The Contribution of Interdisciplinary Teaching to the Development of Students' Employability

Alex Crombie

Sheffield Hallam University

Submitted in Partial Fulfilment of the Requirements for the Degree of Doctor of Philosophy

October 2023

Candidate Declaration

I hereby declare that:

1. I have not been enrolled for another award of the University, or other academic or professional organisation, whilst undertaking my research degree.

2. None of the material contained in the thesis has been used in any other submission for an academic award.

3. I am aware of and understand the University's policy on plagiarism and certify that this thesis is my own work. The use of all published or other sources of material consulted have been properly and fully acknowledged.

4. The work undertaken towards the thesis has been conducted in accordance with the SHU Principles of Integrity in Research and the SHU Research Ethics Policy.

5. The word count of the thesis is 48,433

Name	Alex Crombie
Date	October 2023
Award	PhD
Research Institute	MERI
Director of Studies	Peter Rowlett

Abstract

Employability, a multifaceted and elusive concept, proves challenging to define and measure. It involves a complex interplay of skills, knowledge, attitudes, and personal attributes that individuals bring to the workplace. To make this concept more tangible, various authors have attempted to formulate employability models tailored for higher education settings. While these models differ in their emphases, a recurring theme across them is the significance of self-efficacy. This work contends that self-efficacy can serve as a parametric measure to assess the effectiveness of employability interventions. Specifically, it explores the impact of interdisciplinary teaching on students' employability, positing that such pedagogy can illuminate overlooked mastery experiences within a subject and alleviate disciplinary egocentrism—both of which are expected to positively influence employability outcomes. It has been discussed in the literature that graduate employability is often poor and, in this work, we aim to examine the relationship between this and students' non-disciplinary understanding. To establish this connection a teaching intervention was devised to examine how interdisciplinary teaching can affect students' feelings of self-efficacy and their understanding of their own level of knowledge – to this end the *generalised self-efficacy scale* along with a *false consensus effect* tool were used to gather data pre- and post-intervention to make comparisons. We find weak to moderate agreement that this intervention style improves self-efficacy and limited evidence that the false consensus effect is impacted. These results suggest that this form of teaching intervention has the potential to benefit students beyond their disciplinary education, however more work is necessary to establish the level and longevity of this benefit.

Contents

1 Introduction

In recent years, the United Kingdom's higher education sector has experienced unprecedented growth, resulting in a surge of graduates entering the job market (Tight, 2019). This expansion, while indicative of increased educational accessibility, has led to a paradigm shift where possessing a degree is no longer sufficient for consideration in certain employment sectors, echoing Tomlinson's assertion that "the degree is not enough" (Tomlinson, 2008). This evolving landscape, coupled with the rise in tuition fees and the market-oriented nature of higher education, has transformed students into discerning consumers making strategic choices about their education (Bunce, Baird, & Jones, 2017; Molesworth, Scullion, & Nixon, 2010).

As higher education institutions grapple with these changes, the imperative to understand and enhance graduate employability becomes increasingly crucial. Graduates are not only seeking academic knowledge but are also navigating a complex job market that demands a diverse skill set (Figueiredo, Biscaia, Rocha, & Teixeira, 2017). The intersection of higher education and employability is a critical juncture that necessitates exploration, especially as universities adapt to meet the demands of an ever-evolving job market. (Bowden, Hart, King, Trigwell, & Watts, 2000) In this context, research on employability assumes great significance, offering insights that can inform practices and policies across the educational spectrum.

The notion of employability is complex and multifaceted. Various researchers have attempted to define and operationalise this concept to better understand its implications for both students and educators; Hillage & Pollard's (Hillage & Pollard, 1998) definition emphasizes knowledge and attitudes, stating that employability is "about being capable of getting and keeping fulfilling work" and involves the capability to navigate the labour market independently for sustainable employment. Bowden et al. adopt a broader perspective, defining employability as a set of graduate attributes that a university community agrees its students should develop during their time at the institution, shaping their contributions to their professions and society. Knight and Yorke (Knight, Peter & Yorke, 2003a) offer a comprehensive definition, viewing employability as "a set of achievements—skills, understandings, and personal attributes—that make individuals more likely to gain employment and be successful in their chosen occupations".

While these definitions contribute to the theoretical understanding of employability, they often remain abstract and less instructive for educators seeking practical ways to enhance students' employability. To bridge this gap, several authors have proposed employability models aimed at providing tangible frameworks for educators.

The changing dynamics of the job market and the increasing expectations placed on graduates have transformed the role of higher education. Traditionally, a university education was seen as a pathway primarily for future academics and researchers (Klein, 1990). However, degrees are now a starting point for diverse career trajectories. The proliferation of graduates has altered the competitive landscape, making it essential for universities to focus not only on academic excellence but also on preparing students for the demands of a dynamic job market (Sam & Van der Sijde, 2014).

In this evolving environment, employability has become a valued feature for stakeholders across the educational spectrum. Graduates leaving with enhanced employability are more likely to secure employment and employers' benefit from recruiting immediately useful employees (Wakeham, 2016). As such, employability research becomes increasingly timely as the nature of higher education continues to change, and this research has the capacity to be informative to a wide audience.

Much research has been dedicated to employability, aiming not only to define the concept but also to develop models that guide educators in enhancing this critical skill set. Notable among these models is the emphasis on self-efficacy development as a component of employability (McArdle, Waters, Briscoe, & Hall, 2007). Self-efficacy, a concept rooted in Bandura's social cognitive theory, refers to an individual's belief in their ability to perform a specific task or achieve a particular goal (Bandura, Freeman, & Lightsey, 1999a). In the context of employability, self-efficacy becomes pivotal as it influences one's confidence in meeting the demands of the workplace.

Hillage & Pollard's model, for instance, aligns with the broader definition of employability and emphasizes the role of self-efficacy in navigating the labour market. Bowden et al.'s model incorporates self-efficacy as part of the graduate attributes that contribute to employability. Knight and Yorke's extensively cited definition explicitly includes self-efficacy, viewing it as a

personal attribute that contributes to an individual's likelihood of gaining employment and being successful in their chosen occupations.

While these models contribute to the conceptualisation of employability, they often remain within the domain of researchers and do not readily translate into actionable strategies for educators. Recognising this gap, a subset of researchers has attempted to provide more practical insights by developing employability models tailored for educators. These models, often emphasizing self-efficacy, aim to sub-divide and categorise the field, making it more relevant to individuals delivering teaching material.

1.1 The Traditional Pedagogical Approach: Disciplinary Silos.

In the UK, the traditional method of delivering curricula in higher education involves guiding students through a singular discipline within single intake groups. This approach, while efficient in certain aspects, has been critiqued for creating what can be described as academic cloistering (Cohen, E. B. & Lloyd, 2014). Within these disciplinary silos, students interact predominantly with peers who share their academic focus. While this approach allows for deep engagement within a specific field, it inadvertently limits interactions that could contribute to a more holistic educational experience.

This academic cloistering is argued to have a detrimental effect on employability (Bear & Skorton, 2019). The restriction of students' interactions to academic peers denies them the benefits that would be present in a mixed 'society' of learners. One key consequence is the potential overlooking of mastery experiences, a critical component of self-efficacy development. Mastery experiences, as conceptualized by Bandura, refer to successful achievements that contribute to an individual's belief in their abilities (Bandura, Freeman, & Lightsey, 1999a). In disciplinary silos, the exposure to varied contexts and applications is limited, thus restricting the identification of these mastery experiences.

Furthermore, the traditional approach to higher education contributes to the development of disciplinary egocentrism (Richter, Paretti, & McNair, 2009). This term, coined by sociologist Michael Polanyi, refers to the tendency of individuals to view their discipline as the central reference point, often dismissing or undervaluing insights from other fields (Richter & Paretti, 2009). Disciplinary egocentrism can hinder adaptability and creativity, both of which are crucial attributes in today's rapidly evolving job market.

1.2 The Hypothesis: Interdisciplinary Teaching as an Intervention

This work argues that interdisciplinary teaching can serve as a transformative intervention to address the limitations of the traditional pedagogical approach. Interdisciplinary teaching involves integrating concepts and methods from multiple disciplines, encouraging students to engage with diverse perspectives and apply knowledge across boundaries. The hypothesis driving this exploration is twofold.

Firstly, interdisciplinary teaching is posited as a means to illuminate mastery experiences that might be overlooked in traditional, discipline-specific approaches. By exposing students to a variety of contexts and applications, interdisciplinary teaching provides a fertile ground for the identification of mastery experiences, consequently contributing to the development of self-efficacy.

Secondly, interdisciplinary teaching is expected to mitigate disciplinary egocentrism. By breaking down disciplinary silos and fostering a collaborative learning environment, students are encouraged to appreciate the interconnectedness of knowledge across various fields. This holistic perspective is anticipated to better prepare students to navigate complex, real-world challenges, thus enhancing their employability.

1.3 Challenges and Considerations

While the potential benefits of interdisciplinary teaching for employability are promising, several challenges and considerations must be acknowledged. Implementation hurdles, resistance to implementation, and the need for ongoing professional development are common challenges in adopting interdisciplinary approaches (Holley, 2009). Moreover, the diverse nature of interdisciplinary programs makes it challenging to develop standardised assessments for employability outcomes.

Addressing these challenges requires institutional support, faculty training, and continuous evaluation of the effectiveness of interdisciplinary initiatives. Collaborative efforts between educators, administrators, and policymakers are essential to navigate these challenges and create an environment conducive to the successful integration of interdisciplinary teaching within higher education.

2 Research Questions

This work intends to address the questions of whether interdisciplinary teaching has an overall beneficial effect on students and more specifically, if a benefit can be demonstrated, whether this benefit can be seen in their employability. In addressing these questions this work has a number of intermediate aims and ultimate objectives.

This research seeks to explore the impact of interdisciplinary teaching on students' educational experiences and future career prospects. The core question driving this investigation is whether the integration of interdisciplinary approaches within higher education curricula provides tangible benefits to students. Specifically, the study aims to determine if such benefits extend beyond academic enrichment to positively influence students' employability upon graduation.

To address this overarching inquiry, the research is designed to explore a series of related sub-questions: Does interdisciplinary teaching enhance students' ability in specific cognitive areas? How do students perceive the value of interdisciplinary learning? Furthermore, if interdisciplinary teaching is found to have a positive impact, what specific aspects of employability are most significantly affected?

In pursuing these questions, this research encompasses a range of intermediate aims, including the assessment of students' skill development and the evaluation of their preparedness for employment. The ultimate objectives are to provide evidence-based insights into the effectiveness of interdisciplinary teaching and to identify best practices for its implementation in higher education. By doing so, the study aims to contribute to the broader discourse on how educational strategies can be aligned with the evolving demands of the job market, thereby enhancing the employability of graduates.

This work intends to gather a knowledge base on the current state of the art in interdisciplinary education research along with developing a theoretical grounding in the field of social research. By investigating these two areas of theory it is hoped that any conclusions drawn from the outcomes of this research will be more defensible.

Ultimately it is hoped that a defensible statement about the effect of interdisciplinary teaching on graduate employability can be made through this research. Through documenting the

research process, it is hoped to be able to make recommendations on how to practically apply the findings, where interdisciplinary teaching may be most appropriate and identify areas where this form of intervention may be difficult to apply. Essentially, I would hope to produce a 'how to guide' to inform the practice of others who wished to implement this form of teaching in their own practice.

Through this work, developing a deeper understanding of the social process involved in this form of interaction, such that this knowledge would be able to inform future research and it intends to add to the current body of the knowledge in both the field of higher education research and social theory.

2.1 Aims

1. To assess the impact of interdisciplinary teaching interventions. This focuses on determining whether interdisciplinary approaches, have a measurable impact on students.

2. To explore the relationship between interdisciplinary learning experiences and the development of employability skills. This seeks to identify specific skills that could be enhanced through interdisciplinary teaching and determine their relevance to employability.

3. To contribute to the development of best practices for implementing interdisciplinary teaching interventions in higher education curricula. This involves using the findings to inform and guide educational institutions on how to effectively integrate interdisciplinary approaches to improve student outcomes.

2.2 Objectives

1. To design and implement an interdisciplinary teaching intervention within a higher education curriculum.
   - Develop a teaching intervention that integrates multiple disciplines

2. To develop a method for measuring employability.
    - Use current theory and practice to inform the development and/or deployment of method of identifying changes in student employability

3. To develop a mixed methods approach for measuring the impact of this interdisciplinary teaching intervention.
    - Create quantitative surveys and qualitative interview protocols to assess students' skill acquisition, confidence, and perceptions of their employability.
    - Implement pre- and post-intervention assessments to measure changes in employability-related skills and attributes.

4. To collect and analyse quantitative data on outcomes of students who participated in the interdisciplinary intervention.

5. To conduct qualitative research through interviews and focus groups with students and educators.
    - Explore perceptions of the effectiveness of the interdisciplinary intervention.
    - Identify specific skills and competencies gained through the intervention.

6. To evaluate the overall impact of the interdisciplinary teaching intervention on graduate employability.
    - Integrate the findings from both quantitative and qualitative data to provide a comprehensive assessment of the intervention's effectiveness.
    - Identify key factors that contribute to the success or limitations of the intervention in improving employability.

7. To disseminate the research findings and recommend strategies for higher education institutions to enhance employability through interdisciplinary approaches.
    - Present the findings through academic publications, conferences, and workshops.
    - Provide actionable recommendations on how to effectively incorporate interdisciplinary teaching to improve employability outcomes.

3 Background theory

This section examines various employability models, providing a comprehensive overview of their strengths and weaknesses. Additionally, the section explores the role of self-efficacy as a crucial component in these models and discusses the impact of disciplinary egocentrism on employability. Grounded in social theory, particularly Bandura's concept of self-efficacy, Mead's social philosophy, and Piagetian developmental theory, this exploration aims to lay the theoretical foundation for the subsequent empirical investigation.

3.1 Interdisciplinarity

Interdisciplinarity, a term frequently encountered in higher education and beyond, represents a profound departure from traditional disciplinary boundaries, fostering collaboration and innovation across various domains of knowledge (Nissani, 1995). To comprehend the intricate tapestry of interdisciplinarity, it is crucial to first differentiate it from related concepts like multi-disciplinarity, trans-disciplinarity, and cross-disciplinarity. In support of this we consider the historical evolution of interdisciplinarity in higher education and exploring its roots in the German concept of 'wissenschaft,'.

3.1.1 Differentiating Interdisciplinarity:

3.1.1.1 Multi-disciplinarity

Multi-disciplinarity, as a collaborative approach, involves the simultaneous engagement with multiple disciplines, each maintaining its distinct methodologies and frameworks. This mode of collaboration occurs at the intersection or interface of disciplines, aiming to harness the strengths of each field without fully integrating them. It stands as a middle ground between the specialised focus of individual disciplines and the more comprehensive integration seen in interdisciplinary or transdisciplinary approaches.

In multi-disciplinary endeavours, people different fields come together to address complex issues, drawing on the unique perspectives and methodologies inherent to their respective domains. The intention is not to create a new, synthesized discipline but to leverage the diverse expertise available for a more nuanced understanding of a particular problem or question.

However, the depth of integration in multi-disciplinarity remains limited compared to more integrated approaches. The distinctive methodologies and frameworks of each discipline are preserved, often resulting in parallel investigations that contribute complementary perspectives to the overarching theme. While this approach facilitates a broader understanding, it may sometimes lack the depth achieved through a more intensive interdisciplinary or transdisciplinary collaboration.

3.1.1.2 Trans-disciplinarity

Trans-disciplinarity represents a paradigm shift in collaborative approaches, going beyond the confines of disciplinary boundaries to achieve a holistic understanding of complex issues. Unlike multi-disciplinarity, which engages with multiple disciplines while maintaining their distinct methodologies, trans-disciplinarity seeks integration and synthesis across diverse perspectives.

The essence of trans-disciplinarity lies in fostering a comprehensive and interconnected framework that surpasses the limitations of disciplinary silos. It not only involves collaboration among researchers from different academic domains but can also extend its reach to include insights from non-academic stakeholders such as community members, policymakers, and industry experts. This inclusive approach acknowledges that complex challenges often demand a convergence of diverse knowledge sources.

Trans-disciplinary research often operates within real-world contexts, emphasizing the practical application of knowledge. The integration of academic and non-academic perspectives is crucial for generating solutions that are not only scientifically sound but also socially and culturally relevant. This approach aligns with the growing recognition that many global challenges, such as public health crises or environmental degradation, cannot be adequately addressed through isolated disciplinary lenses.

Trans-disciplinarity represents a forward-thinking approach to collaborative problem-solving, emphasizing integration and synthesis across diverse perspectives. By transcending disciplinary boundaries, trans-disciplinary initiatives strive for a holistic understanding of complex issues, acknowledging the multifaceted nature of real-world challenges.

3.1.1.3 *Cross-disciplinarity*

Cross-disciplinarity represents a collaborative approach that emphasizes the intersection of insights from closely related fields. Unlike trans-disciplinarity, which transcends disciplinary boundaries entirely, and multi-disciplinarity, which engages with multiple disciplines simultaneously, cross-disciplinarity seeks to blend the strengths of adjacent fields with shared methodologies and terminologies.

The essence of cross-disciplinarity lies in recognising that neighbouring disciplines often hold complementary perspectives and methodologies that, when combined, can lead to more comprehensive and nuanced solutions. This collaborative model fosters a synergistic relationship between disciplines that share common ground, encouraging researchers to look beyond the confines of their specific field and leverage the strengths of related domains.

Cross-disciplinarity offers a middle ground between multi-disciplinarity and trans-disciplinarity, emphasizing collaboration between adjacent fields with shared methodologies and terminologies.

3.1.1.4 *Interdisciplinarity*

Interdisciplinarity stands as a powerful approach that transcends traditional disciplinary boundaries, fostering a deep and integrated collaboration to address complex issues. Unlike multi-disciplinarity, which engages with multiple disciplines simultaneously, and trans-disciplinarity, which aims for a holistic understanding but often involves collaboration outside academia, interdisciplinarity focuses on creating a unified and synergistic framework within the academic realm.

The essence of interdisciplinarity lies in its commitment to breaking down the silos that typically separate academic disciplines. It goes beyond merely acknowledging the existence of multiple perspectives and methodologies, striving instead to integrate these diverse elements into a cohesive and unified approach. The goal is not just to coexist or cooperate but to create a synthesis where the whole is greater than the sum of its parts. By combining expertise from diverse fields, researchers can analyse vast datasets, uncover patterns, and derive meaningful insights that would be challenging for a single discipline to achieve.

Moreover, the emergence of interdisciplinary research centres in universities reflects a growing recognition of the need for collaborative efforts to tackle complex societal challenges.

These centres often bring together researchers from various disciplines under a common research agenda. For instance, a center focusing on sustainable development might include researchers from environmental science, economics, sociology, and engineering. This interdisciplinary collaboration allows for a more nuanced exploration of sustainable practices, considering ecological, social, and economic dimensions concurrently.

However, interdisciplinarity is not without its challenges. The very nature of breaking down disciplinary barriers can lead to tensions related to differences in language, methodologies, and epistemological foundations. Bridging these gaps requires open communication, mutual respect, and a willingness to engage in a shared learning process. The success of interdisciplinary initiatives often hinges on the ability of team members to navigate and leverage these differences, turning them into strengths rather than obstacles.

The benefits of interdisciplinarity extend beyond research. Interdisciplinary education has gained prominence, emphasising the importance of preparing students to navigate complex and interconnected real-world challenges. Institutions offering interdisciplinary programs seek to equip students with a broader skill set that encompasses critical thinking, communication, and problem-solving skills—attributes valued by employers in an increasingly dynamic and interconnected global landscape (Edmondson, Formica, & Mitra, 2020).

3.1.2 The Historical Evolution of Interdisciplinarity in Higher Education

The roots of interdisciplinarity in higher education in the United Kingdom can be traced back to the early 20th century, reflecting a response to the evolving nature of knowledge and education. By the mid-20th century, a significant expansion of interdisciplinary initiatives was in place in UK universities (Chandramohan & Fallows, 2008). This period saw the establishment of interdisciplinary studies programs and departments, reflecting a conscious effort to dismantle the rigid boundaries between disciplines. The goal was to provide students with a more holistic and interconnected understanding of knowledge that could be applied to real-world challenges (Frodeman, Klein, & Pacheco, 2017).

However, as the 20th century progressed, challenges emerged. The logistical complexities of providing higher education on a larger scale, coupled with the increasing depth of specialist knowledge, led to a partial return to disciplinary silos. The sheer volume of information and

the growing specialisation in various disciplines made it convenient to organise educational programs along disciplinary lines.

In the latter half of the 20th century and into the 21st century, the UK has continued to grapple with the tension between disciplinary depth and interdisciplinary collaboration. Global challenges, such as public health crises, climate change, and technological advancements, necessitated collaborative approaches. Universities are responding by recognising the importance of interdisciplinary research and education in addressing these complex issues (Power & Handley, 2019).

The historical trajectory of interdisciplinarity in UK higher education reveals a dynamic and evolving landscape. While influenced by global trends, the UK's journey reflects its unique educational context. As the 21st century unfolds, the challenges and opportunities of interdisciplinarity persist, prompting UK universities to navigate the delicate balance between disciplinary depth and collaborative exploration.

3.1.3 The Concept of 'Wissenschaft'

To truly grasp the philosophical foundations of interdisciplinarity, one must consider concept of *wissenschaf*t, particularly within the German intellectual tradition. Emerging in the 19th century, wissenschaft embodies a systematic and scholarly approach to knowledge creation that stands in contrast to the compartmentalised nature of disciplinary knowledge. It advocates for a more interconnected and holistic understanding of the world, emphasizing the synthesis of diverse perspectives (Klein, 1990).

The term wissenschaft encompasses a broad range of scholarly activities, including research, teaching, and the pursuit of knowledge. Unlike the rigid divisions found in traditional disciplinary boundaries, it encourages scholars to transcend these confines, fostering collaboration and the integration of insights from various fields.

While wissenschaft does not prescribe a specific methodology, it advocates for an attitude of openness to diverse perspectives and a commitment to holistic understanding. It offers profound insights into the philosophical underpinnings of interdisciplinarity. It promotes a scholarly approach that encourages collaboration, transcending disciplinary constraints. Its enduring influence highlights the enduring relevance of interconnected knowledge

production, providing a philosophical compass for those navigating the complex landscape of interdisciplinary exploration.

3.1.4 Challenges and Benefits of Interdisciplinarity:

The pursuit of interdisciplinarity, while promising, is not without its hurdles. Traditional academic structures, deeply ingrained in disciplinary frameworks, can pose formidable challenges to the seamless integration of diverse fields (Ashby & Exter, 2019). Issues such as funding mechanisms, promotion criteria, and institutional silos often hinder the progress of interdisciplinary endeavours. Additionally, effective communication between experts from different disciplines becomes a critical factor in the success of collaborative initiatives.

In the realm of academia, the established norms for funding allocation and promotion are often tailored to support discipline-specific research. This can create an environment where interdisciplinary projects struggle to secure the necessary resources (Mazzocchi, 2019). Funding agencies, accustomed to traditional disciplinary boundaries, may find it challenging to evaluate the merit of projects that transcend these confines. As a result, interdisciplinary researchers may face increased competition for limited resources, impacting the feasibility and sustainability of their initiatives.

Institutional silos, both physical and administrative, represent another formidable challenge. Universities and research institutions often compartmentalise departments and research units, making it difficult for interdisciplinary teams to collaborate seamlessly (Rogora & Tortoriello, 2021). Administrative structures may lack the flexibility needed to accommodate interdisciplinary initiatives, hindering the fluid exchange of ideas and expertise.

Communication barriers emerge as a significant impediment when experts from disparate fields come together. Each discipline has its own language, methodologies, and theoretical frameworks (Ashby & Exter, 2019). Bridging these gaps requires not only effective communication skills but also a willingness to engage in a mutual learning process. Misunderstandings, differing expectations, and conflicting approaches can arise if interdisciplinary teams do not invest time and effort in establishing shared understandings.

However, often the benefits of interdisciplinarity outweigh these challenges, making it a compelling and necessary approach in contemporary research and problem-solving. Embracing diverse perspectives from multiple disciplines can lead to a more comprehensive

understanding of complex issues (Maass, Geiger, Ariza, & Goos, 2019). While interdisciplinarity encounters obstacles within the existing academic landscape, its potential to drive innovation and provide comprehensive solutions to real-world problems cannot be overstated. Overcoming the challenges requires a collective effort to reshape structures and norms, fostering an environment where interdisciplinary collaboration is not only supported but also celebrated. The transformative impact of interdisciplinarity on research and society underscores its significance in shaping the future of knowledge creation and problem-solving.

3.1.5 Summary

Interdisciplinarity serves as a transformative paradigm in higher education and research, offering a dynamic approach to addressing the intricate challenges of the modern world. In navigating the complexities that define contemporary issues, both challenges and opportunities often arise at the intersections of traditional academic disciplines. Embracing interdisciplinarity enables us to transcend disciplinary boundaries and cultivate holistic solutions that resonate with the multifaceted nature of our global challenges.

The roots of interdisciplinarity can be traced back to the German concept of wissenschaft, embodying a systematic and scholarly approach to knowledge production. This historical evolution signifies a quest for a more integrated and comprehensive understanding of the world. In contemporary academia, interdisciplinarity serves as a guiding principle for navigating the evolving landscape of knowledge production.

Higher education institutions must continually adapt to the changing dynamics of our world. Interdisciplinarity emerges as a guiding philosophy for adaptations by fostering collaboration, encouraging innovative thinking, and promoting a deeper engagement with the complexities of our interconnected reality. It provides a framework where scholars from diverse fields can converge, exchange ideas, and co-create knowledge that transcends the confines of individual disciplines.

Interdisciplinarity is not merely a contemporary trend but a fundamental orientation that aligns with the essence of knowledge exploration. It encourages a synergistic approach to learning and research, fostering collaboration and innovation. If higher education institutions champion interdisciplinarity, they pave the way for a more connected future where the pursuit of knowledge transcends disciplinary silos.

3.2 The Definition of Employability

Before considering any potential interventions to address employability, it is essential to understand what is meant when we discuss employability. Employability encompasses a range of attributes, including but not limited to technical skills, communication prowess, adaptability, and critical thinking. It is not merely the possession of knowledge but the ability to apply it effectively in diverse professional contexts (Bonnard, 2020).

The term 'employability' is a multifaceted concept that encompasses a range of attributes, skills, and qualities that make an individual not only eligible for employment but also well-equipped to navigate the dynamic and competitive job market. Employability is more than merely securing a job; it reflects an individual's capacity to sustain meaningful and fulfilling work, adapt to changing professional landscapes, and contribute effectively to their chosen field (Yorke, 2006). At its core, employability involves a combination of 'hard' and 'soft' skills. Hard skills refer to the specific, teachable abilities and expertise related to a particular job or industry. These may include technical proficiencies, educational qualifications, and specialised knowledge. Soft skills, on the other hand, pertain to the interpersonal, communication, and emotional intelligence aspects that enable individuals to collaborate effectively, lead teams, and navigate workplace dynamics. Moreover, employability extends beyond the confines of technical competence. It encompasses a proactive attitude towards continuous learning and professional development. In today's rapidly evolving job market, being employable requires individuals to embrace a growth mindset, demonstrating a willingness to acquire new skills and adapt to emerging trends in their respective fields (Yorke, 2006).

The concept of employability is closely tied to the broader socio-economic landscape. In a globalised world, being employable often involves possessing a diverse skill set that aligns with the demands of an interconnected and technologically driven economy (Cheng, Adekola, Albia, & Cai, 2022). Employability is, therefore, linked to a person's adaptability and openness to working in diverse and cross-cultural environments. The evolving nature of work adds layers of complexity to the employability paradigm. Individuals with high employability are those who can navigate these changes with agility, leveraging technology, and embracing remote collaboration. Furthermore, employability is not a static trait but a dynamic quality that evolves throughout an individual's career journey. It is cultivated through a combination of formal education, on-the-job experiences, and continuous professional development. Lifelong

learning, curiosity, and resilience become key components of sustaining and enhancing employability over time (Knight, Peter & Yorke, 2003a).

We see that 'employability' encapsulates a comprehensive set of attributes and skills that extend beyond the basic ability to secure employment. It involves a proactive and adaptive mindset, a blend of technical and interpersonal competencies, effective communication, and an awareness of the broader socio-economic context. As the nature of work continues to evolve, the concept of employability will remain a central focus for individuals, educational institutions, and policymakers alike.

In terms of its development in higher education settings, the development of the 'hard' skills side of this concept is clearly straightforward – instructing students in the practicalities of CV writing, cover letters, the use of digital technologies, and other tangible skills has been part of the university offer for many years and indeed almost all universities have a dedicated careers service tasked with supporting student in developing these skills. It is the 'soft' skills side of employability that is often a much more difficult topic to introduce to students, especially as it may not be even possible to *teach* the elements of employability. In order to develop a greater insight into what this side of employability entails, a number of academics have formed employability models that can be used to help codify the development of good instruction in this area. Below we discuss a number of the more regularly used and referenced models that have been developed.

3.3 Exploring Employability Models

Employability, a multifaceted concept, has been a subject of intense scholarly scrutiny. Various employability models have been proposed, each offering unique perspectives tailored to different contexts and audiences. This survey considers a selection of prominent models, critically assessing their strengths and limitations while seeking a comprehensive understanding of employability.

3.3.1 The DOTS Model: Law and Watts (1977)

The DOTS model, developed by Law and Watts in 1977, stands as one of the early attempts to conceptualise and operationalise the idea of employability (Healy, 2023). This model, often utilised in careers education, simplifies the multifaceted notion of employability into four key topics: Dependability, Occupational Competence, Teamwork, and Self-Management. To

comprehend the significance of the DOTS model, we will consider its purpose, philosophy, uses, successes, and criticisms.

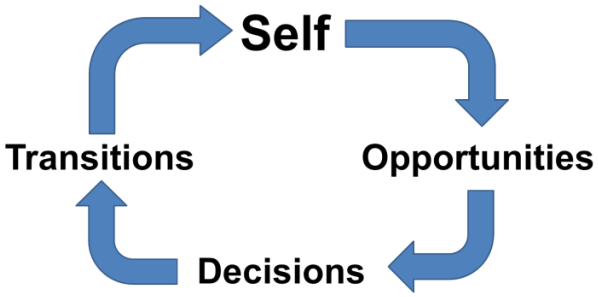


Figure 1 - Overview of the DOTS model

3.3.1.1 Purpose and Philosophy:

The primary purpose of the DOTS model is to offer a straightforward framework for assessing and enhancing employability skills. It is designed to be a practical tool for careers educators, providing a systematic way to guide individuals in understanding and developing the fundamental attributes needed in the world of work.

The philosophy underpinning the DOTS model is rooted in simplicity and practicality. Law and Watts aimed to distil the complexities of employability into a manageable set of dimensions. The model assumes that by focusing on these four key areas, individuals can develop a well-rounded skill set that is highly valued in the workplace.

3.3.1.2 Components of the DOTS Model:

Dependability:

This facet emphasizes the importance of being reliable and trustworthy. Individuals are expected to demonstrate consistency and fulfil their responsibilities in a timely and dependable manner.

Occupational Competence:

This dimension centres on the mastery of the skills and knowledge required for a particular occupation or profession. It underscores the importance of continuous learning and staying abreast of developments in one's field.

Teamwork:

Recognising the collaborative nature of most workplaces, teamwork in the DOTS model highlights the ability to work effectively with others. It involves communication, cooperation, and a commitment to collective goals.

Self-Management:

The self-management aspect revolves around an individual's ability to organise and direct their own efforts. This includes time management, goal setting, and the capacity to work independently.

3.3.1.3 Uses and Successes:

One of the primary uses of the DOTS model is in educational settings, especially in careers guidance (Healy, 2023). It provides a structured framework for educators to help students understand and develop the skills necessary for future employment. The simplicity of the DOTS model is one of its strengths. Its straightforward nature makes it accessible to a broad audience, including students, educators, and professionals. The model's simplicity is an asset, particularly for those who may find more complex employability frameworks daunting (McCash, 2006). By breaking down employability into four discrete dimensions, the DOTS model offers clarity in terms of skill development. It allows individuals to identify specific areas for improvement and provides a tangible roadmap for enhancing employability. The DOTS model successfully bridges the gap between theoretical discussions on employability and practical application. Its pragmatic approach allows users to translate abstract concepts into actionable steps for personal and professional development.

3.3.1.4 Criticisms and Limitations:

Perhaps the most significant criticism of the DOTS model is its tendency to oversimplify the concept of employability (McCash, 2006). By reducing the multifaceted nature of employability to four broad categories, the model may fail to capture the intricacies and nuances of individual skills and attributes. Critics argue that the DOTS model has a relatively narrow scope, primarily focusing on behavioural competencies. It may not adequately address other critical aspects of employability, such as emotional intelligence, adaptability, or cultural competence (Dacre Pool & Sewell, 2007a). Another criticism is that the model, in its simplicity, places a considerable burden on individuals (Law, 1999). It implies that employability success

or failure rests solely on the individual, neglecting systemic factors that influence employability outcomes. The applicability of the DOTS model might vary across different contexts and industries. Some argue that its generic nature may not sufficiently account for industry-specific demands and nuances in the evolving job market (McCash, 2006). In an era of rapid technological advancements and evolving job roles, the DOTS model might be critiqued for not adequately addressing the dynamic changes in the nature of work. It can be seen as somewhat static in a world where skills and job requirements are continually shifting.

3.3.1.5 *Summary*

While the DOTS model has its share of criticisms, it has undeniably played a crucial role in shaping early discussions around employability. Its enduring use in educational settings attests to its practical utility. The model's simplicity, while a strength for certain users, necessitates a cautious approach to avoid oversimplification of the multifaceted concept of employability.

3.3.2 Bridgstock's Approach: A Socio-Economic Perspective (2009)

Bridgstock's employability model, developed in 2009, offers a distinctive socio-economic perspective on the concept (Bridgstock, 2017). This analysis will look at the purpose, philosophy, uses, successes, and criticisms of Bridgstock's approach to provide a comprehensive understanding of its contributions and limitations.

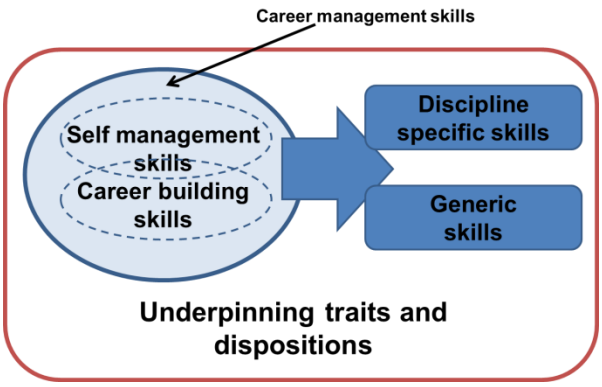


Figure 2 - Overview of the Bridgstock employability model

3.3.2.1 *Purpose*

Bridgstock's primary purpose was to provide a nuanced framework for understanding employability that acknowledges the shifting landscape of work in the emerging knowledge economy (Bridgstock, 2017). The model seeks to move beyond a purely skills-based view of employability, incorporating socio-economic and political considerations. It aims to equip

individuals, educators, and policymakers with a holistic perspective that goes beyond technical competencies.

3.3.2.2 *Philosophy:*

The philosophy underpinning Bridgstock's approach is rooted in the recognition that employability is not solely determined by technical skills but is intricately tied to socio-economic and political contexts. The model reflects a broader understanding of work, emphasizing the importance of career management skills in navigating a dynamic job market. It aligns with the idea that employability is not a static attribute but a dynamic, evolving capacity shaped by external factors.

3.3.2.3 *Components of Bridgstock's Employability Model*

Career Management Skills:

A central component of Bridgstock's model is the emphasis on 'career management skills.' This includes the ability to navigate one's career trajectory, make informed decisions, and adapt to the changing demands of the knowledge economy.

Contextual Awareness:

Bridgstock's model recognises the influence of broader societal, economic, and political contexts on employability. It encourages individuals to develop an awareness of these contextual factors and integrate this awareness into their career management strategies.

Adaptability:

Given the dynamic nature of work, adaptability is a key aspect of Bridgstock's model. Individuals are encouraged to develop the ability to learn continuously, stay updated with industry trends, and adjust their career strategies accordingly.

3.3.2.4 *Uses of this approach*

Bridgstock's model finds application in educational settings, particularly in career guidance. It provides a framework for educators to go beyond traditional skill-based approaches, incorporating socio-economic considerations into career development programs. The model has implications for policymakers shaping education and employment policies. Bridgstock's emphasis on career management skills and contextual awareness suggests a need for policies

that foster these capacities, aligning education with the evolving needs of the job market. On an individual level, Bridgstock's model encourages self-reflection and awareness. It prompts individuals to consider not only their technical competencies but also their ability to navigate complex career paths within the broader socio-economic landscape.

3.3.2.5 *Successes*

One of the model's notable successes is its contribution to a more holistic perspective on employability. By incorporating career management skills and contextual awareness, Bridgstock's approach broadens the understanding of what makes individuals employable. The model remains relevant in the contemporary knowledge economy, where career trajectories are less linear, and adaptability and contextual understanding are increasingly crucial. Its emphasis on continuous learning aligns with the demands of industries undergoing rapid transformations. The model's success lies in its recognition that employability cannot be divorced from the broader societal and economic contexts. This integration provides a more realistic and actionable framework for individuals navigating their careers (Krouwel, van Luijn, & Zweekhorst, 2020).

3.3.2.6 *Criticisms*

Some critics argue that Bridgstock's model introduces jargon and complexity that might hinder accessibility, especially for individuals who are not well-versed in socio-economic and political concepts (Higgs, Crisp, & Letts, 2019). This could limit its effectiveness, particularly in educational settings. While the model provides a broad framework, some critics contend that it lacks specificity in terms of actionable steps (Cook, 2022). The emphasis on career management skills, while valuable, might require additional clarification on practical strategies for development. There is a risk that, in emphasizing the contextual aspects of employability, individual agency and responsibility might be overshadowed. Critics argue that a balance is needed to ensure that individuals still recognise their capacity to shape their own career paths (Higgs, Crisp, & Letts, 2019). Some critics contend that Bridgstock's model may have limited applicability across different sectors. The emphasis on career management skills might be more relevant in certain professions and industries, potentially overlooking the diversity of skills needed in various domains (Cook, 2022).

3.3.2.7 *Summary*

Bridgstock's approach to employability, with its socio-economic perspective, represents a valuable contribution to the discourse on career development. Its emphasis on career management skills and contextual awareness aligns with the complexities of the modern job market. While it has garnered praise for offering a holistic view of employability, criticisms regarding accessibility and specificity warrant consideration.

In the dynamic landscape of work, where individuals navigate intricate career paths influenced by global and local factors, models like Bridgstock's provide a lens to understand and develop employability beyond a checklist of skills. As educators, policymakers, and individuals continue to grapple with the challenges of employability in the 21st century, frameworks that acknowledge the interplay of skills, context, and adaptability remain essential for shaping meaningful and sustainable careers.

3.3.3 The USEM Model: Knight and Yorke (2003)

In the realm of employability research, Knight and Yorke's USEM model (Knight, Peter & Yorke, 2003b) stands as a seminal framework (Sumanasiri, Yajid, & Khatibi, 2015b). Developed in 2003, the model aims to provide a comprehensive understanding of employability by identifying key attributes and their interconnections. This analysis will discuss its contributions to the field of career development.

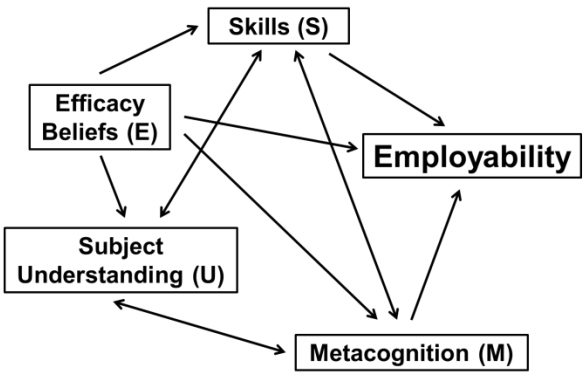


Figure 3 - Overview of the USEM model

3.3.3.1 *Purpose and Philosophy*

The primary purpose of the USEM model is to offer a structured and research-grounded framework for conceptualising employability (Knight, Peter & Yorke, 2003b). Knight and Yorke sought to move beyond simplistic views of employability, recognising it as a multifaceted

concept influenced by various factors. The model serves as a guide for educators, employers, and policymakers, offering a nuanced understanding of the attributes that contribute to an individual's employability.

Knight and Yorke's USEM model stands not just as a pragmatic tool for understanding employability but as a philosophical exploration into the complex nature of readiness for the workforce. They argue that employability is not a static trait, but a dynamic quality influenced by an individual's subject understanding (U), skills (S), efficacy beliefs (E), and metacognition (M). The model aligns with the idea that employability is not solely about technical competencies but encompasses broader cognitive and metacognitive dimensions. Beyond its surface utility, the model reflects a commitment to moving beyond reductionist perspectives on employability, delving into the intricacies of individual and contextual elements.

At its core, the USEM model reflects a departure from reductionism in understanding employability. Knight and Yorke's philosophical stance asserts that employability is not a singular trait or a checklist of skills but an intricate interweaving of subject understanding, skills, efficacy beliefs, and metacognition. This holistic perspective aligns with a philosophical orientation that rejects oversimplified views, acknowledging the dynamic and interconnected nature of employability.

