eAssessment in engineering mathematics: gaps in perceptions of students and academics

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Abstract

This research investigated the perceptions held by first-year undergraduate engineering students and academics regarding the assessment of mathematics in online environments. The study was motivated by hearing students' voices, in a moment of serendipity, and realizing that academics do not always hear those voices when teaching in online environments. Currently, there is no literature providing an insight to engineering students' perceptions of eAssessment in Irish institutes of technology.

The research considered students' perceptions of self-efficacy, expectancy, motivation, and barriers to learning in parallel with those held by academics towards their students. The aim was to develop an understanding of students' perceptions of eAssessment to help address the concerns of academics involved with online assessment of engineering mathematics. The population of interest in this study comprised first and second year undergraduate engineering students and academics from an Irish institute of technology as the principal group, and first year students from its higher education equivalent in six European countries. A convergent mixed methods design, where surveys and interview data were integrated, interpreted, and analysed, was employed. The convergent mixed methods design permitted flexibility in the data gathering stages to accommodate cultural and language differences within the academic and student populations. The findings of the research are presented under three themes: preparation for eAssessment and barriers to eAssessment; expectations, values, reward, and effort; motivational emotions and self-regulation. The three findings provide valuable insights and adds new knowledge to an understanding of the processes in eAssessment for engineering mathematics. Without listening to and hearing students' voices, it is not possible for academics to gain an understanding of their students' perceptions, emotions, and motivations. I therefore argue that higher education institutions take cognizance of the need for a meta-dialogue between students and academics to aid an understanding of the processes of eAssessment.

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I lost my mother and father during the Covid-19 pandemic, and this was a major blow to me. I want to dedicate this thesis to the love they both had for me and the many sacrifices they made to ensure I succeeded in life. I am so proud of you both, you were my inspiration. To my dear wife, Liz, I will never be able to repay you for all your love and support, you are my rock, my friend, my soulmate. To my children, Emma and Mark, I love you both and am constantly inspired by you. To Charlie, you are not just a dog, as my daily companion you give me strength.

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Author's Declaration

I declare that, except where explicit reference is made to the contribution of others, this dissertation is the result of my own work and has not been submitted for any other degree at the University of Glasgow or any other institution.

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Chapter 1 – INTRODUCTION

I am standing at the front of a classroom and a student asks permission to complain about his results in a recent online assessment. He asks why the system doesn't award attempt marks and why the computer can't see that a space has been inserted by mistake. I hear anguish in his voice and visually witness the upset in his demeanour. Other class members also comment, with a result akin to a landslide as more voices are added. My pedagogical misperceptions are exposed leaving a state of bewilderment knowing there are questions to be answered. Determining an evidence base for this crisis requires access to a wider database of student abilities, experiences, and perceptions, whilst maintaining linkages with the experiences and perceptions of academics.

The purpose of this study was to investigate the processes of eAssessment within engineering mathematics during the first year of undergraduate study. The study addressed the following issues relating to assessment of engineering mathematics:

- Conceptualisation of students' and academics' perceptions
- Exploration of students' and academics' perceptions in different geographic locales
- Relationships between students' and academics' perceptions

This introductory chapter describes the problem addressed within the research, the rationale for the research study and the impact of the research. The chapter begins with an overview of the higher education landscape in Ireland, and how the landscape and student profile has changed significantly since the turn of the twenty first century. The rationale is established to demonstrate the potential value of the research study. The chapter then introduces the research problem within a socio-cognitive critical realist onto-epistemology, woven with the philosophical approach of phenomenology, to address the students' hidden voices. The significance of the research is discussed, and an overview of the thesis structure is provided.

1.1 Educational Landscape in Ireland

The higher education landscape has transformed through widening of participation (Weedon & Riddell, 2016) to include non-standard students, and those described as second-chance students (Van Laer & Elen, 2018), alongside standard-entry students. Widening participation and access to higher education has taken place within the European Union (EU), aided in part by the 1999 Bologna declaration (Bonjean, 2018). The core principle of the Bologna Process is increased coherence in higher education in Europe through three strands: standardised cycles at bachelor's, master's, and doctoral studies; mutual recognition of qualifications and learning periods; quality assurance practices. The three strands are intended to provide pathways to social reform of higher education through enhanced inclusion and accessibility opportunities for *learning mobility* of all European Union citizens (Bonjean, 2018).

