratio of $2\frac{3}{4} : 1\frac{1}{2} : 2\frac{1}{4}$. Calculate the amount that each individual receives.

[3 marks]

Q9. The ratio of Jake's age and Alan's age is 10:9. The ratio of Erin's age and Alan's age is 29:27. Alan is over 40 years old but under 70 years old.

What is Alan's age? **[4 marks]**

Q10. Divide the sum of £7890 between Charlotte and Ali. Given that the Shares of Charlotte at the end of 6 years may be equal to the shares of Ali at the end of 8 years, Compound interest being 5%?

[4 marks]

[Section Total 30 Marks]

Please see next page for Data Analysis section.

Section 2: Data Analysis

Q1. The following data represents the 50 consecutive breakdown times, in minutes during working hours, of a particular machine.

10	10	11	12	15	16	16	17	17	24	25	27	29
30	31	31	37	41	43	44	44	46	48	49	49	50
52	55	56	56	56	61	62	62	67	73	78	83	84
84	84	86	87	87	87	88	89	89	90	98		

You are required to:

a) Calculate the median, mode, range and IQR. The first quartile for the above

data set is 28.5 and the third quartile is 83.25.
[5]

b) Using the **ungrouped data set:**

(i) Estimate the mean, giving your answers to 2 d.p.

[3]

(ii) Estimate the standard deviation, giving your answers to 2 d.p.

[5]

[13 marks]

Q2. A University has four sports clubs, which are football, rugby, basketball and badminton. Some of the data representing the number of club members for the selected clubs across a 3 year period was collected and is displayed in the table below.

	Year 1	Year 2	Year 3	Total
Football	550	350		1140
Rugby	200		40	320
Basketball		15	2	
Badminton	7		3	12
Total		447	285	**1512**

a) Complete the table.
[2]

b) Calculate the following probabilities for a person chosen at random from the above table. (Write your answer in fraction first and then 4 decimal places).

i. P(Year 3)
[2]
ii. P(Year 3 and Basketball)
[2]
iii. P(Year 1 OR Rugby)
[4]
iv. P(Year 2 | Football)
[2]
v. P(Badminton | Year 1)
[2]

c) Are the events “Year 3” and “Rugby” independent? Explain your answer.
[4]

[18 marks]

Q3. A commodity's stock price on Day 1 is £10. A financial expert forecasts this stock's trend for the next two days: Day 2 and Day 3. The probability of the stock price going up on Day 2 is 0.1. If it does go up, the probability of it going up again on Day 3 is 0.3. If not, the probability of the stock price going up again on Day 3 is 0.8.

a) Construct a tree diagram to show the probabilities of the stock price going up or down in the next two days.

[5]

b) Find the probability that the stock price:

(i) goes down on Day 3;

[3]

(ii) goes up on Day 2 given that it goes up on Day 3.

[4]

[12 marks]

Q4. A restaurant based in a city centre monitors the rate at which customers are arriving and leaving. It finds during a particular lunchtime, it finds that customers arrive at a mean rate of 4.5 in 30 minutes, while they leave at a mean rate of 2.2 in 30 minutes. Giving your answers to 2 d.p. calculate the probability that

a) exactly 6 customers arrive in one 30-minute period.
[3]

b) at most 3 customers leave in one 30-minute period.

[2]

c) between 2 and 5 customers inclusive leave in one 30-minute period.

[4]

d) at most 12 customers arrive in a 1-hour period.

[2]

e) between 5 and 7 customers inclusive leave in a 1-hour period.

[4]

[15 marks]

Q5. Following a survey, it is found that students at MMU are talented at playing football. Following physical assessments by coaches, results show that 5% of MMU students possess football skills classed at the professional level. A random sample of 10 students from the campus is obtained, and measurements of their football skills are taken.

a) Find the probability that none of the 10 students are classed at professional level.

[3]

b) Calculate the probability that fewer than 2 students in the sample are classed at professional level.

[3]

c) Find the probability that there are between 2 and 3, both inclusive, players classed at professional level in the sample.