The philosophical intention of the USEM model is deeply rooted in holism, emphasizing the interconnectedness of the identified attributes. Holism, as a philosophical concept, contends that the whole is more than the sum of its parts (Freeman, 2005). In the context of employability, this implies that subject understanding, skills, efficacy beliefs, and metacognition are not isolated components but elements that gain significance in their interrelations. This departure from reductionism signifies a shift towards a more comprehensive and nuanced understanding of the factors contributing to employability.

The model's philosophical underpinnings also touch upon epistemological considerations – how knowledge is understood and acquired. Subject understanding, as a dimension, goes beyond mere acquisition of facts; it delves into a deeper comprehension of concepts, theories, and the contextual relevance of knowledge (Knight, Peter T. & Yorke, 2002). This aligns with epistemological frameworks that emphasize the significance of contextual understanding and the application of knowledge in diverse situations.

The USEM model exhibits a humanistic approach to employability, recognising the individual as a complex and evolving entity. Efficacy beliefs, a central dimension, draw from Bandura's social cognitive theory, emphasizing an individual's confidence in their ability to apply skills effectively. This humanistic perspective considers not just the tangible skills but also the subjective realm of beliefs, aspirations, and self-perceptions, echoing a broader outlook.

From an educational standpoint, the USEM model's philosophical intentions are evident in its emphasis on metacognition (Nimmi & Zakkariya, 2016). Metacognition involves self-awareness and reflection, reflecting a belief in the transformative power of individuals actively engaging with their learning processes. This aligns with educational philosophies that emphasize not just the transmission of knowledge but the cultivation of learners who are reflective, adaptable, and capable of continuous improvement.

In contributing to the broader discourse on employability, the model philosophically challenges reductionist and deterministic perspectives that view employability as a fixed set of skills. By introducing efficacy beliefs and metacognition, the model acknowledges the agency of individuals in shaping their employability. This philosophical shift has implications for how employability is perceived, taught, and assessed in educational and professional contexts.

The model transcends its role as a practical framework; it is a philosophical exploration into the nature of employability. Knight and Yorke's intentions extend beyond creating a checklist for educators and employers; they explore the essence of what makes an individual employable. Its holistic, interconnected, and humanistic philosophy challenges conventional wisdom, opening avenues for a more nuanced understanding of how individuals navigate their careers (Knight, Peter & Yorke, 2003b). As educators, employers, and policymakers engage with the USEM model, they participate in a broader philosophical conversation about the complexities and richness inherent in the concept of employability.

3.3.3.2 Components of the USEM Model:

Subject Understanding (U):

This dimension refers to an individual's depth of knowledge and understanding within a particular subject or field. It goes beyond mere technical skills, encompassing a broader comprehension of concepts, theories, and contextual relevance.

Skills (S):

The 'Skills' dimension focuses on the practical and technical competencies that individuals bring to the workplace. This includes both domain-specific skills and generic skills that are transferable across various contexts.

Efficacy Beliefs (E):

Central to the USEM model is the concept of efficacy beliefs, drawing from Bandura's theory of self-efficacy. 'Efficacy Beliefs' refer to an individual's confidence in their ability to apply their skills effectively in different situations.

Metacognition (M):

The 'Metacognition' dimension highlights the importance of self-awareness and reflection. It involves an individual's ability to understand their own thinking processes, adapt strategies based on feedback, and engage in continuous learning.

3.3.3.3 Uses

One of the primary uses of the USEM model is in educational settings (Small, Shacklock, & Marchant, 2018). Educators can employ the model to design curricula that go beyond technical skills, fostering a holistic development of students' subject understanding, skills, efficacy beliefs, and metacognitive abilities. Career support practitioners can utilise the USEM model to guide individuals in understanding their strengths and areas for development. By exploring each dimension, practitioners can provide targeted advice on skill enhancement, confidence-building, and strategies for effective career management.

Institutions can use the model for curriculum development, ensuring that educational programs not only impart technical knowledge but also cultivate the broader attributes crucial for employability in a dynamic job market. Whilst employers can utilise the USEM model as a

framework for assessing potential hires. By considering subject understanding, skills, efficacy beliefs, and metacognition, employers gain insights into the holistic employability of candidates (Lees, 2002).

3.3.3.4 *Successes*

One of the successes of the USEM model is its holistic approach to employability. By encompassing subject understanding, skills, efficacy beliefs, and metacognition, the model provides a more complete and nuanced picture of an individual's readiness for the workforce. The USEM model is grounded in psychological and educational theories, particularly Bandura's self-efficacy theory. This research foundation enhances the model's credibility and its applicability in both academic and professional contexts. The model's flexibility and inclusivity allow for its application across diverse disciplines (Knight, Peter & Yorke, 2003b). It acknowledges that employability is not a one-size-fits-all concept, and the dimensions identified are transferable across various fields. The inclusion of metacognition as a dimension underscores the model's commitment to fostering self-awareness and continuous improvement. This aligns with the modern understanding of employability as a dynamic and evolving quality.

3.3.3.5 *Criticisms*

Some critics argue that the USEM model, while comprehensive, still places a significant emphasis on technical skills (Misra & Khurana, 2017). This emphasis might not fully capture the broader skills needed in the modern workplace, such as emotional intelligence, cultural competence, and creativity. The model's multidimensional nature and reliance on psychological concepts might pose challenges for certain audiences, especially those unfamiliar with educational or psychological theories. This complexity could limit its accessibility in certain educational and professional contexts (Dacre Pool & Sewell, 2007b). The model's development and application have primarily occurred in Western contexts, raising questions about its cultural universality. Some critics argue that the model may not adequately account for cultural variations in the perception of employability attributes. The model's focus on individual attributes might be critiqued for not sufficiently addressing systemic factors that influence employability (Römgens, Scoupe, & Beausaert, 2020). It places the onus on individuals to develop and enhance these attributes, potentially neglecting the role of external factors.

3.3.3.6 *Summary*

Knight and Yorke's USEM model has significantly contributed to the conceptualisation of employability by offering a multidimensional framework. Its emphasis on subject understanding, skills, efficacy beliefs, and metacognition provides a well-rounded understanding of what makes individuals employable. While the model has garnered praise for its holistic approach and research grounding, criticisms highlight the need for ongoing refinement, consideration of cultural factors, and a balanced emphasis on individual and systemic aspects of employability. As the world of work continues to evolve, frameworks like the USEM model remain invaluable tools for educators, practitioners, and employers navigating the complexities of preparing individuals for successful and fulfilling careers.

3.3.4 CareerEDGE Model: Dacre-Pool and Sewell (2007)

Developed by Dacre-Pool and Sewell in 2007, the CareerEDGE model is a multifaceted framework, that seeks to encapsulate the many dimensions that define an individual's readiness for the workforce (Dacre Pool & Sewell, 2007b).

Figure 4 - Overview of the CareerEDGE model

3.3.4.1 *Purpose and Philosophy*

The primary purpose of the CareerEDGE model is to provide a structured and inclusive approach to employability, offering a guide for educators, career advisors, and individuals aiming to enhance their readiness for the job market. The philosophy underpinning the model is rooted in a holistic understanding of employability, incorporating diverse dimensions that collectively contribute to an individual's career success (Dacre-Pool, 2020). At its core, CareerEDGE reflects a commitment to addressing the dynamic and evolving nature of employability. The model goes beyond a mere checklist of skills, recognising the interplay of

personal attributes, experiential learning, and reflective practices. Its philosophy aligns with the evolving landscape of work, emphasizing the importance of adaptability, self-awareness, and continuous development (Dacre-Pool, 2020).

3.3.4.2 *Key Dimensions of CareerEDGE*

The CareerEDGE model comprises four interconnected dimensions, each playing a pivotal role in shaping an individual's employability:

Qualifications and achievements:

This dimension recognises the importance of academic qualifications and achievements in signalling a person's capabilities. It encompasses formal qualifications, certifications, and notable achievements that contribute to an individual's credibility.

Experience:

Experience is considered a crucial element in employability. It includes both formal work experience and informal learning experiences that enhance one's skills and knowledge. The model acknowledges that varied experiences, including internships, volunteer work, and extracurricular activities, contribute to a well-rounded professional profile.

Development and learning:

This dimension emphasizes the continuous process of learning and development. It encompasses both formal and informal learning experiences that contribute to skill enhancement. Professional development activities, training programs, and a commitment to staying abreast of industry trends fall under this category.

Generic abilities:

Generic abilities refer to transferable skills that are valuable across various contexts. These include communication skills, problem-solving abilities, and adaptability. The model recognizes that possessing a set of generic abilities enhances an individual's versatility and resilience in the job market.

3.3.4.3 *Uses of the CareerEDGE Model*

The CareerEDGE model serves as a versatile tool with various applications in educational and professional settings. Career advisors and educators can use the model to guide students in understanding and developing their employability. It assists in creating personalised development plans, aligning educational experiences with future career goals (Yawson & Yamoah, 2023).

Individuals use the model for self-assessment, identifying areas of strength and areas that require further development. It fosters a reflective approach, encouraging individuals to actively engage in their career development journey.

Educational institutions can utilise the model to inform curriculum development, ensuring that programs align with industry expectations. It aids in designing courses that foster not only academic knowledge but also the practical and generic skills demanded by employers (Dacre-Pool, 2020).

Career support practitioners can employ the CareerEDGE model in guiding individuals through career choices and transitions. Its intention is to facilitate discussion about the importance of diverse experiences, continuous learning, and the development of generic abilities.

3.3.4.4 *Successes of the CareerEDGE Model*

The model's success lies in its comprehensiveness. By incorporating multiple dimensions, it provides a holistic view of employability, acknowledging the multifaceted nature of career readiness. Its adaptable nature allows for applicability across diverse sectors and industries. Whether applied to the arts, sciences, or business, the model accommodates the varied nature of professional landscapes (Sumanasiri, Yajid, & Khatibi, 2015a). CareerEDGE's emphasis on development and learning aligns with the contemporary need for lifelong learning. It promotes a mindset of continuous improvement and adaptability. The model's user-friendly structure makes it accessible to a wide audience, from students navigating their educational journey to professionals seeking to enhance their employability.

3.3.4.5 *Criticisms and Areas of Improvement*

The model's reliance on self-assessment and subjective evaluation can introduce biases (Jiang, Chen, & Lei, 2023). Individuals may overstate or understate their achievements and abilities, impacting the accuracy of the employability assessment. Some critiques argue that the

model's inclusion of qualifications and achievements may place undue emphasis on formal credentials, potentially overshadowing other crucial dimensions (Tymon, Harrison, & Batistic, 2020). Critics suggest that the model's universal applicability might lack cultural sensitivity. Employability values and expectations can vary significantly across cultures, and a one-size-fits-all approach may not be entirely effective. For sustained relevance, the model requires continuous validation and updates to align with evolving employment trends and the changing nature of skills in demand.

3.3.4.6 Summary

The CareerEDGE model stands as a robust framework that navigates the complexities of employability. Its purposeful design, rooted in a holistic philosophy, caters to the diverse needs of individuals and institutions involved in career development. Despite criticisms, its successes in promoting comprehensive self-awareness, lifelong learning, and versatility underscore its significance in shaping a future-ready workforce. As the world of work continues to evolve, the CareerEDGE model serves as a valuable compass, guiding individuals and educational institutions toward a deeper understanding of employability in the contemporary landscape.

3.3.5 Other Employability Models

As the landscape of work undergoes rapid transformations, the conceptualisation of employability has evolved. In the last decade, several new employability models have emerged, each offering distinctive perspectives and responses to the complex demands of the contemporary job market.

3.3.5.1 The Employability Capital Model by Hinchliffe and Jolly (2011)

Hinchliffe and Jolly's Employability Capital Model introduces the concept of "employability capital", which encompasses an individual's human, cultural, social, and psychological capital (Hinchliffe & Jolly, 2011). The purpose is to move beyond a skills-centric approach and consider the broader factors that contribute to an individual's readiness for employment. This model is often employed in career guidance and development programs. It aids individuals in recognising and leveraging their various forms of capital to enhance their employability.

The model has been successful in promoting a holistic understanding of employability. By acknowledging the significance of diverse forms of capital, it encourages individuals to consider a broad spectrum of factors in their career development, although some critics argue

that the concept of employability capital may be challenging to operationalise, and its subjective nature might pose difficulties in measurement and evaluation (Tomlinson, 2012).

3.3.5.2 *The Integrated Model of Graduate Employability by Tomlinson (2017)*

Tomlinson's Integrated Model aims to integrate key aspects of employability, incorporating both individual attributes and the broader socio-economic context. The purpose is to provide a framework that recognises the dynamic interaction between personal qualities and external factors (Tomlinson, 2017).

This model is used in higher education for curriculum design and evaluation. It encourages institutions to consider not only the skills they impart but also the socio-economic factors that influence graduates' employability.

The model's success lies in its holistic approach, bridging the gap between micro-level individual attributes and macro-level societal influences. It has been effective in prompting universities to broaden their employability initiatives. However, it is argued that the model's emphasis on the socio-economic context might place undue responsibility on educational institutions for factors beyond their control. There are concerns about the practicality of addressing broader societal issues within a university's scope.

3.3.5.3 *The Career Competencies Framework by Taylor and Riggio (2020)*

The Career Competencies Framework aims to identify and define the key competencies necessary for success in the contemporary job market. It seeks to offer a clear and practical guide for individuals seeking to enhance their career readiness (Riggio, 2020).

This framework is utilised in career development programs and workshops. It helps individuals assess their current competencies and develop targeted strategies for improvement. The model's success is attributed to its specificity and action-oriented nature. It provides individuals with a clear roadmap for developing the competencies most valued by employers in a rapidly changing job market. Critics argue that the framework's emphasis on competencies might oversimplify the complex nature of employability. There are concerns about the potential neglect of broader attributes such as adaptability and resilience.

3.3.5.4 *Summary*

These models reflect the evolving nature of employability thinking, encompassing not only skills but also broader attributes, mindsets, and socio-economic factors. Their purposes, philosophies, uses, successes, and criticisms underscore the diverse approaches scholars and practitioners are taking to navigate the complexities of employability in the contemporary world of work. As the field continues to evolve, ongoing dialogue and critical evaluation of these models will contribute to a more nuanced and effective understanding of employability.

3.3.6 Discussion

Across the spectrum of employability models considered, there is a repeated inclusion of self-efficacy which underscores its foundational role in shaping individuals' readiness for the workforce. These models, such as the DOTS model, Bridgstock's model, the USEM model, and the CareerEDGE model, collectively recognise the integral role of self-efficacy in the development of employability skills.

Mastery experiences, a core concept in Bandura's self-efficacy theory, find explicit mention across these models. Whether it's the DOTS model emphasizing self-reflection and appraisal of capabilities, or the USEM model highlighting the significance of efficacy beliefs, there is a consistent acknowledgment that successful navigation of tasks enhances individuals' belief in their employability.

Social persuasion, another element in Bandura's theory, is subtly embedded in these models. The Career Competencies Framework (Riggio, 2020) implicitly incorporates social persuasion by providing individuals with clear competencies and role models to emulate, fostering a positive reinforcement loop that aligns with Bandura's emphasis on external encouragement.

Vicarious experiences, wherein individuals learn from observing others, are indirectly acknowledged in these models. Bridgstock's model, for instance, incorporates various sections, including 'career management skills,' which indirectly encapsulate the observational learning aspect of self-efficacy.

Motivation and persistence, closely tied to self-efficacy, are explicitly recognized in the USEM model. Knight and Yorke (2003a) argue that beliefs strongly influence one's willingness to act, echoing Bandura's assertion that self-efficacy is a potent motivator. This shared emphasis on

the motivational aspect aligns with the broader understanding that a strong belief in one's capabilities acts as a driving force in employability.

Cognitive appraisal and decision-making, influenced by self-efficacy, find a place in these models. The Integrated Model of Graduate Employability (Tomlinson, 2017) recognises the impact of self-efficacy on cognitive processes, underlining how individuals with a strong sense of efficacy are more likely to approach challenges with a positive mindset.

While each model retains its unique focus and nuances, the recurrent consideration of self-efficacy creates a common thread. Whether it's the explicit inclusion of self-efficacy in the CareerEDGE model or the implicit acknowledgment through the emphasis on skills and competencies in the EmployABILITY Thinking Framework, the shared language of self-efficacy underscores its crucial role in enhancing employability skills.

The pervasive consideration of self-efficacy within these frameworks reflects a consensus among diverse models regarding its significance in shaping individuals' career trajectories. The shared language of self-efficacy provides a unifying element, acknowledging its pivotal role in the multifaceted landscape of employability. So, while no single model encapsulates the entirety of employability, each contributes valuable insights. It is imperative to foster a holistic understanding that integrates technical skills, cognitive processes, and socio-economic considerations when considering employability targeted interventions. A nuanced approach, considering the strengths of various models, can guide educators, students, and policymakers in developing strategies that enhance not only employability but also the adaptability required in the dynamic professional world. However, as we have seen, the major elements of these models can be shown to be somewhat aligned along certain themes, the most notable among these in the consideration of this work is the inclusion of self-efficacy.

4 Self-Efficacy

Self-efficacy, a concept introduced by the eminent psychologist Albert Bandura, holds a pivotal place in the realm of psychology and has far-reaching implications in diverse fields such as education, healthcare, and organisational behaviour. Rooted in Bandura's social cognitive theory, self-efficacy refers to an individual's belief in their capacity to execute actions and produce desired outcomes. This foundational concept diverges from earlier behaviourist perspectives by emphasising the active role of individuals in shaping their destinies (Lianto, 2019).

Bandura's introduction of self-efficacy was a response to the limitations of behaviourism and a shift towards recognising cognitive processes as integral to understanding human behaviour. Its far-reaching implications are particularly evident in education, where it profoundly influences learning outcomes, academic achievement, and the development of crucial skills.

Furthermore, in organisational behaviour, self-efficacy is a key determinant of workplace performance, job satisfaction, and the ability to navigate challenges. The belief in one's capabilities influences motivation, resilience, and the pursuit of challenging goals. Its applicability across various domains underscores its significance as a psychological construct that not only explains individual behaviour but also shapes the dynamics of entire systems and institutions (Maddux, 2013).

4.1 Origins of Self-Efficacy

The roots of self-efficacy can be traced back to Bandura's social cognitive theory (Bandura, 1977), which posits that individuals learn from observing others and that cognition, behaviour, and the environment interact reciprocally. Bandura initially introduced the concept of self-efficacy in the early 1970s, emphasizing the role of an individual's beliefs in their capabilities to produce desired effects and outcomes. The development of self-efficacy theory was a response to the limitations of behaviourism and the recognition of the cognitive processes shaping human behaviour.

At its core, self-efficacy is grounded in the philosophical notion that individuals are not passive recipients of external influences but active agents who can exert control over their actions and environments. This perspective aligns with humanistic and existential philosophies that

emphasize personal agency, free will, and the capacity for self-determination. Bandura's departure from deterministic views of behaviour marked a significant shift in psychological thought towards acknowledging the active role of individuals in shaping their destinies.

The theory of self-efficacy theory draws heavily from social learning theory, emphasizing the importance of observational learning, imitation, and modelling in the acquisition of new behaviours. The concept also integrates elements of cognitive psychology, particularly the role of cognitive processes in mediating between stimuli and responses. Self-efficacy is not a static trait but a dynamic belief that influences how individuals think, feel, motivate themselves, and behave in various situations.

4.1.1 Bandura's Four Sources of Self-Efficacy

4.1.1.1 Mastery Experiences

Mastery experiences, represent individuals' *acknowledged* personal successes and accomplishments in performing specific tasks or activities. *M*astery experiences considered the most influential *of the four sources*. This component of self-efficacy theory has been widely researched and has important implications across various domains, including education, healthcare, and organisational psychology (Welch & West, 1995).

4.1.1.1.1 Definition

Mastery experiences involve successfully completing tasks or overcoming challenges, contributing to an individual's belief in their capabilities. These experiences are deeply personal and subjective, tied to the individual's past achievements. When individuals perceive that they have effectively performed a task, their self-efficacy for that specific activity tends to increase.

4.1.1.1.2 The Importance of Mastery Experiences

Bandura suggested that mastery experiences are the most powerful source of self-efficacy because they provide tangible evidence of an individual's ability to succeed. Through the process of mastering tasks, individuals receive direct feedback about their competence, reinforcing their belief in their capabilities. Bandura emphasized that successful mastery experiences lead to a stronger sense of efficacy, increased motivation, and a willingness to take on more challenging tasks (Bandura, Freeman, & Lightsey, 1999a).

A substantial body of research supports the significance of mastery experiences in shaping self-efficacy beliefs. In education, studies have shown that students who experience academic success are more likely to believe in their ability to tackle challenging subjects and persist in the face of difficulties (Pajares, 2002). Similarly, in the context of health *behaviour*, individuals who successfully manage aspects of their health, such as weight control or chronic disease management, are likely to develop higher self-efficacy for health-related tasks (Schwarzer, Ralf & Renner, 2000).

In educational settings, as we are considering here the concept of mastery experiences can inform teaching practices. Providing students with opportunities for small, incremental successes can build their confidence and self-efficacy. Additionally, constructive feedback and acknowledgment of their achievements contribute to the development of a positive self-perception.

4.1.1.1.3 Summary

While mastery experiences are powerful, their impact is *context specific*. Success in one domain may not necessarily translate to confidence in another. Additionally, individuals may interpret the same task differently, leading to variations in the perceived level of mastery. Mastery experiences *play* a central role in shaping individuals' beliefs about their capabilities. As a dynamic and context-dependent construct, mastery experiences have far-reaching implications for learning, motivation, and *behaviour* across diverse domains. Recognising the importance of creating environments that foster positive mastery experiences is crucial to enhance individuals' self-efficacy and, consequently, their performance and well-being.

4.1.1.2 *Vicarious Experiences*

Vicarious experiences, also known as observational learning or modelling, involve learning by observing the successes and failures of others in similar situations. This component of self-efficacy theory has profound implications in various fields, including education, psychology, and organisational behaviour (Wilde & Hsu, 2019).

4.1.1.2.1 Definition of Vicarious Experiences

Vicarious experiences occur when individuals witness someone else perform a task or navigate a situation, observing the consequences of their actions. The key mechanism at play

is the observer's ability to learn and gain insights into their own potential capabilities through the experiences of others.

Vicarious experiences operate through a process of social modelling, wherein individuals learn by observing the behaviours and outcomes of others. According to Bandura, witnessing someone successfully perform a task or overcome a challenge enhances observers' self-efficacy beliefs for similar activities. Conversely, observing failure or negative outcomes may decrease self-efficacy unless mitigated by other sources, such as social persuasion or physiological states.

4.1.1.2.2 Bandura's Bobo Doll Experiment

One of the seminal studies illustrating the impact of vicarious experiences is Bandura's Bobo doll experiment (Bandura, Ross, & Ross, 1961). In this study, children who observed an adult model displaying aggressive behaviour towards a Bobo doll were more likely to replicate similar aggressive behaviours. This experiment demonstrated that observational learning significantly influences individuals' behaviours, highlighting the role of vicarious experiences in shaping responses.

4.1.1.2.3 Educational Implications

In educational settings, the influence of vicarious experiences is profound. Students not only learn from their own successes and failures but also from observing the achievements and struggles of their peers. Teachers, as models, can impact students' self-efficacy by demonstrating effective problem-solving, resilience, and academic success. Incorporating positive role models and showcasing individuals who have overcome challenges can enhance students' belief in their own capabilities.

4.1.1.2.4 Summary

While vicarious experiences are a potent source of self-efficacy, their effectiveness can be influenced by factors such as the perceived similarity between the observer and the model, the model's competence, and the degree of attention paid by the observer. Additionally, individuals may selectively attend to and remember vicarious experiences that align with their pre-existing beliefs.

Vicarious experiences, as a central component of Bandura's social cognitive theory, contribute significantly to the development of self-efficacy. Whether in the classroom, therapy sessions,

or organisational contexts, the power of observational learning is evident. Understanding how individuals learn from observing others provides valuable insights for educators, psychologists, and leaders seeking to foster positive self-efficacy beliefs and promote adaptive behaviours in diverse settings.

4.1.1.3 Social Persuasion

Social persuasion refers to the influence that verbal encouragement or discouragement from others has on an individual's beliefs about their capabilities. This source operates through communication from external sources and plays a significant role in shaping individuals' self-perceptions, impacting various aspects of human behaviour (Capa-Aydin, Uzuntiryaki-Kondakci, & Ceylandag, 2018).

Social persuasion involves communication that either boosts or undermines an individual's confidence in their capabilities. Positive verbal persuasion, such as encouragement and supportive feedback, can enhance self-efficacy. Conversely, negative or discouraging comments can weaken self-efficacy beliefs. Bandura proposed that individuals are more likely to engage in activities and persevere when they receive positive reinforcement and encouragement.

4.1.1.3.1 Role of Social Persuasion in Behaviour Change

In various fields, including education, healthcare, and organisational development, social persuasion is a powerful tool for behaviour change. For instance, in educational settings, teachers' constructive feedback and encouragement can positively influence students' self-efficacy, motivating them to tackle challenging tasks (Honicke & Broadbent, 2016). In healthcare, effective communication from healthcare providers can impact patients' confidence in managing their health conditions and following prescribed treatments (Jerant, Franks, & Kravitz, 2011).

Social networks, including family, friends, and colleagues, contribute significantly to an individual's self-efficacy through verbal persuasion. Constructive feedback and positive reinforcement within these social networks can foster a sense of competence and belief in one's abilities. Conversely, criticism or lack of support may contribute to self-doubt and diminished self-efficacy.

4.1.1.3.2 Educational Applications

In educational psychology, understanding the role of social persuasion has implications for instructional practices. Teachers can create a positive learning environment by providing constructive feedback, acknowledging effort, and offering verbal encouragement. This not only enhances students' self-efficacy but also fosters a growth mindset, encouraging a belief in the potential for improvement (Dweck, 2006).

While social persuasion is a potent source of self-efficacy, its effectiveness may be influenced by factors such as the credibility of the source, the specificity of the feedback, and the individual's receptiveness to persuasion. Moreover, overly optimistic praise without genuine merit may lead to a mismatch between perceived and actual competence.

4.1.1.3.3 Summary

Social persuasion, as a source of self-efficacy, reflects the impact of verbal encouragement or discouragement on individuals' beliefs about their capabilities. Understanding how communication from external sources shapes self-perceptions has far-reaching implications in diverse fields. Leveraging the power of positive social persuasion can contribute to the development of self-efficacy, motivation, and resilience.

4.1.1.4 Physiological and Emotional States

Physiological and emotional states emphasize the influence of an individual's emotional and physiological experiences on their beliefs about their capabilities. Bandura posited that an individual's emotional and physical states significantly impact their perceived self-efficacy, affecting various aspects of human behaviour (Bandura, Freeman, & Lightsey, 1999a).

Emotional states, including arousal levels and the nature of emotions experienced, play a crucial role in shaping self-efficacy beliefs. Bandura suggested that high levels of emotional arousal, such as anxiety or stress, can negatively impact self-efficacy. In contrast, positive emotional states, like enthusiasm or joy, can enhance one's belief in their capabilities (Bandura, Freeman, & Lightsey, 1999a).

Physical sensations, including bodily reactions to stress or excitement, contribute to the physiological component of self-efficacy. Bandura argued that physiological responses, such as increased heart rate, sweating, or muscle tension, can influence individuals' perceptions of

their ability to handle specific tasks or challenges. For instance, if a person interprets these physiological responses as signs of anxiety, it may diminish their self-efficacy.

The interplay between emotional states and cognitive processes is central to Bandura's theory. Emotional reactions to past experiences or anticipations of future events can shape an individual's beliefs about their capabilities in similar situations. Cognitive appraisal of emotional experiences, where individuals interpret the meaning of their emotional responses, influences self-efficacy judgments (Bandura, 1982).

Individuals are more likely to engage in activities and persist in the face of challenges when they experience positive emotions and low levels of stress or anxiety. Positive emotional states can enhance creativity, problem-solving abilities, and motivation, contributing to a higher likelihood of success (Fredrickson, 2001). Conversely, negative emotional states can lead to self-doubt, hesitation, and avoidance behaviours.

Cultural factors and individual differences influence the relationship between emotional states and self-efficacy. Cultures that emphasize emotional expressiveness and regulation may shape individuals' emotional responses differently (Matsumoto, Yoo, & Nakagawa, 2008). Moreover, personality traits, coping styles, and past experiences contribute to the variability in how individuals interpret and respond to emotional and physiological cues.

While the physiological and emotional states significantly contribute to self-efficacy, individuals' interpretations of these states vary. For example, some may interpret heightened arousal as excitement, while others may perceive it as anxiety. Therefore, interventions aimed at enhancing self-efficacy should consider individual differences in emotional appraisal.

4.1.1.4.1 Summary

The physiological and emotional states component of Bandura's self-efficacy theory underscores the intricate connection between emotional experiences and individuals' beliefs about their capabilities. Recognising the impact of emotional arousal and physiological sensations on self-efficacy has implications for education, therapy, and various areas of personal and professional development. Strategies aimed at managing emotional responses and fostering positive emotional states can contribute to the cultivation of robust self-efficacy beliefs.

4.1.2 Empirical Evidences

Self-efficacy theory has been widely researched, and numerous experimental studies provide robust evidence supporting the key tenets of this theory. Later in this work, we discuss experimental evidence across various domains, emphasizing the impact of self-efficacy on learning, performance, and psychological well-being.

Academic Achievement

Experimental studies in education consistently demonstrate the role of self-efficacy in academic performance. A meta-analysis by Honicke and Broadbent (2016) found a strong positive correlation between self-efficacy and academic achievement across various subjects and educational levels. For instance, a study by Pajares and Miller (1994) showed that self-efficacy beliefs in mathematics significantly predicted students' mathematical performance.

Health Behaviour and Management

Self-efficacy plays a crucial role in health-related behaviours. In a study by Schwarzer and Renner (2000), self-efficacy beliefs were associated with better adherence to health-promoting behaviours, such as regular exercise and a balanced diet. Experimental interventions targeting self-efficacy have been successful in promoting health behaviour change, as seen in programs addressing smoking cessation, weight management, and chronic disease management (Luszczynska, Sobczyk, & Abraham, 2007).

Occupational Performance

Research in the workplace context highlights the impact of self-efficacy on occupational performance. A study by Stajkovic and Luthans (1998) found that self-efficacy significantly predicted job performance. Experimental interventions aimed at enhancing self-efficacy have been implemented in organizational settings, leading to improvements in employee productivity and job satisfaction (Bandura, Freeman, & Lightsey, 1999b).

Athletic Performance

Bandura's self-efficacy theory has been applied in the realm of sports psychology. Experimental research in sports settings demonstrates that athletes with higher self-efficacy are more likely to set challenging goals, persist in the face of obstacles, and achieve better

performance outcomes (Feltz, Short, & Sullivan, 2008). Interventions targeting athletes' self-efficacy have shown positive effects on performance (Moritz, Feltz, Fahrbach, & Mack, 2000).

Career Development

Self-efficacy plays a crucial role in career decision-making and performance. A longitudinal study by Lent, Brown, and Hackett (Lent, Brown, & Hackett, 1994) found that self-efficacy beliefs significantly predicted career-related outcomes over time. Experimental interventions focusing on career self-efficacy have been effective in enhancing individuals' career exploration and decision-making (Betz & Hackett, 2006).

4.1.3 Considerations

While the experimental evidence for Bandura's self-efficacy theory is substantial, researchers acknowledge the complexity of this construct. Factors such as context, domain specificity, and individual differences influence the relationship between self-efficacy and outcomes. Additionally, the bidirectional relationship between experiences and self-efficacy suggests that successful outcomes can reinforce and further strengthen self-efficacy beliefs.

4.1.4 Summary

Experimental evidence spanning diverse fields consistently supports Bandura's self-efficacy theory. The demonstrated impact underscores the pervasive influence of self-efficacy across various aspects of human functioning. Interventions designed to enhance self-efficacy have shown promising results, emphasizing the practical significance of this theoretical framework in promoting positive outcomes in education, health, work, and personal development. It is these links to producing positive changes to people behaviours that we will use within this body of work. We can engineer an educational intervention which focusses on these areas of development alongside content delivery with the intention of improving students reported academic self-efficacy and hence their employability.

5 Disciplinary Egocentrism

Disciplinary egocentrism, a term coined by Richter and Paretti (2009a), refers to the tendency of individuals to view their discipline as the central reference point, often dismissing or undervaluing insights from other fields.

> *"Importantly, lack of perspective is not only a rejection of other viewpoints, but often, as the case study data suggests, a failure to recognize differences in perspectives and contributions."*
>
> (Richter & Paretti, 2009a)

It is a cognitive phenomenon rooted in Piagetian developmental theory, describing the cognitive bias wherein individuals, particularly within educational contexts, struggle to transcend the boundaries of their specific discipline. This phenomenon has significant implications in higher education, affecting students' ability to engage in interdisciplinary thinking and potentially limiting their adaptability in a rapidly evolving professional landscape.

5.1 Basis in Piagetian Theory

Jean Piaget's theory of cognitive development, particularly the concept of egocentrism in the preoperational stage, laid the groundwork for understanding disciplinary egocentrism. In the preoperational stage, children struggle to distinguish their perspective from others and assume that everyone sees the world as they do (Piaget, J., 1936). Disciplinary egocentrism extends this idea to academia, where individuals find it challenging to step outside the confines of their specific field of study. It has been shown that this form of cognitive bias increases in developmental boundary crossing (Blackburn & Papalia, 1992) – a description that can be applied to students moving into higher education.

5.2 In Higher Education

Disciplinary egocentrism manifests in higher education when individuals, particularly students, find themselves confined within the boundaries of their specific discipline. This limitation can impede the richness of learning experiences, hinder interdisciplinary thinking, and compromise the adaptability needed in a rapidly evolving professional landscape (National Academies of Sciences, Engineering, and Medicine, 2018).

In the academic realm, disciplinary egocentrism can be considered to create conditions that mirror the preoperational stage described by Jean Piaget, where individuals struggle to distinguish their perspective from others. This cognitive barrier impedes the ability to comprehend viewpoints and methodologies outside their specific field of study (Piaget, J., 1936). One prominent example of disciplinary egocentrism is observed in science, technology, engineering, and mathematics (STEM) disciplines. Students immersed in rigorous STEM programs may become so focused on the methodologies and problem-solving approaches within their field that they struggle to appreciate insights from disciplines such as the humanities or social sciences (Connor, Karmokar, & Whittington, 2015). This limited perspective can hinder the development of holistic solutions to real-world problems, where a multidisciplinary approach is often essential.

The traditional model of higher education often reinforces disciplinary egocentrism (Robertson, 1999). Students are typically organised into single-discipline cohorts, progressing through a curriculum that seldom encourages interactions with diverse fields of study. This compartmentalised approach fails to prepare students for the collaborative and interdisciplinary demands of the modern workforce (Salas, Cooke, & Rosen, 2008).

5.3 Addressing this issue

Higher education institutions are increasingly incorporating interdisciplinary teaching and learning approaches into curricula (Bear & Skorton, 2019). Interdisciplinary courses and projects expose students to diverse perspectives, breaking down the barriers of disciplinary silos. For instance, a collaborative project involving engineering and design students may encourage them to appreciate the aesthetic and functional aspects of their work, fostering a more holistic understanding.

Despite these efforts, challenges exist in finding the right balance between disciplinary depth and interdisciplinary flexibility. Critics argue that an overemphasis on interdisciplinary approaches may dilute the depth of knowledge within specific disciplines (Repko, Newell, & Szostak, 2011). Striking this balance requires thoughtful curriculum design and pedagogical strategies that encourage exploration beyond disciplinary boundaries.

The concept of disciplinary egocentrism also intersects with broader issues of diversity and inclusion within higher education (Wächter, 2012). When students are predominantly exposed

to perspectives within their discipline, they may miss out on the richness that diverse voices bring. In fields such as business and management, for instance, a narrow focus on traditional models of leadership may exclude insights from diverse cultural perspectives that are increasingly valuable in a globalised business environment.

Interdisciplinary teaching, which seeks to break down the barriers between academic disciplines, therefore becomes a crucial strategy to counteract disciplinary egocentrism. By exposing students to diverse perspectives and methodologies, interdisciplinary approaches aim to broaden their cognitive horizons (Richter & Paretti, 2009b). This approach fosters an environment where students learn to appreciate the value of different disciplines and develop a more flexible and adaptive cognitive framework.

While breaking down disciplinary boundaries is essential, it's not without challenges. Critics argue that an overemphasis on interdisciplinary approaches may dilute the depth of knowledge within specific disciplines (Repko, Newell, & Szostak, 2011). Striking the right balance between disciplinary depth and interdisciplinary flexibility remains a challenge for educators.

5.4 Applications to employability

Disciplinary egocentrism has tangible implications in the workplace. As individuals transition from academic settings to professional environments, the challenges posed by disciplinary egocentrism become evident, impacting collaborative dynamics, problem-solving approaches, and overall adaptability.

In a workplace setting, collaboration is often paramount for tackling complex challenges that require a multidisciplinary approach. Disciplinary egocentrism, however, can hinder effective teamwork (Jensen, Utriainen, & Steinert, 2018). For instance, in a project team consisting of professionals from diverse backgrounds—engineering, marketing, and finance. If an engineer, deeply immersed in the technical aspects of the project, struggles to appreciate the marketing perspectives or financial constraints, the viability of the project may be at risk (this was experienced quite famously in the development and sale of the original mini, which was released for a price less than it cost to build due to poor communication between engineers and other teams and strongly contributed to the demise of British Leyland (Clifford Webb,). This lack of interdisciplinary understanding can impact the overall success of commercial projects.

Leadership roles within workplaces often require a holistic understanding of organisational dynamics, encompassing diverse functions and perspectives. Disciplinary egocentrism can pose challenges for leaders who emerge from specialised backgrounds. A leader with a technical background, for instance, may find it challenging to navigate human resources issues or understand the intricacies of marketing strategy. This limited perspective can hinder effective decision-making and leadership effectiveness (Bass & Stogdill, 1990).

In the contemporary workplace, where diversity and collaboration are celebrated as key drivers of success, addressing disciplinary egocentrism is imperative. The examples provided illustrate how this cognitive phenomenon can influence team dynamics, innovation, leadership effectiveness, and overall professional adaptability. Employees that collaborate more effectively are better positioned to thrive in a rapidly changing and interconnected business environment. As the nature of work continues to evolve, the ability to transcend disciplinary boundaries becomes a hallmark of agile and successful professionals and organisations alike.

5.5 Conclusion

Disciplinary egocentrism is a cognitive challenge deeply ingrained in traditional educational models. Recognising its impact on learning and professional adaptability, efforts to foster interdisciplinary thinking are increasingly vital. Higher education institutions must reimagine curricula, teaching strategies, and institutional cultures to cultivate graduates capable of navigating the complex, interconnected challenges of the modern world. The development of a more flexible and interdisciplinary mindset is not only an academic pursuit but a crucial preparation for the dynamic and interdisciplinary nature of contemporary professional environments.

6 The False Consensus Effect

The false consensus effect is a cognitive bias that leads individuals to overestimate the extent to which their beliefs, opinions, or behaviours are shared by others. It involves a tendency to believe that one's own preferences, values, and choices are more common in the general population than they actually are. This psychological phenomenon was first identified by social psychologist Lee Ross and has since been a subject of extensive research (Marks & Miller, 1987; Ross, Greene, & House, 1977).

6.1 Theoretical Underpinnings

The false consensus effect can be understood through various cognitive theories. One of the foremost theories regarding this bias is the anchoring and adjustment heuristic. According to this heuristic, individuals anchor their judgments based on their own opinions, using them as a starting point, and then adjust from that anchor to estimate the opinions of others (Tversky & Kahneman, 1974). In the context of the false consensus effect, this means that individuals tend to perceive their own beliefs, attitudes, and behaviours as the norm or anchor. Once this anchor is established, they make adjustments to this value to estimate how prevalent their opinions are in the wider population. If someone believes that their viewpoint is widespread or normative, they will anchor their estimate of others' opinions accordingly, leading to an overestimation of consensus.

6.1.1 The Anchoring and Adjustment Heuristic

To illustrate the anchoring and adjustment heuristic in the context of the false consensus effect, consider an individual who strongly supports a specific political candidate. This person, influenced by their own political preferences, uses these preferences as an anchor. When estimating the political preferences of others, they adjust from this anchor. If their initial anchor is the belief that their chosen candidate is widely popular, they might adjust insufficiently, leading to an overestimation of how many people share their political views. Numerous studies have provided empirical support for the anchoring and adjustment heuristic as a mechanism behind the false consensus effect (Hoch, 1987; Ishii & Takezawa, 2019; Tamir & Mitchell, 2013).

6.1.2 Egocentric Bias

Another theoretical explanation contributing to the false consensus effect is the egocentric bias. This bias reflects the tendency of individuals to struggle in separating their own perspectives from those of others. In the realm of social cognition, people often assume that others are more similar to them than they actually are. This cognitive bias leads to the perception that one's own beliefs, values, and behaviours are more widely shared than they truly are (Krueger & Clement, 1994a).

Consider an individual who holds a particular dietary preference, such as being a vegetarian. Due to the egocentric bias, this person might find it challenging to accurately perceive the dietary preferences of others. The assumption that vegetarianism is widespread among their peers becomes the anchor, and adjustments made from this anchor result in an overestimation of the prevalence of vegetarianism in the general population.