Re-mapped government policies in Ireland (McCoy et al., 2014), cognizant of the Bologna Declaration, produced a marked increase in the proportion of non-standard entry students entering Irish higher education institutions prior to 2008 (Weedon & Riddell, 2016). Weedon & Riddell use the term *nontraditional* (Weedon & Riddell, 2016, p. 49) to describe non-standard students, as *those targeted as requiring additional support measures*. Different EU countries apply their own variations of the definition, and it is difficult to compare like with like across all countries. However, it is recognised that non-standard students enter higher education through alternative routes and qualification pathways. A non-standard student may not be in a position to present academic qualifications; an alternative pathway for non-standard students to higher education in Ireland is through accreditation of recognised prior learning or work experiences (*National Strategy for Higher Education 2030*, 2011).

The process of widening access to the Irish higher education system has taken place in a relatively short time frame, accompanied by a period of severe financial austerity. The restricted economic conditions in Ireland created tensions for higher education academics and institutions (*Education Policy Outlook IRELAND*, 2013). Reduced budgets, increased student numbers and rationalization of programmes in Irish higher education institutions, have affected the operationalization of programmes. Additional tensions are created for academics through pressures (*Higher Education System Performance Framework 2018 2020*, 2018) to improve learners' learning experiences, improve the progress of at-risk learners and innovate in areas of the digital economy.

The learning spaces and practices presented by higher education are recognised as being significantly different from second level. However, the physical learning spaces offered by many higher education institutions have changed very little, whilst learning practices are dominated by conservative pedagogies. Even though the Higher Education Authority in Ireland is cognizant of the changing profiles offered by students entering third-level, policies supporting redesign of the learning space to support all students are difficult to ascertain. Policies associated with transition to third-level are dominated by the standard student profile, and higher education institutions are expected to assimilate non-standard entry students, providing a less than optimum learning experience (Hagerdorn, 2014).

Transitioning to third-level education creates liminal experiences for students as they engage: new forms of subject timetabling; interactions with peers from a wider community base; alternative learning methods; academic and institutional expectations (Van Laer & Elen, 2018; van Rooij et al., 2017b, 2017a; Pennington et al., 2017; Pampaka et al., 2016; Bowles et al., 2014; Rienties et al., 2012; Aspelmeier et al., 2012; Artino, 2010; R. W. Baker & Siryk, 1984). Many students experience feelings of confusion, which may be perceived as a barrier to learning, as they adapt to a new learning environment where they are expected to demonstrate independence (Van Rooij & Jansen, 2018; Pennington et al., 2017).The students' confusing situation is exacerbated because traditionally Irish higher education institutions were designed to support the academic elite. Inclusion of non-standard students, and second-chance students, create tensions within the model of Irish higher education, resulting in a need to accommodate perceived and actual students with lower levels of educational attainment (Faulkner et al., 2014). The transitional phase between second-level and third-level is recognised as problematic in Ireland (HEA, 2015), with a requirement for greater cohesion in the learning experience. It is within the transitional phase of first-year undergraduate study in engineering mathematics that this research study is located.

1.2 Rationale for the research study

A moment of clarity in the noise of a mathematics classroom and was the impetus necessary to recognise the importance of the students' hidden voices. Mathematics is a core subject within every engineering undergraduate programme, and is considered to be a *functional skill* (*Transforming Engineering Education*, 2009) central to the role of the engineer (*Mathematics – SEFI*, 2017); proficiency in mathematics in the engineering profession is an expected graduate attribute (Gould, 2012; Nguyen, 1998). A frustrated student in my class brought attention to a problem within the eAssessment process (Good, 2011) that I was not aware of. Ensuing discourse with students and academics provided anecdotal evidence that the students' frustrations were not unique. The anecdotal evidence pointed to differences between students' and academics' perceptions of eAssessment in engineering mathematics.

Third-level engineering students are expected to demonstrate literacy, not only in mathematics, but also in digital literacy (Becker et al., 2017). The first year of undergraduate study of engineering mathematics includes the use of eAssessment at several stages within the programme. The assumption that students have an appropriate level of digital knowledge and competency was deemed by me to be a fallacy when the anecdotal classroom evidence was reflected on; evidence confirms the fallacy (Munoz-Escalona et al., 2019). Students were not as confident in eAssessment as I expected and displayed feelings of confusion and frustration. Students' displays of confusion and frustration caused personal tensions for me as I struggled to understand why students were not cognizant of the eAssessment tools.

Dissonances exist for students in the Irish higher education system caused by: transition to third-level; digital literacy competencies and skills; academics' perceptions (Kinnari, 2010; McCraith, 2015; Rinneheimo, 2010; Treacy & Faulkner, 2015a). A particular dissonance for students in Irish higher education is the decline in mathematical skills (Treacy & Faulkner, 2015) especially for students entering institutes of technology. The problems associated with mathematical skills, transition to third-level and digital literacy are not unique to Ireland (Csuday, 2019; Cole, McCartan, Tuohi & Steinby, 2014; Kinnari, 2010; Rinneheimo, 2010).