[4]

d) Find the probability that 8 or more of these students in the sample are classed at professional level.

[2]

[12 marks]

[Section Total Marks 70]

Numeracy Section + Data Analysis Section = Assignment Total

30 Marks + 70 Marks = 100 Marks

University

Science and Engineering

Foundation Year 2021– 2022

6G3Z3105: Numeracy and Data Analysis 2

Unit code:	**6G3Z3105 Numeracy and Data Analysis 2**
Assignment set by:	**Rahma Jawad**
Assignment type:	**Individual**
Date handed out:	**March 2022**
Date handed in (the deadline):	**12th May 2022** before 9pm
Percentage weighting towards total unit mark:	**100%**

Criteria for Assignment

- Re-arranging mathematical formulas
- Linear equations and graphs
- Logarithms and exponential functions
- Continuous random variables and normal distribution
- Solving inverse problems for the normal distribution
- Distribution of the sample mean for the normal distribution
- Confidence intervals for the mean of the normal distribution
- Simple linear regression and correlation

Guidelines:
1) Answer all of the following questions. You must clearly show all your working and formulas to gain full marks. Please do not use this question paper for your working. Part marks are shown in square brackets.

2) Write the name of your lecturer and group number on the front cover page of your assignment so that we can sort out the scripts easily.

3) You can type the solutions or submit a properly scanned neatly handwritten work.

4) Make sure all assignment pages are numbered. Once complete, scan all the pages. Save all the scanned pages as a single Pdf file and name it with your student ID number. Submit this file online via Moodle.

5) You should be aware that evidence of copying will be severely penalized and dealt as a serious disciplinary matter in accordance with the University regulations.

You are advised to back up a copy of your assignment or to ensure you have the means of re-creating it.
Please do not leave your submission to the last minute as you run the risk of it being recorded as a late submission. You should receive an e-mail receipt confirming your submission. For online submissions this is normally sent immediately.

If you are having problems submitting an assignment online, you should contact the IT Helpline on xxxxxx or e-mail ithelpline@xx.ac.uk.

This coursework contains two sections: Numeracy (30 marks) and Data Analysis (70 marks). Total marks: 100.
Feel free to contact your tutor if you need any guidance regarding this work.

Appendix G: Phase 1: Semi-Structured Interview Questions

1. **Usage of Multimedia Resources** a. Do you watch the videos provided on Moodle for learning in this module? b. If yes, how often do you utilize them, and do you find them useful? c. If no, can you explain why you choose not to use them and whether you plan to use them in the future? d. Do you prefer watching the videos before the lecture in advance? e. Does pre-viewing help clarify or confuse the lecture content for you? f. Were you able to attempt the exercise questions after engaging with Rich Media Resources (RMR)?
2. **Student Preferences and Engagement** a. Which forms of rich media do you find most engaging, and why? b. How many times do you typically use rich media resources?
3. **Impact on Learning Ability and Emotional State** a. To what extent do you believe the resources improved your ability to learn? b. Did you experience any anxiety or emotional stress while using these resources?
4. **Efficacy of Multimedia Resources** a. How did you integrate the use of multimedia resources into your learning process? b. How effective were the rich-media materials as learning tools compared to traditional lectures?

Reflection on Interview Structure and Execution

Please note that not every participant was asked every question listed in the structured interview. The dynamic flow of the conversation and the distinctive context of each discussion dictated the selection of questions. I chose to ask questions that were most pertinent and suitable, depending on the evolving narrative and context of each individual conversation, to ensure relevance and coherence in the dialogue. This approach allowed for a more nuanced and contextually rich exploration of each participant's experiences and perceptions.