6.1.3 Social Validation

Additionally, the false consensus effect can be linked to a fundamental human need for social validation. Individuals may overestimate the prevalence of their beliefs as a mechanism to maintain a positive self-image and feel accepted by their social groups. The desire to be part of the majority or to conform to perceived social norms contributes to the overestimation of consensus (Sherman, Presson, & Chassin, 1984).

For example, consider a scenario where an individual strongly identifies with a particular subculture or lifestyle. To enhance their sense of belonging and social acceptance, they may assume that a majority of people share their subcultural preferences, leading to an overestimation of consensus within that specific group.

6.1.4 Evidence for the false consensus effect

Empirical evidence supporting the link between the false consensus effect and these cognitive mechanisms is robust (Gilovich, Jennings, & Jennings, 1983; Marks & Miller, 1987; Wolfson, 2000). Studies have consistently demonstrated that individuals anchor their estimates on their own attitudes, struggle with egocentric biases, and seek social validation, contributing to the overestimation of consensus.

Numerous studies have provided empirical support for the existence of the false consensus effect. In their classic study, Ross, Greene, and House (1977), participants were asked to perform a variety of tasks, such as selecting their favourite poster or solving hypothetical problems. Regardless of the task, participants consistently believed that their choices were more popular among their peers than they actually were.

In Marks and Miller's experiment (Marks & Miller, 1987), participants were asked to indicate their agreement or disagreement with a set of statements. The researchers found that participants who held unpopular opinions systematically overestimated the prevalence of those opinions in the general population.

6.1.5 Summary

The false consensus effect represents a cognitive bias that influences how individuals perceive the prevalence of their own beliefs in society. Rooted in theories such as anchoring and adjustment and egocentric bias, this phenomenon has been consistently demonstrated through various experiments.

We have touched on this briefly in the foregoing consideration, but it can be seen that the False Consensus Effect is closely linked to egocentrism (Krueger & Clement, 1994b; Ross, Greene, & House, 1977; Yinon, Mayraz, & Fox, 1994), and as we have discussed in preceding sections this can be shown to have negative outcomes on employability. If we are considering this impact through the lens of the False Consensus Effect, we can consider that a person's view on the correct way to approach a problem impact on their ability to consider other viewpoints and methods. If then we can lower the presence of the False Consensus Effect, we may argue that this is a positive step towards improved employability.

7 Systematic Literature Review

To establish the current state-of-the art in the field considered in this work, a systematic literature review has been conducted to evaluate existing literature. The primary purpose of this is to gain a comprehensive understanding of the current state of knowledge, theories, methodologies, and findings related to the concept of interdisciplinary teaching interventions in higher education and their impact on employability.

7.1 Search Methodology

Performing a systematic literature review within the PRISM framework involves a structured methodology that ensures a comprehensive and unbiased synthesis of existing research. Using the PRISM approach:

Purpose

The review aimed to explore the intersection of interdisciplinarity, higher education, and employability.

Range

The search was conducted across multiple academic disciplines and time periods, focusing on literature that examines the relationship between these concepts.

Identifiers

The key identifiers used in this search were the terms:

- ‘Interdisciplinarity’
- ‘Higher education’
- ‘Employability’

Search Terms

These terms were used in various combinations, with ‘interdisciplinarity’ consistently included in every search to ensure relevance to the research objective.

Methods

The search was conducted across several major academic databases, including:

- ERIC (Education Resources Information Center)
- PubMed

- PsycINFO
- Scopus
- Web of Science
- Google Scholar

By applying the PRISM framework, the literature search was systematic, thorough, and aligned with the research goals, ensuring that all relevant studies were captured and assessed. From the initial search 952 sources were identified these were screened for duplicates and irrelevance reducing the number to 643. From this a limit on the age of sources was applied and set to the previous 10 years, this reduced the number down further to 72 relevant sources, these were categorised as follows: Interdisciplinarity in Teaching and Learning (44), Teaching Excellence and Pedagogical Innovations (15), Challenges in Higher Education (13). These categories were used as they best described recurring themes in the literature, often the focus of the sources was on the interdisciplinarity itself, however sometime the focus was on the impact this form of teaching could have on learning – these then form the first two categories. The third category arose because of the focus of a number of authors was on the difficulty of structural change in higher education teaching, which often considered the implementation of novel interventions, such as interdisciplinarity.

7.2 Themes Identified in the Literature

7.2.1 Interdisciplinarity in Teaching and Learning

Interdisciplinarity was understandably a regularly occurring theme in the literature. Many sources discussed the advantages of interdisciplinarity to the process of teaching in higher education for 'soft skills' and professional development, Filipe, Coelho, and Barbosa (2018, p712) discuss how an interdisciplinary teaching intervention can *'integrate knowledge of two or more subjects to produce a complex cognitive skill, developing boundary-crossing skills'*, they go on to demonstrate the development of interpersonal and communication competencies. Derbyshire, Fretwell, & Harvey (2023, p324) discuss the potential outcomes of an interdisciplinary teaching intervention,

> *"The project aimed to provide several outcomes including increased confidence across teamworking; project management; leadership; negotiation skills; time management; communication; and presentation skills."*

In their review of interdisciplinary teaching activities, Lindvig & Ulriksen (2019, p710) discuss how interdisciplinary teaching can alter students' academic identity to reduce disciplinary egocentrism,

> *"They came with the academic identity of an engineer "and approached student learning as an 'engineering problem', […] but during the program they negotiated and adjusted that identity."*

Catz, Kolodny, & Gero (2023) focus on the academic advantages conveyed in the learning process for delivering what would be traditionally singe discipline topics, they did however report comments from students about the increased cognitive load this form of teaching creates.

Many authors examined how interdisciplinary teaching impacted students' perception of their own skills (Hains-Wesson & Ji, 2020; Ferns, Phatak, Benson, & Kumagai, 2021; Daley & Thompson, 2015). Hains-Wesson and Ji explained the process allowed students to *'to quickly re-assess their skills before trying new ways of working with others'.*

Other key points raised in the literature were around the greater capacity of interdisciplinary teaching to tackle large, and complex problems, such as are becoming increasingly prevalent. (Rogora & Tortoriello, 2021; Jensen, Stentoft, & Ravn, 2019; Scanlon & Conole, 2018; McCright, O'Shea, Sweeder, Urquhart, & Zeleke, 2013). Indeed, Power and Handley (2019, p554) contend,

> *"In the modern, global, landscape we are faced with many complex challenges requiring novel solutions. It is recognised that innovative and sustainable approaches to addressing today's and tomorrow's global challenges reach far beyond the boundaries of a single academic discipline or methodological approach and require new ways of working"*

Some authors discuss a certain inevitability in the need for interdisciplinary teaching (Trowler, 2012; Anderson & Barthelemy, 2014; Kim, 2020; Ash, 2019; Wolkenhauer & Hofmeyr, 2013; Ayar & Yalvac, 2016; Woelert & Millar, 2013). It is often described as part of the progression of disciplines, especially sciences that whilst disciplinary skill remains important, deploying it increasing involves collaboration.

The concept of disciplinary silos and the presence of disciplinary egocentrism is discussed in many areas, where interdisciplinarity is introduced or proposed to combat theses features of traditional pedagogy (Richter & Paretti, 2010; Coso & Bailey, 2010; Bhaskar, 2010; Priaulx & Weinel, 2018; Roper, 2021; Chew, 2021; Luke, Carothers, Dhand, 2015; Skains, et al., 2021; Goedereis & MacCartney, 2019). Klaassen (2018, p843) discusses the causes of disciplinary silos and finds that,

> *"Boundedness depends on the social and epistemological status of a field of study and its interrelatedness with the market it might serve"*

He goes on to stress that especially in engineering aligned disciplines this has been the paradigm for a long time.

We find other sources have included consideration of the impact on self-efficacy of interdisciplinary teaching (Schaffer, Chen, Zhu, Oakes, 2012; Santaolalla, Urosa, Martín, Verde, Díaz, 2020; Watt, 2021; Claus, Wiese, 2019). Maybe the starkest statement about this link was made by Semilarski, Soobard, Holbrook, and Rannikmäe, (2021, p1),

> *"Outcomes showed that the intervention (guiding students in creating disciplinary and interdisciplinary core idea maps to visualize their learning) supported students significantly in their perceived self-efficacy"*

Other authors considered interdisciplinarity in terms of the false consensus effect (Gurung, & Schwartz, 2013; Kolbe, et al., 2013; Skains, et al., 2021; Bruine de Bruin, & Morgan, 2019; Leitner, et al., 2021) and more broadly there was a consideration of heuristics and biases and how these are impacted by interdisciplinarity (Hernoff, & Sriraman, 2020; MacLeod, & Van der Veen, 2020; Singh, et al., 2018; Heitzmann, et al., 2021; Xefteris, & Palaigeorgiou, 2019; Jahnke, Riedel, Singh, Moore, 2021)

7.2.1.1 Summary

The general focus of these sources is that with judicious integration of interdisciplinary teaching and learning methods, improvements can be introduced to how students learn. It is clear from the literature that interdisciplinary teaching interventions can have multiple advantages and are often associated with delivering changes in student attitudes and opinions. This provides an evidential basis for the assertion that an interdisciplinary-style

teaching intervention would be effective in developing employability. The consideration of sociological concepts such as heuristics and biases, false-consensus effect, and self-efficacy indicates that there are a great many dimensions to the effects of interdisciplinary teaching and careful consideration will have to be made of what measurements are made.

7.2.2 Teaching Excellence and Pedagogical Innovations

Much of the discourse in these sources is around the development of pedagogy. The regularly accepted view is that there are advantages conferred from introducing interdisciplinarity, however a number of authors consider how this is changing the way teachers and students are considering teaching itself.

Holley (2009, p339) considers data gathered in a case study of 21 US universities and found that through the drive to implement interdisciplinary activities culture change was brought about in institutions. They quote references from materials published by the University of Pennsylvania as an example of the drive for change,

> *"The University must create an environment that breaks down the real or psychological barriers of school-based spaces that can impede collaboration and result in duplicative efforts"*

Klein and Miller (1983) discuss many of the structural issues and challenges of interdisciplinarity and reference Donald Campbell's fish-scale model specifically to describe the differences in 'overlapping' disciplines and how a true 'fish scale model' would look.

In their book *Reimagining the Higher Education Student* Brooks & O'Shea (2021), whilst not explicitly citing interdisciplinary interventions as the driving factor, none the less are clear that students need to be well versed in the capabilities required by employers in order to be successful post-graduation, and this leads to a need for radical overhaul of the higher education delivery paradigm.

Numerous authors discuss the advantages that interdisciplinary teaching can confer to learning through increased engagement (Neill, Corder, Wikitera, Cox, 2017; Moser, Ivy, Hopper, 2019), with another theme regularly occurring concerned with the capacity to increase realism of professionality into teaching (You, 2017; Kivunja, 2014; Van den Beemt, et

al., 2020; Czerniak & Johnson, 2014). One set of researchers (Alonso Sáez, & Berasategi Sancho 2017, p132) even considered the impact of interdisciplinary teaching on both,

> *"From the different evaluations of the IAM [Interdisciplinary Activity Module] that have been carried out, we may highlight some aspects that will be repeated, which are: a) greater motivation than with other teaching methods; b) a positive evaluation of learning that is based on real professional situations with which the student has to work independently"*

By far and away the largest body of literature was concerned with the learning outcomes of students undertaking interdisciplinary teaching. These universally considered the interdisciplinary teaching an educational success to some degree (Bachmann, et al., 2013; O'Leary, et al., 2011; Papaioannou, Milosis, Gotzaridis, 2019; Biasutti & EL-Deghaidy, 2015; Berger, Scott, Axe, Hawkins, 2013; Hobggod, 2010; Lattuca, 2017; Rooks & Winkler, 2012; Acarli, 2020). Ultimately it is said best by the title of a piece of research by Kjerstin Åseng and Anniina Riekki (2021, title page).

> *"Regardless if you succeed or not, interdisciplinary teaching is not a wasted effort.*

7.2.2.1 Summary

Interdisciplinary education in higher education is recognised as having the potential to have a transformative effect on the sector and that more is needed to be understood about how this will affect the operation of courses and the universities themselves. It is clear that the utility of interdisciplinary learning has an important place in the current dialogue centered around the modernisations of institutions for the current landscape and supports the rationale for completing this research in this era.

7.2.3 Challenges in Higher Education

One of the major themes present in the considered literature was that of the challenges faced by practitioners and institutions when trying to introduce or implement interdisciplinary interventions - financial, structural, and philosophical.

Falcus, Cameron, & Halsall (2019) consider many different aspects of the introduction of interdisciplinarity and make a clear link between the financial difficulties that an

interdisciplinary approach might introduce to higher education institutions and how a transition to a different teaching paradigm has to contend with barriers to entry.

Morace et al (2017, p152) consider the challenges of developing a coherent approach to the new curricula and the diverse stakeholders responsible:

> *"In the future, one of the major tasks of German engineering education will be to secure the high level of technical training and to include more humanities and intercultural issues in the standard curricula. To do so, there is a need for closer cooperation between representatives of industry, politics and higher education to ensure that all interests are equally represented to meet future challenges."*

In their work, *Creating spaces for interdisciplinary exchange in higher education: A case study,* Consorte-McCrea & Newing (2015, p275) discuss a specific interdisciplinary event and highlight the difficulty of identifying funding streams for activities because of their novelty:

> *"Thus, the added value of this kind of event is clearly very high. However, in spite of ample rhetoric on the importance of interdisciplinarity and sustainability in teaching, events such as this remain scarce, and their funding and implementation face some of the same institutional barriers as interdisciplinary teaching in itself."*

Many authors discuss the difficulty of enlisting disciplinary practitioners to engage with a new teaching paradigm (Al Salami, Makela, De Miranda, 2017; Rooks & Winkler, 2012; McCuaig, Carroll, Geidne, Okade, 2020), indeed it was put plainly by David Dalton (2015, p1) when he identifies:

> *"To participate in interdisciplinary teaching is not necessarily a choice many teachers would willingly make, perhaps because it can bring with it added and unexpected challenges and pressures as well as additional work."*

And even more starkly by Campos and Domitti (2007, p404):

> *"Interdisciplinary work also depends on a certain subjective predisposition to deal with uncertainty, to receive and make criticisms, and to make decisions in a shared way, [and this is not] the dominant subjectivity pattern in environments of exacerbated competition, the predominant way of functioning of contemporary institutions"*

The challenges around in the coordination and administration of interdisciplinary education were frequently focussed on (Gantogtokh & Quinlan, 2017; West, 2016; Lyall, Bruce, Tait, Meagher, 2011; Al Salami, Makela, De Miranda, 2017)

Other authors considered the response of students themselves to being taught in an interdisciplinary way (Gill, et al., 2021; Kelly, McLoughlin, Finlayson, 2020) with Kelly, Mcloughlin and Finlayson (2020, p1018) examining how the participants of an interdisciplinary intervention viewed it:

> *"From the students' perspective, they felt more inclined to attend collaborative class sessions and to work harder in timetabled sessions. Students felt motivated to attend timetabled sessions due to the collaborative nature of the course, as they did not want to disappoint their group members."*

7.2.3.1 Summary

Whilst the utility of interdisciplinary teaching is regularly emphasised, the limiting fact often is that it is outside the 'normal' operation of universities. This creates a web of interlinked problems that require solving simultaneously. In this work we hope to establish further the use of this type of intervention, but also demonstrate a pathway to implementation.

7.2.4 Discussion

These themes reveal a delicate balance between the recognised utility of interdisciplinary teaching and the inherent challenges associated with its adoption. While interdisciplinary interventions show promise in enhancing students' holistic skills and reshaping academic identities, the structural and financial challenges within higher education institutions remain formidable. The pathway to implementation involves addressing these challenges simultaneously, requiring a paradigm shift that aligns pedagogy, institutional structures, and community involvement.

The literature reviewed in this work provides evidence for the effectiveness of interdisciplinary-style interventions in addressing employability issues. The transformative potential of interdisciplinarity, highlighted in teaching and learning, teaching excellence, and the challenges faced, underscores the need for a comprehensive and integrated approach to higher education. This need makes it increasingly pressing that the sector has a range of

examples of practice supported through research in order for this type of teaching intervention to become more widespread.

8 Theoretical Rationale

This work considers how the concept of disciplinary egocentrism can develop in students taught on single discipline courses; a paradigm prevalent in the UK. It is argued that the immediate society of peers created by holding students in disciplinary silos strongly resembles the pre-operational phase of Piagetian Developmental Theory. The egocentric features of pre-operational behaviour arise from a lack of understanding that a person may have *private knowledge*, the belief that others are party to the same information that an individual holds is eventually eroded through experiences. However, Piaget noted that egocentrism persists into adulthood and tends to increase following the crossing of developmental boundaries (Long, McCrary, & Ackerman, 1979). Following the significant personal boundary crossing of starting university, single discipline courses restrict students' daily peer group interaction to others studying the same course at the same time. Now as a student develops academically so too do their local society and in any interaction with peers the knowledge, they have acquired is likely to be available to all. We have then created a situation reminiscent of the early pre-operation period of Piaget's developmental theory where knowledge (in this instance restricted to disciplinary knowledge) is believed to be universal and we greatly reduce the occurrence of experiences that contradict this view, through the maintaining of the disciplinary silo. This then is febrile ground for disciplinary egocentrism to grow in.

8.1 Mead's Development of the Self

One area that is important to consider when theorising mechanisms for the existence of poor self-efficacy and consequently employability is the concept of in individual's constructed identity.

George Mead considered that the self was socially constructed; there could be no identity without interaction within a society and that those interactions shaped the way the self formed, indeed: *"The self is something which has a development; it is not initially there, at birth, but arises in the process of social experience and activity"* (Mead, 1934, p135). Mead describes the self as being formed of two parts, the 'I' (the subjective self) and the 'me' (the objective self). In his social philosophy the individual interacts with society through a series of 'gestures', and how these gestures are received and interpreted moulds the self's interaction with the world. The 'me' is built from learnt socially acceptable responses through interaction

with society and controls the impulsive prompting of the 'I'. The 'me' defines how the self fits into the world in which it operates and is dependent on external cues to shape this image:

> *"What the individual is for himself is not something that he invented. It is what his significant others have come to ...treat him as being."*
> (Mead & Morris, 1967, p228)

In some way similar to the Freudian concept of ego and id, Mead's theory of the self tries to explain how the society in which a person operates, moulds their behaviour responses, which effectively constitute the personality, or self. In a way, Mead's 'gestures' can be thought of as similar to questions a person asks of their surroundings and the response gesture as an answer. Through repeated questioning, a person builds up a collection of answers which shape the way they perceive the world. If we apply this theoretical framework to the development of the disciplinary self in higher education, we can envision that the answers a student gets from their academic surroundings will define their academic self.

When we consider single discipline cohorts, we find we have a collection of students held in a society whose members are developing academically at a rate we may model as roughly identical. Now when an individual asks a 'question' of their society about their academic performance, the answer comes back relative to the societal average, which for the restricted group that they occupy is increasing in step with their own development over time. The 'answer' therefore appears as the difference in performance of an individual against the skilled group average, as opposed to the absolute progress made relative to the static, global average skill level. Shown in Figure 5 is a graphic representation of this effect. In this scenario the individual has continuous absolute improvement (relative to their initial stating point) but appears to have a continuously *declining* ability relative to their local society.

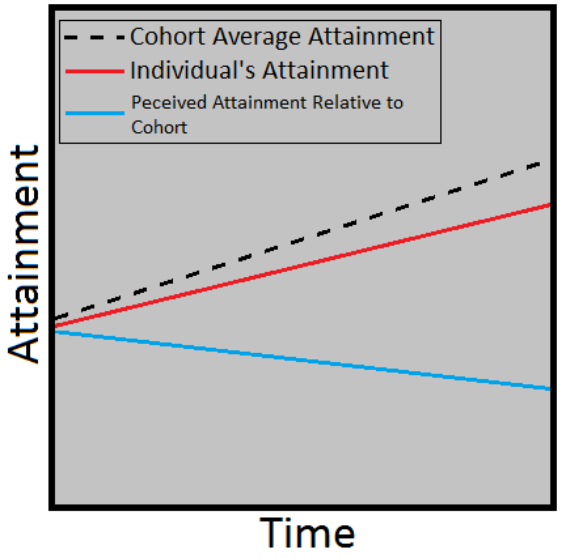


Figure 5 - Illustration for a theoretical student, of actual academic progress vs perceived progress

This effect is present for all learners in the cohort and has the effect of masking absolute performance - even the students achieving at the top of their cohort have a diminished relative performance in comparison to their absolute success.

Looking at this phenomenon though the lens of Bandura's self-efficacy theory, we can see that this foreshortened belief in one's attainment impacts on the realm of *mastery experience*. An individual fails to reflect on the progress they have made and instead tacitly tells themselves that they are just getting by, or ticking-over academically, instead of recognising the absolute advancements they have made.

Through Mead's social philosophy, we find agreement with the argument that one's academic self is formed through interactions with a local society, and when students are held in single discipline cohorts their interactions are with peers. Comparisons are then made against others within the cohort instead of a global society. This negative affects academic self-efficacy and the development of the self within discipline.

8.2 Piaget and Disciplinary Egocentrism

As discussed, in Piaget's theory of cognitive development he describes the behaviour of *preoperational* children (children under the age of 7) as egocentric; their cognitive development has yet to include the understanding that others are separate from one's self. Egocentrism refers to the inability to distinguish one's own perspective from that of others -

preoperational children believe that all others are party to exactly the same knowledge as them. This egocentrism fades with age as children develop but doesn't entirely disappear and has been shown to persist into adulthood. Piaget also described an increase in egocentrism as children enter new developmental stages - the mental strain engenders a greater awareness and focus on the self (Piaget, Jean, 1959). Much criticism of Piaget's theories has been made, often towards the timeline that Piaget applied to child development, however the existence of childhood egocentrism and its resurgence through adolescence and into adulthood has been corroborated by a number of other researchers and it is this element of Piagetian developmental theory that this work uses as its foundation.

As with Piaget's increase in egocentrism at stage boundaries, this work argues that as the transition to university comprises such a shift for students, the natural inclination to increased egocentrism is present. Following this transition, students are restricted to their disciplinary silo, in which every member is party to the same knowledge, afforded by the curriculum. Here now we have a situation reminiscent of the preoperational stage of Piaget's cognitive development - the belief that everyone is party to one's knowledge is reinforced through experience, the majority of people encountered share a relatively similar level of disciplinary knowledge as the individual. We have no social interaction which refutes the notion that the individual's knowledge is available to all. This then can lead to *'…the inability to distinguish one's own perspective from that of others'*, and further, to the belief that this disciplinary specific knowledge and behaviour is the only correct approach. This form of egocentrism was later described by Richter and Paretti as *'disciplinary egocentrism'*.

8.3 Advantages of interdisciplinary learning

The overwhelming focus of the gathered literature is on the various advantages that an interdisciplinary approach can have in teaching practice. Many focus on the changing nature of challenges faced by industry in tackling large scale problems and the need to integrate the input from disparate disciplines. Another heavily stressed area is the effect on students' learning experience and the opportunities to develop capabilities that lie outside the scope of traditional disciplinary teaching.

Many fields are looking to solve difficult and complex problems, with far reaching scope and implications for their solution. In order to solve such problems and develop the best solutions

it is necessary to consider the input from a wide selection of stakeholders. The ability then to work in this paradigm is vital to the graduating student.

> *"Interdisciplinary approaches are necessary for attacking the most critical technological and socio-technological challenges facing the world today, including climate change, sustainability, energy, and public health. Graduate students and their training programs are recognized as central to increasing interdisciplinary research capacity."*
>
> (Cohen, J. J. et al., 2021, p2)

Interdisciplinary working can encourage the development of skills that would be absent from a single discipline curriculum, through integrating different approaches to a problem a more comprehensive solution can be reached.

> *"[Interdisciplinarity is] the capacity to integrate knowledge and modes of thinking in two or more disciplines or established areas of expertise to produce a cognitive advancement—such as explaining a phenomenon, solving a problem, or creating a product—in ways that would have been impossible or unlikely through single disciplinary means."*
>
> (Boix Mansilla, Miller, & Gardner, 2000, p341)

In general, an interdisciplinary approach can foster greater understanding of problems, especially more complex problems.

> *"Interdisciplinarity can help to address today's complex issues since it is believed that a cross-disciplinary approach facilitates a comprehensive understanding"*
>
> (Elisabeth, Harm, Tobi, Luning, & Mulder, 2009, p366)

8.4 Disadvantages of introducing interdisciplinary teaching

Much of the literature is concerned with evaluating interdisciplinary teaching and so often focusses on the difficulties encountered in delivering programs in this way. A common theme was the difficulty practitioners encountered in the mechanical execution of teaching - the added complexity of the inclusion of other disciplines was commented on from different points of view:

> *"Removing the scaffolding of learning offered by a single discipline […] adds complexity to the learning process, to the supervision of students and to the design of curriculum. It may not be immediately obvious from the problem at hand which literature to read, which theories and scientific methods to apply, or how to organise complex and conflicting perspectives and epistemologies."*
>
> (Stentoft, 2017, p56)

Often, it seems the biggest challenge to the introduction of interdisciplinary teaching is who starts. Academics who have developed through a single cohort program of learning often have little to no experience of interdisciplinary teaching and so moving into this form of teaching may be more uncomfortable.

> *"The tutors have found the changes [to interdisciplinary teaching] equally challenging. True interdisciplinarity is more expensive in tutor time in requiring team teaching and team assessment. The latter highlight the need for an individual tutor to relinquish 'ownership' of an interdisciplinary module."*
>
> (Toynton, 2005, p114)

9 Research Methodology

To identify changes in self-efficacy, students will be asked to complete the *general self-efficacy scale* questionnaire tailored towards disciplinary efficacy. This is a long-standing, validated research tool designed to calculate a self-efficacy score which can be used as a relative scale to track changes (Schwarzer, R. & Jerusalem, 1993). Alongside this the students will also be asked to complete a research tool designed to test the *False Consensus Effect*. Its intention is to identify the level of over-estimate of the general support for one's point of view. For the purpose of this research, a tailored version is being used which aims to identify the level of disciplinary egocentric bias and use this as a relative measure to track changes. This panel of investigations will be delivered at the start and end of the teaching intervention and then six weeks after the teaching has been completed. Following this quantitative intervention a series of follow-up interviews will be conducted to further investigate anything that presents itself in the data.

9.1 Site of Research

The intended site of research for this work is a case study jointly taught between two courses in the Engineering and mathematics department at Sheffield Hallam University. For 6 teaching weeks in the second semester of delivery the Module *Modelling 2,* which is a core module for student studying on the BSc Mathematics degree is jointly taught and assessed with *Professional Practice,* A core module for student studying on the BSc and MEng Aerospace Engineering courses. The delivery consists of 2 weeks of subject specific content taught to the two disciplines separately with the intention of creating an expertise in their area of the problem they were addressing. For mathematicians this consisted of learning about modelling using cellular automata and for engineers they were instructed in the regulatory issues around certifying aircraft structures to fly. Following this two-week separation, the students were brought together to work in mixed groups (engineers and mathematicians) toward a solution of the proposed problem. The problem (discussed in more detail in chapter 10) required students to establish the optimal arrangement of the interior of the cabin to permit a new restriction on evacuation of the aircraft. There was a proposed reduction in the capacity of the aircraft, which was explained to be unfeasibly punitive to the ‘client’ and so the groups needed to develop a solution to the problem that would result in the reduction of fewer seats.

The students were given a pre-prepared excel simulation of evacuation (see chapter 10 for details) of an aircraft using an agent-based modelling approach in which to enact changes and simulate their effect. The rational of this project was that there were areas of specialty that were needed from both groups of students and so a successful project would require the input of both. The assessment of the module required the groups to produce a report on their findings and present that report to the 'client'.

9.2 Participant recruitment

Participants were recruited from the pool of students who experienced this teaching intervention, they were contacted to ask if they would like to take part in the research and it was stressed that this was separate from the grade bearing aspects of the module. From this pool of volunteers students were asked to sign a consent form (Appendix II) after reading the participant information (Appendix III). This consent covered all three instances of data gathering (pre-, post-, and 6 weeks after). However not all students complete all three qualitative surveys, therefore only participants who had completed pre- and post- surveys were considered for comparison of the immediate impact of the intervention, and subsequently only students who had completed all three were considered for the full consideration.

The consent form included an opt-in question that participants could choose if they were happy to be contacted about doing a follow-up interview. It was from this pool of participants that interview candidates were recruited. All volunteers were used for follow-up interview, and they could self-select whether they wanted to be interviewed in groups or singularly. The participant information and consent for are shown in Appendices IV and V.

9.3 Ethical considerations

As with all research performed within an academic institution this work was required to be scrutinised and recorded by the university's research ethics system which approved the work before data gathering started (see appendix VI).

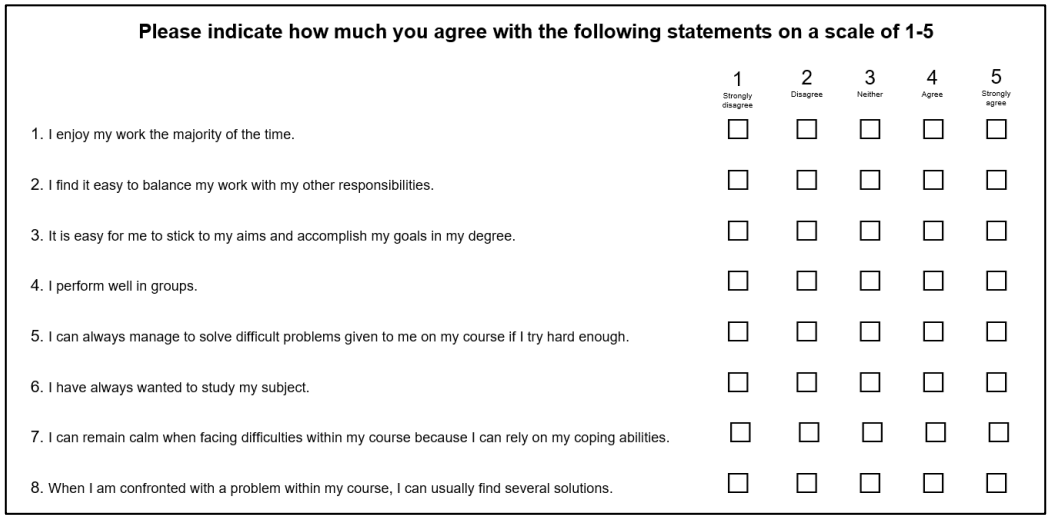
The research was deemed to be low risk, however there are a number of issues that required careful consideration to mitigate their effects on participants. The most apparent of these was the difficulty of avoiding conflation of the researcher role with that of instructor, and how to avoid participants either feeling forced to take part as though it were a mandatory part of the

module or feeling a sense of coercion that may accompany the desire to please an assessor. To minimise this, the teaching team arranged it so that as a researcher I had minimal involvement in the student facing aspect of delivering the intervention. My supervisor delivered the taught content and fielded the majority of questions, the only time I as the researcher was required to be involved with delivery was on specific simulation related questions and in this capacity, I positioned myself as a technician rather than an instructor.

Another ethical consideration was the need to maintain participant anonymity. This was achieved through the use of replacing student numbers with a randomly created signifier across all responses. The key to this pairing was stored separately to the research data in a password protected document on a restricted research server. The data management plan in shown in Appendix VII.

9.4 General self-efficacy scale

The General Self-Efficacy (GSE) Scale is a widely used research tool designed to measure an individual's perceived self-efficacy, which refers to their belief in their capability to accomplish tasks and navigate challenges in various domains of life. This scale, developed by Ralf Schwarzer and Matthias Jerusalem (1995) has become a prominent instrument in psychological research, particularly in areas related to personality, motivation, and well-being.



Please indicate how much you agree with the following statements on a scale of 1-5

	1 Strongly disagree	2 Disagree	3 Neither	4 Agree	5 Strongly agree
1. I enjoy my work the majority of the time.	☐	☐	☐	☐	☐
2. I find it easy to balance my work with my other responsibilities.	☐	☐	☐	☐	☐
3. It is easy for me to stick to my aims and accomplish my goals in my degree.	☐	☐	☐	☐	☐
4. I perform well in groups.	☐	☐	☐	☐	☐
5. I can always manage to solve difficult problems given to me on my course if I try hard enough.	☐	☐	☐	☐	☐
6. I have always wanted to study my subject.	☐	☐	☐	☐	☐
7. I can remain calm when facing difficulties within my course because I can rely on my coping abilities.	☐	☐	☐	☐	☐
8. When I am confronted with a problem within my course, I can usually find several solutions.	☐	☐	☐	☐	☐

Figure 6 - The first eight question on the GSE scale used in this research (see Appendix II for further details)

9.4.1 Purpose and Development

The primary purpose of the GSE Scale is to assess the general sense of self-efficacy, representing a broad and stable trait rather than a situational or context-specific measure. Self-efficacy, as defined by Albert Bandura, is a key component of social cognitive theory and plays a crucial role in individuals' motivation, decision-making, and overall psychological well-being. The GSE Scale was developed to provide a reliable and valid measure of this construct.

The scale consists of a set of statements describing various situations and challenges, and respondents indicate their level of agreement or disagreement with each statement. The items cover a range of scenarios, from coping with difficult tasks to overcoming adversities. Respondents rate their perceived ability to handle these situations on a Likert scale.

9.4.2 Philosophy and Theoretical Underpinnings

The GSE Scale is grounded in Bandura's social cognitive theory, which emphasizes the role of self-efficacy beliefs in shaping individuals' thoughts, actions, and emotional responses. According to Bandura, individuals with higher levels of self-efficacy are more likely to approach challenges with confidence, persistence, and resilience.

The scale reflects the fundamental idea that self-efficacy is a generalised belief that transcends specific situations. It is not domain-specific; instead, it captures a person's overall confidence in their ability to handle diverse tasks across different life domains. The items are carefully crafted to cover a broad spectrum of challenges, contributing to the scale's capacity to measure general self-efficacy.

9.4.3 Structure and Composition

The GSE Scale consists of 10 items, each formulated as declarative statements. Respondents rate their agreement with these statements based on their perceived level of self-efficacy in the described scenarios The items are designed to be straightforward, avoiding complex language and jargon. This simplicity is intentional, ensuring that the scale can be easily understood and administered across diverse populations. These 10 items are combined with 10 filler questions intended to obscure the underlying theme of the survey.

9.4.4 Validation and Reliability

The GSE Scale has demonstrated robust psychometric properties, including reliability and validity. Researchers have conducted numerous studies across various cultural contexts and populations, consistently finding evidence supporting the scale's reliability. Internal consistency, measured by Cronbach's alpha, is typically high, indicating that the items in the scale are interrelated and consistently measure the underlying construct.

The scale has also shown good construct validity, correlating with related constructs in theoretically predictable ways. For instance, individuals with higher general self-efficacy tend to report lower levels of stress, better coping strategies, and higher levels of life satisfaction (Lennings, 1994).

9.4.5 Summary

The General Self-Efficacy Scale stands as a cornerstone in the study of self-efficacy beliefs, offering researchers a reliable and valid tool to assess individuals' general confidence in their ability to meet challenges. Its broad applicability across diverse domains has contributed to its widespread use in various fields of psychology, enriching the understanding of how self-efficacy influences human behaviour, well-being, and achievement.

9.5 A False Consensus Effect Measurement Tool

The False Consensus Effect (FCE) refers to the psychological bias where individuals tend to overestimate the extent to which their beliefs, attitudes, preferences, or behaviours are shared by others. While there might not be a single standardised measurement tool exclusively designed for assessing the False Consensus Effect, researchers often use specific methodologies and questionnaires to examine this cognitive bias.

The tool used in this work is intended to be a paper-based activity that respondents can report their answers on.

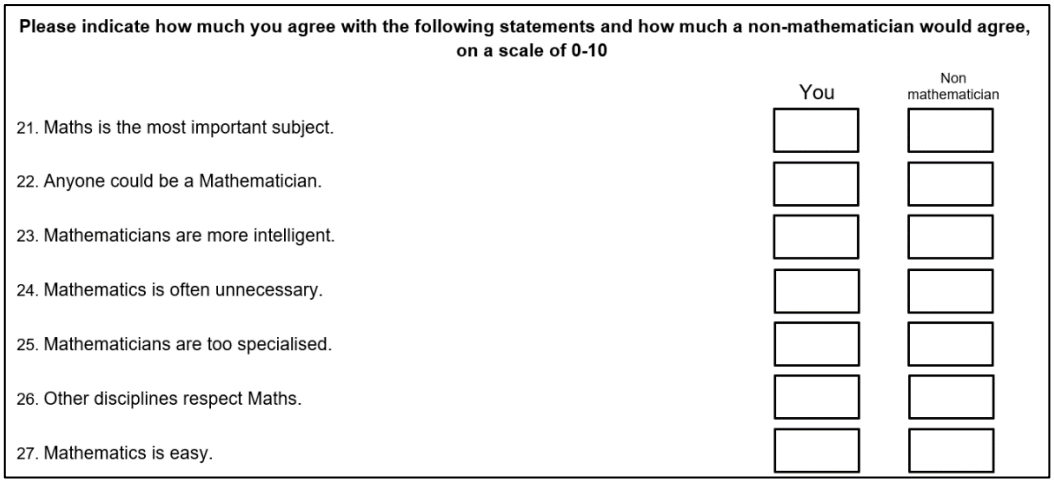


Figure 7 - The first seven questions in the FCE tool used in this research (see Appendix II for further details)

9.5.1 Scenario-Based Questions

The survey initially asks participants to report on their agreement with a set of statements that describe short positive and negative opinions about the students' specific academic discipline. Following this they are asked to estimate the percentage of people who would agree the same statements.

While there might not be a single standardised tool for measuring the False Consensus Effect, this methodology follows a well-used approach to identifying the existence of the FCE in a respondent.

9.6 Semi-structured interviews

To accompany the quantitative data, as series of semi-structured interviews will be performed, the purpose of this is multifaceted.

While quantitative surveys provide structured and standardised data, they may lack the depth needed to fully understand the nuances of participants' experiences, attitudes, or perspectives. Semi-structured interviews will allow this research to delve deeper into the experiences of participants, capturing context-specific information. By conducting interviews following a quantitative survey, we will be able to complement statistical findings with qualitative insights. This mixed-methods approach provides a more comprehensive understanding of the research question, allowing for a triangulation of data sources.

Unforeseen or unanticipated issues may arise during the survey, and qualitative interviews provide an opportunity to explore these unexpected findings in more detail. This may lead to the discovery of new and important insights. Quantitative surveys also may lack the context needed to fully interpret the numerical results. Semi-structured interviews allow participants to elaborate on topics considered in the survey and provide context and personal anecdotes. This can contribute to a more nuanced interpretation of quantitative findings.

Semi-structured interviews enable the identification of patterns and themes that may not be evident in quantitative data alone. Open-ended questions allow participants to express their thoughts freely, contributing to the emergence of themes and trends that might guide further research or intervention strategies. The combination of quantitative and qualitative data can enhance the validity of research findings through triangulation. Inconsistencies or convergences between survey data and interview responses can be explored, providing a more robust and reliable interpretation of the overall results.

Conducting semi-structured interviews following a quantitative survey can enhance the depth, context, and interpretive power of research. This mixed-methods approach will allow this researcher to gain a holistic understanding of the effect of this teaching intervention on the students who take part and contribute to the generation of more informed and nuanced conclusions.

9.6.1 Interview questions

The interviews will be based around the following core questions:

- How did you find the project?
- What went well for you?
- Did you enjoy it?
- Do you think the concept - working more mixed teams is a good idea?
- What solution did you come up with for the problem?
- Did you work on that in separate disciplines?
- Do you think the solution you came up with was a good solution?
- How do you think it'd have been different if were just a team of Engineers/Mathematicians?

- How many [other discipline] were in your group?
- How many [your discipline] were in your group?
- Do you think if you were just a group of [your discipline] you would have come up with a similar idea? Or a better or a worse idea?
- Could you have done it without the [other discipline]?
- Do you think they could've completed this project without you?
- Do you think you had different approaches to solving the problem?
- Did you have to do much explaining to the [other discipline]?
- Did you ask many questions about to the [other discipline]?
- Do you feel that you, personally, were necessary to complete the task?
- Do you think it was a good task to do?
- Do you think it would be better as just an engineering task or just a mathematics task?
- Do you think there were any particular downsides to this task?

These were not intended to be asked in any particular order, however the more personal questions (e.g. Do you feel that you, personally, were necessary to complete the task?) were asked later in the interview with the intention that the participant may have become more comfortable with the questioning.

9.6.2 Thematic analysis

Thematic analysis is a method of qualitative data analysis that involves identifying, analysing, and reporting patterns (themes) within a dataset, often derived from interviews or other textual sources. The process typically follows a set of systematic steps.

Thematic analysis is deeply rooted in the qualitative research paradigm. It aims to explore the richness and complexity of human experiences, attitudes, and perspectives. This method of analysis often aligns with a constructivist epistemology, recognising that knowledge is co-constructed by researchers and participants. It acknowledges the subjectivity of interpretations. The method is primarily inductive, meaning that themes emerge from the data rather than being imposed beforehand. This aligns with the idea that participants' voices should be central to the analysis (Terry, Hayfield, Clarke, & Braun, 2017).