From an engineering perspective, an initial consideration was to address the technology of eAssessment. However, it became apparent that irrespective of technical deficiencies, the underlying difficulties associated with the processes of eAssessment had to be addressed as a priority. Reflection on students' and academics' comments revealed that a discourse on eAssessment cannot be developed without listening to the evidence. The initial technical solution did not create a synergy with engaging the voices of students leading me to consider an alternative approach.

An approach based on constructs such as effort, worth, value, and belonging, was required; these were the main constructs used by students. The study relocated from the technical to the socio-cognitive – an area completely outside my comfort zone – but deemed critical if an understanding of the issues associated with eAssessment was to be gained. The ability to elucidate the concerns of students, in conjunction with the concerns held by academics, was paramount to ensure optimum communication of the students' pertinent issues.

The extant literature was found to concentrate on university students (Becker et al., 2017; Cole et al., 2014; Drumm, 2020; Faulkner et al., 2010, 2014; Gill, Mac An Bhaird, et al., 2010; HEA, 2015; Johnson & O'Keeffe, 2016; Ní Shé et al., 2017a, 2017b; Ni Shuilleabhain et al., 2016; Prendergast et al., 2017; Treacy & Faulkner, 2015a), however the students at Irish institutes of technology are not of an equivalent academic standing. Irish research universities account for the top 5% of students in terms of second-level achievement in the Irish Leaving Certificate. The students entering Irish institutes of technology represent the top 67% (HEA, 2020), presenting a greater width of academic abilities. In addition to supporting a considerable width in academic abilities, institutes of technology also cater for a high percentage of non-standard students (approximately 20%). Therefore, as a lecturer in an Irish institute of technology, it was not possible to obtain evidence from the literature to address the concerns of the students.

The purpose of this study is to explore how students perceive the processes of eAssessment in their first year of undergraduate study in engineering mathematics, and to ascertain if a gap exists between the students' perceptions and the perceptions held by academics.

A socio-cognitive framework (Bandura, 1989) allows the research to focus on students' perceptions of barriers, pre-existing attributes and self-confidence, whilst developing an understanding of students' and academics' awareness of pertinent issues. Referring to the students' voices as the most important aspect of the research, an ontology of Critical Realism (Bhaskar, 1998; Scott, 2005; Gorski, 2018) permits the research to prioritise the students' and academics' descriptions of their lived experiences or Lebenswelt (Romdenh-Romluc, 2011).

Research concerning students' and academics' perceptions have primarily focused on the use of surveys to provide quantitative analyses. Few studies have engaged with engineering students and academics using mixed methods to relate quantitative and qualitative data, and I am not aware of any such studies involving an Irish institute of technology. The primary concern of addressing students' and academics' concerns in engineering mathematics eAssessment within an Irish institute of technology was modified during the research study. Involvement in Erasmus teacher mobility in Finland and presentation of findings at European Education conferences led to requests to engage with non-Irish higher education institutions.

The opportunity to widen the evidence base within the boundaries of engineering mathematics enables the original students' issues to be explored across different cultures, languages, and education environments, whilst also considering academics' perceptions and concerns. Thus, an inclusive research study involving several countries helps to address elements of the EU goal of learning mobility, by creating a greater understanding of issues perceived and experienced in institutes of technology, universities of applied sciences and polytechnics.

The ubiquitous nature of the use of Information and Communications Technology (ICT) for assessment in STEM education means that the opportunity for students to engage in eAssessment is being explored by educators (Heerwegh et al., 2016). The role of the ICT offers opportunities as well as barriers in the design, delivery and assessment of learning (Smirnov & Bogun, 2010). Students in higher education are expected to be computer literate (Brubaker et al., 2017) and able to exercise additional ICT skills depending on their particular STEM domain (Miliszewska, 2008); especially true for use of software and the responsible use of Internet services. The consequences of appropriate pedagogical application of ICT, and design, within engineering mathematics rests not on the shoulders of students but on academics. Digital literacy (Ilomaki, Paavola, Lakkala & Kantsalo, 2016) includes competence to use digital tools and also the ability to critically evaluate the technologies within an ICT culture.

Reported lack of preparedness for ICT in higher education affects both academics and students, calling into question the notion of the ‘digital native’ (Kirschner & De Bruyckere, 2017; Prensky, 2001). Considerations of ICT preparedness, barriers to learning and students’ perceptions are issues of concern for academics in the design and delivery of engineering mathematics programmes.