Appendix H: Assessment NDA 1

Numeracy section:

Q1 Simplify the following expressions:

a. $\sqrt{\left(\frac{27}{x^3}\right)^{-\frac{2}{3}}}$

b. $\left(\frac{48x^7y^{-1}}{3x^{-1}y^{-3}}\right)^{-\frac{3}{4}}$

[3+3=Total 6 Marks]

Q2. Transpose the following algebraic expressions to make **z** their subject. To obtain the full marks, you must show all the steps of your working.

a) $z^4 - 2z^2 + 1 = Y \qquad 0 \leq Y \leq 1$

b) $\frac{1}{z} + \frac{1}{y} = \frac{1}{x}$

c) $7 = \frac{ac+b}{zc+d}$

[3+3+3= Total 9 marks]

Q3. Use the three laws of logarithms to simplify the following expression:

$$\log_8\left(\frac{64r^6}{m^3}\right)$$

[4 marks]

Q4. A straight line passes through the points (-2,9) and (4,6)

a. Explain, with the help of a diagram, how you can tell that the line passes through the point (2,7) as well.

b. Explain how you can tell that the line has a gradient of -1/2. Show your full working. Also, explain the reason behind the negative gradient.
c. Write the equation of the line.
d. This line also passes through a point (10,*k*). Find the value of *k*.

[3+3+2+3= Total 11 marks]

[Section Total 30 Marks]

Please see next page for Data Analysis Section.

Data Analysis section:

Q1. A biologist investigates the intelligence of a flock of parrots with population standard deviation as 10. A sample of 7 parrots was randomly selected from the larger group. The scores in an animal perception test (out of 100) of each parrot in the sample are given below:

75 87 72 96 78 63 76

a) Calculate the sample mean **[2]**

b) A score of 75 is classed as 'intelligent'. Use a *z*-test to test the hypothesis that the mean perception score for this sample is 75 and determine whether the parrots are classed as intelligent. State any assumptions you make to carry out this test.
[8]

c) Calculate a 99% confidence interval for the mean perception score.
[3]

d) Calculate a 95% confidence interval for the mean perception score.
[3]

[Total marks 2+8+3+3=16]

Q2. A study investigates the effect of the number of hours of physical exercise per month, x, has on the score in a mental wellbeing test, y, for a number of patients suffering from depression. A scientist investigates the relationship between x and y, arguing that y depends on x, and obtains the measurements below:

x	Y
15	18
30	33
45	40
60	49
75	74
90	82

a. Plot the data on a scatter diagram using the graph paper. **[5]**
b. Label both of your axes and provide a suitable graph title. **[2]**
c. Estimate the equation of the regression line relating the mental wellbeing test score, y, to the number of hours of physical exercise, x. **[10]**
d. Superpose the regression line accurately on your diagram. **[3]**
e. Use the regression line in order to estimate the mental wellbeing test score, y, for an individual who engages in 50 hours of physical exercise per month. **[2]**

[Total marks 22]

Q3. A study is conducted to assess the extent to which anxiety score is related to work hours. The researchers believe that these variables are positively correlated

a) Plot the data on a graph and comment on the relationship **[3]**
b) Find the linear correlation coefficient **"r"** **[5]**
c) Is it a strong correlation? Explain your answer **[2]**

X	Y
14.2	21.5
16.4	32.5
11.9	18.5
15.2	33.2

18	40.6
22	52.2
25	61.4
23	54.4
17	40.8
18	40.2

Formula:

$$r = \frac{n\sum XY - (\sum X)(\sum Y)}{\sqrt{(n\sum X^2 - (\sum X)^2).(n\sum Y^2 - (\sum Y)^2)}}$$

[Total marks 10]

Q4. The haemoglobin levels for healthy adult females are approximately normally distributed with a mean of $\mu = 17$ and standard deviation $\sigma = 0.9$.

$$X \sim N(17, 0.9^2)$$

b. Find the probability that a randomly chosen healthy female adult has a haemoglobin level
   - **i.** Less than 15 **[3]**
   - ii. Between 16 and 18 **[4]**
   - **iii.** More than 17.5 **[3]**

c. Find the probability that the mean haemoglobin level of a group of five adult females will be above 17.5 **[4]**

d. Find the probability that the mean haemoglobin of a group of 20 female adults will be between 17.5 and 17.75 **[4]**

e. Find the haemoglobin level X for which 90% of the adult females have haemoglobin level less than X **[4]**