Thematic analysis is known for its flexibility, making it accessible. It doesn't require adherence to a specific theoretical framework, making it applicable across various disciplines. The analysis is grounded in the participants' own words, allowing themes to emerge organically. Furthermore, it allows for a deep exploration of the data, enabling the nuances and complexities of participants' experiences to be captured. It's particularly valuable when exploring complex social phenomena.

The process is iterative, allowing researchers to refine and revise themes as they progress through the analysis. This iterative nature enhances the rigor of the analysis. The dataset is systematically coded to identify interesting features of the data in a way that summarises and captures key concepts. Codes are then organised into potential themes by identifying patterns and connections. Themes are overarching concepts that represent a central idea or topic. Themes are then reviewed and refined, checking if they accurately represent the coded extracts and the dataset as a whole. This step involves constant comparison and ensures the coherence of themes. Themes are clearly defined, and each is given a descriptive and meaningful name. This step involves interpreting the underlying meaning of each theme.

Throughout the process, researchers reflect on their preconceptions, biases, and how these may have influenced the analysis. Reflection is crucial for maintaining the integrity of the research.

9.7 Research Philosophy

This research is situated within a pragmatic research epistemology, signifying a commitment to practical, real-world problem-solving, and it adopts a mixed methods approach to address its research objectives. The ontological foundation of this research aligns with constructivism.

At its core, a pragmatic research epistemology underscores the importance of practical solutions and actionable outcomes. This approach is particularly suited to complex issues that require nuanced insights and feasible applications. By employing mixed methods, which integrate qualitative and quantitative techniques, this research aims to leverage the strengths of both approaches, providing a more holistic understanding of the phenomena under investigation.

The ontological stance of constructivism asserts that individuals actively create their understanding of the world. Jean Piaget’s theory posits that cognitive development is an

adaptive process wherein individuals construct knowledge by assimilating new information into existing mental structures (schemas) or accommodating existing schemas to incorporate new information. This perspective is foundational to understanding how individuals navigate and make sense of their experiences.

The selection of a constructivist ontological approach requires a commitment to exploring the subjective experiences and interpretations of individuals. It recognises the dynamic nature of reality, acknowledging that different perspectives contribute to a multifaceted understanding of phenomena. By embracing this worldview, the research aims to uncover the details of human experiences and the intricate ways individuals construct knowledge and meaning.

The influence of Piaget and Mead in shaping the ontological stance of this research provide a lens through which to explore how individuals, particularly in educational or developmental contexts, assimilate and accommodate information. Mead's emphasis on symbols and social interactions informs the exploration of how individuals derive meaning from their interactions with others and their environment.

This research embraces a pragmatic research epistemology, emphasizing practical solutions, and employs a mixed methods approach to gather comprehensive insights. The ontological underpinning draws from constructivism, guided by the theories of Piaget and Mead. This perspective acknowledges the dynamic and interactive nature of human experiences, providing a robust framework for investigating complex phenomena in diverse contexts. Through this philosophical and methodological integration, the research seeks not only to understand but also to contribute actionable knowledge to address real-world challenges

10 Intervention Tool Development

The site of research for this work was a jointly taught part of two 20 credit level five modules, one in mathematics and one in aerospace engineering. These two disciplines were brough together for a 6-week joint project as has been discussed in the preceding chapter. These two disciplines were used for practical reasons – there was curriculum space available to run this intervention for both – more ideally the disciplines chosen would come from more separated epistemological basis.

The modules in which this intervention was sited for each discipline were, 'mathematical modelling 2' - a level 5 module teaching difference mathematical modelling techniques, and 'commercial and professional practice' – a level 5 module dedicated to teaching aspects of the professional industry of aerospace engineering. The teaching intervention delivered therefore had to accommodate both of these content areas and it was in order to satisfy this requirement that the topic of the intervention was decided to be evacuation modelling of an aircraft. This satisfied these two requirements as it involved teaching a mathematical modelling technique – cellular automata and agent-based modelling and required an understanding of the certification process to determine airworthiness for aircraft.

Bothe cellular automata and agent-based modelling develop in time steps based on their previous configuration. This requires a great many computational steps and so this modelling method is most commonly developed as a computer simulation. There are a number of commercial packages available that concern agent-based modelling for evacuation situations, however these were either too expensive or too complex to be used in a 6-week project. To address this a bespoke simulation was designed and developed for the specific needs of this teaching intervention.

The plane to be evacuated in the simulation was decided to be a Boeing 737 in economy configuration as this is one of the most widely used aircraft especially for smaller companies (Bailey & Karuwa, 2023) as well as having a mostly identical layout to the second most popular passenger aircraft the Airbus A320 series. This has a single aisle layout with rows of three seats on each side, two large exits at the front and rear and two smaller overwing exits in the middle, service areas and toilets at the front, and toilets at the back.

10.1 Development of an agent-based model for evacuation

The for the evacuation model an agent-based model was implemented in which the space is divided into a grid of squares and people are represented by occupied squares and space by unoccupied ones. The key aspect of an agent-based model is that each 'agent' – in this case passenger, obeys a simple rule in order to progress. In our simulation the agent's rule was that they should always move closer to the *nearest* exit where possible, this has been shown to be likely exit seeking behaviour in emergency situations (Fang, et al., 2010). This model was then developed to represent a more complex picture with competing populations of agents who obeyed different rules:

- Agent 1 – seeks nearest exit
- Agent 2 – seeks their luggage (located in the nearest luggage location) and then once they have reached the nearest luggage location becomes agent 3
- Agent 3 – pauses for one iteration (to represent the delay encountered in collecting luggage) and then becomes agent 1
- Agent 4 – pauses for one iteration at the exit (to represent the evacuation stalling encountered at exits) and then becomes agent 1

This was to satisfy the brief that was given to student about how they were to use the model. As agent-based models work on a grid one option for developing this simulation was through excel, using VBA programming to build the model described. The advantage of this method was that students were familiar with excel as a user interface and so for a short intervention we would avoid the need to take up time with learning a new system. Mathematics student had also encountered VBA programming in other previous module and would have a basic understanding of the simulation's operation. The drawback to this method was that the simulation was computationally large and would often run slowly (this is due to the requirement of updating the graphical code associated with excel itself). The user interface of the simulation is shown in figure 8.

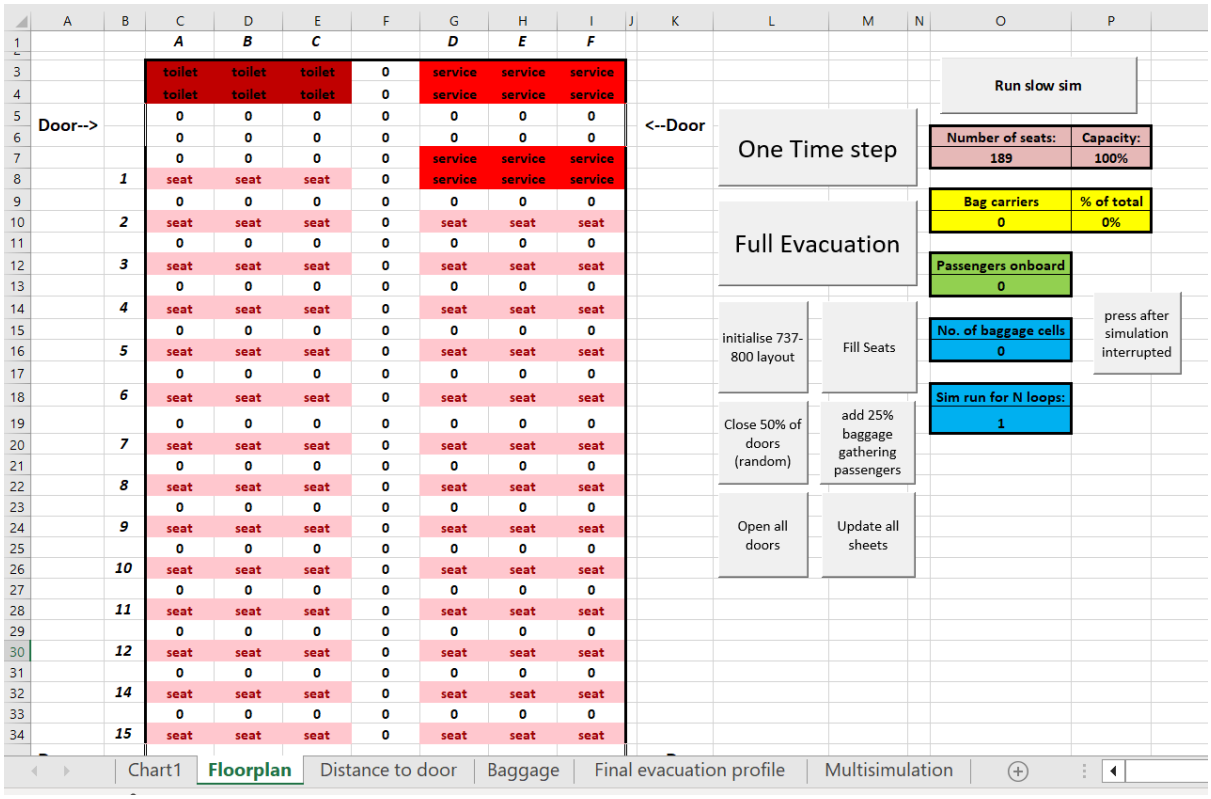


Figure 8 - layout of the excel sheet given to students to use to model evacuation.

The user interface of the simulation is located on the first worksheet of the workbook. The active area of the simulation is within the black rectangle and within this rectangle the layout is fully customisable. There are three labels shown in Figure 8 that indicate a cell is impassible – 'toilet', 'service', and 'seat'. The toilet label indicate that this area is occupied by a toilet in the layout of the cabin, the service label indicates this area of the layout is occupied with the infrastructure of the operation of the cabin crew, and the seat label indicates that this is the location of a seat. All other cells showing a zero represent free space for the agents to move in, before running the simulation the user can replace the zero with a number from 1-4 in these cells representing their occupation with passengers with agent rules 1-4. In practice only agents 1 and 2 were used to initialise the layout.

The operation of this agent-based model required agent 1 type agents to know which there nearest exit was (as labelled by 'door →' or '← door' on the interface) and as such the simulation had to calculate the shortest distance each cell is from this location. To achieve this code ran to calculate this path based only on up, down, left, right motion (no diagonal moves) and this distance is displayed on the second worksheet in the workbook. Agent 2 type agents needed to be aware of the shortest distance to baggage locations and this was similarly

calculated in worksheet three of the workbook, however this sheet required the user to select locations within the cabin layout to be designated as luggage retrieval cells.

The interface of the simulation allowed users to modify a number of parameters of the model and automate some setup steps, these actions were achieved through editable cells (the number of loops that the simulation ran for) and ActiveX control buttons whose operations were:

- One timestep

  This advanced the simulation a single timestep to allow users to more easily see the evolution of the model.
- Full evacuation

  This ran the simulation until all the agents had exited the plane.
- Initialise 737-800 layout

  This reset all sheets to the standard layout of the 737 and removed baggage locations.
- Fill seats

  This makes all cells immediately in front of seats into agent 1 type agents.
- Close 50% of doors (random)

  This function removes three of the six doors from the evacuation map (a specification of evacuation certification).
- Add 25% baggage gathering passengers

  This action replaces 25% of the agent 1 type agents in the simulation with agent 2 type (baggage seeking) at random.
- Open all doors

  This action reset all doors to open in the evacuation map
- Update all sheets

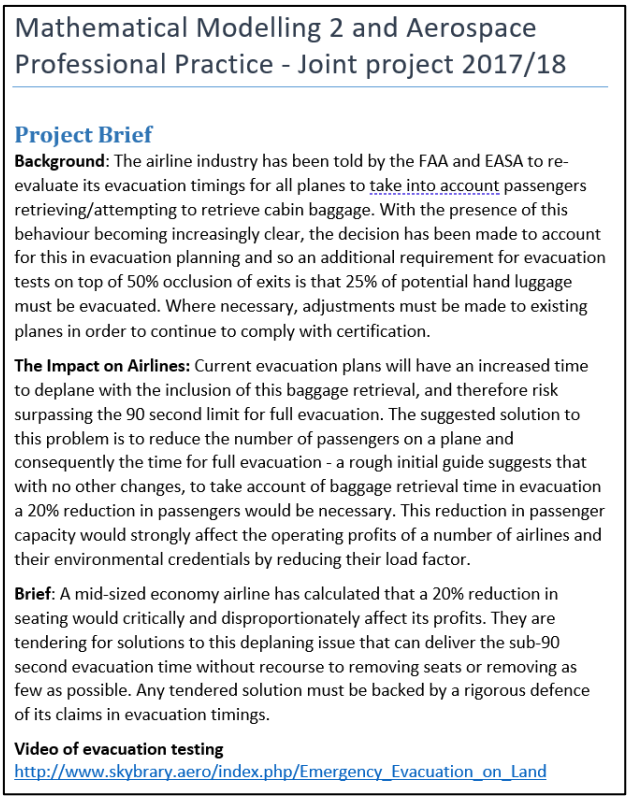
  Many of the actions involved changes that would propagate through different worksheets of the workbook and this button ensures that those changes were made across all worksheets (this was done as the first step of ‘Full evacuation’ but could be done manually here too).

Also present of the interface are information boxes to easily see important features of the simulation, these show: how many seats the simulation contains and what that is as a

percentage of the maximum allowed number, the number of passengers (all types of agent) that were still within the simulation, how many baggage seeking (type 2 agents) are present with the simulation and what percentage of the total number of passengers this is, and how many cells with the simulation are designated as baggage retrieval cells.

Finally, the workbook recorded some of the key data created by the simulation and displayed it in both tabular and graphical form.

10.2 Project brief



Mathematical Modelling 2 and Aerospace Professional Practice - Joint project 2017/18

Project Brief

Background: The airline industry has been told by the FAA and EASA to re-evaluate its evacuation timings for all planes to take into account passengers retrieving/attempting to retrieve cabin baggage. With the presence of this behaviour becoming increasingly clear, the decision has been made to account for this in evacuation planning and so an additional requirement for evacuation tests on top of 50% occlusion of exits is that 25% of potential hand luggage must be evacuated. Where necessary, adjustments must be made to existing planes in order to continue to comply with certification.

The Impact on Airlines: Current evacuation plans will have an increased time to deplane with the inclusion of this baggage retrieval, and therefore risk surpassing the 90 second limit for full evacuation. The suggested solution to this problem is to reduce the number of passengers on a plane and consequently the time for full evacuation - a rough initial guide suggests that with no other changes, to take account of baggage retrieval time in evacuation a 20% reduction in passengers would be necessary. This reduction in passenger capacity would strongly affect the operating profits of a number of airlines and their environmental credentials by reducing their load factor.

Brief: A mid-sized economy airline has calculated that a 20% reduction in seating would critically and disproportionately affect its profits. They are tendering for solutions to this deplaning issue that can deliver the sub-90 second evacuation time without recourse to removing seats or removing as few as possible. Any tendered solution must be backed by a rigorous defence of its claims in evacuation timings.

Video of evacuation testing
http://www.skybrary.aero/index.php/Emergency_Evacuation_on_Land

Figure 9 - Project brief given to students

In order to bring an element of realism to the intervention the project brief was designed to engage with a current area of discourse in airplane emergency evacuation – the anecdotal increase in the prevalence of passengers seeking to take baggage with them in emergency evacuations. This has been documented and commented on (Hodgson, Tonge, & Amos, 2023), and the discourse has turned to whether the current certification rules which don't consider this aspect of passenger evacuation should be updated to include it. With the current regulations designers have to demonstrate that their aircraft can be evacuated in under 90 seconds with half of the exits occluded, in the brief this was then built on to

imagine that this was changed to include 25% of passenger retrieving their luggage. Aircraft would then have to be redesigned to allow for this in their cabin layout. It was this aspect of the project that was intended to engage the aerospace engineers, as any changes to aircraft have to comply with a rigorous set of regulations and it would be beholden to the engineers to establish whether any proposed changes were permissible under these rules.

10.3 Operation of agent-based model

In execution of the project brief teams needed to identify a cabin layout and/or distribution of bag collection that was physically feasible, permitted by legislation, cost efficient, and could be modelled in the simulation given. They could then compare this evacuation time as calculated by the simulation with the one calculated for the original layout. Beyond this the task could be extended to included deeper aspects in both disciplines. For the engineers, the change in weight and weight distribution would have impact on running costs as well as the length of time planes would have to be out of operation to be refitted. These considerations and others required knowledge or study of aspects of commercial operation of aircraft – in line with the brief of the module this intervention was sited in. For the mathematicians, a large body of data could be collected and analysed in an appropriate way that would further defend any solutions to the problem they produced. This again related back to the concept of mathematical modelling developed in this module.

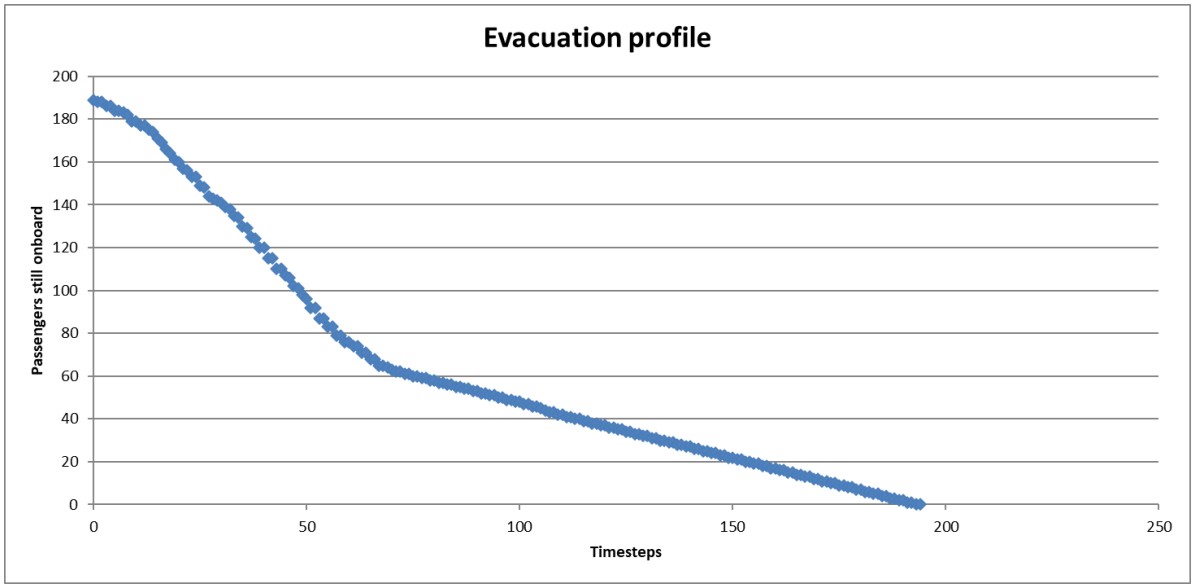


Figure 10 - graph produced by the simulation of the progression of one evacuation, showing how many passengers are onboard at each timestep.

11 Intended Original Contribution to Knowledge

11.1 Parametric measurement of employability

As discussed previously, any intervention that hopes to affect employability in some way, suffers through the difficulty of measurement. The esoteric and sometimes subjective nature of employability leads to a lack of analytical certainty in considering outcomes. This research argues that a parametric measurement of employability can be made through recording self-efficacy levels. The ubiquity with which self-efficacy is present in many widely used employability models lends weight to the argument that change in this capability is the accompaniment of a similar change in employability. Whilst it is understood that this parametric measurement would fail to capture some more nuanced changes in employability, through this research it is hoped that an equivalence can be argued which then may be useful more widely.

11.2 Piagetian egocentrism as applied to academic boundary crossing

As we have seen previously in Piaget's theory of development, crossing developmental boundaries causes an increase in egocentrism. This work intends to apply this theory's findings to the crossing of academic boundaries - notably the transition to higher education. Here, this innate rise in egocentrism occurs at the same time as a narrowing of academic activity and a restriction of day-to-day academic interaction. This research intends to investigate if this constriction of outlook creates a development regime similar to that in the preoperational period of childhood development, where it is assumed that one's knowledge is universal, leading to an entrenchment of disciplinary egocentrism - an innate barrier to effective working practices in mixed groups and a key competency in most work environments.

The expansion of Piagetian developmental theory to the field of disciplinary egocentrism has yet to be considered in the literature. The development of this theory could be used to inform any other research into student development in higher education.

11.3 Moving average comparisons

In higher education in the UK, the majority of students are taught within their own discipline, alongside peers of similar experience; this then becomes their society. In this society the average discipline-specific ability is increasing over time (the dotted line in figure 5) and so as a student develops, so does the average of their society. Therefore, absolute increases in

ability (relative to the starting level) may be underestimated through comparisons with a moving average.

Through expanding the local society to include non-disciplinarians - as is the case in interdisciplinary teaching - we introduce static points of reference against which absolute improvement can be measured, in other words, students have the opportunity to see that the skills they have developed aren't generic, are useful and valued by those who don't possess them and mark them as skilled practitioners in their field. This has a positive effect on their self-efficacy through highlighting mastery experience, which in turn should result in increased employability.

This theoretical framework linking the works of Mead and Bandura and using this as a lens through which to consider interdisciplinary teaching has not been considered in the literature and would provide further theoretical support for the introduction of this style of teaching.

12 Results and Analysis

The survey was administered during two deliveries of the case study over two years. In the first year there was a potential survey cohort of 144 (83 mathematics students and 61 aerospace engineering students) and there was an uptake of 82 participants (43 mathematics students and 39 engineering students) who completed at least 2 surveys (pre- and post-). In the second year there was a potential survey cohort of 122 (75 mathematics students and 47 aerospace engineering students) and there was an uptake of 74 participants (58 mathematics students and 16 engineering students).

12.1 GSE results

The average response for each GSE question over the two years that data was gathered is shown in Table 1:

Year	Cohort	pre/post	Q3	Q5	Q7	Q8	Q10	Q12	Q13	Q15	Q17	Q19
2018	Maths	Pre	2.88	3.08	2.85	2.78	2.93	2.87	3.27	2.98	2.81	2.95
		Post	**3.00**	**3.19**	**2.88**	**2.84**	**2.95**	**2.83**	**3.30**	**2.95**	**2.97**	**3.07**
	Eng	Pre	2.67	2.90	2.74	2.56	2.62	2.77	3.28	2.79	2.67	2.85
		Post	**3.00**	**3.23**	**3.05**	**2.86**	**2.91**	**2.77**	**3.23**	**2.82**	**2.91**	**3.05**
2019	Maths	Pre	3.36	3.60	3.31	3.38	3.92	3.27	3.93	3.54	3.30	3.72
		Post	**3.48**	**3.70**	**3.43**	**3.48**	**3.45**	**3.22**	**3.95**	**3.60**	**3.31**	**3.64**
	Eng	Pre	3.62	3.95	3.71	3.65	3.76	3.48	4.14	3.90	3.81	3.81
		Post	**4.06**	**4.13**	**4.00**	**3.75**	**3.81**	**3.50**	**4.06**	**4.00**	**3.81**	**3.81**

Table 1 - the average GSE data for each year (green highlighted cell correspond to an increase, red a decrease)

Following this we can display the distribution of Likert scores for each question pre- post intervention.

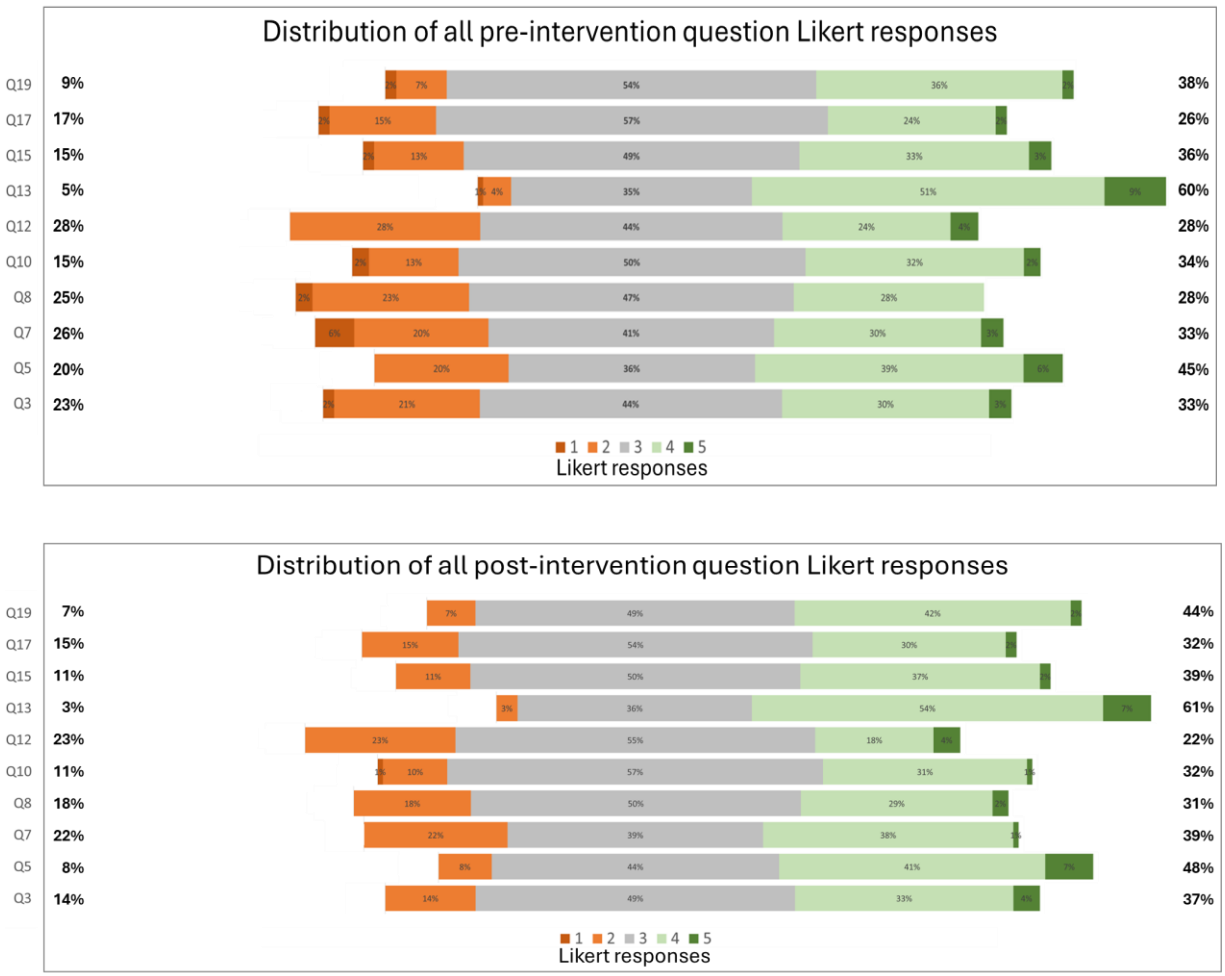


Figure 11 - Distribution of Likert scores for pre-intervention (upper figure) and post-intervention (lower figure)

The Generalised Self-Efficacy scale is however a recorded as a score across the 10-question measure per respondent, therefore the measure we are interested in is this value pre- and post-intervention.

The averaged self-efficacy scores across all respondents in the survey for pre- and post-intervention is shown in Figure 12:

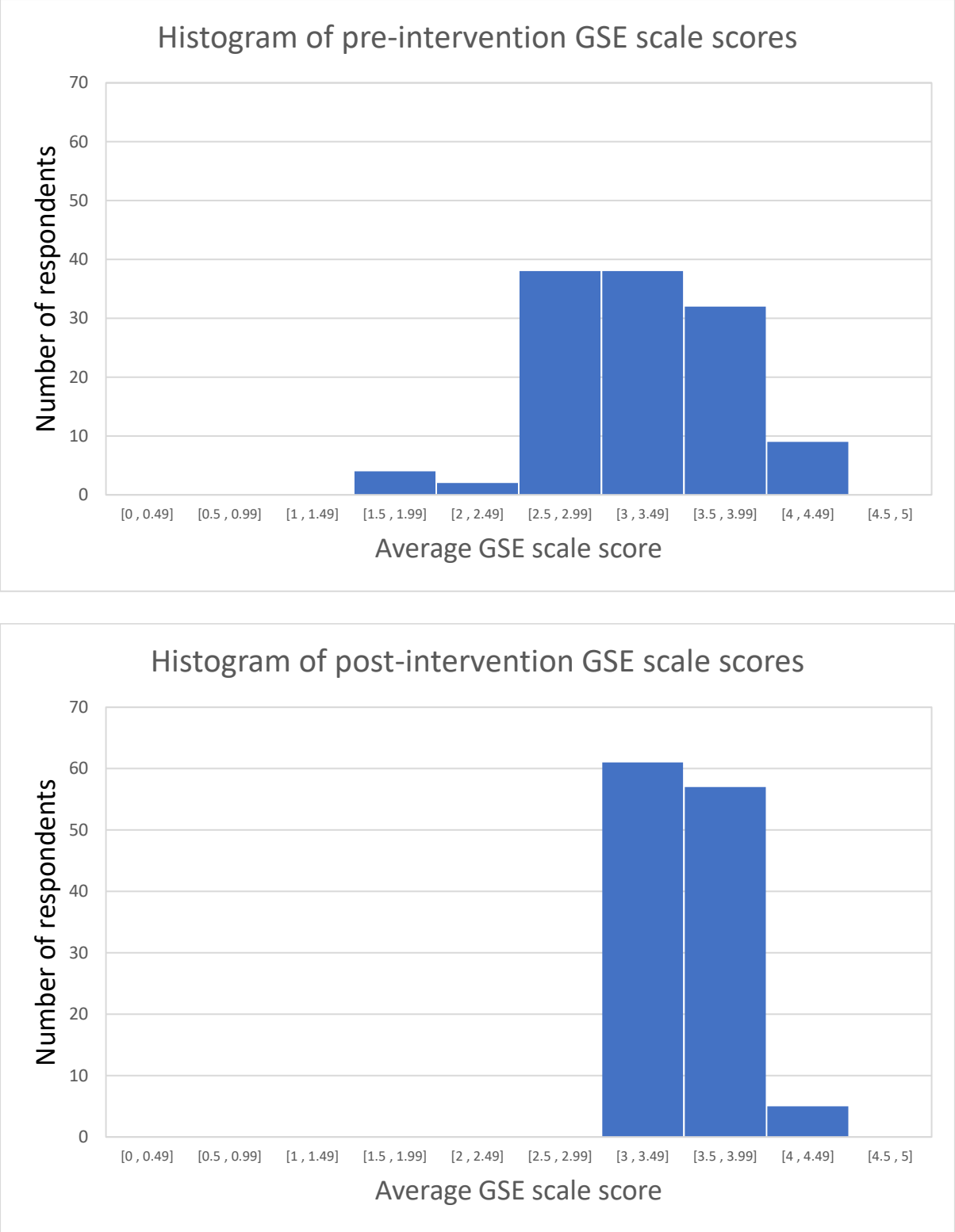
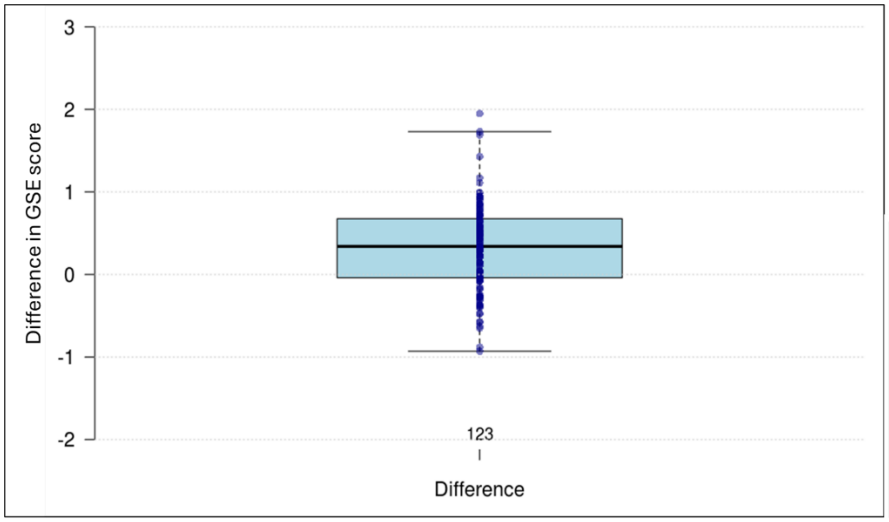


Figure 12 - Histograms representing the spread of averaged GSE scale scores for pre- (upper figure) and post-intervention (lower figure)

As we are most interested in how these two measures differ, we can demonstrate this by their algebraic difference.



Box Plot Statistics

	Difference
Upper whisker	1.73
3rd quartile	0.68
Median	0.34
1st quartile	-0.04
Lower whisker	-0.93
Nr. of data points	123.00

Figure 13 - Box plot shows the distribution of difference in GSE scores between pre-intervention and post

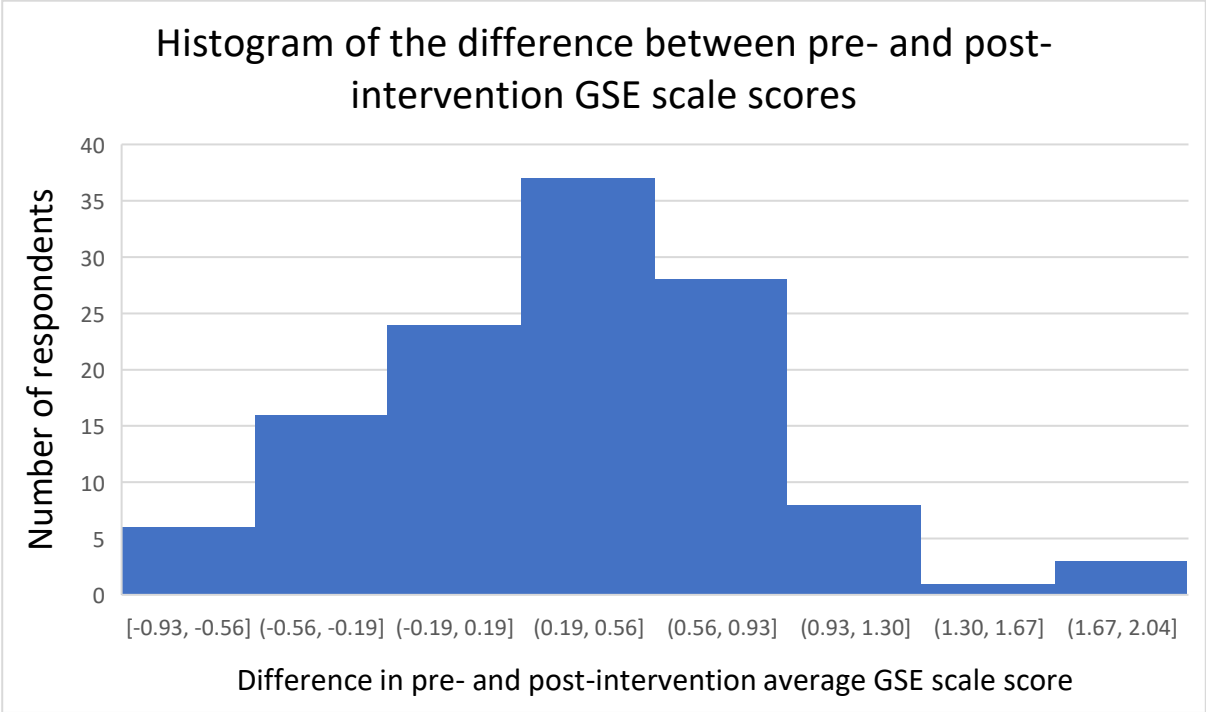


Figure 14 - Histogram of the difference in averaged GSE score

12.2 Statistical testing and analysis

The primary method of statistical analysis for this data is the paired t-test, which is suitable for comparing the means of two related groups—specifically, the same participants before and after the intervention. The paired t-test allowed us to determine whether there was a statistically significant difference in the outcomes measured before and after the intervention.

The paired t-test is used when we want to compare the means of two related groups. In this case, the groups are related because they consist of the same participants measured at two different points in time: before and after the teaching intervention. The test accounts for the fact that the data points are not independent, as each participant's pre-intervention score is related to their post-intervention score. This method is particularly powerful because it reduces variability by focusing on the differences within each pair of observations.

The paired t-test directly measures whether there is a statistically significant difference in students' outcomes before and after the interdisciplinary teaching intervention and it is important in the support of the research questions of this work to frame the findings in statistical rigour. By comparing pre- and post-intervention survey scores, the analysis can objectively determine if students experienced an improvement in specific cognitive areas or other relevant metrics. The use of a paired t-test allows for the quantification of the magnitude of this change, indicating whether interdisciplinary teaching has a meaningful and measurable impact on students' learning and skills development. If the test reveals significant and statistical improvements this supports the hypothesis that interdisciplinary teaching has an effect on the areas of interest in this work.

The paired t-test calculates the t-statistic using the following formula:

$$t = \frac{\sum d}{\sqrt{\frac{n(\sum d^2) - (\sum d)^2}{n-1}}}$$

Where *d* is the difference between paired samples and *n* is the number of samples.

To validly apply a paired t-test, several assumptions and conditions need to be met:

- The differences between the paired observations should be approximately normally distributed. This is the case for this data as we can see from the Q-Q plot in Figure 15.
- The data should be continuous, meaning the outcome variable should be measured on an interval or ratio scale. This is achieved as the mean differences of the GSE scale turn the discrete data of the Likert scale to a continuous distribution.
- The paired data points should be independent of other pairs in the dataset.

To quantify the magnitude of the effect, we also calculate *Cohen's d* for paired samples, which is given by the formula:

$$\frac{\mu_1 - \mu_2}{\sigma}$$

Where μ_1 and μ_2 are the mean values of population 1 and 2 and σ is the standard deviation of the differences between the paired observations.

Cohen's d provides a standardised measure of the effect size, allowing us to understand the practical significance of the results. The typical thresholds for interpreting Cohen's d are:

- Small Effect: $d = 0.2$
- Medium Effect: $d = 0.5$
- Large Effect: $d = 0.8$

These thresholds help position the results within a broader context, offering insights into the practical significance of the observed changes.

Figures 12 to 14 demonstrate visually that the data recorded is majority positive demonstrating an increase in reported self-efficacy and close to normally distributed, we can further demonstrate this through displaying this feature on a QQ plot.

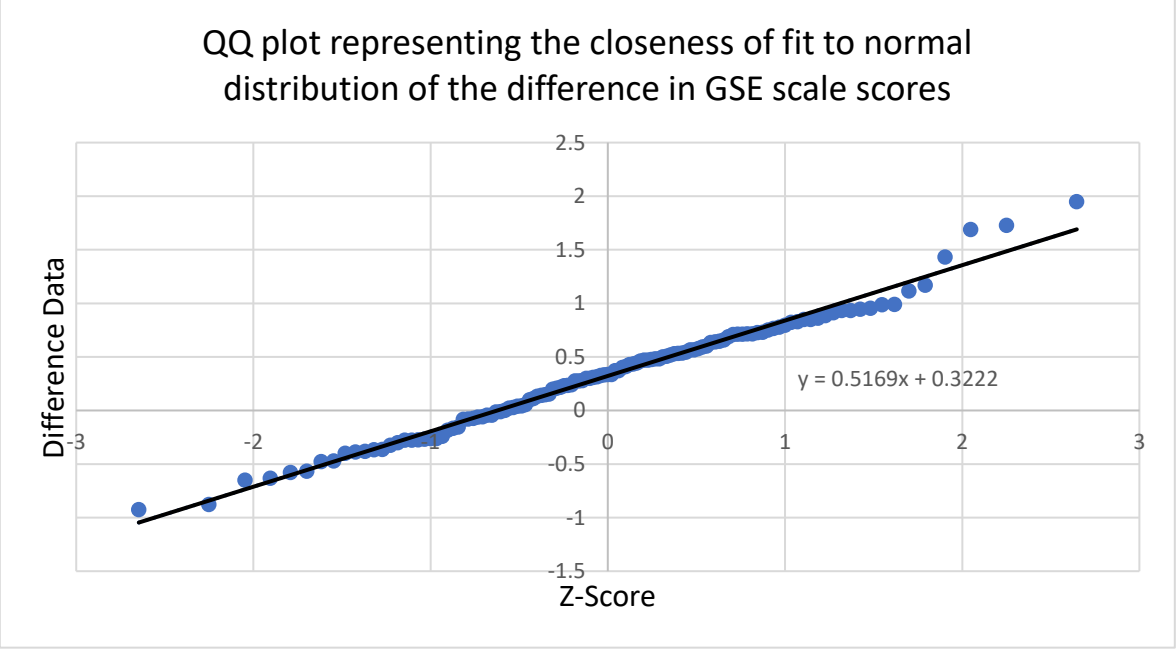


Figure 15 - QQ plot of the difference in GSE scale score pre- and post-intervention

As we can see in Figure 15, the data is well matched to the linear trendline overlaid, however we can see that the gradient of this line is roughly 0.5 demonstrating a lower variance than would be expected in normal distribution, however this may be accounted for by the nature of the similarity of respondents and the underlying ordinality of the data. The intercept in Figure 15 is roughly 0.3 indicating a very slightly higher mean value than the normal distribution. The purpose of demonstrating normality is to ensure that we are able to use a paired T-test to examine the significance of any changes in the distribution of GSE scores after the planned teaching intervention. As the difference data follows a normal distribution reasonably closely a standard 'student's paired T-test' is an appropriate tool to use here. The pre-intervention average for all respondents GSE scale score is 3.201 and the average for post-intervention is 3.523, this represents an increase in reported self-efficacy of roughly 10%, we need to examine however whether we can reject the null hypothesis with confidence in this case.