1.3 Aims of the Research

The aims of this research are as follows:

1. To develop an understanding of engineering mathematics students’ perceptions of eAssessment.
2. To develop an understanding of the perceptions held by engineering mathematics academics of eAssessment.
3. To explore perceptions and expectations of first-year undergraduate engineering mathematics students in different geographic locales.
4. To explore engineering mathematics academics’ perceptions and concerns in different geographical locales.
5. To develop an understanding of the issues arising from any differences in perceptions of eAssessment in engineering mathematics held by students and academics.

1.4 Research Problem

The following main research problem will address the aims of the research through five sub-research questions:

> There appears to be a significant mismatch between students’ perceptions of assessment processes in engineering mathematics and those of academics

that raises issues in relation to secondary to tertiary education transition, digital skills readiness, and assessment related dialogue.

To address the overarching problem, the following sub-questions form the foundation for analysis:

1. What are the perceptions held by students regarding assessment processes of engineering mathematics in an Irish Institute of Technology?

2. What are the perceptions held by academics engaged in assessing engineering mathematics in an Irish Institute of Technology?

3. What are the perceptions held by students regarding assessment processes of engineering mathematics in higher education institutes, of similar academic standing to Irish institutes of technology, in other countries?

4. What are the perceptions held by academics regarding assessment processes of engineering mathematics in higher education institutes, of similar academic standing to Irish institutes of technology, in other countries?

5. What issues arise from the difference in perceptions of assessment processes of engineering mathematics between students and academics?

To address the research sub-questions, a literature review was conducted to ascertain the existence of a similar study, or set of studies, examining perceptions held by students and academics in the engineering mathematics domain. The literature review revealed a dearth of studies in this area, and there was sufficient evidence within the literature to support the claim that this study would make a scholarly contribution in the domain of engineering mathematics education. Based on the evidence of the literature review, a socio-cognitive conceptual framework for the research was developed to consider the prime motivating factor for the study, i.e., the students' hidden voices.

Determination of students' voices is based on 'self', the reality expressed or perceived is different for each student and a socio-cognitive framework supports the pluralism of society. Designed as a meta-theory, the onto-epistemology of critical realism within a socio-cognitive conceptual framework supports both qualitative and quantitative methods for data gathering. The continuum of reality within society makes it necessary to provide a temporal interpretation of the students' accounts – and academics' accounts. Therefore, an interpretivist model examining the voices' phenomena was designed using a novel two-stage convergent mixed methods approach. The two-stage convergent mixed methods model was adapted from the standard convergent model to enable the interpreted phenomena of the local Irish student data to be contextualized with the data from different geographic locales. Statistical analyses from surveys were integrated with data from the interpreted phenomena at each stage. In parallel, a series of qualitative interviews with academics responsible for engineering mathematics was conducted. The students' and academics' data were designed to be integrated at each stage in the process. The voices of students and academics are clearly established within the methodology allowing both to be heard.

The outputs from the two-stage convergent design have provided rich data, producing a narrative supporting the claim that students' voices are hidden or attenuated within the assessment process.

1.5 Significance of the research

The main aim of this study is to generate new knowledge in relation to how students perceive the processes of eAssessment in their first year of undergraduate study in engineering mathematics, and to ascertain if a gap exists between the students' perceptions and the perceptions held by academics. The outputs from the study will feed into the knowledge base to help students understand their situational dispositions within the higher education environment. It is anticipated that new knowledge on the value of understanding students' perceptions will aid academics in engineering mathematics, and potentially other academic domains. Academics in engineering mathematics will be able to generate a bigger picture of the role of dynamic dialogic interactive feedback within the eAssessment process. The role played by engineering mathematics is pivotal within the engineering education curriculum and crucial to the professional engineer. The findings of this study will have implications not only for institutes of technology in Ireland but also for higher education institutions of similar standing in other geographic locales.

1.6 Structure of the thesis

This thesis describes a mixed methods approach, without hypothesis for the quantitative data, to investigating the relationship between the perceptions held by students and those held by academics, if any, as emerging issues of online assessment of engineering mathematics.

Chapter 2: Literature Review

This chapter contains a review of the literature about mathematics in Ireland and the global mathematics context, the transition to third level, the role of cognition in engineering mathematics, assessment and eAssessment, the role of feedback and psychography of belonging in engineering mathematics. The purpose of the chapter is to establish the current context of the study by examining the role(s) played by mathematics particularly within engineering. To establish the role(s) of mathematics the chapter examines the issues pertaining to engineering students as: they make the transition to third level; they conduct studies in different geographic locales; a review of provision of available eAssessment tools; a socio-cognitive activity; they experience eAssessment and the effects of feedback; psychographic factors; and a summary discussion of eAssessment.