[Total marks (3+4+3=10)+4+4+4=22]

[Section Total Marks 70]

Numeracy Section + Data Analysis Section = Assignment Total

30 Marks + 70 Marks = 100 Marks

Appendix I: Phase 2 Participants

Pseudonym	**Gender**	**Link Degree**	**Special Learning Needs (PLP)**
Ayesha	Female	Social Care & Social Work	No
Ben	Male	Computing & Mathematics	Yes
Alexa	Female	Computing & Mathematics	No
Hazel	Female	Health Professions	No (Mature student)
Harper	Female	Health Professions	No
Oliver	Male	Department of Computing & Mathematics	No
Aly	Prefer not to say	Health Professions	No
Maggy	Female	Psychology	No
Burnie	Female	Health Professions	Yes (Anxiety)
Huma	Female	Social Care & Social Work	No
Sammy	Female	Mathematics	No (Mature student)
Bina	Female	Health Professions	Yes (Confidential)
Olivia	Female	Social Care & Social Work	Yes
Siddiq	Male	Department of Natural Sciences	Yes (Anxiety/Diabetes)
Chloe	Female	Computing & Mathematics Department	No

Pseudonym	Gender	Link Degree	Special Learning Needs (PLP)
Alishbah	Female	Health Professions	No
Mandy	Female	Health Professions	No

Appendix J: Phase 1 Participants

Pseudonym	**Gender**	**Link degree**	**Special Learning Needs** (**PLP:** *stands for* **Personal Learning Plan)**	**Phase 1: Data type**
Ayesha	Female	Social Care & Social Work	No	Observations and Field notes, Semi-structured interview (not recorded)
Ben	Male	Computing & Mathematics	Yes	Observations and Field notes, Semi-structured interview (recorded)
Alexa	Female	Computing & Mathematics	No	Observations and Field notes, Semi-structured interview (recorded)
Hazel	Female	Health Professions	No (Mature student)	Observations and Field notes, Semi-structured interview (not recorded)
Harper	Female	Health Professions	No	Observations and Field notes, Semi-structured interview (recorded)
Oliver	Male	Department of Computing & Mathematics	No	Observations and Field notes, Semi-structured interview (not recorded) Online via MS teams
Aly	Prefer not to say	Health Professions	No	Observations and Field notes, Semi-structured interview (recorded)
Maggy	Female	Psychology	No	Observations and Field notes, Semi-structured interview (recorded)
Burnie	Female	Health Professions	Yes (Anxiety)	Observations and Field notes, Semi-structured interview (not recorded) online via MS teams
Huma	Female	Social Care & Social Work	No	Observations and Field notes, Semi-structured interview (not recorded)
Sammy	Female	Mathematics	No (Mature student)	Observations and Field notes, Semi-structured interview (not recorded)
Bina	Female	Health Professions	Yes (Confidential)	Semi-structured interview (not recorded) online via MS teams
Ollie	Prefer not to say	Health Professions	Yes (Autism)	Semi-structured interview Face to face (not recorded)

Appendix K: Further analysis on SAS

The descriptive statistics for the examination anxiety subscale and asking for help anxiety subscale.

However, it is important to note that the correlation between Examination anxiety and Help-seeking anxiety, regardless of whether students viewed RMR or not, remains very low (as shown in Figure 22). This suggests that the Examination Anxiety subscale and Help-seeking Anxiety subscale contain distinct information, while Interpretation anxiety overlaps with the other two subscales. The exclusion of the interpretation anxiety from the current analysis was not supported by the output of factor analysis. As highlighted by O'Bryant (2019), this decision also seemed conceptually justifiable, given that taking an exam and asking for assistance are discrete tasks whereas interpreting numbers is not.