Null Hypothesis (H0): There is no significant difference between the means of the two groups.

	Pre	*Post*
Mean	3.201	3.523
Variance	0.299	0.024
Observations	123	123
Pearson Correlation	0.312	
t Statistic	-6.871	
P(T<=t) two-tail	2.89E-10	
Size effect (Cohen's d)	0.614	

Table 2 - Statistical data taken from performing a paired T-test of the GSE scale score differences

Interpretation:

1. **t Statistic:** The t-statistic is -6.871. This indicates the difference between the means is -6.871 standard deviations away from the expected difference under the null hypothesis.
2. **P-value:** The extremely low p-value 2.890×10^{-10} suggests strong evidence to reject the null hypothesis.
3. **Effect Size (Cohen's d):** The effect size is 0.614, suggesting a moderately large effect.

Given the very low p-value, rejecting the null hypothesis is a comfortable conclusion. There is strong evidence to suggest that there is a statistically significant difference between the means of the two groups (pre- and post-). The effect size is also moderately large, indicating a practical significance in addition to statistical significance.

This data is the combined responses from two academic cohorts separated by one year and also two populations of students in each of those cohorts (mathematicians and engineers). We are interested in examining whether these individual populations and cohorts show similar results when considered separately. Firstly, we consider the difference between the two cohorts, described here are 2018 and 2019.

The reported statistics for the two cohorts gathered from a paired T-test performed on both is shown in Table 3.

t-Test: Paired Two Sample for Means 2018

	pre-	*post-*
Mean	2.893	3.338
Variance	0.146	0.029
Observations	61	61
Pearson Correlation	-0.146	
t Statistic	-7.887	
P(T<=t) two-tail	7.632E-11	
Size effect (Cohen's d)	3.831	

t-Test: Paired Two Sample for Means 2019

	pre-	*post-*
Mean	3.505	3.704
Variance	0.266	0.016
Observations	62	62
Pearson Correlation	0.021	
t Statistic	-2.974	
P(T<=t) two-tail	4.201E-03	
Size effect (Cohen's d)	0.796	

Table 3 - Separate paired T-tests for each of the two cohorts considered in this work

As we can see, the same effect as reported in the full data is reported in each individual cohort. We find that the size effect is different in the two tests representing a more impactful outcome in 2018 than 2019. To see if this difference is significant, we can perform a two-sample T-test assuming equal variances on the GSE scale score differences the result of which is shown in Table 4.

t-Test: Two-Sample between cohorts assuming equal variance

	2018	*2019*
Mean	0.445	0.200
Variance	0.194	0.279
Observations	61	62
Pooled Variance	0.237	
t Statistic	2.796	
P(T<=t) two-tail	0.006	
Effect size (Cohen's d)	-0.50414	

Table 4 - Two-sample T-test to establish the significance of the difference in the two cohorts

As can be seen from this data, the effect size of the reported self-efficacy change reduces by a moderately large amount, which is shown to be significant at the 5% level.

We can perform similar analysis for the two populations studied in this work, mathematicians and engineers. The reported statistics for the two populations gathered from a paired T-test performed on both is shown in Table 5.

t-Test: Paired Two Sample for Means (mathematicians)

	pre-	*post-*
Mean	3.226	3.472
Variance	0.269	0.003
Observations	95	95
Pearson Correlation	0.431	
t Statistic	-4.827	
P(T<=t) two-tail	5.345E-06	
Size effect (Cohen's d)	0.496	

t-Test: Paired Two Sample for Means (engineers)

	pre-	*post-*
Mean	3.118	3.699
Variance	0.407	0.054
Observations	28	28
Pearson Correlation	0.632	
t Statistic	-5.874	
P(T<=t) two-tail	2.951E-06	
Size effect (Cohen's d)	0.762	

Table 5 - Separate paired T-tests for each of the two populations considered in this work

As we can see, the same effect as reported in the full data is reported in each individual population. We find that the size effect is slightly different in the two tests representing a more impactful outcome in engineers than mathematicians. To see if this difference is significant, we can perform a two-sample T-test assuming equal variances on the GSE scale score differences the result of which is shown in Table 6.

t-Test: Two-Sample Assuming Equal Variances
(mathematicians vs engineers)

	Maths	*Engineering*
Mean	0.246	0.581
Variance	0.247	0.274
Observations	95	28
Pooled Variance	0.2526	
t Statistic	-3.101	
P(T<=t) two-tail	0.002	
Effect size (Cohen's d)	0.667	

Table 6 - Two-sample T-test to establish the significance of the difference in the two populations

As can be seen from these data, the effect size of the reported self-efficacy is larger in the engineering population by a moderately large amount, which is shown to be significant at the 5% level. We can further consider the change in reported self-efficacy by subdividing each cohort into its distinct student populations.

t-Test: Paired Two Sample for Means (Maths 2018)

	pre	*post*
Mean	2.936	3.428
Variance	0.116	0.001
Observations	43	43
Pearson Correlation	-0.007	
t Statistic	-9.416	
P(T<=t) two-tail	6.547E-12	
Size effect (Cohen's d)	0.701	

t-Test: Paired Two Sample for Means (Maths 2019)

	pre	*post*
Mean	3.465	3.508
Variance	0.271	0.002
Observations	52	52
Pearson Correlation	0.179	
t Statistic	-0.594	
P(T<=t) two-tail	0.555	
Size effect (Cohen's d)	0.206	

t-Test: Paired Two Sample for Means (Eng 2018)

	pre	*post*
Mean	2.789	3.572
Variance	0.212	0.034
Observations	18	18
Pearson Correlation	0.270	
t Statistic	-7.425	
P(T<=t) two-tail	9.918E-07	
Size effect (Cohen's d)	0.885	

t-Test: Paired Two Sample for Means (Eng 2019)

	pre	*post*
Mean	3.710	3.928
Variance	0.217	0.007
Observations	10	10
Pearson Correlation	0.091	
t Statistic	-1.482	
P(T<=t) two-tail	0.172	
Size effect (Cohen's d)	0.467	

Table 7 - Separate paired T-tests for each of the four combinations of population and cohort considered in this work

Each of these groups still manifests an increase in self-efficacy over the course of this teaching intervention. However, only the 2018 cohort groups show significance.

Included in the survey instrument for the 2019 cohort were demographic questions, namely gender and whether the student had completed a foundation year. These were included to see if the presence of an effect on self-efficacy was universally experienced or affected by external factors.

t-Test: Paired Two Sample for Means
(2019 - women)

	pre-	*post-*
Mean	3.250	3.338
Variance	0.315	0.315
Observations	24	24
Pearson Correlation	0.817	
t Statistic	-1.264	
P(T<=t) two-tail	0.219	
Size effect (Cohen's d)	0.593	

t-Test: Paired Two Sample for Means
(2019 - men)

	pre-	*post-*
Mean	3.666	3.713
Variance	0.175	0.167
Observations	38	38
Pearson Correlation	0.601	
t Statistic	-0.790	
P(T<=t) two-tail	0.435	
Size effect (Cohen's d)	0.542	

Table 8 - Separate paired T-tests for the populations of men and women as reported in the 2019 survey

t-Test: Two-Sample Assuming Equal Variances
(2019 women-men)

	Women	Men
Mean	0.088	0.047
Variance	0.115	0.137
Observations	24	38
Pooled Variance	0.128	
t Statistic	0.430	
P(T<=t) two-tail	0.669	
Effect size (Cohen's d)	-0.398	

Table 9 - Two-sample T-test to establish the significance of the difference in the different genders in the 2019 survey

The reported change in self-efficacy is shown to be moderately large in the male population and very large in the female population, however given the data set recorded these results are not statistically significant.

t-Test: Paired Two Sample for Means
(no foundation year)

	pre-	*post-*
Mean	3.549	3.621
Variance	0.259	0.231
Observations	53	53
Pearson Correlation	0.740	
t Statistic	-1.460	
P(T<=t) two-tail	0.150	
Size effect (Cohen's d)	0.430	

t-Test: Paired Two Sample for Means
(foundation year)

	pre-	*post-*
Mean	3.244	3.256
Variance	0.258	0.308
Observations	9	9
Pearson Correlation	0.771	
t Statistic	-0.092	
P(T<=t) two-tail	0.929	
Size effect (Cohen's d)	0.050	

Table 10 - Separate paired T-tests for the populations student who had progress through a foundation year and those who hadn't as reported in the 2019 survey

t-Test: Two-Sample Assuming Equal Variances
(foundation year/no foundation year)

	no foundation year	foundation year
Mean	0.072	0.011
Variance	0.128	0.131
Observations	53	9
Pooled Variance	0.128	
t Statistic	0.469	
P(T<=t) two-tail	0.641	
Effect size (Cohen's d)	-0.169	

Table 11 - Two-sample T-test to establish the significance of the difference of the foundation year populations as reported in the 2019 survey

The reported change in self-efficacy is shown to be moderately large in both populations, however given the data set recorded these results are not statistically significant.

A further expansion of the survey protocol that was introduced in the 2019 administration of the instrument was to re-measure students GSE scores 6 weeks post teaching intervention. This was introduced to examine the volatility of any effect recorded pre- and post-intervention.

Figure 16 shows the changes in the averaged GSE scale scores for the three interventions included in this protocol.

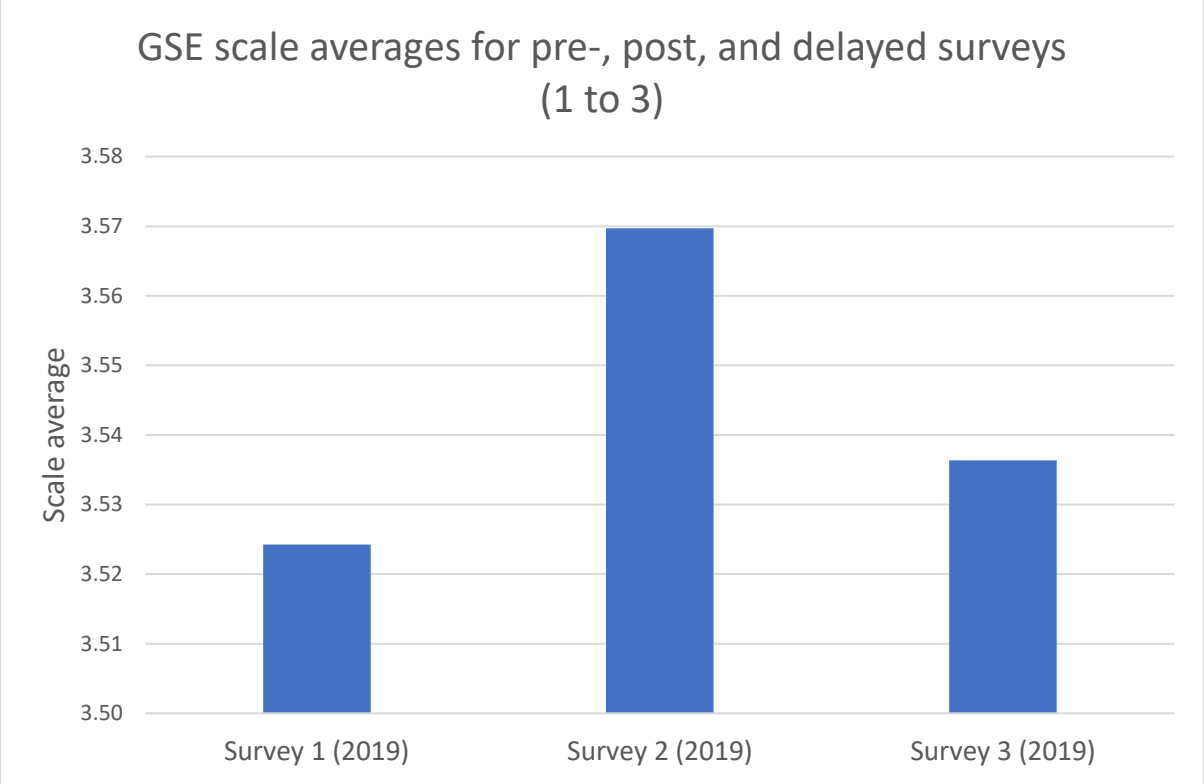


Figure 16 - Averaged GSE scale score for 2019 pre-, post, and delayed surveys

We can examine the significance of the changes through repeated paired T-test.

Data Summary:

Groups	*Count*	*Sum*	*Average*	*Variance*
Survey 1	33	116.3	3.524	0.288
Survey 2	33	117.8	3.570	0.229
Survey 3	33	116.7	3.536	0.567

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.037	2	0.018	0.051	0.951	3.091
Within Groups	34.687	96	0.361			
Total	34.723	98				

Interpretation:

- The null hypothesis (H0) is that there are no significant differences between the means of the groups.
- The between-groups variability (0.0366) is small compared to the within-groups variability (34.6867).
- The F-ratio (0.0506) is less than the critical F-value (3.091) at a significance level of 0.05.
- The p-value (0.951) is much higher than 0.05.

Given the p-value exceeding the significance level, the null hypothesis cannot be rejected. There is no sufficient evidence to conclude that there are significant differences in means between the three survey groups. The F-ratio is small, indicating that the variation between groups is not statistically significant compared to the variation within groups. Therefore, the data does not provide support for the idea that the means of the groups are different. This follows on from the lack of statistical significance found earlier when we considered the paired T-test for the 2019 cohort maths population, pre- and post-intervention.

12.3 Analysis of gendered trends in GSE data

In the data collected during the 2019 intervention the survey instrument was modified to include a question on the participants' gender identity, this would allow for an interrogation of the data to see if there were any gender-based trends present. We have examined the differences in pre and post data, but it may be instructive to explore the absolute value of the GSE scale scores.

We can examine the absolute value of the cohorts GSE scale scores across the three surveys (pre-, post-, and 6-week after) in this way we can examine not only changes across the data, but also whether gender impacts the underlying base level. Figure 16a shows the distribution of scores in a box plot.

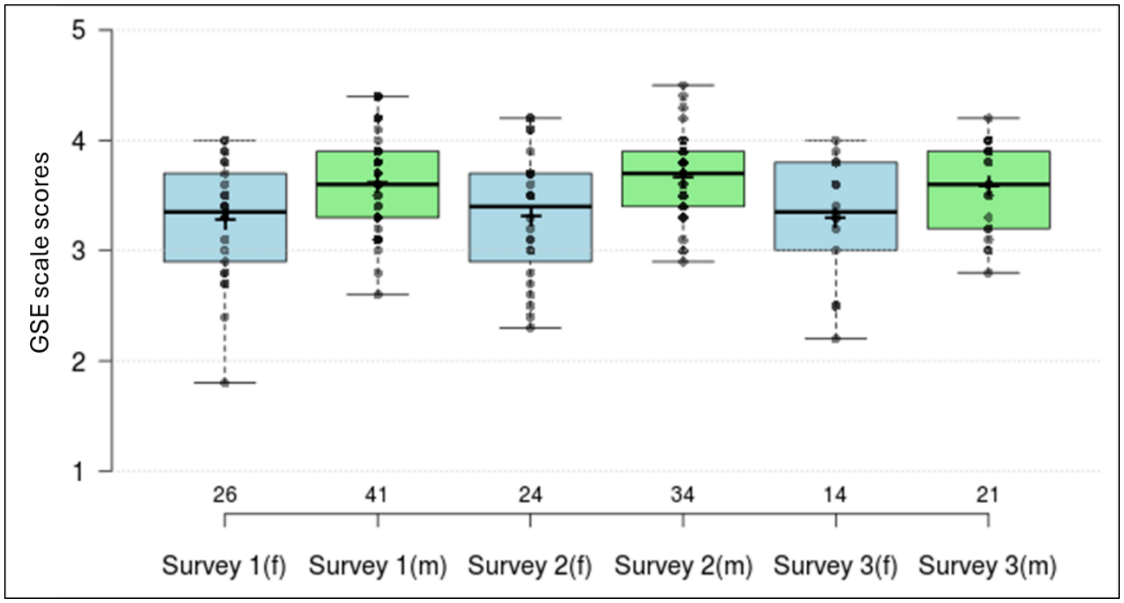


Figure 16a - Box plot showing the GSE scale scores for men and women in the 2019 cohort

Here we can see the GSE scale score for the female participants was consistently lower over the three surveys. As each subsequent survey is not independent from the first, we are limited in using the data from survey 1 to examine if this is significant.

t-Test: Two-Sample Assuming Equal Variances		
	Average women	*Average men*
Mean	3.281	3.615
Variance	0.2848	0.1913
Observations	26	41
Pooled Variance	0.2272	
Hypothesized Mean Difference	0	
df	65	
t Stat	-2.7935	
P(T<=t) two-tail	0.00684	
t Critical two-tail	1.9971	

Table 12 - Unpaired T-test to determine the significance of the difference in mean GSE scale score for men and women

From Table 12 we can see that the p value is less than 5% and so we can reject the null hypothesis that the means are equal. From this we can assume the difference in the means of 0.334 is statistically significant. The difference in mean for survey 2 and survey 3 were 0.35 and 0.293 respectively.

12.4 FCE Data

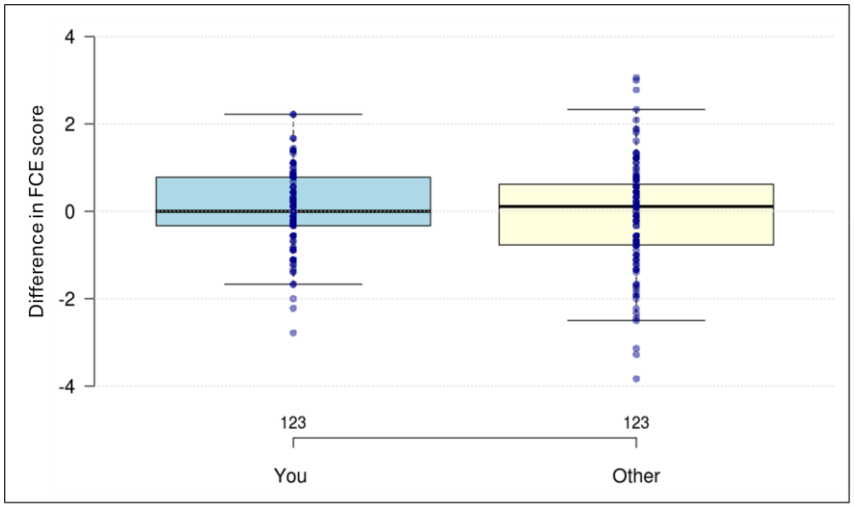
The False Consensus Effect is measured through examining respondents' agreement with a statement compared to their estimation of agreement with the same statement of the general population. The theory suggest that these responses should be linked. There is however no set system of recording these interactions and so, in line with recommended practice a survey instrument was developed that asked respondents to rate their agreement with a statement on a scale of 0-10 followed by rating the level of agreement in the general public on the same scale. These two question parameters are referred to as 'you' and 'other' respectively in this analysis.

Table 12 shows individual questions used on the FCE instrument and their average score pre- and post-intervention along with their difference.

	Q21		**Q22**		**Q23**		**Q24**		**Q25**	
	you	**other**	**you**	**other**	**you**	**other**	**you**	**other**	**you**	**other**
Pre	7.724	5.380	5.459	3.473	6.199	6.175	4.205	4.811	5.411	5.530
Post	7.539	5.246	5.801	3.472	5.953	5.860	4.585	5.125	5.329	5.307
Difference	-0.185	-0.134	0.341	-0.001	-0.246	-0.315	0.380	0.315	-0.081	-0.223
	Q26		**Q27**		**Q28**		**Q29**			
	you	**other**	**you**	**other**	**you**	**other**	**you**	**other**		
Pre	5.963	5.085	4.382	2.977	6.002	4.850	6.939	5.873		
Post	6.033	5.112	4.711	2.977	5.843	4.538	6.943	6.014		
Difference	0.069	0.027	0.329	0.000	-0.159	-0.312	0.004	0.141		

Table 13 - Pre- and post-intervention average scores per question and their difference

As with the GSE instrument however the FCE score is intended to be considered as a scale number for the whole instrument we can therefor consider the averaged FCE scale scores. The average change in the component of the FCE instrument between pre- and post-intervention are 0.0504 for the 'you' condition and 0.0558 for the 'other' condition, the distribution of averaged scores is shown Figures 15 to 19.



Box Plot Statistics

	You	Other
Upper whisker	2.22	2.33
3rd quartile	0.78	0.62
Median	0.00	0.11
1st quartile	-0.33	-0.77
Lower whisker	-1.67	-2.50
Nr. of data points	123.00	123.00

Figure 17 - Box plot of FCE scale score average differences between pre- and post-intervention for the two conditions ('You' and 'Other')

Figure 17 shows the distribution of the difference in pre- and post- FCE scale scores they both show reasonably close distribution about a value of zero

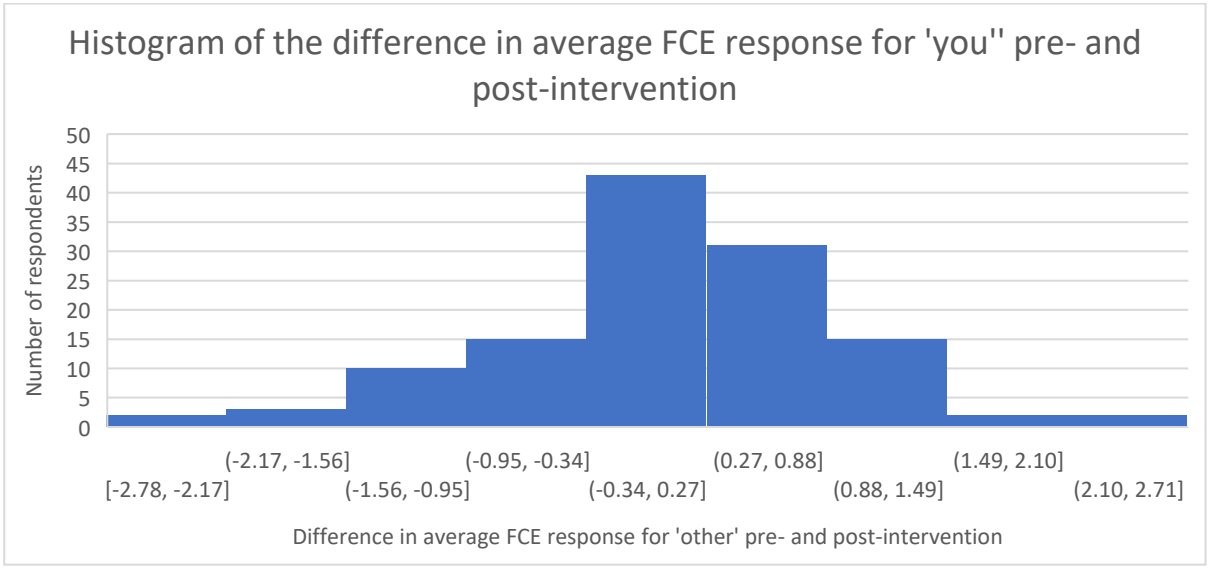


Figure 18 - Histogram of the difference in average FCE response for 'you'' pre- and post-intervention

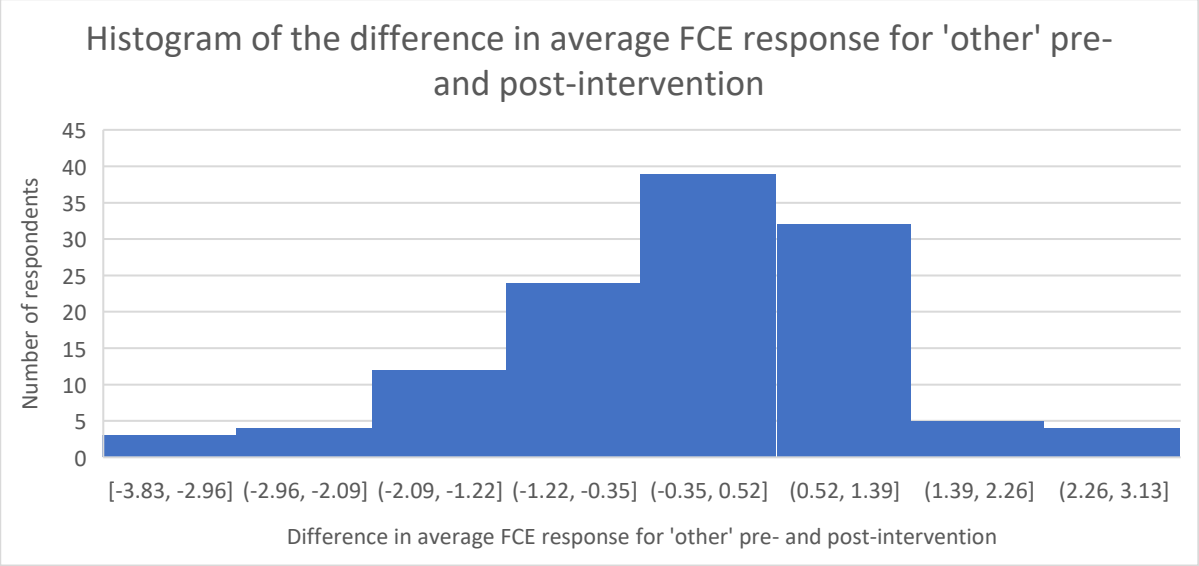


Figure 19 - Histogram of the difference in average FCE response for 'other' pre- and post-intervention

The histograms of the distribution of difference scores for both components show a close to normal distribution this is also seen in the QQ plot shown in Figure 20.

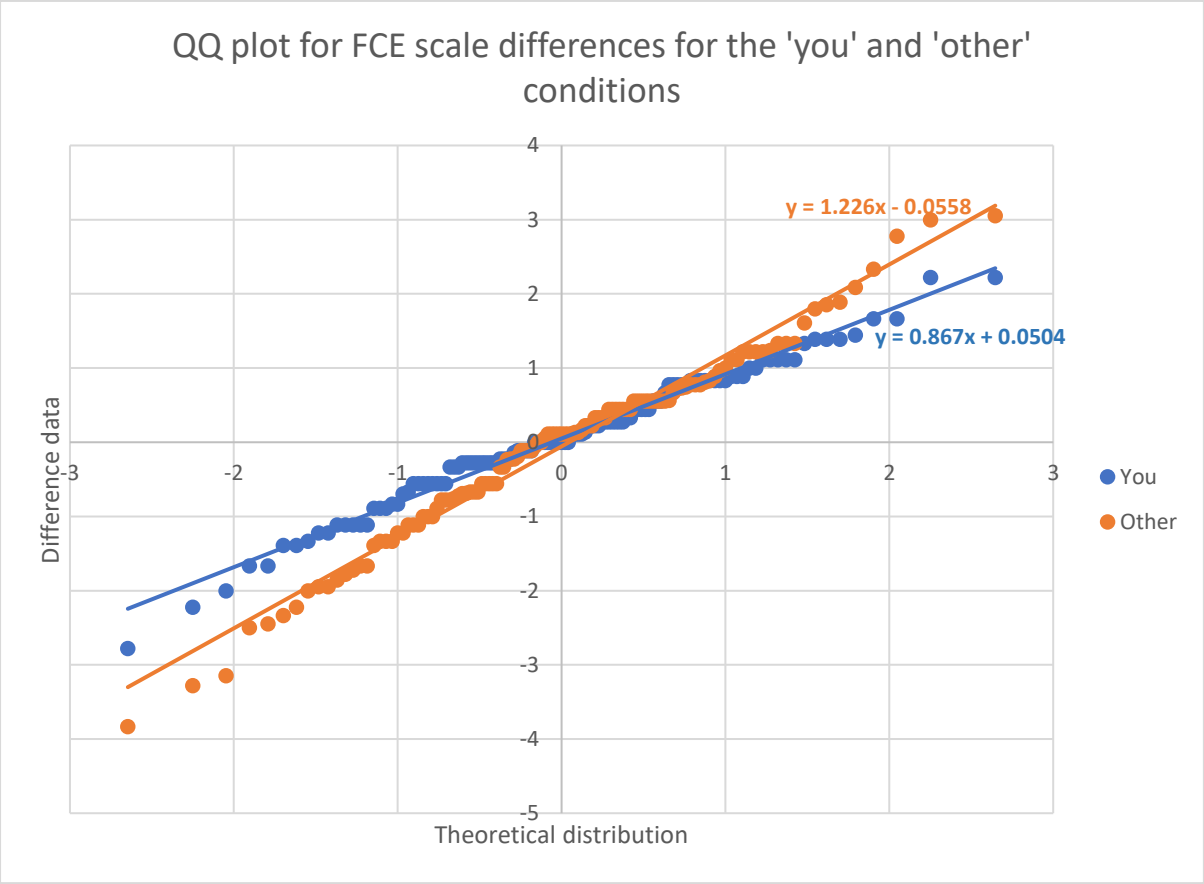


Figure 20 - QQ plot to demonstrate normality of the FCE difference data

As the data is close sufficiently to normally distributed, we can use paired T-tests to examine the significance of the difference in mean scores for the 'you' and 'other' conditions. The outcome of these is shown in Table 13.

t-Test: Paired Two Sample for Means (all)

	You	*Other*
Mean	0.0504	-0.0558
Variance	0.7609	1.5277
Observations	123	123
Pearson Correlation	0.4128	
t Statistic	0.9960	
P(T<=t) two-tail	0.3212	
Size effect (Cohen's d)	-0.1213	

t-Test: Paired Two Sample for Means (2018 cohort)

	You	*Other*
Mean	-0.0296	-0.2419
Variance	0.6456	2.1711
Observations	61	61
Pearson Correlation	0.4163	
t Statistic	1.2255	
P(T<=t) two-tail	0.2252	
Size effect (Cohen's d)	-0.1719	

t-Test: Paired Two Sample for Means (2019 cohort)

	You	*Other*
Mean	0.1290	0.1272
Variance	0.8740	0.8512
Observations	62	62
Pearson Correlation	0.4356	
t Statistic	0.0143	
P(T<=t) two-tail	0.9886	
Size effect (Cohen's d)	-0.0119	

t-Test: Paired Two Sample for Means (Maths population)

	You	*Other*
Mean	0.1260	0.0429
Variance	0.8075	1.6134
Observations	95	95
Pearson Correlation	0.3660	
t Stat	0.6437	
P(T<=t) two-tail	0.5213	
Size effect (Cohen's d)	-0.0926	

t-Test: Paired Two Sample for Means (Engineering population)

	You	*Other*
Mean	-0.2063	-0.3907
Variance	0.5381	1.1355
Observations	28	28
Pearson Correlation	0.5643	
t Statistic	1.0968	
P(T<=t) two-tail	0.2824	
Size effect (Cohen's d)	-0.2386	

Table 14 - the table shows a series of paired T-test which examine the statistical significance of changes in the reported FCE score

A we can see from Table 13 the comparison of differences for different populations shows no statistically significant results. For the paired T-test for all results we find:

Interpretation:

- The null hypothesis (H0) in a paired t-test is typically that there is no significant difference between the means of the paired groups.
- The t-statistic is 0.9960. This indicates that the difference between the means is approximately 0.996 standard deviations away from the expected difference under the null hypothesis.
- The p-value (0.3212) is higher than the conventional significance level of 0.05, suggesting that there is not enough evidence to reject the null hypothesis.
- The effect size (Cohen's d) is -0.1213, indicating a small effect size.

Given the p-value exceeding the significance level, we cannot reject the null hypothesis. There is no sufficient evidence to suggest a significant difference between the means of the "You" and "Other" groups. The effect size is small and provides additional context regarding the practical significance of the observed difference, a small effect may require more data to be established as significant.

Further decomposition of the FCE data set also shows no significant results in any category.

12.5 Interview Data

Over the course of the two years of data gathering, 20 short semi-structured interviews were conducted with small groups of students who had experienced the teaching intervention and responded to the survey instrument. These were distributed amongst the 4 different populations; 4 interviews were conducted with the engineering students in the 2019 cohort as well as 4 in the 2019 mathematics cohort. 6 interviews were conducted with engineering students in the 2018 cohort and 6 with the mathematicians from the same year. These interviews were held after the teaching intervention in the following week.

The interviews were scheduled in 15-minute slots and students were encouraged to sign up to slots with up to 2 people, the intention was to facilitate inter-student discussion seeded from the initial questions being asked. The range of the number of interviewees per session was one to four. To analyse the content of the interviews this work will use thematic analysis to compare the themes arising in the different populations.

12.5.1 2018 interview data

12.5.1.1 Thematic analysis

When conducting a thematic analysis of interview transcripts, the six-phase framework proposed by Braun and Clarke (2006) was followed. This method ensures a thorough and systematic approach to identifying, analysing, and reporting themes within data.

1. Familiarization with the Data

   In this phase I read and re-read the transcripts. Allowing me to gain a deeper understanding of the content, context, and nuances within the data. Whilst reading the transcripts I made initial notes and observations about potential patterns or interesting points.

2. Generating Initial Codes

   According to Braun and Clarke, coding involves identifying features of the data that appear interesting or significant and systematically labelling them. This process was inductive, meaning that the codes emerged directly from the data itself rather than being imposed by a preconceived framework.

3. Searching for Themes

   The next step involved sorting the different codes into potential themes and collating all the relevant coded data extracts within those themes. This process helped to organise the data in a way that highlighted the main patterns.

4. Reviewing Themes

   Braun and Clarke stress that themes should have internal coherence and be distinct from one another. Each theme was assessed for these qualities, ensuring that they fitted well with the coded data and were clearly distinguishable from other themes.

5. Defining and Naming Themes

   Each theme was then defined clearly, outlining what it captures and why it is important. This step involved going beyond mere description to interpret the data and link it back to the research questions. Themes were given concise, descriptive names that reflected their essence.

6. Producing the Report

   Finally, a coherent and compelling narrative was produced that aimed to integrate the themes and provide a clear response to the research questions. The intention is that the final analysis tells a clear story, supported by direct quotes from the interview transcripts.

12.5.1.2 *Table of Themes*

Year	2018		2019	
Discipline	**Mathematics**	**Engineering**	**Mathematics**	**Engineering**
Themes	Communication and Coordination Challenges	Perception of Interdisciplinary Collaboration	Collaborative Dynamics	Interdisciplinary Learning
	Role of the Engineers	Recognition of Challenges	Role of Mathematicians	Project Evaluation and Reflection
	Mixed Reactions to Working with Different Disciplines	The Role of Mathematicians	Role of Engineers	The role of mathematicians and engineers
	Reflections on Enjoyment and Engagement	Role of Engineers	Project Evaluation and Reflection	Team Dynamics
	Personal Development	Overall Experience and Enjoyment	Learning Experience	
		Professional development	Disciplinary Integration	

Table 15 - Table of themes produced from thematic analysis of the interview transcripts

12.5.1.3 *Mathematicians*

The thematic analysis of the transcripts created from interviews with mathematicians post intervention is shown here.

1. **Communication and Coordination Challenges**

   The participants highlighted challenges in communication and coordination, specifically mentioning issues with timetabling and logistics. Timetable misalignments and lack of synchronised schedules were identified as obstacles to effective collaboration.

   Illustrative quotes:

   "I thought it was well laid out because we were able to delegate different jobs in the assignment..."

   This positive view of the project is actually at odds with the aims of the intervention. Whilst it is gratifying to see that the respondent here found the assignment straightforward, this description of the distribution of tasks is firmly in

a siloed approach to work. This, at best, describes and multidisciplinary approach to the task and one that could affect the findings of the research.

"The first lesson was very much awkward because we were in mixed groups."

"It took a bit longer to get going. We had to get to know each other and understand our skill sets."

"The first lesson, we all got together, we were talking, but we weren't actually getting anywhere substantially until we had to get to know each other."

We find here very classic responses to team formation, Tuckman's group developmental sequence (Tuckman, 1965) is well established, whilst this aspect of group work is not considered here, it must be noted that all interdisciplinary work involves the formation of mixed teams and so will encounter this feature of sociology regularly. In future work more attention should be paid to the support of team dynamics.

"They didn't really communicate with us."

"We've been asking like 50 questions, but we've got no replies."

Once again, we find evidence of teams failing to progress past the storming phase of team development and whilst in single disciplinary teams this would be assigned to an individual's behaviour, we have the danger interdisciplinary work that this is considered a characteristic of the other discipline and deepen tribal boundaries. This could have the reverse effect of the aims of this intervention.

"The group was quite unwieldy."

Due to the logistics of teaching and infrastructure team sizes were roughly 8-9, this could lead to a level of difficulty in organisation as well as a sense of anonymity amongst team members that could overwhelm the intended mastery experiences. In future work, if possible, this number should be reduced.

"It is hard to work with people on other courses. It was hard because your timetables clash."

The direct mention of timetable clashes as a difficulty in working with people from other courses highlights the logistical challenges of introducing interdisciplinary activities. Timetable misalignments can hinder effective coordination and collaboration.

2. **Role of the Engineers**

The engineers played a crucial role in providing valuable insights and suggestions early in the project, contributing to the formation of ideas and solutions. The mathematicians' perspectives on the assignment shifted after interaction with the engineers, who brought a prepared and thoughtful approach.

Illustrative quotes:

"And you could tell that they were just more capable, I suppose with the technical report writing."

This response can be seen to demonstrate two important features considered in this work. The respondent here clearly has low disciplinary egocentrism as they respect the contribution of the engineers, however it also may suggest low levels of self-efficacy as the statement seems to denigrate the respondent's own skills.

"If they'd had that first week and had a look at the model, you know, there might be some parts of it that they struggle with more because they're not. You know, they don't do as much maths..."

This quote touches on potential challenges the engineers might face, particularly in areas requiring mathematical expertise – this demonstrated that the mathematicians had started to identify that their skillset was distinct and useful.

"I feel like they didn't really know where we actually could have come from, what credentials we had, what we were good at, etc."

This quote reflects a communication and coordination challenge between the teams. The lack of understanding about each other's backgrounds and credentials contributes to the overall theme and speaks to an underlying fear on the mathematicians' part of appearing inadequate of ineffective. Effective

collaboration requires a clear understanding of individual roles and expertise and for participants to feel comfortable in their roles.

"I think coming up with the original ideas of how to change the model, they [the engineers] were actually really helpful with that."

The acknowledgment of engineers being helpful in generating original ideas emphasizes their creative contribution and is tacit acknowledgement that the engineers had information and skills that were distinct from the mathematicians. This aligns with the theme by recognising the role of engineers in shaping the project through their distinct contributions.

"I think if the task was like we said, if it was more in depth and more difficult then it would have been obviously easier to sort of utilise them [the engineers]."

This quote reflects the understanding that there were distinct skills needed to complete the project that were separate from the skillset of the mathematicians, however it was seen as only important for 'complex' tasks, which in itself suggests the mathematician's lack of understanding of what these skills are. This relates to the theme by highlighting the how the mathematicians considered the impact of engineers and the understanding of their role.

3. **Mixed Reactions to Working with Different Disciplines**

Mixed feelings were expressed regarding the collaboration between mathematicians and engineers. While some involvement was positive, some interactions with engineers were less impactful. The mathematicians found the interdisciplinary collaboration to be less challenging when working with someone who brought valuable ideas and insights.

<u>Illustrative quotes:</u>

"I still think we could have done more on it, but they [engineers] do add something."

This quote reflects a mixed sentiment where the mathematicians acknowledge the engineers' contribution, however they minimise their role and seem to relegate their presence to minor improvements rather than any structural value.

This speaks to the heuristics of disciplinary egocentrism as it is clear that the engineers' contribution was undervalued as compared to their own. It relates to the theme by highlighting the complexity of mixed feelings in interdisciplinary collaboration.

"So, you can sort of perform the tests that were completed by either side [engineers or mathematicians]. Yeah, any specific background."

"Because I feel the majority of the work that was shifted between everyone was just trying different methods, so anyone could do it."

These quotes highlight both the undervaluing of the mathematicians' own knowledge alongside undervaluing the engineers; the suggestion I that each group were amorphous and not distinct. This suggest both a low self-efficacy as well as disciplinary egocentrism. This lack of agency in performing in the task may give rise to difficulties for the participant in engaging well. This relates to the theme by pointing to the challenges in evaluating and incorporating contributions from different disciplines.

"Working with other disciplines doesn't work."

This rather bald statement is a classic manifestation of disciplinary egocentrism. The participant sees no value in the role of a group trained in aerospace engineering for a project concerning the design of a plane. Heuristically this sentiment arose frequently during the sessions on the mathematicians' side as they saw the project exclusively through the lens of a numbers problem and found it difficult to breakout of that mindset to see the project as a more complex entity. It aligns with the theme by emphasizing the challenges and scepticism that some participants might have faced, indicating that collaboration with other disciplines is often not always straightforward.

"Just I feel like they didn't. Really have much input."

"Yeah, our end [mathematicians] was more prepared than their end [engineers]."

"Not many people sort of volunteer. They just sort of, I feel like that the engineers sort of just expected somebody to say to them, 'can you do this?'"

"We [the mathematicians in the group] were the ones that actually came up with the main solution."

These quotes follow on from the previous one and is in the same vein, however one mitigation for these egocentric views it that the groups were comprised of different numbers of mathematicians and engineers – the latter being outnumbered to quite a large degree. Another heuristic from the sessions in which these teams were working was that sometimes the larger group of mathematicians tended to be able to pull the direction of their work towards their field of expertise (to the detriment of the development of a solution). This has the follow-on consequence that the mathematicians did the majority of the group work as it was in their field of expertise and led to the opinion that the engineers weren't pulling their weight as their role had been minimised. It relates to the theme by addressing the variable impact of interdisciplinary collaboration. The perceived lack of input contributes to mixed feelings.

"It's just a bit hard to kind of communicate between each other."

This quote succinctly captures the essence of communication challenges within the interdisciplinary group – the difference in background and even the conflicting argots make efficient communication difficult. This can however be overcome with time and familiarity as is acknowledge in the literature of group formation. It relates to the theme by underscoring the difficulty in establishing effective communication channels, which can impact collaboration and coordination.

"It was different, but it was a good kind of different. It was more based in reality."

This quote reflects an understanding of the broader context of working in interdisciplinary teams. There is clear acknowledgement here that working with other groups is a beneficial thing beyond the immediate. This broader perspective potentially indicates lower levels of egocentrism in this participant allowing them to view the work from a broader perspective. It relates to the theme by indicating that while the experience was different, that difference can be beneficial.

"Yeah, it was definitely two groups - one group with two [sub] groups."

The statement points to a perceived division within the interdisciplinary collaboration and is descriptive of the difficulty in finding truly interdisciplinary projects – in this case the team members worked solely within their discipline and ultimately just shared their work with the other disciplines in their team rather than blurring or crossing boundaries, they strongly maintained them. This is tacit acknowledgment of the uncomfortable nature of interdisciplinary work – stepping out of one's silo takes energy and confidence whereas it is much easier to remain within it. It relates to the theme by underscoring the challenge of establishing cohesive teamwork. The idea of "two groups" reflects the difficulties in overcoming the interdisciplinary boundaries.

"We didn't really know about the cost implications and stuff that we didn't really know about, and regulations. We didn't know; it was just like a separation all the time."

The mention of not knowing about important aspects like cost implications and regulations points to an understanding of the value of the engineers – that in completing the project there was knowledge that was not possessed by the mathematicians and is the first steps toward reduced disciplinary egocentrism. However, the maintaining of disciplinary silos remains – the value of collaborating fails to be acknowledged and only the exchange of knowledge is considered. The perceived separation suggests a lack of shared understanding, contributing to the sentiment that interdisciplinary collaboration did not significantly enhance the assignment's outcome.

4. **Reflections on Enjoyment and Engagement**

Overall, there was a positive reflection on the intervention, with participants expressing interest and enjoyment in the unique and different nature of the case study. The diverse perspectives and challenges were seen as contributing to a stimulating and engaging experience.

Illustrative quotes:

"It was a nice change of pace. It's fun as well because you get to see a different perspective."

This quote shows at face value the benefit of a varied curriculum with students enjoying a range of task that maintain their interest. We can also view this sentiment as an acknowledgment of the benefit of interdisciplinary work – the participant mentions the 'different perspective' in in understanding not only that one exists, but that it has value.

"I think it's a really quite interesting project with the modelling of actual real-world situations and also the way you linked it to the evacuation of plane, which is also what made it a little more frustrating."

We find again the benefit of variety in the curriculum through retaining interest in subject matter. The identification of the project as based in real-world applications can also be seen as a climbing out of a disciplinary silo to be able to survey things from a broader perspective and with it this acknowledges that this broadening horizons comes at the cost of comfort.

"I think it's [the intervention] quite interesting, quite different. I quite enjoy that."

"Yeah, it's [the intervention] definitely different and interesting."

We find in these quotes continued reference to the positive aspects of novelty within the curriculum which in itself may be considered a benefit. We can also view these as subtle acceptances of interdisciplinary work as worthwhile – the participants appreciate the novelty of the task, but that novelty itself is embedded in the different approach to project work.

5. **Personal Development**

Participants acknowledged learning from the engineers about aspects related to aerospace, expanding their knowledge beyond their usual mathematical domain, as well as benefitting from disseminating their knowledge to others. The collaborative

experience provided insights into different disciplines and problem-solving approaches.

Illustrative quotes:

"When trying to explain to someone else, you get a better understanding of why you're doing it."

This quote underscores a key aspect of the personal development theme by highlighting the learning that occurs through the act of explaining and is the essence of improved self-efficacy. The benefit this participant evinces is on their own disciplinary knowledge, yet as we've seen in the discussion of self-efficacy, this reinforcement their speciality will have a positive effect on their own self-regard. The participant recognises that explaining concepts to others leads to a deeper understanding. In the context of collaboration, this implies that working with other disciplines necessitates explaining mathematical concepts and contributes to bridging disciplinary gaps.

"We learned some cool stuff about what's done by playing with stuff, and that was really cool."

This participant's acknowledgement that they had learned from the project is a positive response, especially as this knowledge is described favourably. Whether this extends to knowledge outside their disciplinary speciality is not mentioned, however the baseline statement here is that the aims of the module on which they were enrolled were still met with this different delivery.

"I think it was valuable in a way that you can say you've worked with different kinds of people and like you've got experience from working with someone from a different course."

The acknowledgement of the value of this type of project links with reduced egocentrism and can be seen to accept the benefits of interdisciplinary work, as well as identifying that developing skills in this area is beneficial for their future. This exposure to diverse perspectives and problem-solving approaches contributes to the participants' personal and professional development.

12.5.1.4 *Engineers*

The thematic analysis of the transcripts created from interviews with aerospace engineers post intervention is shown here.

1. **Perception of Interdisciplinary Collaboration**

   The perception of interdisciplinary collaboration reflects an awareness of its relevance in real-world scenarios. The emphasis on working with diverse groups aligns with the demands of the industry, suggesting a forward-looking attitude and an understanding of the importance of collaborative skills in professional settings.

   Illustrative quotes

   "I think overall it was good. I think it's a good idea [...] As Engineers out in Industry, we'll have to work with different groups of people."

   "Because we do a lot of group work anyway to try and get as used to working with people in industry."

   "Because when we go out into industry, I suppose it's like good to get a bit of practise because we won't just be dealing with engineers. We'll be dealing with mathematicians, control people, businesspeople."

   These quotes highlight a recurring concept throughout the responses of the engineers – they were more aware of the idea of professional life after university. This is unsurprising as aerospace engineering is an inherently more vocational discipline that mathematics and career paths are more regularly laid out. However, this doesn't diminish the fact that this perspective is aligned with a reduced level of disciplinary egocentrism – understanding that there are multiple skillsets that make up a team is a clear indicator of a broader view. This hypothesis of a low egocentric start point may explain trends in the quantitative data.

   "It was pretty good, yeah. I wasn't averse to it, it's quite nice working with people you don't know sometimes..."

   "It was quite nice to work with different people that I probably won't get to work with again, because we don't do much of that sort of thing here."

"It was nice working with maths."

These statements once again seem to denote a lower level of disciplinary egocentrism. The fact that these respondents were happy to work alongside a different discipline suggests that they acknowledged that the mathematicians' contribution was useful. There are potentially explanatory factors for the origin of this mindset as the engineers within Hallam university study some topics all together (aerospace, mechanical, chemical, etc.) and so these students would have experience of at least working alongside other disciplines. Which may in turn foster this broader mindset.

"It was really good because you're able to find information out from a broader range of people. So, people who are good at particular things [...] because they were maths, they were able to do the more maths-y side and we were able to input our side."

"I think it was good to mix two groups of people who have got similar skills, but then specialise in different things."

Acknowledgement is clearly shown here that the respondents quoted here are aware of the benefit of mixing disciplines. Their descriptions here however are not of interdisciplinarity, more akin to multidisciplinary. As we have discussed earlier in this work, true interdisciplinarity is difficult to establish and requires great commitment to abolish the safety of boundaries. Potentially we can see indications in these quotes that the project failed to achieve true interdisciplinarity and that further work is needed in this area. Despite this these statements clearly demonstrate a positive attitude toward the other discipline and are indicators of the capacity of the respondent to reach beyond their own silo.

"Everyone kind of did quite a fair share of work because I know other people struggled trying to get the mathematicians or the engineers to actually work together, but I think ours went quite well."

Inevitably with groupwork the commitment of participants is normally distributed with a certain number showing very low engagement and it is this extreme end of the continuum that is often the most visible – people rarely go out of their way to

discuss adequately achieving teammates but will seek to share their woes if they feel cheated in some way. The respondent alludes to this here and heuristically it could be seen that the low engagers within both disciplines were disproportionately visible. These comments were however almost exclusively made about team members from the other discipline, very little intra-disciplinary consternation was shown. This was true for both engineers and mathematicians. This feature could be attributed to in group psychology or other features of group formation, however this all could also be view through the lens of egocentrism.

"It was more like Engineers doing maths, as opposed to teaching the maths people the engineering side of it."

"But I think we were quite content to let each side handle what they knew."

"I think they could have done it without us, but it would have taken longer."

"It wasn't the easy ride, because I ended up writing the whole tender document for it based on their solution."

These quotes describe once again multidisciplinary working rather than interdisciplinarity, which again suggests a failure of the intervention design to promote more blended working practices. We also see from the last quote signs of low self-efficacy; the respondent is reporting a low sense of individual usefulness and doesn't recognise the importance of their contribution.

"So, it was good-could delegate stuff to certain subjects, and you learned from them, they learned from us."

"Because you've got to explain it to them [the mathematicians] in a way as if they've never done it before, you think about everything first."

Despite the many quotes to the contrary discussed above, we can see here faint light that in some teams the boundaries of the work began to be more blurred which is the foundational set towards an interdisciplinary approach to the problem and that the respondent here see value in this blurring of responsibility.

2. **Recognition of Challenges**

The participant's acknowledgment of the project's initial roughness indicates a realistic understanding of the challenges associated with interdisciplinary collaboration. By attributing the challenges to the "first time around," the participant shows a willingness to learn and improve, setting the stage for iterative refinement in subsequent collaborative endeavours.

Illustrative quotes

"It was a bit sort of rough in places; it needed a bit refining... but I think that's just the nature of it, it's the first time around."

This indeed was the first iteration of this intervention, and some things were not as developed at this stage as they needed to be. This quote, however, hopefully illustrates that this was not an insurmountable issue for the students.

"I found that it was... because it was very maths heavy; I wasn't actually able to put in as much as I would have wanted to in a bit of group-piece of work."

As we have discussed previously, the differing sizes of the disciplines within groups may have affected their approach – in groups with large majorities of mathematicians, inevitably the focus was directed towards the mathematical aspects of the work. In this quote we can see that the respondent felt that the engineering aspect of the work was minimised – this is an interesting aspect of self-efficacy, as the respondent failed to see the utility of their skills as an engineer in completing this project. This may suggest that there is a potential for this type of intervention to have a negative impact on participants.

“The only thing that I found challenging - like putting the work in, was because we have such different timetables, we couldn't really collaborate."

“Maybe increase the time scale so then you actually get to know who you're working with, and you can work more as a team than just, Six hours."

The logistical challenges of setting up this teaching intervention were many, and these quotes illustrates the inescapable factors of its operation. Whilst we

addressed what we could to facilitate the running of this project, inherently interdisciplinary teaching comes with added complexity.

"Organisation was quite difficult."

Whilst this work focusses on the employability aspects of this intervention, there is a large body of research concerning the formation and operation of teams – this quote can be seen as the team failing to exit the forming/storming stage of team development. (Tuckman, 1965)

"I feel like there was a bit of disparity between what each individual group was to do."

"If there was more clarity as to which of the tasks we were to do, then I think it could've worked a bit better."

These two quotes are illustrative of the desire to remain within one's own silo, the messy area beyond can be stressful and tiring to navigate. In order to accommodate this the participants are looking for a structured path to follow that narrows down options to make themselves feel more comfortable. This response speaks to the innate difficulty of interdisciplinary work in that it requires a great deal of effort to get started. We could infer form these responses that more scaffolding was needed to ease students into a new paradigm of work.

"I found myself there was like two of my [engineering] students and me who were like we were like the solid core, right. Then everyone would say come meet up, then maybe someone else would turn up and week to week. It varied quite a lot."

"We had three Engineers of which two of them didn't turn up for one week and one of them didn't turn up for two weeks, and then five maths people, four maths people?"

"So, it was like me and seven mathematicians for the first week."

"Yeah, it probably wasn't very good because it sort of got taken over by the maths people."

The disparity in the numbers within teams sometimes caused difficulties in the operation of the teams. The lower number of engineers within the team meant that it was easy for them to become passengers in the project. It also meant that

any volatility in attendance had a greater effect on the team. In future implementation of this style of intervention this would be a key consideration.

3. **The Role of Mathematicians**

The participant's evaluation of the solution and speculation about the independence of the engineering team without mathematicians reflects a critical analysis of the interdisciplinary collaboration. This suggests a consideration of the unique contributions of each discipline and raises questions about the necessity of certain roles in the collaborative process.

Illustrative quotes

"Well, we reached what we're supposed to reach... I think we could have done it without them; they could have read up on the legislation of planes and that sort of stuff."

We find here evidence of a low sense of self-efficacy. The respondent feel anonymity within the project and fails to value not just their own contribution, but the contribution of their entire discipline. The intention of this intervention was partly to produce *mastery* experiences, but from this quote we can see that this wasn't a universal - potentially this experience could have had the opposite effect to the intended and reduced self-efficacy. Greater concern needs to be paid to this issue in future iterations.

"I think it benefited them more having us, than us having them."

This quote is a classic example of disciplinary egocentrism – the respondent here couldn't see a benefit from having mathematicians' part of a project involving data analysis. Sometimes this opinion was based in the experience of the team, but there were participants who held this view from the outset.

"Their [the mathematicians] goal was 'can we get the Excel spreadsheet to work?' And what's the-can we manipulate this spreadsheet to get the time down as much as possible, as opposed to 'Is this realistic?'"

‘To a hammer, everything’s a nail…’ this clear example of siloed thinking on the part of the mathematicians, appears to have been confusing to this respondent – the natural tendencies of their discipline led them to minimise the numerical solution rather than address it as a physical problem. The engineer here, however, is focussed on the application of the solution. This is a good example of the difficulty of merging approaches and even language when bringing disciplines together. This quote once again indicates that greater scaffolding may need to be in place for guidance.

"I think they brought some, I guess, fresh ideas, fresh perspective which a lot of us - maybe would not have initially seen."

"So, it worked out quite well because we put forward the initial ideas and then they came in with extra ideas-simulated all."

Here, however we find indication of interdisciplinary work underway – the blending of approaches with the benefits of each acknowledged is a first step towards a truly synthesised solution. These respondents became aware of the broader aspects of the problem and the need for a distributed approach.

"Because the mathematicians were more familiar with the mathematical modelling, they sort of dealt with more that side and we did more like the legislation sort of side."

"[The mathematicians did] Just the model really."

"And they [the mathematicians] were very content to handle, like all the mathematical model stuff."

Sadly, not all is bread and honey! We see here a counter example of teams which remained rigidly within their own discipline. Hopefully, however this foray into multidisciplinary work can act as the scaffolding discussed above that could lead to interdisciplinarity in the future.

4. **Role of Engineers**

The participant asserts that the engineers played a crucial role in shaping the solution, emphasizing the engineers' contribution as more significant. This perception suggests

an understanding of the unique value brought by the engineering perspective and skills to the collaborative process.

Illustrative quotes

"I feel confident they probably would have done it without me because there was still seven of them. But I think I had a positive influence on it."

Underneath the self-effacement of this statement, we can view the evidence of mastery experience in this quote. The respondent was in a small minority within their group however they fielded a great number of questions on their specialty and remained an active part of the work. Conversely the mathematicians within the group approach the partnership openly and appeared to see the necessity of the two disciplines working together. For this respondent especially this experience was the model example of how interdisciplinary work can affect participants.

"I think if it was just the mathematicians, they'd have probably come up with a bit more of a crude solution, Yeah, maybe."

The acknowledgement of the utility of their contribution here suggests a greater level of self-efficacy from the respondent – they are no longer anonymous but had a meaningful impact on the outcome of the work.

"No, because we weren't doing principles of engineering, it was more like what can't you do on a plane, which they could have researched because we didn't know it either."

However, this respondent failed to see that they had any specialist knowledge to provide to this work, they demonstrate a sense of anonymity in this quote potentially leading to lower self-efficacy. This response could suggest that greater preparation would have benefitted the respondent.

"They made me realise things that I had just assumed, so they [the mathematicians] hadn't appreciated that you couldn't just widen the doors."

This is the essence of mastery experience! The process of discovering that the knowledge you possess is distinct form others. If we consider this in terms of the

hypothesis illustrated in Figure 5, this realisation is akin to no longer assuming that the average understanding is that of the specialists but actually more correctly the general level of understanding. This is one of the intended consequences of this teaching intervention.

"There were two of us [engineers] in our team, and our role was to answer the questions about the impact it would have on the airline, and the business holders and things like that within the tender document."

"It was useful to have the other engineers and me to sit there and be like, well, it is possible, but it could mess with the structural integrity."

Here too we find an example of the understanding that the knowledge these respondents possesses is useful and unique (to the engineers). Whilst these quotes make no suggestion that the work was a synthesis of disciplines, the fact that this understanding is made clear is a beneficial result of the intervention.

"I felt definitely the beginning, the engineer role was quite important. But then as it progressed into more maths, I felt like the engineer role dropped off and we were just able to do the other work wasn't so maths-y."

"Because we came up with a lot of different ideas, and were able to whittle them down to a few that were feasible, I think that if the maths people had been given a set of ideas, then they'd have been absolutely fine, but because they were unaware of certain things that you can and can't do, I felt definitely the beginning, the engineer role was quite important."

Once again, we see indications that participants are acknowledging the utility of their membership of the team, however here we find that tempered with this sense of lower worth in the larger picture of the whole project. I would ascribe this as before to the disparity of the teams, with the mathematicians tending to direct the work towards their own discipline, so we can see here that after an initial sharing of knowledge the work became focused mainly on the theoretical data aspects rather that the applied situation. Hopefully the initial feelings of utility would support an improved sense of self-efficacy.

"I don't know whether we [the group] would have thought of a better solution [as a single discipline group] because a lot of the ideas that were proposed were from the engineering side."

When groups became led by a strong or forceful group of engineers, often the opposite would happen – the data aspects of the project would become merely mechanical aspects of the project and the engineers saw no specialty in them. In this quote we can see that the respondent is of this opinion, that the mathematicians added little value to the work.

"Yeah, I contributed quite a lot to the task. I feel confident they [the mathematicians within the respondent's group] probably would have done it without me because there was still seven of them. But I think I had a positive influence on it."

"For me, it felt a bit redundant, didn't really know what my part was."

"I think I could have been replaced if necessary."

In these quotes we find an interesting mixture of feelings about individual utility. The intention of the intervention was that students would have opportunities to be made aware of the specialist knowledge they possessed and this in turn would improve self-efficacy. Practically this was dependent on the student and the team they were in. Some, like the respondent from the first quote here, found they were in an inclusive team who valued the insight they provided. Others had less positive experiences, either because they found it difficult to provide their knowledge, or it wasn't as willingly received. This feature of interdisciplinary teaching is a difficult one to overcome, in future iterations clear accommodations for it would need to be made.

5. **Overall Experience and Enjoyment**

Despite the challenges, the participant expresses overall enjoyment and positive aspects of the interdisciplinary collaboration. They value the different perspective brought by mathematicians and appreciate the unique experience. There are a number of positive responses discussed in this section – it is acknowledged that there is an inherent difficulty in receiving unbiased responses when respondents often feel

it would be impolite to criticise the teaching. The findings here must be tempered by this understanding.

Illustrative quotes

"I enjoyed it though, it was good. It was nice working with maths."

"I quite liked it. I liked working with them."

"It was pretty good, yeah. I wasn't averse to it, it's quite nice working with people you don't know sometimes."

There were many positive sentiments expressed during the course of the interviews, here we find respondent remarking positively on the opportunity to work with a more diverse group of people – in terms of reduced disciplinary egocentrism this is a positive emotional starting point.

"Yeah, I think that's what I enjoyed about it; it was different."

"Yeah, it was different, yeah. I quite liked it."

“It was more interesting because there were more things you could do with it as supposed to just like designing a triangle [reference to the engineers' previous task in this module].”

The novelty of this kind of intervention was seen as a positive by many of the interviewees, using knowledge in a more practical context seemed to appeal to many of the engineering students. This positive attitude hopefully engenders greater engagement with the task.

"I think it was a good concept. Yeah. Definitely sort of skills we'll need to develop before we get out there."

"I think overall it was good. I think it's a good idea."

Often the engineering students framed their responses in terms of the work’s relevance to future employment. The attitudes expressed in these quotes can be seen as a starting point to overcome disciplinary boundaries – the acknowledgement that the process is useful or good engenders engagement with it.

"Personally, I found it useful."

"I do think it was useful. Yeah, I think it's a good project."

Again, by acknowledging the utility of the intervention these respondents demonstrate that they are accepting the value and use of other disciplines. This reduction in disciplinary egocentrism is an important aspect of the intended consequence of this intervention

"It was interesting, but it would have been-you could have probably done something - a good project on it with a proper document as opposed to just doing like a thousand words between eight of you."

"Yeah, I think in principle, yeah, it's good."

Some qualified positive comments were given expressing the sentiment that the intervention was beneficial, but that there were aspects that could be improved. This resonates with earlier quotes which discussed some failings of the intervention. In future iterations addressing these concerns would be an important starting point.

6. **Professional development**

Participants highlight the benefits of mixing two groups with similar skills but different specialisations (engineering and mathematics). The collaboration allows for the delegation of tasks based on individual strengths, and participants express that both groups learned from each other, and these are the sorted of situations and task they will encounter in their professional life

Illustrative quotes

"I think overall it was good. I think it's a good idea. I think it was last week I was speaking to [engineering academic] about it, he was asking me what I thought about it and how'd it go and everything I thought-I think it's like a good idea because as Engineers out in Industry we'll have to work with different groups of people."

"I think it'd be good because we do a lot of group work anyway to try and get as used to working with people in the industry, but obviously we work with different areas, so

I think it's good for knowing about how to work with people and communication and stuff."

"But also, like just the mixing of cross disciplines. Because when we go out into industry, I suppose it's good to get a bit of practice because we won't just be dealing with engineers. We'll be dealing with mathematicians, control people, businesspeople."

"I think it was a good concept. Yeah. Definitely sort of skills we'll need to develop before we get out there."

The engineering students demonstrated repeated understanding of the need to prepare for future employment – as discussed previously, this could be attributed to the more vocational nature of the discipline, with a clearer pathway to employment after study. This facet of their background potentially makes them a more initially responsive audience to these kinds of teaching methods.

12.5.1.5 *Comparison of themes emerging across the two disciplines for the 2018 data*

Year	**2018**	
Discipline	**Mathematics**	**Engineering**
Themes	Mixed Reactions to Working with Different Disciplines	Perception of Interdisciplinary Collaboration
	Communication and Coordination Challenges	Recognition of Challenges
	Role of the Engineers	The Role of Mathematicians
		Role of Engineers
	Reflections on Enjoyment and Engagement	Overall Experience and Enjoyment
	Personal Development	Professional development

Table 16 - A table showing the identified themes from the two disciplines compared and colour coded for similarity for the 2018 data

Table 15 illustrates the themes arising from the mathematicians and the engineers' interviews, colour coded to mark areas of similarity. We will discuss these now.

Mathematicians showed more apprehension about collaborating with engineers, indicating a higher level of disciplinary egocentrism. Some did demonstrate and understanding of the utility of this partnership, especially in providing practical insights into theoretical models. However, some viewed their own contributions as the crucial component, with no real regard for the value of the engineering knowledge.

Engineers displayed a more immediate and positive attitude towards interdisciplinary collaboration, reflecting a lower level of disciplinary egocentrism from the start. Their vocational training might have predisposed them to value collaboration, as they understood that real-world engineering involves working with various disciplines.

Mathematicians seem more likely to view the contribution of the other discipline poorly, as discussed this maybe an artifact of the team construction; with a larger number of mathematicians the tug-of-war of the direction of the work often inevitably went towards them. This then diminished the utility of specialist engineering knowledge. In groups in which this didn't happen greater levels of respect for the other discipline could arise.

Overall, both groups expressed positive sentiments about the intervention finding interest in the novelty, with the engineers demonstrating a broader sense of its use in their preparations for future work, whereas the mathematicians' enjoyment seemed to stem more from the intellectual challenge. A large proportion of respondent, when describing the work they completed, described a multidisciplinary approach rather than an interdisciplinary one. This may be unsurprising as the intervention only ran for a short time which may have not been enough to establish true interdisciplinarity – the task too may not have engendered this kind of working. Both these issues should be addressed in future work.

12.5.2 2019 Interview Data

12.5.2.1 Mathematicians

These data explore different aspects of teamwork, interdisciplinary collaboration, challenges faced during the project, and reflections on the collaborative experience. Whether it's differences in backgrounds, expectations vs. reality, group dynamics, the role of mathematicians vs. engineers, or communication challenges, the overarching theme revolves around how individuals work together, learn from one another, and address various challenges within a collaborative project. The items touch upon leadership, decision-making, workload distribution, communication, and overall project evaluation, emphasizing the intricacies of working as a team and the impact of collaboration on the project's outcomes.

1. **Collaborative Dynamics**

   The thematic thread of "Collaborative Dynamics" links the four interviews included in this section. It functions as a descriptor that encapsulates the multifaceted nature of interactions, relationships, and teamwork inherent in collaborative projects. This overarching theme is present across various dimensions. The exploration of differences in backgrounds and group dynamics unveils the initial challenges posed by diverse participant backgrounds. Collaborators find themselves navigating unfamiliar territory, emphasizing the pivotal process of acquainting oneself with team members and adapting to a collective rhythm. The theme extends into discussions on expectations versus reality, where interviewees reflect on the intricacies of assumptions and realities within collaborative efforts. Noteworthy are instances where preconceived notions about the knowledge or skills of fellow group members clash with the reality of their expertise, underscoring the need for transparent communication channels to harmonise expectations.

   Illustrative quotes.

   "It was hard to get all of us together in one room at a time... It was hard to equally weigh work to each other."

   "Feel like if this group's as big as seven, you want to be together, you want to be coordinated very well. You don't want to be dependent on other people; you want to

know what's going on, what's doing what, and who's doing what when which is difficult."

"It did work quite smoothly, but I think it was just a large size, it was hard to give everybody something to do."

As discussed previously the logistics of running the teaching intervention meant that group sizes were relatively large (again roughly 8-9). This impacted the behaviour of the teams as this respondent discusses, managing a large team adds complexity to an already cognitively complex task. Students from both years studied found this an issue and so clearly this should be addressed in future.

"The first week we didn't really get anywhere because everyone had their own spreadsheet open."

"Then some of the engineers say I'm not coming in today... because we're not seeing the work, we're just kind of hoping they're doing what we in our heads we think they're doing."

Once again, we find aspects of group formation in participant's responses and the frustration that accompanies the forming and storming phases. This feature is present across responses and years.

"You have to get a little bit lucky with the people you get put with, because obviously we know who we want to work with on this course [mathematics]."

"A big challenge is not knowing the people. So, when we get group projects, [normally] you get to pick your friends, so you'll know each other."

"A big change is not knowing the people... Doing work with a completely new set of people that you've never met before, so you have to get acquainted and stuff before you figure out each other's rhythm."

The difficulty of forming a team with no prior acquaintance is something regularly reported in the interviews. As discussed above this feature of group formation is unavoidable. However, care must be taken to encourage groups to proceed past the first few phases of group formation otherwise poor group performance and

cohesion can be attributed to the ‘others’ in the group leading to a fortifying of disciplinary boundaries.

"People would get left out if we didn't do things in groups, but it was literally engineers gave us an idea and the modelling guys, which was me and somebody else, made the model said this is what we got."

This response underlines the difficulty of getting groups to work toward a solution as one unit. Here we see that, although not discussed in the negative, there are clear delineations between disciplinary roles within this group. The participant’s response alludes to their comfort with this bounded role. This difficulty may be overcome in future through increased training or preparation for the project.

"So, we all just kind of mutually agreed on specific ideas, you know, mix and match and from other ones. That's why what we got was actually quite successful."

“It was nice having a fresh mind on it, looking at and trying different ideas. When the actual model came around, the engineers, if they were getting involved, were putting different ideas together themselves."

We do find some hints here as elsewhere that groups are working towards a more synthesised approach – it is gratifying that some responses like the ones provided here describes work happening between disciplines, one of the main intentions of this intervention.

"I think you kind of have to put things, explain things a little bit easier to someone who has never looked at anything like this."

This quote illustrates the experience of the participant that was intended in the completion of this intervention – through an exchange supporting the work undertaken the students could reset their view of what *average* knowledge was in their discipline, and so support the development of improved self-efficacy.

2. **Role of Mathematicians**

The theme "Role of Mathematicians" serves as a descriptive lens that discusses the distinctive contributions, challenges, and dynamics that the mathematicians within

this collaborative project felt they experienced. This theme captures the multifaceted nature of their perceived role, providing insights into their involvement, interactions, and impact on the collaborative process.

Illustrative quotes

"It wasn't very dependent on maths."

This stark statement on the contributions that the mathematical group members were capable of providing conveys much. The task itself required groups to create a dataset and defend their chosen solution through evidenced argument. The only evidence that could be collected was the data set and so the only analysis that could be performed was mathematical – inherently this task required a grounding in mathematics. The respondent here overlooked all these requirements and focussed only on the other aspects of the work. Whether this can be attributed to poor self-efficacy is debatable. It could also be seen as a rigid adherence to boundaries – the novel nature of the work not conforming to the traditional task of mathematics and therefore not part of that discipline.

"We [mathematicians] directed ourselves more towards this solution that was less work for the companies and less changes to the plane."

"Most of the mathematicians pushed on the solution because we understood the idea of how it works, the concept of it."

"We [mathematicians] kind of did everything together, except us [mathematicians] asking them questions about planes, they [the engineers] didn't really ask us much."

A strong sense of disciplinary egocentrism can be felt in these quotes. In all three responses the participants demonstrate little respect for the contributions of the engineers. The presence of this attitude following the intervention suggests that not all participants experienced the benefits intended. If these participants are holding these views, then it is unlikely that the work they completed could be considered interdisciplinary, it may even have not involved any great contributions from engineers – as we have seen before, if this were the case, there is the potential that this intervention could have a negative effect on those participants.

In addressing this future work could examine what proportion of participants this affected.

"In the long run, it was more so mathematicians - put more into the simulation than the engineers where they more put into the report or the certification [of the plane in the scenario]."

Here again we see evidence that mathematicians were happy to remain in their disciplinary silo – the tacit understanding in this quote is that the report and the certification were nothing to do with the respondent. This attitude prevents teams from engaging in true interdisciplinarity.

"Because there were so many mathematicians, if one of us guys was not there, it wouldn't be the end of the world."

"Because there's five mathematicians within one aspect and the two engineers looking at certification, I feel like it wasn't necessarily me working less than others. It was more because there was that many of us, we had much of a much smaller workload to do."

One concept explored in these interviews was that of individual contribution. Participants were asked about whether they felt that they had individually contributed to the work and whether that work could've been achieved by someone else. The intention was to examine whether participants acknowledged mastery experiences – a key to self-efficacy. As we can see for these two quotes, this was not always the case – especially in larger teams the capacity for individual, meaningful contribution may be limited. The group size again becomes an issue in the successful delivery of this intervention.

3. **Role of Engineers**

The theme of "The Role of Engineers" emerges prominently in the interviews. This section, offering a descriptive lens into the perceived contribution of the engineers, considers challenges, and dynamics within collaborative projects.

The mathematicians' view that the engineers play a part mostly in executing practical tasks and bringing technical expertise to the table is raised. With the interdependence of mathematicians and engineers, the view that the engineers' responsibility to carry

out tangible work based on the mathematical concepts provided is regularly highlighted. This theme is descriptive in capturing the engineers' perceived multifaceted contributions, challenges faced, and collaborative dynamics explored within the interviews.

Illustrative quotes

"It was very dependent on the engineers [...] We'd have to just hope that they were doing what they were required."

"And because we're not seeing the work, we're just kind of hoping they're doing what we in our heads we think they're doing."

Here we find an interesting mix of cognitive behaviours, pleasingly we find evidence the engineers' contribution is being valued, however this sentiment is shrouded somewhat in mistrust. We can infer from these responses' difficulty in groups cohesion, but also a certain amount of disciplinary egocentrism fuelling this mistrust.

"I feel like the engineers could have done it themselves. It would have been hard for them because obviously, [they've] never seen it [the simulation] before."

"The engineers could have done it more easily alone than maths students could have."

Again, we find these quotes feed into two narratives; we find lower levels of disciplinary egocentrism from the positive regard these respondents have for the engineers; however, this doesn't seem to be tempered by a similarly positive opinion of their own skills. Whether these two factors are inversely correlated would be a useful thing to examine in the future.

"I think the engineers completed it [the project work] efficiently."

"They kind of knew what they're [the engineers] talking about - Once they looked up."

Here however, we have less effusive praise of the activities of the engineers – and could even be considered denigrations of their abilities. This more measured response could be due to respondents wanting to put forward their views in a more politic way and to not appear too belligerent. Tanking them at face value

though, we can imagine this measured approach to be a product of a positive opinion built alongside a good level of self-efficacy leading to a more considered tone.

"The engineers, I don't think they would have thought to improve the maths side of it."

"Things about legal things and certification really didn't impact [the project]. I think it might have been because we just changed the seats."

“We went in thinking they [the engineers] would know more about certain specs than they did."

"The engineers like were they getting involved? They were. They put different ideas together themselves, but in the long run, it was more so mathematicians."

Four different ways to demonstrate a lower opinion of the capacity of the engineering students! Each of these quotes is distinct, yet conveys the same emotions – an us vs. them mentality potentially fuelled through an inability to see beyond one’s own experience and background. As these sentiments are expressed after the completion of the intervention, the prevalence of these feelings could impact on the findings of this work.

"I think they [engineers] knew we knew what we were doing on the Excel, so just let us do what we knew we had to do."

"I don't think they [the engineers] expected us to know much. I think if they asked us to try something on the model, we could. We just did it."

Quotes here represent a misalignment in two different directions of the understanding of the other discipline. In these quotes we can infer poor communication and a sense of othering the engineers – they were unknowable and unknown. The lack of understanding suggests these groups would have struggled to produce well synthesised work.

"I think they [engineers] had a different approach to the problem."

Here we find an excellent example of nascent interdisciplinary behaviour – the respondent identifies the engineers’ approach as different, this is presented in

bald terms with no indicator as to their opinion on this fact, however the mere identification of a different approach rather than a ‘wrong’ approach is progress towards integration.

4. **Project Evaluation and Reflection**

The theme of "Project Evaluation and Reflection" emerges as a descriptive lens through which the participants assess and reflect upon the collaborative projects in these datasets. The theme encompasses diverse dimensions, including the evaluation of group dynamics, challenges faced, and insights gained throughout the collaborative process.

Quotes provide glimpses into the challenges faced during the projects. These challenges, expressed through the participants' perspectives, contribute to the descriptive nature of the theme by shedding light on the intricacies of coordinating diverse group members and navigating through initial hindrances.

Illustrative quotes

"For five of us to do a task that maybe two people could have done, it was very hard to equally weigh work to each other. So, we just had to find each part to do and then put it all together."

"I think if it was a smaller group then it probably would have been OK."

"We were kind of forced to do it in groups because we had quite a large group with eight of us. We were constantly figuring out how we should shape it, like they gave an idea and said, 'Okay, how should we implement it?'"

"Group size made a much bigger difference than I thought it would, to be honest... Three to two is perfect. Obviously, we were way off three to two."

Group size is a common theme running through responses throughout the interviews. As mentioned previously, in any future work this issue should be addressed.

"But the changes that we made to the plane were so minuscule it's like we haven't really done anything which was kind of odd because like obviously this is a case that it's a big assignment."

The respondent here expresses a lack of appreciation for the whole task – whilst only small changes to the layout may have been required to successfully achieve the project brief, the steps needed to validate and describe the impact were not trivial. If we consider this statement through the lens of self-efficacy, we could assume that this feeling arises out of a lack of sense that any uncommon skill was necessary to complete the work.

"It was very open. You know, it was very applied to the real-world, it wasn't just, when you write it down, the past few projects we've done are very maths-y - it's not really thinking outside the box."

"It's good to have a bit more freedom with it. The other ones [case studies in that model] were both more rigid with what we have to do."

"I liked it better because it was more like, you had to think about things; This is what you can do."

The open-ended nature of the work was received positively by many participants. The capacity to apply learning in a real way was enjoyable. This is also the beginning of mastery experiences, where students can unpack their learning and really examine its breadth.

"I think some people didn't, really, know what to do. How to help sometimes."

However, this open-endedness could engender a negative response as illustrated by this quote – when all scaffolding is removed, some students may find the freedom paralysing.

"I think it [the project] works well."

"It did work quite smoothly, but I think it was just a large size [group], it was hard to give everybody something to do."

"I Enjoyed it. It was a genuine, enjoyable experience"

Participants responded positively to the intervention as a whole often the novelty seemed sufficient to maintain interest, however a number of factors were alluded to. This positive opinion of the intervention makes implementation of this kind of teaching easier through student buy-in.

5. **Disciplinary Integration**

The theme of "Disciplinary Integration" serves as a descriptive lens through which the participants articulate the intricate interplay of different academic disciplines within this collaborative project. This theme unfolds as a narrative that illustrates how individuals from mathematics navigate the challenges and opportunities of working with engineers.

Descriptive elements within this theme become apparent in the participants' reflections on the differences between working in interdisciplinary groups and more homogeneous ones. Considering logistical challenges tied to the integration of participants from different disciplines. This logistical complexity, described by the participants, contributes to the nuanced understanding of disciplinary integration within collaborative dynamics.

<u>Illustrative quotes</u>

"It wasn't very dependent on maths. It also was rather nerve-wracking, because although it was nice to not have to do the entire assignment and weigh it equally between the engineers and the maths at the same time, it was very dependent on the engineers, or they'd be dependent on us [the mathematicians]."

"You have to rely on the work being done."

"You want to be coordinated very well. You don't want to be dependent on other people, you want to know what's going on, who's doing what, and who's doing what when."

In these quotes the respondents discuss a lack of control and the anxiety this leads to. One of the cognitive stumbling blocks to interdisciplinary work is the discomfort participants can encounter through moving beyond their well-trodden path. Hopefully with exposure and practice, this feeling however would be

mitigated as the act of interdisciplinarity supplanted the learned behaviours of an individual discipline.

"...it was very hard to equally weigh work to each other. So, we just had to find each part to do and then put it all together."

"We obviously had other people proposing solutions in the first week or so. We didn't really have much coordination."

Similarly, the logistics of projects involving this kind of project can be complex and navigating these complexities can overshadow the intention of bringing together disciplines. As discussed above the default behaviour of participants was often to remain within their own realm of expertise and as difficulty increased this retreating could become more pronounced.

"The mathematicians pushed on the solution because we understood the idea of how it works, the concept of it, […] I'd say the mathematicians, more certainly than the engineers [made suggestions], they just kind of nodded and agreed and then said, right, let's look at this to see if it passes in right?"

"They were more focused on having to pass a certification rather than having to get everyone off the plane, which obviously is [the point]."

“Mathematicians put more into the simulation than the engineers where they put into the report of the certification, which is obviously aspect we didn't know."

The difficulty of encouraging groups to confer equal weight to tasks within and without participants own discipline is illustrated palpably here. If work is completed in silos, the understanding of complexity and progression is lost. With practice a reduction in disciplinary egocentrism may be possible, and in future work more emphasis should be placed on early knowledge exchange and integration.

"It wasn't such a strict one person's alone idea; it was brought together by everyone's final result."

This quote ends this analysis of the mathematician's responses on a positive note, we can see in this response that some groups were actually working towards an interdisciplinary solution. This hopefully provides evidence that the intentions of the intervention could be at least partially realised.

12.5.2.2 Engineers

1. **Interdisciplinary Learning**

The theme of interdisciplinary learning emerges prominently across the interview texts in this section, providing a comprehensive view of how collaboration between individuals from different disciplines affects the learning experience.

Within the interviews, participants highlight the advantages of having both engineering and mathematics perspectives in their collaborative projects. The division of roles between engineers and mathematicians is mentioned. The interviews underscore the importance of effective communication in ensuring that team members understand and appreciate the unique contributions of each discipline.

Moreover, the interviews reveal how interdisciplinary learning stimulates problem-solving approaches. Participants express that working with individuals from different disciplines brings diverse perspectives, enabling them to approach challenges in innovative ways.

<u>Illustrative quotes</u>

"And I think we did explain just because that's part of good teamwork. If they're going to be changing something on a spreadsheet based on just what we say, they might be thinking to themselves, 'Oh, well, why don't we do this?' And actually, we know that we can't do that because of XY and Z elements."

What the participant refers to here as 'good teamwork' is a demonstration of a blended approach to the project and is working towards an interdisciplinary solution. The shared approach detailed here would ultimately arrive at both parties having the same understanding and approach.

"It comes back to the different point of view side of it. So that sort of helped me, you know, next time I'm thinking about something, if I just thought to myself, 'Well, hang

on. Maybe if I thought of it from this sort of view instead of from purely my own aim and goals.'"

"Because if you're doing it just as an engineer, you only see your side of it. But then if you've got someone from a completely different discipline who's looking at it from a different point of view, you can sort of take the good bits from both sides and work together."