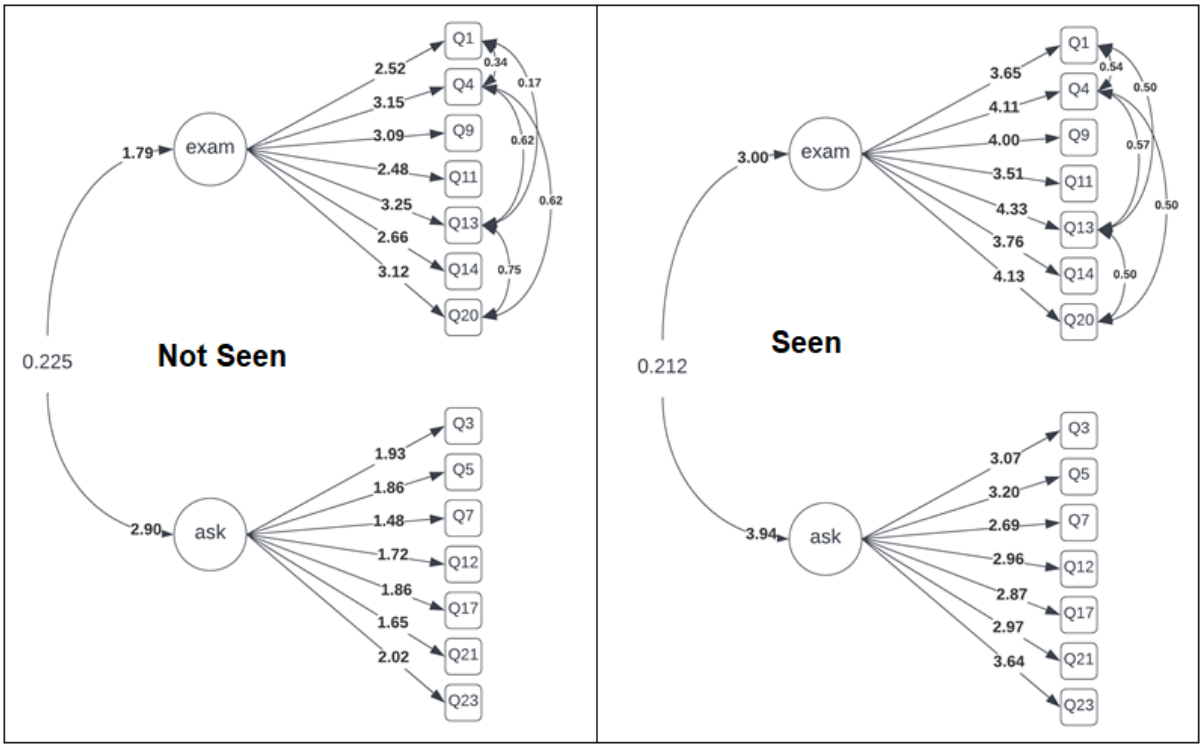


Figure 22: Tree diagram shows correlations and averages split by Content seen or not seen groups with breakdown

The descriptive statistics for the examination anxiety subscale and asking for help anxiety subscale

Students who engaged with rich media resources reported significantly higher levels of both exam anxiety and anxiety associated with asking for help compared to those who did not use such resources, as is evident from the data presented in Table 6.

Table 6. Descriptive statistics of the two subscales of SAS

	RMR viewed ?			Statistic	Std. Error
Exam Anxiety related Questions Average	No	Mean		2.8864	.14131
		95% Confidence Interval for Mean	Lower Bound	2.6014	
			Upper Bound	3.1713	
		Std. Deviation		.93732	
	Yes	Mean		3.8820	.12562
		95% Confidence Interval for Mean	Lower Bound	3.6290	
			Upper Bound	4.1350	
		Std. Deviation		.85200	
Asking for help anxiety related Questions Average	No	Mean		1.7662	.11012
		95% Confidence Interval for Mean	Lower Bound	1.5442	
			Upper Bound	1.9883	
		Std. Deviation		.73044	
	Yes	Mean		2.9876	.16339
		95% Confidence Interval for Mean	Lower Bound	2.6585	
			Upper Bound	3.3167	
		Std. Deviation		1.10813	

The mean difference in exam anxiety SAS score between those who viewed RMR and those who did not was 0.9956, while the mean difference in help-anxiety between these two groups was 1.221. The effect sizes for Exam Anxiety (d = 1.112) and Asking for Help Anxiety (d = 1.301) were calculated using Cohen's d, suggesting a large effect size between the groups.