"I like the idea of bringing two different fields together to work on kind of how to think that way."

"I think we're all a bit more productive than we probably would normally be because when you're working with someone, you can encourage each other and get stuff going."

The engineers in this cohort once again appear much more open to working with other disciplines, this could further reinforce our hypothesis from the previous year's interviews that the nature of the discipline instils a greater awareness of the benefit of this.

"Because the course is similar but different, you can connect and discuss things. We understand what each other's doing, what we like to learn, what different things they've done."

"We help each other because it's just more helpful. Some people might grasp the maths, or some people might get the aerodynamics more, but because we've all had the year of going through the maths and the aerodynamics, we're closer to the same level at this point."

"They [the mathematicians] were asking us about regulations and stuff on where the baggage should be. It's difficult to say […] I don't think there's gonna be that much of a discrepancy between engineering and math students two years into a course."

Here again we find further positive quotes on working with other disciplines. However, these respondents view the separation of the two disciplines after one and a half years of higher education as minor and so should be approaching the task from the same starting point anyway. The disciplinary similarity of the two

subjects brought together was considered not ideal in the planning phase of the intervention, as a much greater effect was assumed to be possible from joining people from very distinct epistemological backgrounds. However, the logistics of the development of this intervention was not possible. Potentially these respondents are correct in their assessment of the distinction between the two disciplines, if this is so, then the effects of the intervention may be muted.

"I do find that if I either have to teach somebody else or somebody asks me a few questions about it, it helps me develop my understanding of it as well."

"You never learn something so well as when you have to teach. If you happen to explain it, you can't exactly explain it if you don't understand what you're saying."

These quotes illustrate both the capacity of this form of teaching intervention as a learning tool and how the students can achieve mastery experiences.

Speaker 2: "Obviously some things are common sense, like moving the doors, you'd have to change the whole plane."
Interviewer: "But did they? Did anyone suggest that?"
Speaker 2: "Yeah, they did."

In this rather flippant exchange and important feature emerges – the realisation that the respondent's specialist knowledge isn't universal. This understanding should theoretically improve the respondent's self-efficacy.

2. **Project Evaluation and Reflection**

The theme of 'project evaluation and reflection' emerges as a descriptive lens through which the interviews can be analysed. It provides insights into how the participants assess the collaborative projects in retrospect, examining both the successes and challenges encountered during the teamwork. Project evaluation and reflection are critical components of the learning process, allowing individuals and teams to gain a deeper understanding of their strengths, weaknesses, and areas for improvement.

Throughout the dataset, there are indications that project evaluation and reflection played a significant role in shaping the participants' perceptions of their collaborative experiences. The discussions often touch upon aspects such as the effectiveness of

team dynamics, the distribution of roles, and the impact of interdisciplinary collaboration on project outcomes.

The theme of 'project evaluation and reflection' provides a descriptive framework for understanding how the participants assess their collaborative experiences. The quotes extracted from the interviews shed light on the ongoing evaluation of team dynamics, communication strategies, and collaborative effectiveness. This theme highlights the participants' self-awareness and their efforts to derive meaningful insights from the collaborative projects.

Illustrative quotes

"Letting people go off and figure out exactly what they need to do is quite good. Letting people go into the groups they like within their course and then matching with a similar group on the other course, that was a good idea."

The support provided through assigning self-forming single discipline groups of one discipline to self-forming group of another is commented on positively here, and it was the intention to provide some emotional security to participants through this group formation scheme. However, this may have led to poorer intervention outcomes – as we can see from this quote this group formation may have encouraged a retreat to the safety of one's own discipline and there was companionship there. In future iterations of this intervention, potentially a purely random allocation of team would have a greater effect.

"I think a business type of joint thing would be interesting because we do professional practice, there is always business involved."

As discussed in previous sections, the engineers were often more focussed on the future professional relevance of the activity and here we can see this feature again; the respondent sees the benefit of working with other disciplines, but only to further develop their skills for their own purposes.

"I think it's worthwhile doing the task. I think I learned quite a bit from it, but I found it probably more pleasant than just working with engineers, so I guess as a whole, I'd say it's worthwhile."

"The joint thing was good."

Engineers continue to demonstrate a greater openness to the joint nature of this project, as is demonstrated by these quotes and many of those from the previous cohort. This higher level of availability should lead to a different experience of the intervention, a feature that may be read in the quantitative data.

"If the project was more [complex], I think I would have learned more - got more benefit from it being a combined task."

"I think the problem needs to be a bit slightly harder."

"I like the idea of bringing two different fields together, […] but it didn't really catch my engagement that much."

"Well, I really enjoyed the course, but to be honest, I thought it was a good thing to do, but the only thing I found was that we [the engineers] ended up not doing really that much."

From these quotes we can infer something about the approach of the respondents. The task was designed to be open ended and could be taken to as great depth as the groups saw fit. However, this in itself is a blurry edge to the students' discipline. As discussed earlier there is increased cognitive difficulty in moving into these blurry regions where great effort has to be expended in just deciding what the next steps are. The respondents of the above quotes appear to see the task in an isomorphic way – it's just another task to apply a known algorithm to. This approach may prove to have negative consequences in terms of interdisciplinarity, if these participants experience difficulty in areas of less sure footing within their own discipline, the barrier to entry to undertake interdisciplinary work will be artificially higher.

"Looking through certifications is helpful because just being explained certifications is very different than 'here's the thing, look through for what you need'."

The benefit of an interdisciplinary intervention is considered in this work in terms of its relevance to employability, but beyond this the intervention could be examined as a novel learning tool for use with students. The interdisciplinary

approach provides novelty and may promote greater engagement than classical didactic teaching.

3. **The role of mathematicians and engineers**

The theme of 'the role of mathematicians and engineers' emerges as a descriptive lens. These interviews shed light on the views the engineers held on the distinctive roles each group played in the collaborative project, offering insights into their perceived responsibilities and the dynamics that unfolded. Throughout the dataset, the roles of mathematicians and engineers come to the forefront, shaping the collaborative efforts.

Illustrative quotes

"Yeah, with it being our subject [engineering], we sort of know that something might not work. Let's give it a Google. Yeah, it's something like that. So yeah, potentially with a lot of research, they [the mathematicians] could have done it."

We find in this quote an interesting mix of high and low self-efficacy. The respondent is aware of the specialised knowledge they posses as something useful and distinct, but then the qualified denigration of its worth by considering it attainable by non-specialists. This may just be a measured response designed to mitigate any sense of bragging that the first sentence may have created. In either case this response illustrates a key aspect of the experience that the intervention was intended to provide.

"We [the engineers] couldn't have made the spreadsheet. if we've been given the spreadsheet and had maybe like, you know, a couple of lessons on learning how to use it then potentially yeah. But then again, with it being sort of a clear split, it helped us focus on our tasks more if we knew that the simulation side was being taken care of. You could delegate rather than abdicate [sic] tasks."

This quote demonstrates an entrenchment into the participant's disciplinary silo, the casual assessment of the work of the mathematicians leads into a description of maintaining those silos through the distribution of tasks. This positive opinion of what could only loosely be described a multidisciplinary may have a more

negative impact on achieving interdisciplinarity that outright hostility to it; the contentment of the approach evident in the response could inhibit the respondent from exploring any deeper.

"OK, so there's a bit on the specifications for the aeroplane? That's clearly a job for the engineers' side of it. And there was a bit about how to use the spreadsheet. You know, that's not clearly a job for the mathematicians."

"I had a bit of a problem with it because I didn't really understand why the maths people were there because they didn't design the simulation. They didn't make the simulation."

These respondents exhibit high level of disciplinary egocentrism, which may have been a cognitive bias that they have strongly held throughout the intervention, or there is potential that this intervention deepened its effects. Neither respondent here provides any commentary on the positive impact the mathematicians in their team may have contributed. As discussed elsewhere, if these participants had a negative experience of another discipline through this intervention, then disciplinary egocentrism may become entrenched. In future work this potential effect should be examined more.

"I think they [the mathematicians] were more methodical with what they did."

This response provides a straightforward example of a participant understanding the value of the other discipline's contribution. In the wording of this response, we may infer that this understanding was achieved through the teaching intervention providing the participant with the opportunity to personally experience this value. This is one of the main intentions of this intervention.

Interviewer: "So if it was just a team of engineers, do you think you could have it without the mathematicians?"
Speaker 2: Probably, I think they could have done it without us."

This rather dour assessment of the specialties on both sides evinces a low sense of self-efficacy. The anonymity of their contribution and that of others reported in this response run counter to the intentions of the intervention.

"We [the engineers] ended up not doing really that much because we were doing a simulation."

The response here indicates that the participant felt the task was best completed in a mathematical direction. As discussed previously the disparity in the teams may have led to mathematicians overwhelming the engineers and pulling the direction of work towards themselves. This could have a depressive effect on the data gathered for the engineers in these groups.

4. **Team Dynamics**

The theme of 'team dynamics' is present in the interviews considered here, offering a descriptive lens through which to understand the interactions, challenges, and collaborations within the respective groups. Team dynamics encompass the complex interplay of personalities, roles, and communication styles within a team, influencing its effectiveness and outcomes.

In this dataset, the discussion finds the team dynamics marked by frustration as the engineers express concerns about the mathematicians' perceived lack of contribution. This frustration suggests a breakdown in communication and a struggle to establish a cohesive working relationship, emphasizing the importance of effective team dynamics.

Overall, the theme of 'team dynamics' serves as a descriptive lens, offering insights into the functioning of these teams. These interviews reveal challenges arising from communication gaps, power imbalances, and differing levels of engagement. Understanding team dynamics is crucial for improving collaboration, ensuring equitable contributions, and ultimately achieving successful project outcomes.

<u>Illustrative quotes</u>

"Yeah, it was a good sort of split, whereas you had the clear engineering side to the principal and the mathematics side, that sort of made it easier to collaborate and work together."

"We sort of split up a bit, so like, we were me and [other engineering student] we were doing sort of like the research on towards the plane. We're all like bouncing ideas around."

The tendency of groups to default to a multidisciplinary approach is understandable as it provides the path of least resistance. With most of these groups being successful in their solution to a greater of lesser degree the intervention may have failed in its aim to encouraging interdisciplinary working. In future work this potential failing would need to be addressed.

"We found that when we sorted out a Facebook group chat, we managed to get a lot more done. Because before, we just met up within the scale-up session [the room the timetabled session was held in]."

"Trying to get them [the mathematicians] to actually meet up and do work outside of those things [the timetabled sessions] is like pulling teeth."

The logistics of group formation were left to the groups to arrange themselves. This was an intentional part of the open-ended nature of the project. This may have had an effect however of failing to promote progression through the stages of group formation and as discussed previously it is only really in the performing stage of group development that the benefits of this type of intervention are truly achieved.

"It needs to find something where both parties can learn the equal amounts from each other, not something that literally one has the ability to do on their own. There was nothing going through it that I didn't know what was going on. There wasn't anything that I was actually learning from the maths people."

"We just got given the simulation thing. And we just did it. They did it, and then we just sat there for the rest of it."

The epistemological closeness of the disciplines had the unintended consequence that for some groups, one discipline felt confident in competing the task on their own. This clearly doesn't create the opportunities to establish the experiences intended in the design of this intervention and may even work counter to them.

Future work should aim to start with disciplines with greater epistemological distance between them.

"There was always communication going backward and forwards that helped out with the project."

Hopefully we can end on a more positive response from a participant whose clear statement here attests to the positive experiences that this intervention was intended to create. It is in the nature of interdisciplinary work to require regular good quality communication and it appears that, for this group at least, this was achieved.

12.5.2.3 *Comparison of themes emerging across the two disciplines for the 2019 data*

Year	2019	
Discipline	Mathematics	Engineering
Themes	Role of Mathematicians	The role of mathematicians and engineers
	Role of Engineers	
	Project Evaluation and Reflection	Project Evaluation and Reflection
	Disciplinary Integration	Interdisciplinary Learning
	Collaborative Dynamics	Team Dynamics

Table 17 - A table showing the identified themes from the two disciplines compared and colour coded for similarity for the 2019 data

There are similar themes emerging from the two datasets for the 2019 data. Both cohorts share similar thoughts and concerns. The major difference between the two, is the overall tone of the quotes. By taking the overview of the interview transcripts, of which the selected quotes are a sample, we find the mathematicians more readily couch their commentary in negative term than do the engineers. The lens through which they view the interaction often demonstrates high levels of disciplinary egocentrism. Whereas a holistic reading of the engineers' interview transcripts appears more positive in a broad range of topics.

We have hypothesised that the disparity in team composition may have led to this feature of the data. By being in the large majority within groups, the mathematicians experienced the intervention differently from the engineers who formed the minority in the partnership. The larger group is more likely to have dominant personalities and more likely to direct the work toward their discipline. They are also less likely to experience situations that underscore their individual utility to the project. We can see for the datasets these themes coming out – Mathematicians reporting more frustration with the engineers and seeing the work through their own discipline, and engineers seem to report more favourably on the contribution of the mathematicians and their own contributions to the task. We also could consider this a feature of the engineers' disciplinary background as that is often more vocationally focussed.

Future work should either aim to manage these issues to promote more a successful intervention or examine their causes and effects more closely.

12.5.2.4 *Comparison of themes emerging across the two cohorts, 2018 and 2019*

Year	2018		2019	
Discipline	Mathematics	Engineering	Mathematics	Engineering
Themes	Communication and Coordination Challenges	Recognition of Challenges		
	Role of the Engineers	The Role of Mathematicians	Role of Mathematicians	The role of mathematicians and engineers
		Role of Engineers	Role of Engineers	
	Reflections on Enjoyment and Engagement		Project Evaluation and Reflection	Project Evaluation and Reflection
	Mixed Reactions to Working with Different Disciplines	Perception of Interdisciplinary Collaboration	Disciplinary Integration	Interdisciplinary Learning
			Collaborative Dynamics	Team Dynamics
	Personal Development	Professional development		
		Overall Experience and Enjoyment		

Table 18 - A table showing the identified themes from both disciplines across both years compared and colour coded for similarity

The overarching themes emerging across the two years of data gathering remained largely the same, and the differences between the responses of the two disciplines also maintained. This is an encouraging sign that the themes extracted were based in innate features of the disciplines rather than of the particular cohorts. Between the years we still find that there are issues arising from the group construction and dynamics, there are levels of respect and mistrust from both parties with regards to their opposites, but that the engineers seem in

general to be more open to the project than do the mathematicians. This lasting disparity may be innate or may be an artifact of the intervention. In future work it would be instructive to explore this.

13 Discussion

The quantitative survey showed that there is a consistent and statistically significant effect across all groups of participants in terms of an increase in their GSE score. This would indicate that the interdisciplinary teaching intervention performed as anticipated in this sense; the bringing together of different disciplines highlighted the skill set that each individual student had gained.

The data showed that there existed a small difference in the effect for gender, with the women demonstrating a greater increase in GSE score than men this effect is moderate with the statistical test showing a size effect of 0.398 for the comparison of average GSE score differences. We also see in section 12.3 that there is a statistically significant difference between the absolute scores of the male and female cohorts that persists through all three surveys with the women reporting lower self-efficacy. We may potentially explain this result through the known existence of a higher rate of imposter syndrome amongst women, a lower starting point to begin with which would allow for greater relative increase. This is borne out in the data gathered, as the average GSE score for women pre-intervention is 87% of the value of the Men's GSE score at the same point and rises only slightly to 90% of the men's score post intervention. This difference may also be attributed to the difference in cohort size for women and men. Whilst the mathematic course was close to an even split in the gender of participants (41% women), the engineering course however had a female population of 10% (this is only data for the 2019 intervention, as previously no demographic data was recorded and relates to demographic information recorded through the survey instrument), overall, the gender split was 39% female, 61% male. This discrepancy in numbers may have affected the two group differently – we consider this further when discussing the difference in academic discipline populations. It may be true, however that this intervention has a greater effect on the self-efficacy of female students than male in future work this should be explored. There was no significant difference in the presence of the effect for educational background.

The effect on GSE score was more pronounced in the engineering cohorts than the mathematicians, with the overall size effect in the comparison of pre- and post-intervention score differences being 0.667. One explanation for this could be linked to the fact that the engineers were outnumbered by the mathematicians at a ratio of roughly 3:2 with 155

mathematicians and 112 engineers included in the teaching intervention (this represents the total possible number of participants, then number of these who actively took part was less) so in each group there were fewer engineers to spread the workload and therefore they would be required to disseminate knowledge more frequently. Notably one group had a single engineer as part of their team and his response to this situation when discussed in interviews was very positive. We see more often in the interview data comments from the engineers about providing useful information to the mathematicians.

> *"They [the mathematicians] were asking us about regulations and stuff on where the baggage should be."*

> *"It benefited them [the mathematicians] more having us [the engineers] than us having them."*

> *"I feel confident they probably would have done it without me because there was still seven of them. But I think I had a positive influence on it."*

These kinds of statements appear frequently in the discussions with engineers, whereas the comments most frequently appearing in the interviews with mathematicians are more measured.

> *"I still think we could have done more on it, but they [engineers] do add something."*

> *"Yeah, yeah, I think. Coming up with the original ideas of how to change the model, they [the engineers] were actually really helpful with that."*

> *"I don't think they [the engineers] expected us to know much. I think if they asked us to try something on the model, we could. We just did it."*

Anecdotally we can say that the engineering students had, or experienced, a greater role in the project work in terms of skills. Whilst we there are evident discussion about the usefulness that respondents felt working on the project, with so few engineers engaged on a team, specialist knowledge – and often knowledge they didn't realise was specialist – was more thoroughly extracted by the mathematicians. In the reverse not only did the large group of mathematicians mean that answering questions would be spread round more people, but also the nature of the intervention made the role of the mathematicians potentially less creative

and more algorithmic, a feature that would reduce the necessity to explain the process or explore options with the engineers.

As self-efficacy is a key part of most of the employability models we have considered in this work, the hypothesis that has been put forward is that it is possible to parametrically measure the effect of an intervention aimed at improving employability through measuring participants' self-efficacy. Whilst this contention is not proven by this work, if we accept this as a proxy measure, then we can say that the teaching intervention introduced in this work has had a positive effect on students' employability. This is, however, tempered by the fact that there is some evidence that the effect is transient, as we can see through the repeated measurement in the 2019 dataset of the mathematician cohort 6 weeks post intervention - the elevated GSE score dropped down to a similar level to pre-intervention, 3.524 pre-intervention, 3.570 immediately post-intervention and 3.536 at 6-weeks remove. This can also be viewed positively in term of our conclusions – learning a new skill creates memory 'traces' which are strengthened with repetition, therefore if we consider this teaching intervention as introducing a new skill to be learned, we would expect the memory volatility encountered without repeated strengthening of the memory trace. This data however is not statistically significant and so further speculation on its meaning is not profitable

The data for the false consensus effect was limited – whilst the theorised differing shifts in scale score for the 'you' and 'other' conditions was seen, (with the average scale score for the 'you' condition decreasing and the average for the 'other' condition increasing) it was statistically insignificant at every level. This data may be better interpreted in conjunction with the qualitative data recorded through the semi-structured interviews. The false consensus effect is linked to the level of disciplinary egocentrism evinced by a person. The hoped for outcome of this intervention was that it would force students to cross disciplinary boundaries and experience different approached to projects and problem solving, this in turn would lower disciplinary egocentrism by providing concrete counter examples of the anchoring bias. However, from the interview data we encounter two main hurdles to this outcome. One, the intervention as experienced by many of the students questioned was not *interdisciplinary*, it was as best cross-disciplinary or trans-disciplinary. There was no synthesis of two knowledge sets, rather it seems most groups stayed remarkably separate and only tried to combine their

work and findings at the very end of the project, or occasionally at the beginning to share knowledge.

> *"We stayed quite separate. It was only towards the end that we tried to weave our work together. It was more like parallel play than true collaboration."*

> *"Yeah, it was a good sort of split, whereas you had the clear engineering side to the principal and the mathematics side, that sort of made it easier to collaborate and work together."*

The second issue with such a short project, is that (something we find heuristically in the interview) we often fail to move past the 'storming' phase of Tuckman's theory of team development – students were reporting a lack of faith that their opposite disciplinary group partners were useful in completing the project. Without moving past this stage toward a successful division of labour, many of the respondents seem to have come away maintaining, or even potentially strengthening their pre-held views of themselves and others academically.

> *"We [the engineers] couldn't have made the spreadsheet. if we've been given the spreadsheet and had maybe like, you know, a couple of lessons on learning how to use it"*

> *"We were constantly figuring out how we should shape it, like they gave an idea and said, 'Okay, how should we implement it?'"*

> *"A big change is not knowing the people... Doing work with a completely new set of people that never met before, so you have to get acquainted and stuff before you figure out each other's rhythm."*

> *"Their [the mathematicians] goal was 'can we get the Excel spreadsheet to work?' And what's the-can we manipulate this spreadsheet to get the time down as much as possible, as opposed to 'Is this realistic?'"*

Ultimately then, the structure of this teaching intervention may have failed to facilitate a change in the disciplinary egocentrism of the student participants.

From the qualitative data however, we can see that the intervention was popular.

"I liked it better because it was more like, you had to think about things; This is what you can do."

"I Enjoyed it. It was a genuine, enjoyable experience"

"I think it's worthwhile doing the task. I think I learned quite a bit from it, but I found it probably more pleasant than just working with engineers, so I guess as a whole, I'd say it's worthwhile."

Beyond this, many students recognised the benefit of such a learning experience in terms of long-term development, and even that it would benefit them in a future professional role.

"Because when we go out into industry, I suppose it's like good to get a bit of practise because we won't just be dealing with engineers. We'll be dealing with mathematicians, control people, businesspeople."

"I think overall it was good. I think it's a good idea [...] As Engineers out in Industry, we'll have to work with different groups of people."

"Because we do a lot of group work anyway to try and get as used to working with people in industry."

This was more often commented on by the engineering students in interview than the mathematicians. Potentially this arises as engineering is more clearly a vocational discipline with a strong sense of what professional activities students will go into, as well as clear links with professional societies promoting things such as charterships. The increase in positive attitude could also arise from the expectations of the two disciplines. The mathematicians were being taught the content in their 'modelling two' module – an eclectic and varied set of case studies to help develop mathematical modelling skills, whereas the engineers were being taught within their 'professional practice' module, the content of which was directed largely at developing 'soft' skills – a topic which is often disliked by STEM students [find a reference for this attestation]. The aerospace students may have been pleasantly surprised at finding themselves tasked with a design challenge, whereas the mathematicians may have seen this as just another similar task.

Quotes from engineers regarding the content:

“It was more interesting because there were more things you could do with it as supposed to just like designing a triangle [reference to the engineers' previous task in this module].”

"I think it's worthwhile doing the task. I think I learned quite a bit from it, but I found it probably more pleasant than just working with engineers, so I guess as a whole, I'd say it's worthwhile."

Quotes from mathematicians regarding the content:

"It was very open. You know, it was very applied to the real-world, it wasn't just, when you write it down, the past few projects we've done are very mathsy - it's not really thinking outside the box."

"It's good to have a bit more freedom with it. The other ones [case studies in that model] were both more rigid with what we have to do."

Ultimately, the difficulty with measuring the false consensus effect arises from the lack of a standardised scale, quantitative efforts may have too many axes of freedom to ever be a useful measure and another way to examine the role of disciplinary egocentrism is needed. Elements of disciplinary egocentrism were clearly present in the interview data, with both sides being hostile to the value of the other.

"I had a bit of a problem with it because I didn't really understand why the maths people were there because they didn't design the simulation. They didn't make the simulation."

"I still think we could have done more on it, but they [engineers] do add something."

"Working with other disciplines doesn't work."

These antagonistic feelings were evident in a lot of the interview transcripts but were often accompanied by a discussion of an overall bad experience the respondent had had during the teaching intervention. There were, as in any group assessment, a number of low-engaging students. This often went together with poor attendance, and as there were milestones that needed to be achieved throughout the 6-week project, this meant that any more studious

members of a group would have to take up more work to keep the project on track. This clearly has a negative impact on the experience of those students who are working more assiduously and clearly has the potential to entrench bias if the split in work ethic occurs along disciplinary lines. There is also present across the interviews some very positive feelings towards other disciplines, many students found the experience to be enlightening as to the role that the different disciplines play when integrated.

> *"And you could tell that they were just more capable, I suppose with the technical report writing."*
>
> *"They [the mathematicians] were necessary to complete it. It relied heavily on the mathematical model, and they provided confirmation for our ideas."*
>
> *"I think coming up with the original ideas of how to change the model, they [the engineers] were actually really helpful with that."2*
>
> *"It was really good because the-you able to find information out from a broader range of people. So, people who are good at particular things - there were more of us and people who'd been like-because they were maths, they were able to do the more maths-y side and we were able to input our side."*

The problem of poor experiences is not easily solved with a single intervention, the only recommendation that can be made is to consider the law of large numbers and assume that with greater exposure to this kind of project, students will be increasingly likely to experience repeated positive events. This would also support the reinforcement issues raised earlier in this section.

The interview texts provide insight into the beliefs and understandings of the students who participated in the teaching intervention. What must be address first, is that this was a self-selecting group, as survey respondents were asked to volunteer to be interviewed. How this impacts the data gathered is unclear, many of the students who agreed to be interviewed were much more active during the sessions and played a greater role in their group's project. Some, it was clear from the interviews felt this quite keenly and wanted to share their grievances. However, this was not a common reason for taking part it would seem. The fact that these interviews were completed mostly by the more engaged students in the cohort

clearly prevents the dataset from being a truly representative sample of all who took part, however I would raise a point here that the greatest benefit of this intervention would be conferred upon those who were most heavily involved in all aspects of it, therefore, if it is these participants who are describing their experiences of the teaching intervention, we are get a picture of the aspects of the process that are most useful and impactful. We may then be able to extrapolate this to all participants through focussing on developing successful aspects.

The thematic analysis gathered together groups of similar concepts discussed by the interviewees. These tended to be drawn on similar lines for each cohort and population – there were considerations of the activity as a whole, the role that each discipline played in completing the project, and a reflection on the process. These topics were potentially seeded by the questions presented in the interview; however, they did provide an illuminating insight into how respondents view their experience. From the interview datasets one can see that each of these topics in particular is both positively and negatively coded, however we can see through strength of numbers that the positive sentiments outweigh the negative in most of the themes considered, this fact suggests that the intervention was a positive experience for most students.

As discussed above, much of these themes emerged in the review of the literature on the topic. We have encountered in this work all the aspects that other researchers have discussed, starting from the logistical difficulty in establishing this teaching intervention all the way through the sociological concepts considered to the reported feelings of the student participants. The themes emerging from the literature were 'Interdisciplinarity in Teaching and Learning', 'Teaching Excellence and Pedagogical Innovations', and 'Challenges in Higher Education'. The findings from the first theme were that there is educational benefit to the introduction of interdisciplinary teaching, and this was the essence of the findings of this work. The ideas of interdisciplinary teaching as best practice and an innovative step we not explored by this research, but anecdotally it may be possible to see a thread of beneficial teaching development through the responses from the interviews. Finally, challenges in higher education brought together issues across a range of structural and logistical components of the intervention which were all encountered in this work. The similarity of themes arising in

the literature with features of this work, suggests that this work is well situated within the research and may be able to inform further the discourse on this topic.

The work completed here, makes clear the case for this kind of teaching to enhance students' curricula and in defence of removing 'content' from any existing course, this work shows that the benefits to students are manifest and strongly relate to addressing current issues in graduate employment.

14 Conclusion

This research aimed to unravel the effects of interdisciplinary teaching on graduate employability, employing a mixed-methods approach incorporating a GSE scale-based survey, an investigation into the False Consensus Effect (FCE), and insights from semi-structured interviews. The robust GSE data indicated a statistically significant increase in self-efficacy, while the FCE findings were inconclusive. The interviews presented a nuanced picture, revealing mixed feelings about interdisciplinary interactions but generally positive sentiments. Here we aim to examine these findings and outlines avenues for future research in enhancing the link between interdisciplinary education and long-term employability.

The GSE scale served as a valuable instrument in quantifying the impact of interdisciplinary teaching on self-efficacy. The consistent and statistically significant increase in GSE scores across all participant groups provides a strong foundation for understanding how teaching interventions influence students' perceptions of their own abilities. The observed transient nature of the effect, as evidenced by a decline in GSE scores for mathematicians post-intervention, introduces an interesting evanescent dimension, which suggests a need for continued reinforcement and iterative interventions to solidify and potentially prolong the observed positive impact.

In contrast, the FCE data yielded inconclusive results. This may be attributed to several factors, including the design and duration of the teaching intervention. The FCE is sensitive to individual perceptions and attitudes, and the short duration of the project might not have allowed for the necessary shifts in these perceptions. The FCE findings may benefit from qualitative insights gathered through interviews, offering a more comprehensive understanding of disciplinary egocentrism and its potential evolution.

The semi-structured interviews provided a qualitative layer, offering insights into students' experiences and perceptions. While mixed feelings were expressed about interdisciplinary interactions, the overarching sentiment was positive. The complexity of interdisciplinary collaborations was evident, with challenges such as a perceived lack of integration and the struggle to move past early team phases. However, positive attitudes, recognition of the long-term benefits, and a willingness to engage in such collaborations were prevalent.

This research contributes to the theoretical grounding of employability measurement. The use of the GSE scale as a proxy for employability offers a direct quantitative approach to assessing the impact of teaching interventions. This work posits that enhancing students' employability can be measured through examining their reported self-efficacy. This theoretical framework provides a basis for future studies aiming to measure employability directly and understand the intricacies of this complex construct.

The interdisciplinary teaching intervention examined in this research stands as a robust case study. It offers insights into the potential of such interventions to influence students' perceptions of their capabilities, a critical component of employability. The inconclusive FCE data and the mixed sentiments in interviews highlight the need for refinement in the design and implementation of further interdisciplinary projects. Future research should build upon this foundation, incorporating longer interventions and greater academic distance between collaborating disciplines.

To enhance the reliability and generalisability of findings, future iterations of the teaching intervention should be conducted at intervals over an extended period. This longitudinal approach would shed light on the sustainability and permanence of the observed self-efficacy improvements. Introducing more academic distance between collaborating disciplines is crucial for fully realising the proposed benefits of interdisciplinary education. This could involve creating projects that necessitate a deeper integration of diverse knowledge sets from the outset, encouraging true synthesis and collaboration.

This research establishes a foundation for understanding the relationship between interdisciplinary teaching and long-term employability. The self-efficacy enhancements observed through the GSE scale underscore the positive impact of teaching interventions on students' perceptions of their abilities. The inconclusive FCE data and mixed sentiments in interviews illuminate areas for improvement in the design and execution of interdisciplinary projects. This work sets the stage for future research, urging a more nuanced exploration of the dynamics between mixed disciplinary teaching and sustained employability improvements. As the labour market becomes increasingly competitive, this research contributes to the ongoing efforts to better support students in their academic and professional journeys.

This work adds to the body of work already completed in this field. An argument has been made for the use of self-efficacy as a proxy measure for employability, the defence of which comes from consideration of some of the most notable theories on this topic. If we then accept this hypothesis this work establishes that interdisciplinary teaching has a positive effect on students' self-efficacy and therefore their employability. In future further work would be able to build on this and establish firstly, an evidentiary link between self-efficacy and employability and secondly examine in great depth how interdisciplinary teaching can impact this. Further to this, this body of work adds to the current discourse on the execution of this type of teaching intervention; using interdisciplinary teaching may indeed be beneficial but it comes with a high complexity cost. Navigating this complexity becomes easier with practice but for projects at their outset it is instructive to have some vicarious experience to use to scaffold one's development. This work therefore can be instructive in this realm and, while falling short of the initial aim of developing a 'how to' guide for interdisciplinary teaching, many aspects of this work are instructive to the practitioner. We also find that the focus of this work on the sociological concept of self-efficacy adds to the body of work in this topic. The novel scale deployed to examine the dimension of self-efficacy that most directly could feed into graduate employability, provides another dimension for researchers to use in the examination of the topic as a whole.

Ultimately this work set out to achieve a set of aims ranging from assessing the impact of the intervention to developing a manual of best practice for implementing interdisciplinary teaching. The research performed achieved these aims to differing degrees. From the data gathered on the self-efficacy of participants pre- and post-intervention we can see that there is good evidence to support the argument that this form of intervention has a positive impact on students. The use of the FCE survey was inconclusive and potentially the wrong tool to examine the heuristics affected by siloed teaching. It is unfortunate that this was unable to corroborate the finding of the GSE survey. The hypothesis posed in this work is that self-efficacy can be used as a proxy measure for employability. It was argued that it's inclusion in the majority of well-respected employability models strongly supports this assertion, and indeed the definition of self-efficacy meant that it records *capacity* to achieve in some way. Therefore, in consideration of the aim to assess whether interdisciplinary teaching interventions have and effect on the development on employability skills it is argued that with

the demonstrated improvement in self-efficacy we have shown that this intervention does indeed have a positive impact.

The intention set out earlier in this document to develop a series of best practices in interdisciplinary teaching has not been fully achieve in the time. If this work were to continue, it is hoped that the findings would serve initially as a basis to form a set of core practices that could be distributed to those interested in the development of interdisciplinary teaching and then through further work based on this research a more formal recommendation could be made.

References

Acarlı, D. S. (2020). An interdisciplinary teaching application: The topic of proteins. Journal of Baltic Science Education, 19(3), 344–355.

Alonso Sáez, I., & Berasategi Sancho, N. (2017). The integrated curriculum, university teacher identity and teaching culture: The effects of an interdisciplinary activity. Journal of New Approaches in Educational Research, 6(2), 127–134.

Al Salami, M. K., Makela, C. J., & De Miranda, M. A. (2017a). Assessing changes in teachers' attitudes toward interdisciplinary STEM teaching. International Journal of Technology and Design Education, 27, 63–88.

Anderson, L., & Barthelemy, M. (2014). Interdisciplinarity: Its role in a discipline-based academy Oxford University Press, USA.

Åseng, K. A., & Riekki, A. T. T. (2021). "Regardless if you succeed or not, interdisciplinary teaching is not a wasted effort." Benefits, challenges, and facilitating factors for interdisciplinary teaching (master's thesis, UiT Norges arktiske universitet).

Ashby, I., & Exter, M. (2019). Designing for interdisciplinarity in higher education: Considerations for instructional designers. *TechTrends, 63*(2), 202-208.

Bachmann, C., Barzel, A., Roschlaub, S., Ehrhardt, M., & Scherer, M. (2013). Can a brief two-hour interdisciplinary communication skills training be successful in undergraduate medical education? Patient Education and Counselling, 93(2), 298–305.

Bailey, J., & Karuwa, T. (2023). The top 5 most produced commercial aircraft in history. Retrieved from https://simpleflying.com/the-top-5-most-produced-commercial-aircraft-in-history/

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioural change. *Psychological Review, 84*(2), 191.

Bandura, A. (1982). Self-efficacy mechanism in human agency. *American Psychologist, 37*(2), 122.

Bandura, A., Freeman, W. H., & Lightsey, R. (1999a). No title. *Self-Efficacy: The Exercise of Control,*

Bandura, A., Ross, D., & Ross, S. A. (1961). Transmission of aggression through imitation of aggressive models. *The Journal of Abnormal and Social Psychology, 63*(3), 575.

Bass, B. M., & Stogdill, R. M. (1990). *Bass & Stogdill's handbook of leadership: Theory, research, and managerial applications* Simon and Schuster.

Bear, A., & Skorton, D. (2019). The world needs students with interdisciplinary education. *Issues in Science and Technology, 35*(2), 60-62.

Berger, M., Scott, E., Axe, J., & Hawkins, I. (2013). World challenge: Engaging sophomores in an intensive, interdisciplinary course. International Journal of Teaching and Learning in Higher Education, 25(3), 333–345.

Betz, N. E., & Hackett, G. (2006). Career self-efficacy theory: Back to the future. *Journal of Career Assessment, 14*(1), 3-11.

Bhaskar, R. (2010). Contexts of interdisciplinarity: Interdisciplinarity and climate change. Interdisciplinarity and climate change (pp. 15–38) Routledge.

Biasutti, M., & EL-Deghaidy, H. (2015). Interdisciplinary project-based learning: An online wiki experience in teacher education. Technology, Pedagogy and Education, 24(3), 339–355.

Blackburn, J. A., & Papalia, D. E. (1992). The study of adult cognition from a Piagetian perspective. *Intellectual Development,* 141-196.

Boix Mansilla, V., Miller, W. C., & Gardner, H. (2000). On disciplinary lenses and interdisciplinary work. *Interdisciplinary Curriculum: Challenges to Implementation,* 17-38.
Bonnard, C. (2020). What employability for higher education students? *Journal of Education and Work, 33*(5-6), 425-445.
Bowden, J., Hart, G., King, B., Trigwell, K., & Watts, O. (2000). Generic capabilities of ATN university graduates. Canberra: Australian Government Department of Education, Training and Youth Affairs, 20030513-0000.
Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. Qualitative Research in Psychology, 3(2), 77-101. DOI:10.1191/1478088706qp063oa
Bridgstock, R. (2017). The university and the knowledge network: A new educational model for twenty-first century learning and employability. *Graduate Employability in Context: Theory, Research and Debate,* 339-358.
Brooks, R., & O'Shea, S. (2021). *Reimagining the higher education student: Constructing and contesting identities* Taylor & Francis.
Bruine de Bruin, W., & Morgan, M. G. (2019). Reflections on an interdisciplinary collaboration to inform public understanding of climate change, mitigation, and impacts. Proceedings of the National Academy of Sciences, 116(16), 7676–7683.
Bunce, L., Baird, A., & Jones, S. E. (2017). The student-as-consumer approach in higher education and its effects on academic performance. *Studies in Higher Education, 42*(11), 1958-1978.
Capa-Aydin, Y., Uzuntiryaki-Kondakci, E., & Ceylandag, R. (2018). The relationship between vicarious experience, social persuasion, physiological state, and chemistry self-efficacy: The role of mastery experience as a mediator. *Psychology in the Schools, 55*(10), 1224-1238.
Catz, B., Kolodny, A., & Gero, A. (2023). Promoting engineering students' learning: An interdisciplinary teaching approach of electronic circuits. *Inter.J.of Engng.Educ, 39*(1), 208-218.
Chandramohan, B., & Fallows, S. (2008). *Interdisciplinary learning and teaching in higher education: Theory and practice* Routledge.
Cheng, M., Adekola, O., Albia, J., & Cai, S. (2022). Employability in higher education: A review of key stakeholders' perspectives. *Higher Education Evaluation and Development, 16*(1), 16-31.
Chew, J. Y. (2021). Siloed in breaking silos: A case study of interdisciplinary curriculum (mis) alignment.
Claus, A. M., & Wiese, B. S. (2019). Development and test of a model of interdisciplinary competencies. European Journal of Work and Organizational Psychology, 28(2), 191–205.
Clifford Webb. Mini still sold at a loss BLMC says. Retrieved from https://www.aronline.co.uk/cars/mini/archive-mini-still-sold-at-a-loss-blmc-says/
Cohen, E. B., & Lloyd, S. J. (2014). Disciplinary evolution and the rise of the transdiscipline.
Cohen, J. J., Azarova, V., Klöckner, C. A., Kollmann, A., Löfström, E., Pellegrini-Masini, G., Salt, D. (2021). Tackling the challenge of interdisciplinary energy research: A research toolkit. *Energy Research & Social Science, 74*, 101966.
Connor, A., Karmokar, S., & Whittington, C. (2015). From STEM to STEAM: Strategies for enhancing engineering & technology education.
Consorte-McCrea, A., & Newing, H. (2015). Creating spaces for interdisciplinary exchange in higher education: A case study. *Local Economy, 30*(3), 265-279.

Cook, E. J. (2022). A narrative review of graduate employability models: Their paradigms, and relationships to teaching and curricula. *Journal of Teaching and Learning for Graduate Employability, 13*(1), 37-64.
Coso, A., & Bailey, R. (2010). Examining students' perceptions of interdisciplinarity based on gender and disciplinary affiliation. Paper presented at the 2010 Annual Conference & Exposition, 15.546. 1–15.546. 20.
Czerniak, C. M., & Johnson, C. C. (2014a). Interdisciplinary science teaching. Handbook of research on science education, volume II (pp. 395–411) Routledge.
Dacre Pool, L., & Sewell, P. (2007a). The key to employability: Developing a practical model of graduate employability. *Education Training, 49*(4), 277-289.
Dacre Pool, L., & Sewell, P. (2007b). The key to employability: Developing a practical model of graduate employability. *Education Training, 49*(4), 277-289.
Dacre-Pool, L. (2020). Revisiting the CareerEDGE model of graduate employability. *Journal of the National Institute for Career Education and Counselling, 44*(1), 51-56.
Daley, C. P., & Thompson, H. (2015). What has this got to do with my course? widening horizons and enhancing employability of pr and marketing students through the inclusion of an interdisciplinary resource module. Journal of Advances in Higher Education, 7(3), 156–168.
Dalton, D. (2015). Developing effective interdisciplinary team teaching-a case study investigation of some of the issues involved. Paper presented at the ICERI2015 Proceedings, 6038–6045.
De los Ríos-Carmenado, I., Lopez, F. R., & Garcia, C. P. (2015). Promoting professional project management skills in engineering higher education: Project-based learning (PBL) strategy. *International Journal of Engineering Education, 31*(1), 184-198.
Derbyshire, V., Fretwell, L., & Harvey, C. (2023). The big challenge: A case study presenting interdisciplinary development of employability skills. () 9306v.
de Sousa Campos, G. W., & Domitti, A. C. (2007). Apoio matricial e equipe de referência: Uma metodologia para gestão do trabalho interdisciplinar em saúde matrix support and reference team: A methodology for interdisciplinary. Cad.Saúde Pública, 23(2), 399–407.
Dweck, C. S. (2006). The truth about ability and accomplishment. *Mindset: The New Psychology of Success. New York: Ballantine Books,*
Edmondson, J., Formica, P., & Mitra, J. (2020). Empathy, sensibility and graduate employment–Can the humanities help? *Industry and Higher Education, 34*(4), 223-229.
Elisabeth, J. H. S., Harm, J. A. B., Tobi, H., Luning, P. A., & Mulder, M. (2009). Teaching and learning in interdisciplinary higher education: A systematic review. *Educational Psychology Review, 21*(4), 365-378. doi:10.1007/s10648-009-9113-z
Falcus, S., Cameron, C., & Halsall, J. P. (2019). Interdisciplinarity in higher education: The challenges of adaptability. *Mentorship, Leadership, and Research: Their Place within the Social Science Curriculum,* 129-145.
Fang, Z., Song, W., Zhang, J., & Wu, H. (2010). Experiment and modelling of exit-selecting behaviors during a building evacuation. Physics A: Statistical Mechanics and its Applications, 389(4), 815-824.
Fam, D., Smith, T., & Cordell, D. (2017). Being a transdisciplinary researcher: Skills and dispositions fostering competence in transdisciplinary research and practice. *Transdisciplinary Research and Practice for Sustainability Outcomes,* 77-92.
Feltz, D. L., Short, S. E., & Sullivan, P. J. (2008). *Self-efficacy in sport* Human Kinetics.

Ferns, S., Phatak, A., Benson, S., & Kumagai, N. (2021). Building employability capabilities in data science students: An interdisciplinary, industry-focused approach. Teaching Statistics, 43, S216–S225.
Figueiredo, H., Biscaia, R., Rocha, V., & Teixeira, P. (2017). Should we start worrying? mass higher education, skill demand and the increasingly complex landscape of young graduates' employment. *Studies in Higher Education, 42*(8), 1401-1420.
Filipe, S., Coelho, A. S., Barbosa, B., & Santos, C. A. (2018). Fostering students' active commitment during the teaching-learning process: Interdisciplinary innovative practices in higher education. Paper presented at the *EDULEARN18 Proceedings,* 2234-2242.
Fredrickson, B. L. (2001). The role of positive emotions in positive psychology: The broaden-and-build theory of positive emotions. *American Psychologist, 56*(3), 218.
Freeman, J. (2005). Towards a definition of holism. *British Journal of General Practice, 55*(511), 154-155.
Frodeman, R., Klein, J. T., & Pacheco, R. C. D. S. (2017). *The oxford handbook of interdisciplinarity* Oxford University Press.
Gantogtokh, O., & Quinlan, K. M. (2017). Challenges of designing interdisciplinary postgraduate curricula: Case studies of interdisciplinary master's programmes at a research-intensive UK university. Teaching in Higher Education, 22(5), 569–586.
Gill, A. S., Irwin, D. S., Ng, R. Y., Towey, D., Wang, T., Wells, R., & Zhang, Y. (2021). Breaking boundaries: Students' motivation toward interdisciplinary learning in higher education. Paper presented at the 2021 IEEE International Conference on Engineering, Technology & Education (TALE), 268–275.
Gilovich, T., Jennings, D. L., & Jennings, S. (1983). Causal focus and estimates of consensus: An examination of the false-consensus effect. *Journal of Personality and Social Psychology, 45*(3), 550.
Gruenwald, O. (2014). The promise of interdisciplinary studies: Re-imagining the university. *Journal of Interdisciplinary Studies, 26*(1/2), 1.
Gurung, A. R., & Schwartz, B. M. (2013). Contributions from psychology: Heuristics for interdisciplinary advancement of SoTL. The Scholarship of Teaching and Learning in and Across the Disciplines, 34–53.
Healy, M. (2023). Careers and employability learning: Pedagogical principles for higher education. *Studies in Higher Education,* 1-12.
Hains-Wesson, R., & Ji, K. (2020). Students' perceptions of an interdisciplinary global study tour: Uncovering inexplicit employability skills. Higher Education Research & Development, 39(4), 657–671.
Heitzmann, N., Opitz, A., Stadler, M., Sommerhoff, D., Fink, M. C., Obersteiner, A., . . . Seidel, T. (2021). Cross-disciplinary research on learning and instruction–Coming to terms. Frontiers in Psychology, 11, 562658.
Higgs, J., Crisp, G., & Letts, W. (2019). *Education for employability (volume 1): The employability agenda* Brill.
Hillage, J., & Pollard, E. (1998). Employability: Developing a framework for policy analysis.
Hinchliffe, G. W., & Jolly, A. (2011). Graduate identity and employability. *British Educational Research Journal, 37*(4), 563-584.
Hobgood, C., Sherwood, G., Frush, K., Hollar, D., Maynard, L., Foster, B., . . . Wright, M. (2010). Teamwork training with nursing and medical students: Does the method matter?

results of an interinstitutional, interdisciplinary collaboration. Quality and Safety in Health Care, 19(6), e25.
Hoch, S. J. (1987). Perceived consensus and predictive accuracy: The pros and cons of projection. *Journal of Personality and Social Psychology, 53*(2), 221.
Hodgson, D., Tonge, C., & Amos, M. (2023). Impact of baggage collection behaviour on aircraft evacuation. *arXiv preprint arXiv:2303.03264*.
Holley, K. A. (2009). Interdisciplinary strategies as transformative change in higher education. *Innovative Higher Education, 34*, 331-344.
Hollmén, S. (2015). The pedagogical challenge of interdisciplinary university programs. Research in Arts and Education, 2015(2), 1–14.
Honicke, T., & Broadbent, J. (2016). The influence of academic self-efficacy on academic performance: A systematic review. *Educational Research Review, 17*, 63-84.
Ishii, T., & Takezawa, M. (2019). Testing the similarity-projection hypothesis using the reaction time paradigm: Anchoring and adjustment in social judgments.
Jahnke, I., Riedel, N., Singh, K., & Moore, J. (2021). Advancing sociotechnical-pedagogical heuristics for the usability evaluation of online courses for adult learners. Online Learning, 25(4), 416–439.
Jensen, A. A., Stentoft, D., & Ravn, O. (2019). Interdisciplinarity and problem-based learning in higher education. Innovation and Change in Professional Education, 18
Jensen, M. B., Utriainen, T. M., & Steinert, M. (2018). Mapping remote and multidisciplinary learning barriers: Lessons from challenge-based innovation at CERN. *European Journal of Engineering Education, 43*(1), 40-54.
Jerant, A., Franks, P., & Kravitz, R. L. (2011). Associations between pain control self-efficacy, self-efficacy for communicating with physicians, and subsequent pain severity among cancer patients. *Patient Education and Counselling, 85*(2), 275-280.
Jiang, L., Chen, Z., & Lei, C. (2023). Current college graduates' employability factors based on university graduates in Shaanxi province, China. *Frontiers in Psychology, 13*, 1042243.
Kim, E. (2020). The case for interdisciplinary education: A student's perspective. Njcssjournal. Social Studies,
Kelly, R., McLoughlin, E., & Finlayson, O. E. (2020). Interdisciplinary group work in higher education: A student perspective. Issues in Educational Research, 30(3), 1005–1024.
Kivunja, C. (2014). Innovative pedagogies in higher education to become effective teachers of 21st century skills: Unpacking the learning and innovations skills domain of the new learning paradigm. International Journal of Higher Education, 3(4), 37–48.
Klaassen, R. G. (2018). Interdisciplinary education: A case study. European Journal of Engineering Education, 43(6), 842–859.
Klaassen, R. (2020). Disentangling the different layers of interdisciplinarity. *Journal of Science Communication, 19*(4), C03.
Klein, J. T. (1990). *Interdisciplinarity: History, theory, and practice* Wayne state university press.
Klein, J. T., & Miller, R. C. (1983). The dialectic and rhetoric of disciplinary and interdisciplinary. *Issues in Interdisciplinary Studies,*
Knight, P. T., & Yorke, M. (2002). Employability through the curriculum. *Tertiary Education and Management, 8*(4), 261-276.
Knight, P., & Yorke, M. (2003a). *Assessment, learning and employability* McGraw-Hill Education (UK).

Knight, P., & Yorke, M. (2003b). *Assessment, learning and employability* McGraw-Hill Education (UK).
Kolbe, M., Grande, B., Marty, A., Manka, R., Taramasso, M., Nietlispach, F., Reser, D. (2019). Making heart team discussions work. Structural Heart, 3(2), 100–103.
Krouwel, S. J. C., van Luijn, A., & Zweekhorst, M. B. (2020). Developing a processual employability model to provide education for career self-management. *Education Training, 62*(2), 116-128.
Krueger, J., & Clement, R. W. (1994a). The truly false consensus effect: An ineradicable and egocentric bias in social perception. *Journal of Personality and Social Psychology, 67*(4), 596.
Krueger, J., & Clement, R. W. (1994b). The truly false consensus effect: An ineradicable and egocentric bias in social perception. *Journal of Personality and Social Psychology, 67*(4), 596.
Lattuca, L. R., Knight, D., Seifert, T. A., Reason, R. D., & Liu, Q. (2017). Examining the impact of interdisciplinary programs on student learning. Innovative Higher Education, 42, 337–353.
Law, B. (1999). Career-learning space: New-dots thinking for careers education. *British Journal of Guidance & Counselling, 27*(1), 35-54.
Lees, D. (2002). Graduate employability-literature review.
Leitner, S., Gula, B., Jannach, D., Krieg-Holz, U., & Wall, F. (2021). Understanding the dynamics emerging from infodemics: A call to action for interdisciplinary research. SN Business & Economics, 1(1), 23.
Lennings, C. J. (1994). An evaluation of a generalized self-efficacy scale. *Personality and Individual Differences, 16*(5), 745-750.
Lent, R. W., Brown, S. D., & Hackett, G. (1994). Toward a unifying social cognitive theory of career and academic interest, choice, and performance. *Journal of Vocational Behaviour, 45*(1), 79-122.
Lianto, L. (2019). Self-efficacy: A brief literature review. *Jurnal Manajemen Motivasi, 15*(2), 55-61.
Lindvig, K., & Ulriksen, L. (2019). Different, difficult, and local: A review of interdisciplinary teaching activities. *The Review of Higher Education, 43*(2), 697-725.
Long, H. B., McCrary, K., & Ackerman, S. (1979). Adult cognition: Piagetian based research findings. *Adult Education, 30*(1), 3-18.
Luszczynska, A., Sobczyk, A., & Abraham, C. (2007). Planning to lose weight: Randomized controlled trial of an implementation intention prompt to enhance weight reduction among overweight and obese women. *Health Psychology, 26*(4), 507.
Lyall, C., Bruce, A., Tait, J., & Meagher, L. (2011). Interdisciplinary research journeys: Practical strategies for capturing creativity Bloomsbury Academic.
Maass, K., Geiger, V., Ariza, M. R., & Goos, M. (2019). The role of mathematics in interdisciplinary STEM education. *Zdm, 51*, 869-884.
MacLeod, M., & Van der Veen, J. T. (2020). Scaffolding interdisciplinary project-based learning: A case study. European Journal of Engineering Education, 45(3), 363–377.
Maddux, J. E. (2013). *Self-efficacy, adaptation, and adjustment: Theory, research, and application* Springer Science & Business Media.
Marks, G., & Miller, N. (1987). Ten years of research on the false-consensus effect: An empirical and theoretical review. *Psychological Bulletin, 102*(1), 72.
Matsumoto, D., Yoo, S. H., & Nakagawa, S. (2008). Culture, emotion regulation, and adjustment. *Journal of Personality and Social Psychology, 94*(6), 925.

Mazzocchi, F. (2019). Scientific research across and beyond disciplines: Challenges and opportunities of interdisciplinarity. *EMBO Reports, 20*(6), e47682.
McArdle, S., Waters, L., Briscoe, J. P., & Hall, D. T. T. (2007). Employability during unemployment: Adaptability, career identity and human and social capital. *Journal of Vocational Behaviour, 71*(2), 247-264.
McCash, P. (2006). We're all career researchers now: Breaking open career education and DOTS. *British Journal of Guidance & Counselling, 34*(4), 429-449.
McCright, A. M., O'shea, B. W., Sweeder, R. D., Urquhart, G. R., & Zeleke, A. (2013). Promoting interdisciplinarity through climate change education. Nature Climate Change, 3(8), 713–716.
McCuaig, L., Carroll, T., Geidne, S., & Okade, Y. (2020). The interdisciplinary challenge. School Physical Education and Teacher Education: Collaborative Redesign for the 21st Century.New York: Routledge,
Mead, G. H. (1934). *Mind, self, and society* University of Chicago press Chicago.
Mead, G. H., & Morris, C. W. (1967). *Mind, self & society from the stand-point of a social behaviorist [by] George H. mead; edited, with introd., by Charles W. Morris* University of Chicago press.
Misra, R. K., & Khurana, K. (2017). Employability skills among information technology professionals: A literature review. *Procedia Computer Science, 122*, 63-70.
Moggach, D. (2021). 11 the limits of state action Humboldt, Dalberg, and perfectionism after Kant. *Practical Philosophy from Kant to Hegel: Freedom, Right, and Revolution,* 192.
Molesworth, M., Scullion, R., & Nixon, E. (2010). *The marketisation of higher education* Routledge.
Morace, C., May, D., Terkowsky, C., & Reynet, O. (2017). Effects of globalisation on higher engineering education in Germany–current and future demands. *European Journal of Engineering Education, 42*(2), 142-155.
Moritz, S. E., Feltz, D. L., Fahrbach, K. R., & Mack, D. E. (2000). The relation of self-efficacy measures to sport performance: A meta-analytic review. *Research Quarterly for Exercise and Sport, 71*(3), 280-294.
Moser, K. M., Ivy, J., & Hopper, P. F. (2019). Rethinking content teaching at the middle level: An interdisciplinary approach. Middle School Journal, 50(2), 17–27.
National Academies of Sciences, Engineering, and Medicine. (2018). The integration of the humanities and arts with sciences, engineering, and medicine in higher education: Branches from the same tree.
Neill, C., Corder, D., Wikitera, K., & Cox, S. (2017). Embracing the muddle: Learning from the experiences from interdisciplinary teaching and learning collaboration. New Zealand Journal of Teachers' Work, 14(2), 136–154.
Nimmi, P. M., & Zakkariya, K. A. (2016). Developing metacognitive skills: A potential intervention for employability enhancement. *Journal of Contemporary Research in Management, 11*(3), 11.
Nissani, M. (1995). Fruits, salads, and smoothies: A working definition of interdisciplinarity. *The Journal of Educational Thought (JET)/Revue De La Pensée Éducative,* 121-128.
O'Leary, K. J., Buck, R., Fligiel, H. M., Haviley, C., Slade, M. E., Landler, M. P., . . . Cohen, S. E. (2011). Structured interdisciplinary rounds in a medical teaching unit: Improving patient safety. Archives of Internal Medicine, 171(7), 678–684.

Pajares, F. (2002). Gender and perceived self-efficacy in self-regulated learning. *Theory into Practice, 41*(2), 116-125.
Pajares, F., & Miller, M. D. (1994). Role of self-efficacy and self-concept beliefs in mathematical problem solving: A path analysis. *Journal of Educational Psychology, 86*(2), 193.
Papaioannou, A., Milosis, D., & Gotzaridis, C. (2019). Interdisciplinary teaching of physics in physical education: Effects on students' autonomous motivation and satisfaction. Journal of Teaching in Physical Education, 39(2), 156–164.
Piaget, J. (1936). The origins of intelligence in the child (M. cook, trans.) penguin, New York. *Original Work Published, 1977*
Piaget, J. (1959). *The language and thought of the child* Psychology Press.
Power, E. J., & Handley, J. (2019). A best-practice model for integrating interdisciplinarity into the higher education student experience. *Studies in Higher Education, 44*(3), 554-570.
Priaulx, N., & Weinel, M. (2018). Connective knowledge: What we need to know about other fields to 'envision' cross-disciplinary collaboration. European Journal of Futures Research, 6(1), 1–18.
Repko, A. F., Newell, W. H., & Szostak, R. (2011). *Case studies in interdisciplinary research* Sage Publications.
Richter, D. M., & Paretti, M. C. (2009a). Identifying barriers to and outcomes of interdisciplinarity in the engineering classroom. *European Journal of Engineering Education, 34*(1), 29-45.
Richter, D. M., & Paretti, M. C. (2009b). Identifying barriers to and outcomes of interdisciplinarity in the engineering classroom. *European Journal of Engineering Education, 34*(1), 29-45.
Richter, D. M., Paretti, M. C., & McNair, L. D. (2009). Work in progress-disciplinary egocentrism as a barrier to interdisciplinary design. Paper presented at the *2009 39th IEEE Frontiers in Education Conference,* 1-2.
Riggio, R. E. (2020). Social skills in the workplace. *The Wiley Encyclopaedia of Personality and Individual Differences: Clinical, Applied, and Cross-Cultural Research,* 527-531.
Robertson, D. L. (1999). Professors' perspectives on their teaching: A new construct and developmental model. *Innovative Higher Education, 23*, 271-294.
Rogora, E., & Tortoriello, F. S. (2021). Interdisciplinarity for learning and teaching mathematics. *Bolema: Boletim De Educação Matemática, 35*, 1086-1106.
Römgens, I., Scoupe, R., & Beausaert, S. (2020). Unravelling the concept of employability, bringing together research on employability in higher education and the workplace. *Studies in Higher Education, 45*(12), 2588-2603.
Rooks, D., & Winkler, C. (2012). Learning interdisciplinarity: Service learning and the promise of interdisciplinary teaching. Teaching Sociology, 40(1), 2–20.
Roper, L. (2021). Encouraging interdisciplinary collaboration: A study of enablers and inhibitors across silos in higher education. Interdisciplinary Journal of Partnership Studies, 8(1)
Ross, L., Greene, D., & House, P. (1977). The "false consensus effect": An egocentric bias in social perception and attribution processes. *Journal of Experimental Social Psychology, 13*(3), 279-301.
Salas, E., Cooke, N. J., & Rosen, M. A. (2008). On teams, teamwork, and team performance: Discoveries and developments. *Human Factors, 50*(3), 540-547.

Sam, C., & Van der Sijde, P. (2014). Understanding the concept of the entrepreneurial university from the perspective of higher education models. *Higher Education, 68*, 891-908.
Santaolalla, E., Urosa, B., Martín, O., Verde, A., & Díaz, T. (2020a). Interdisciplinarity in teacher education: Evaluation of the effectiveness of an educational innovation project. Sustainability, 12(17), 6748.
Scanlon, E., & Conole, G. (2018). Interdisciplinarity in technology enhanced learning: An interview study. Journal of Interactive Media in Education, 2018(1), 11.
Schaffer, S. P., Chen, X., Zhu, X., & Oakes, W. C. (2012a). Self-efficacy for cross-disciplinary learning in project-based teams. Journal of Engineering Education, 101(1), 82–94.
Schwarzer, R., & Jerusalem, M. (1993). Generalized self-efficacy (GSE) scale: English version.
Schwarzer, R., & Jerusalem, M. (1995). Generalized self-efficacy scale. *J.Weinman, S.Wright, & M.Johnston, Measures in Health Psychology: A User's Portfolio. Causal and Control Beliefs, 35*, 37.
Schwarzer, R., & Renner, B. (2000). Social-cognitive predictors of health behavior: Action self-efficacy and coping self-efficacy. *Health Psychology, 19*(5), 487.
Semilarski, H., Soobard, R., & Rannikmäe, M. (2019). Modelling students' perceived self-efficacy and importance towards core ideas and work and life skills in science education. Science Education International, 30(4), 261–273.
Sherman, S. J., Presson, C. C., & Chassin, L. (1984). Mechanisms underlying the false consensus effect: The special role of threats to the self. *Personality and Social Psychology Bulletin, 10*(1), 127-138.
Singh, P., Teoh, S. H., Cheong, T. H., Rasid, N. S. M., Kor, L. K., & Nasir, N. A. M. (2018). The use of problem-solving heuristics approach in enhancing STEM students development of mathematical thinking. International Electronic Journal of Mathematics Education, 13(3), 289–303.
Skains, R. L., Rudd, J. A., Casaliggi, C., Hayhurst, E. J., Horry, R., Ross, H., & Woodward, K. (2021a). Bridging research silos: Approaches to arts-science collaboration. Using interactive digital narrative in science and health education (pp. 73–89) Emerald Publishing Limited.
Small, L., Shacklock, K., & Marchant, T. (2018). Employability: A contemporary review for higher education stakeholders. *Journal of Vocational Education & Training, 70*(1), 148-166.
Stajkovic, A. D., & Luthans, F. (1998). Self-efficacy and work-related performance: A meta-analysis. *Psychological Bulletin, 124*(2), 240.
Stentoft, D. (2017). From saying to doing interdisciplinary learning: Is problem-based learning the answer? *Active Learning in Higher Education, 18*(1), 51-61. doi:10.1177/1469787417693510
Sumanasiri, E. G. T., Yajid, M. S. A., & Khatibi, A. (2015a). Conceptualizing learning and employability" learning and employability framework". *Journal of Education and Learning, 4*(2), 53-63.
Sumanasiri, E. G. T., Yajid, M., & Khatibi, A. (2015b). Review of literature on graduate employability. *Journal of Studies in Education, 5*(3), 75-88.
Tamir, D. I., & Mitchell, J. P. (2013). Anchoring and adjustment during social inferences. *Journal of Experimental Psychology: General, 142*(1), 151.
Terry, G., Hayfield, N., Clarke, V., & Braun, V. (2017). Thematic analysis. *The SAGE Handbook of Qualitative Research in Psychology, 2*, 17-37.
Tight, M. (2019). Mass higher education and massification. *Higher Education Policy, 32*(1), 93-108.

Tomlinson, M. (2008). 'The degree is not enough': Students' perceptions of the role of higher education credentials for graduate work and employability. *British Journal of Sociology of Education, 29*(1), 49-61.
Tomlinson, M. (2012). Graduate employability: A review of conceptual and empirical themes. *Higher Education Policy, 25*, 407-431.
Tomlinson, M. (2017). Forms of graduate capital and their relationship to graduate employability. *Education Training, 59*(4), 338-352.
Toynton, R. (2005). Degrees of disciplinarity in equipping mature students in higher education for engagement and success in lifelong learning. *Active Learning in Higher Education, 6*(2), 106-117. doi:10.1177/1469787405054236
Trowler, P. (2012). Disciplines and interdisciplinarity: Conceptual groundwork. Tribes and territories in the 21st century (pp. 5–29) Routledge.
Tuckman, B. W. (1965). Developmental sequence in small groups. Psychological bulletin, 63(6), 384.
Tversky, A., & Kahneman, D. (1974). Judgment under uncertainty: Heuristics and biases: Biases in judgments reveal some heuristics of thinking under uncertainty. *Science, 185*(4157), 1124-1131.
Tymon, A., Harrison, C., & Batistic, S. (2020). Sustainable graduate employability: An evaluation of 'brand me' presentations as a method for developing self-confidence. *Studies in Higher Education, 45*(9), 1821-1833.
Van den Beemt, A., MacLeod, M., Van der Veen, J., Van de Ven, A., Van Baalen, S., Klaassen, R., & Boon, M. (2020). Interdisciplinary engineering education: A review of vision, teaching, and support. Journal of Engineering Education, 109(3), 508–555.
Wächter, C. (2012). Interdisciplinary teaching and learning for diverse and sustainable engineering education. *GIEE 2011: Gender and interdisciplinary education for engineers* (pp. 45-63) Brill.
Wakeham, W. (2016). Wakeham review of STEM degree provision and graduate employability. *Innovation and Skills: Department for Business.*
Watt, T. (2021). Effective interdisciplinarity is like alchemy. Paper presented at the 109th ACSA Annual Meeting Proceedings, Expanding the View,
Welch, D. C., & West, R. L. (1995). Self-efficacy and mastery: Its application to issues of environmental control, cognition, and aging. *Developmental Review, 15*(2), 150-171.
West, R. E. (2016). Breaking down walls to creativity through interdisciplinary design. Educational Technology, 47–52.
Wilde, N., & Hsu, A. (2019). The influence of general self-efficacy on the interpretation of vicarious experience information within online learning. *International Journal of Educational Technology in Higher Education, 16*(1), 1-20.
Woelert, P., & Millar, V. (2013). The 'paradox of interdisciplinarity' in Australian research governance. Higher Education, 66, 755–767.
Wolfson, S. (2000). Students' estimates of the prevalence of drug use: Evidence for a false consensus effect. *Psychology of Addictive Behaviors, 14*(3), 295.
Xefteris, S., & Palaigeorgiou, G. (2019). Mixing educational robotics, tangibles and mixed reality environments for the interdisciplinary learning of geography and history.
Yawson, D. E., & Yamoah, F. A. (2023). Towards a framework for the promotion of business management graduate employability: An extended CareerEDGE model. *Studies in Higher Education, 48*(7), 1007-1024.

Yinon, Y., Mayraz, A., & Fox, S. (1994). Age and the false-consensus effect. *The Journal of Social Psychology, 134*(6), 717-725.
Yorke, M. (2006). *Employability in higher education: What it is-what it is not* Higher Education Academy York.
You, H. S. (2017). Why teach science with an interdisciplinary approach: History, trends, and conceptual frameworks. Journal of Education and Learning, 6(4), 66–77.

Appendices

Appendix I- Self-Efficacy Questions

1. I enjoy my work the majority of the time.
2. I find it easy to balance my work with my other responsibilities.
3. It is easy for me to stick to my aims and accomplish my goals in my degree.
4. I perform well in groups.
5. I can always manage to solve difficult problems given to me on my course if I try hard enough.
6. I have always wanted to study my subject.
7. I can remain calm when facing difficulties within my course because I can rely on my coping abilities.
8. When I am confronted with a problem within my course, I can usually find several solutions.
9. There are areas of my discipline I significantly prefer.
10. I am confident that I could deal efficiently with unexpected events within my degree.
11. I work better in silence.
12. If someone opposes me, I can find the means and way to get what I want.
13. I can solve most problems set if I invest the necessary effort.
14. I like all the people I work with.
15. I can usually handle whatever comes my way within my degree.
16. I am confident in the work I produce.
17. Thanks to my resourcefulness I know how to handle unforeseen situations in my work.
18. I see myself working in my degree subject area long-term.
19. If I am in trouble in my work, I can usually think of a solution.
20. I find the work I do satisfying.

The questions used to construct the Self-Efficacy scale for academia are shown in black with the sections in red the elements that have been specialised from the generic GSE instrument. The questions in blue are padding questions as recommended in the method for constructing the scale

Appendix II- Survey instrument

PARTICIPANT CONSENT FORM

TITLE OF RESEARCH STUDY: Identifying the effects of interdisciplinary teaching on the employability of students

Please answer the following questions by ticking the response that applies

	YES	NO
1. I have read the Information Sheet for this study and have had details of the study explained to me.	☐	☐
2. My questions about the study have been answered to my satisfaction and I understand that I may ask further questions at any point.	☐	☐
3. I understand that I am free to withdraw from the study within the time limits outlined in the Information Sheet, without giving a reason for my withdrawal or to decline to answer any particular questions in the study without any consequences to my future treatment by the researcher.	☐	☐
4. I agree to provide information to the researchers under the conditions of confidentiality set out in the Information Sheet.	☐	☐
5. I wish to participate in the study under the conditions set out in the Information Sheet.	☐	☐
6. I consent to the information collected for the purposes of this research study, once anonymised (so that I cannot be identified), to be used for any other research purposes.	☐	☐
7. I am willing to be contacted in future to arranging a follow-up interview (this will not affect the anonymisation process).	☐	☐

Participant's Signature: _____ Date: _____

Participant's Name (Printed): _____ Student Number: _____

Contact details: _____

Researcher's Name (Printed): Alex Crombie

Researcher's Signature:

Researcher's contact details: Alex.Crombie@Shu.ac.uk

Please indicate how much you agree with the following statements on a scale of 1-5

	1 Strongly disagree	2 Disagree	3 Neither	4 Agree	5 Strongly agree
1. I enjoy my work the majority of the time.	☐	☐	☐	☐	☐
2. I find it easy to balance my work with my other responsibilities.	☐	☐	☐	☐	☐
3. It is easy for me to stick to my aims and accomplish my goals in my degree.	☐	☐	☐	☐	☐
4. I perform well in groups.	☐	☐	☐	☐	☐
5. I can always manage to solve difficult problems given to me on my course if I try hard enough.	☐	☐	☐	☐	☐
6. I have always wanted to study my subject.	☐	☐	☐	☐	☐
7. I can remain calm when facing difficulties within my course because I can rely on my coping abilities.	☐	☐	☐	☐	☐
8. When I am confronted with a problem within my course, I can usually find several solutions.	☐	☐	☐	☐	☐
9. There are areas of my discipline I significantly prefer.	☐	☐	☐	☐	☐
10. I am confident that I could deal efficiently with unexpected events within my degree.	☐	☐	☐	☐	☐
11. I am confident making assumptions to build a model.	☐	☐	☐	☐	☐
12. If someone opposes me, I can find the means and way to get what I want.	☐	☐	☐	☐	☐
13. I can solve most problems set if I invest the necessary effort.	☐	☐	☐	☐	☐
14. When building a model I am comfortable justifying my choices.	☐	☐	☐	☐	☐
15. I can usually handle whatever comes my way within my degree.	☐	☐	☐	☐	☐
16. I am confident in the work I produce.	☐	☐	☐	☐	☐
17. Thanks to my resourcefulness I know how to handle unforeseen situations in my work.	☐	☐	☐	☐	☐
18. I see myself working in my degree subject area long-term.	☐	☐	☐	☐	☐
19. If I am in trouble in my work, I can usually think of a solution.	☐	☐	☐	☐	☐
20. I can interpret solutions in context.	☐	☐	☐	☐	☐

Please indicate how much you agree with the following statements and how much a non-mathematician would agree, on a scale of 0-10

	You	Non mathematician
21. Maths is the most important subject.		
22. Anyone could be a Mathematician.		
23. Mathematicians are more intelligent.		
24. Mathematics is often unnecessary.		
25. Mathematicians are too specialised.		
26. Other disciplines respect Maths.		
27. Mathematics is easy.		
28. Mathematicians are the best choice to lead teams.		
29. Mathematicians are more successful.		
30. Mathematicians can over-complicate things.		

Please answer the following questions:

31. What was your age on entering University? _____

32. With what gender do you identify? _____

33. What was your highest qualification before entering university? _____

35. What A-level subjects did you take (if applicable) _____

32. Did you complete a foundation year? _____

Appendix III – Participant information sheet

Sheffield Hallam University

PARTICIPANT INFORMATION SHEET

1. This research is investigating the effects of interdisciplinary teaching on the employability of students.

2. I am researching how delivering teaching to different subject group students at the same time can affect how the students involved view their own discipline and their place within it. This work focusses on the views and opinion of students at Sheffield Hallam University within the two subject groups brought together in the evacuation modelling project. I am looking to survey and potentially interview students involved in the evacuation modelling project.

3. You have been asked to take part as you meet the criteria of the study in terms of taking part in the evacuation modelling project.

4. The survey will comprise a series of short questions in which you are asked to record your views and opinions. The interviews conducted will be a short, recorded conversation in, and a series of short flashcard questions in which you will be asked a series of questions about your views and experiences of the interdisciplinary teaching delivered.

5. The survey will take place during the teaching sessions and any interview will take place at a time and location of your convenience.

6. You will be asked to complete one survey three times over the course of an academic year, each survey should take roughly 15 minutes to complete. Interview that will last no longer than one hour.

7. After completing the survey or interview, you will have the opportunity to discuss any issues or questions you may have about your participation with the researcher.

8. The researcher who conducts the interview and who is listed on the attached consent form will be responsible for all and any data collected during this research.

9. Access to the data will be restricted to the named researcher and the researcher's supervisory team during the term of the research project, after that period, third party access will be available to all anonymised data except audio recordings of interviews. Should you not wish for your data to be made available to third parties, please indicate this on the consent form

10. The data collected in this survey will be kept for 10 years after any access on a secure server at Sheffield Hallam University. All identifying documentation will be destroyed upon completion of the research.

11. The anonymised data collected in this survey will be used as part of an assessed PhD thesis and may be used to form part of published research as well.

12. Participants in this research will have their identity and all identifying details recorded during the research anonymised and replaced with an identifier to link the subject to the data. The record of identifiers to participant identity will be kept separately from the collected data in an encrypted file. If you agree to be contacted for a follow-up interview, this will not affect the anonymisation process

13. The study will continue until the end of 2019

14. If you would like to be informed of the results of the study and where any results may be published, please let the researcher know at the time of the interview, or alternatively contact the researcher on the contact details provided.

15. Participation in this research is totally voluntary and of your own free will.

16. Should you wish to withdraw from the research at any time during the data collection you can inform the researcher and they will stop the interview immediately or terminate the survey and any data collected will be destroyed. If you should wish to be removed from this study after having taken part, you can contact the research within one month of the date of the final survey or interview to request it be removed from the study and destroyed.

17. Please feel free to ask any questions you may have before agreeing to take part in this research.

18. Should you wish to contact the researcher at any time after your participation in the research please contact Alex Crombie at:

Alex.Crombie@SHU.ac.uk

Appendix IV – Participant information sheet for interviews

Sheffield Hallam University

PARTICIPANT INFORMATION SHEET

19. This research is investigating attitudes and approaches towards employability skills teaching in higher education STEM teaching.

20. I am researching people's views on the inclusion of employability skills development within higher education teaching. This work focusses on the views and opinion of staff within STEM departments within universities. I am looking to interview members of the academic staff about their own interaction with employability skill teaching and their views on it.

21. You have been asked to take part as you meet the criteria of the study in terms of providing academic teaching within a STEM degree course.

22. The interview will be a short, recorded conversation, in which you will be asked a series of questions about your views and experiences of employability skills teaching within your subject area level and your own courses.

23. The interview will take place at a time and location of your convenience.

24. You will be asked to complete one interview that will last no longer than one hour.

25. After completing the interview, you will have the opportunity to discuss any issues or questions you may have about your participation with the interviewer.

26. The researcher who conducts the interview and who is listed on the attached consent form will be responsible for all and any data collected during this research.

27. Access to the data will be restricted to the named researcher and the researcher's supervisory team during the term of the research project, after that period, third party access will be available to all anonymised data except the audio recording of the interview. Should you not wish for your data to be made available to third parties, please indicate this on the consent form

28. The data collected in this survey will be kept for 10 years after any access on a secure server at Sheffield Hallam University. All identifying documentation will be destroyed upon completion of the research.

29. The anonymised data collected in this survey will be used as part of an assessed PhD thesis and may be used to form part of published research as well.

30. Participants in this research will have their identity and all identifying details recorded during the research anonymised and replaced with a pseudonym to link the subject to the data. The record of

pseudonyms to participant identity will be kept separately from the collected data in an encrypted file.

31. The study will continue until the end of 2017

32. If you would like to be informed of the results of the study and where any results may be published, please let the researcher know at the time of the interview, or alternatively contact the researcher on the contact details provided.

33. Participation in this research is totally voluntary and of your own free will.

34. Should you wish to withdraw from the research at any time during the data collection you can inform the researcher and they will stop the interview immediately and any data collected will be destroyed. If you should wish to be removed from this study after having taken part, you can contact the research within one month of the date of the interview to request it be removed from the study and destroyed.

35. Please feel free to ask any questions you may have before agreeing to take part in this research.

36. Should you wish to contact the researcher at any time after your participation in the research please contact Alex Crombie at:

Alex.Crombie@SHU.ac.uk

Appendix V – Participant consent form for interview

PARTICIPANT CONSENT FORM

TITLE OF RESEARCH STUDY: Investigating attitudes and approaches towards employability skills teaching in higher education STEM teaching

Please answer the following questions by ticking the response that applies

	YES	NO
8. I have read the Information Sheet for this study and have had details of the study explained to me.	☐	☐
9. My questions about the study have been answered to my satisfaction and I understand that I may ask further questions at any point.	☐	☐
10. I understand that I am free to withdraw from the study within the time limits outlined in the Information Sheet, without giving a reason for my withdrawal or to decline to answer any particular questions in the study without any consequences to my future treatment by the researcher.	☐	☐
11. I agree to provide information to the researchers under the conditions of confidentiality set out in the Information Sheet.	☐	☐
12. I wish to participate in the study under the conditions set out in the Information Sheet.	☐	☐
13. I consent to the information collected for the purposes of this research study, once anonymised (so that I cannot be identified), to be used for any other research purposes.	☐	☐

Participant's Signature: _____ Date: _____

Participant's Name (Printed): _____

Contact details: _____

_____

Researcher's Name (Printed): _____

Researcher's Signature: _____

Researcher's contact details:
(Name, address, contact number of investigator)

Please keep your copy of the consent form and the information sheet together.

Appendix VI – Converis approval

Investigation into the effects of interdisciplinary teaching in higher education

Ethics Review ID: ER5377584

Principal Investigator

Crombie, Alex
(Arts Computing Engineering and Sciences)

Type of Research: ii) Doctoral research

Type of Ethics Review Template: Very low risk human participants studies

Abstract: This research intends to examine the relationship between interdisciplinary teaching and the employability of students. Through examining the levels of disciplinary egocentrism and self-efficacy amongst those taking part in interdisciplinary teaching, both pre- and post-, I hope to be able to conclude what changes have occurred and through such changes consider the effects on employability.

Workflow Status: Application Approved

Appendix VII – Data management plan

Investigation into the effects of interdisciplinary teaching in higher education

Plan Name SHU Template for doctoral students

Plan ID -

Grant number -

Principal Investigator / Researcher Alex Crombie

Plan Data Contact alex.crombie@shu.ac.uk

Plan Description Most employability models make reference to some form of self-reflection and some even explicitly describe this as self-efficacy. This research aims to employ self-efficacy as a measure of the efficacy of employability interventions. Through delivering interdisciplinary teaching it is hoped that students will have the opportunity to reference their ability against a more representative sample of the population and hence encourage reflection on the expertise they have gain during their studies. This should have a positive effect on their efficacy beliefs and therefore their employability. It is also hoped that correcting egocentric beliefs through demonstrating the individuality of one's knowledge are developed. By comparing the performance of students on false consensus effect type task before and after receiving this teaching a statement can be made about its effect on students' egocentrism and thus on their employability.

Funder -

Institution Sheffield Hallam University

Your ORCID 0000-0001-6716-186X

Data collection

What data will be produced?

Physically completed questionnaires and recorded interviews and their transcripts which will then be transcribed onto a database stored on the university's Q drive. The quantitative will then be analysed with a statistics package such as SASS and the qualitative with be considered using a package such as NVivo.

Data created will include: SASS database and Excel

spreadsheets. total data should not exceed 1Gb.

Data documentation

How will your data be documented and described?

Each data entry will be given an identifier to describe when it was created (alongside its anonymised reference) and stored in separate folders for each data gathering phase. These folders will also contain a 'readme.txt' file which describes the nature of the data stored in that folder - when and where it was collected and for what purpose.

Ethical and copyright issues

How will you deal with any ethical and copyright issues?

Before gathering their data, the research participants are asked to agree to their data being stored and shared after anonymisation for up to 10 years.
Participants will be identified through anonymised identifiers and the information linking these will be stored separately from the gathered data.

SHU will own the primary data that it collects, but the secondary data will be owned by Alex Crombie. The data will be open to third parties after the duration of the research project.

Data storage

How will your data be structured, stored, and backed up?

The transcribed data will be stored under the anonymised identifier following the data collection phase descriptor. Files will be grouped into folders named after the data collection phase identifier.

/Interdisciplinary_teaching_research/<data collection phase identifier>/<Participant anonymised identifier>/<version number>

Multiple versions of the files will not be possible.

I will use the University's networked Research Store for all copies of the data.
Data is backed up automatically on a daily basis and can be fully recovered in the case of accidents. All backups are securely kept on two remote locations for a period of 90 days. Access to all folders is restricted to the researcher and
their supervisors, working on the project. At project close down relevant data relating to this project will be securely archived, and all data will be deleted from the Research Store.

Data preservation

What are the plans for the long-term preservation of data supporting your research?

All anonymised data (raw and analyzed) will be deposited in the University's Research Data (SHURDA) before the end of the research project. The data will be retained in the archive for a period of 10 years since the last time any third party has requested access to the data. When depositing the data, no further changes to data formatting will be required as all necessary actions will have been conducted as the research progresses.
All consent forms be retained and stored in the Sheffield Hallam University Research Data Archive. Any identifying data collected will be destroyed upon completion of the research project.

Data sharing

What are your plans for data sharing after submission of your thesis?

A data sharing agreement with re-users of the data will not be required, as the raw anonymized data and the data collection methodologies will be made available on a Creative Commons with Attribution (CC-BY) or equivalent license. While a robust approach to ensuring consent is received from all respondents in the study to allow raw data to be shared, should some respondents refuse permission, these data will be removed before depositing the data in the SHU Research Data Archive (SHURDA). The responsibility for ensuring extraction of data from those declining will ultimately be Alex Crombie.
All consent forms will be retained and stored in the Sheffield Hallam University Research Data Archive.