Delving into the details, for the Exam Anxiety subscale, the mean SAS score for students who viewed RMR was 3.8820 (SD=0.85200), while for students who did not view RMR it was 2.8864 (SD=0.93732). Similarly, for the Asking for Help Anxiety subscale, the mean SAS score for students who viewed RMR was 2.9876

(SD=1.10813), whereas it was 1.7662 (SD=0.73044) for those who did not view RMR.

Notably, the mean scores for both subscales were higher for students who viewed RMR, indicating higher levels of anxiety. This implies that students who make use of RMR are typically those who are already experiencing elevated levels of anxiety in their statistics courses and are seeking additional resources as a potential coping strategy. In light of these results, it can be seen that rich media resources appear to have an appeal for students who are experiencing higher levels of statistics-related anxiety. This initial finding sets the stage for further exploration in Research Questions 3 and 4. The third question will delve into how using rich media resources might aid students in becoming more aware of their embodied reactions to statistics-related texts meant to engage their minds, bodies, and emotions. The fourth question will investigate how students and material things, such as rich media resources, interact to form a holistic statistical e-learning experience. These future investigations will provide a more in-depth understanding of how rich media resources can potentially alleviate statistics anxiety and contribute to a more positive e-learning experience. For the time being, educators could consider the incorporation of RMR into their teaching methods as an additional support for students grappling with heightened anxiety in their statistics courses.

Appendix L: Phase 1 & 2 Quirkos Themes

Quirk Title	Parent	Grandparent	Description	Author	Date	Total Codes
Attendance/engagement in live sessions				rahma jawad	Invalid Date	4
Assignment				rahma jawad	Invalid Date	7
Pause/PLAy				rahma jawad	Invalid Date	7
ARTEFACTS				rahma jawad	Invalid Date	3
Maths prior knowledge				rahma jawad	Invalid Date	9
RMR			View points on RMR. Their usage, any experiences	rahma jawad	Invalid Date	27
Statistics Anxiety				rahma jawad	Invalid Date	9
Location				rahma jawad	Invalid Date	13
Personal learning style/preference				rahma jawad	Invalid Date	17
Fear				rahma jawad	Invalid Date	3
Self-efficacy				rahma jawad	Invalid Date	15
Time of viewing the videos				rahma jawad	Invalid Date	11
Extra Time				rahma jawad	Invalid Date	6
Material(NON HUMAN ACTORS)				rahma jawad	Invalid Date	8
Pressure/stress				rahma jawad	Invalid Date	9
Write notes				rahma jawad	Invalid Date	8
TOTAL NUMBER OF CODES	156					
TOTAL NUMBER OF QUIRKS	16					

Appendix M: Field notes diary

Appendix N: Phase 1 and 2 interview details

Most of my interviews were conducted either before or after study sessions with students. Typically, the semi-structured interviews occurred post-lecture, once the other students had vacated the room, or during my office hours. There were instances when, if I wasn't recording the session and was instead taking notes, I would forget to mark the precise end time of the interview. In those cases, I relied on my recollection to estimate and record an approximate duration. An unexpected situation arose with Bina when a fire alarm interrupted our session, preventing me from noting the exact timing.

Pseudonym	Gender	Participant Interview Length **approx length** (phase 1 and 2 combined)	Academic Year
Ayesha	Female	Two semi-structured interviews: 11 mins, 23 mins	2022
Ben	Male	One semi-structured interview: 28 mins	2022
Alexa	Female	One semi-structured interview: 24 mins	2022
Hazel	Female	Two semi-structured interviews: 12 mins, 21 mins	2022
Harper	Female	Three interviews: approx. 15, 32, 18 mins	2022
Oliver	Male	One interview: 8 mins	2022
Aly	Prefer not to say	One interview: approx. 35 mins	2022
Maggy	Female	One interview: 23 mins	2022
Burnie	Female	Two semi-structured interviews: 16 mins, 11 mins	2022
Huma	Female	Two semi-structured interviews: 12 mins, 26 mins	2022
Sammy	Female	Two semi-structured interviews: 31 mins, 14 mins	2022
Bina	Female	Two interviews: 9 mins, 15 mins (fire alarm interruption)	2022
Olivia	Female	Two interviews: 32 mins, 28 mins	2023
Siddiq	Male	Two interviews: 28 mins, 42 mins	2023
Chloe	Female	One interview: 16 mins	2023
Alishbah	Female	Two interviews: 27 mins, 10 mins	2023
Mandy	Female	Two interviews: 31 mins, 35 mins	2023
Ollie	Prefer not to say	Semi-structured interview: 47 mins Face to face (not recorded)	2023

Appendix O: Statistical Figures

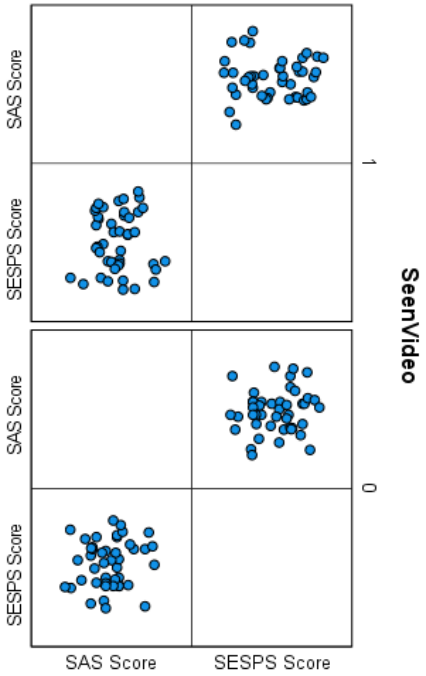


Figure 23. Scatterplots showing correlations between statistics self-efficacy and statistical anxiety

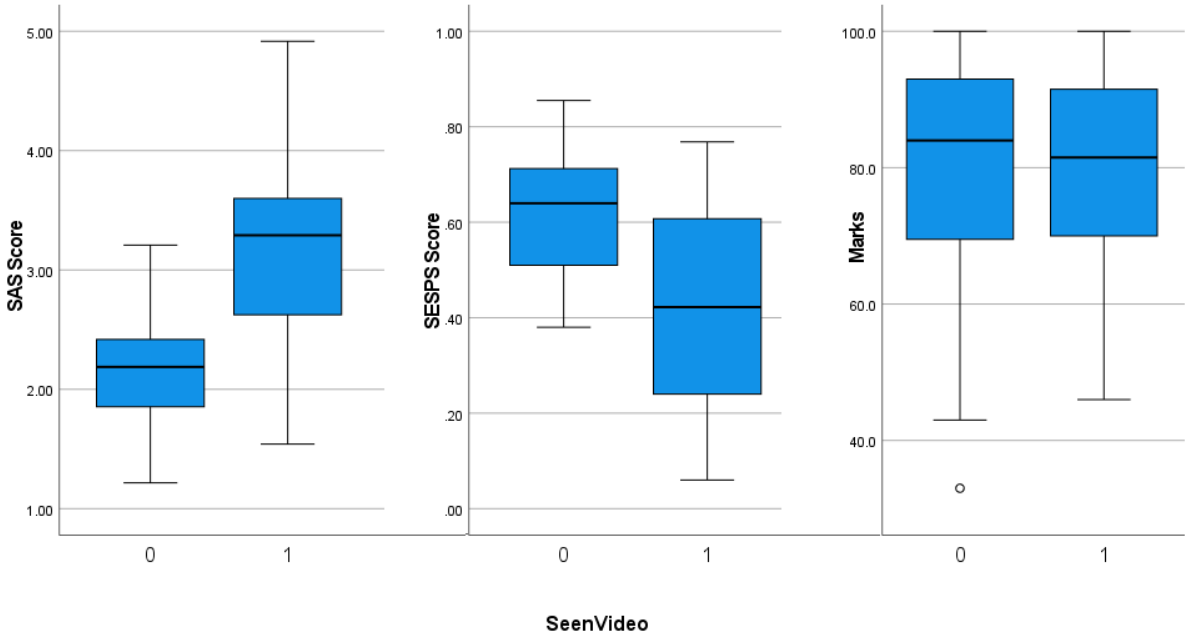


Figure 24. Box plots for SAS score, SESPS score and Marks separated by students who have engaged with the RMR (1) or not (0)

Appendix P: SPSS MANOVA Full Results

a. Design: Intercept + Q3

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[c]
Intercept	Pillai's Trace	.992	5452.229[b]	2.000	85.000	<.001	.992	10904.459	1.000
	Wilks' Lambda	.008	5452.229[b]	2.000	85.000	<.001	.992	10904.459	1.000
	Hotelling's Trace	128.288	5452.229[b]	2.000	85.000	<.001	.992	10904.459	1.000
	Roy's Largest Root	128.288	5452.229[b]	2.000	85.000	<.001	.992	10904.459	1.000
RMR engage-ment (Q3)	Pillai's Trace	.529	47.729[b]	2.000	85.000	<.001	.529	95.458	1.000
	Wilks' Lambda	.471	47.729[b]	2.000	85.000	<.001	.529	95.458	1.000
	Hotelling's Trace	1.123	47.729[b]	2.000	85.000	<.001	.529	95.458	1.000
	Roy's Largest Root	1.123	47.729[b]	2.000	85.000	<.001	.529	95.458	1.000

a. Design: Intercept + Q3
b. Exact statistic
c. Computed using alpha = .05

Levene's Test of Equality of Error Variances[a]

		Levene Statistic	df1	df2	Sig.
SAS score	Based on mean	5.939	1	86	.017
	Based on median	5.654	1	86	.020
	Based on median and with adjusted df	5.654	1	74.998	.020
	Based on trimmed mean	5.985	1	86	.016
SESPS_Log	Based on mean	.767	1	86	.384
	Based on median	.772	1	86	.382
	Based on median and with adjusted df	.772	1	85.977	.382
	Based on trimmed mean	.790	1	86	.377

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + Q3

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[c]
Corrected Model	SAS Score	22.961[a]	1	22.961	61.280	<.001	.416	61.280	1.000
	SESPS_Log	4.269[b]	1	4.269	29.699	<.001	.257	29.699	1.000
Intercept	SAS Score	648.854	1	648.854	1731.711	<.001	.953	1731.711	1.000
	SESPS_Log	1262.145	1	1262.145	8780.674	<.001	.990	8780.674	1.000
RMR engage-ment (Q3)	SAS Score	22.961	1	22.961	61.280	<.001	.416	61.280	1.000
	SESPS_Log	4.269	1	4.269	29.699	<.001	.257	29.699	1.000
Error	SAS Score	32.223	86	.375					
	SESPS_Log	12.362	86	.144					
Total	SAS Score	704.039	88						
	SESPS_Log	1278.775	88						
Corrected Total	SAS Score	55.184	87						
	SESPS_Log	16.631	87						

a. R Squared = .416 (Adjusted R Squared = .409)
b. R Squared = .257 (Adjusted R Squared = .248)
c. Computed using alpha = .05

Table 7. Performance independent sample tests

		Levene's Test for Equality of Variances		t-test for Equality of Means						
						Significance		Difference		95% CI the Diff
		F	Sig.	t	df	One-Sided p	Two-Sided p	Mean	Std. Error	Lower	Upper
Marks	Equal variances assumed	.686	.410	-.311	84	.378	.756	-1.0122	3.2536	-7.4824	5.4580
	Equal variances not assumed			-.309	78.612	.379	.758	-1.0122	3.2796	-7.5406	5.5162