Chapter 3: Philosophy, Methodology & Methods

This chapter is divided into Part A: Research Philosophy, Part B: Research Methodology and Methods.

Part A: Research Philosophy describes the theoretical and ontological assumptions of the study providing the foundation from which it is possible to consider the students' voices and those of academics. I describe my own personal underlying philosophical approach to the study, without which it would not be possible to describe the interpretations of the emerging phenomena with any degree of veracity. The chapter describes the role of critical realism as the vehicle to prioritise the social actors' descriptions through an examination of positivism and interpretivism. The role of critical realism is described to support the use of phenomenology through hermeneutics to establish a temporal narrative for the actors in the study. It is within this chapter that the strength of the mixed methods convergent model is established.

Part B: Methodology describes the methodological framework and how Interpretive Phenomenological Analysis is the central mechanism to access the salient phenomena. The parallel activities of quantitative surveys and the means of integration with the qualitative phenomena are outlined. The study population is detailed along with the rationale for selecting the participants. The rationale for selecting a mixed methods convergent design and subsequently adapting the design to create a two-stage approach is provided. The adapted convergent design conducts an initial analysis to provide an insight to phenomena affecting students and academics. This information offers guidance for the second stage data gathering exercises. The data gathering instruments are described for both qualitative and quantitative processes. Issues relating to quality, validity, reliability, generalizability, ethics, and the role of the researcher. This section then describes the methods used to gather students' quantitative and qualitative data during stage one of the convergent design in parallel with academics' qualitative data in Ireland. The process is then repeated in stage-two to include data gathering from Ireland, Estonia, Finland Poland, Portugal, Romania, and Russia. The section includes details of how: interviews were designed, administered, and conducted; students participated in surveys; ethical approval was established; surveys were administered and analysed; qualitative data was coded and interpreted.

Chapter 4: Quantitative Results

This chapter displays the methodology used for the analysis and interpretation of data during stage one and stage two of the process. Using SPSS and Excel for quantitative analysis of the surveys, the main survey findings are presented.

Chapter 5: Qualitative Results

This chapter presents the qualitative data as analysed and interpreted using manual coding techniques. Manual coding was conducted using Excel in the interpretation of transcripts.

Chapter 6: Synthesis and Discussion

This chapter discusses the salient findings and interpretations. The survey findings are analysed in relation to the research questions in parallel with the qualitative interpretations. The contribution towards research knowledge is provided through the implications of the main findings of the study.

Chapter 7: Conclusion

This chapter discusses the overall findings and presents the study conclusions. Suggestions are made for further work while considering the implications of the new knowledge. The limitations of the research methodology are discussed in the form of the research environment and the research design.

Appendices:

Appendix 1: Support Documents

A copy of the surveys, participant consent and information sheets, Ethics approval and interview protocol. The interview protocol is the list of questions and enquiry themes to be explored during each interview. The semi-structured interview protocol helps to address areas considered off-topic and helps to accommodate group interviews.

Appendix 2

A copy of the quantitative analysis tables and graphs. The tables and graphs are the outputs from Excel and SPSS.

Appendix 3

Data collection design methodology.

Appendix 4

A copy of the qualitative analysis codex, participant response coding, thematic outputs, manual coding, and sample interview transcripts for academics and students.

Chapter 2 – LITERATURE REVIEW

2.1 Introduction

The purpose of this chapter is to provide an account of theoretical research of student voice in the literature. It will provide evidence for barriers to learning and critically discuss eAssessment as a medium for student voice in conjunction with the voices of academics.

The literature review is organised under three sections: Page Number

The focus of this chapter is the student voice, attitudes, and actions, to enable dialogue with their respective academics within engineering mathematics through the medium of eAssessment. To address issues of voice, attitude and action of students and academics in engineering mathematics it is necessary to explore the relationships between students and academics. Developing an understanding of the perceptions held by students and academics enables an understanding of how the voices of all actors can be heard. Simply enabling the student voice does not allow any dissonances, discrepancies, or gaps to be addressed. It is necessary that academic voices are also enabled. Enabling the voices of both parties allows dialogue to develop within engineering mathematics.

Enabling the student voice or the academic voice is only possible if both parties are aware of the metacognitive aspects of the eAssessment processes. Awareness of metacognition allows students and academics to reflect on past and current engagements with eAssessment and to strategize for future engagements with eAssessment. If students do not know why they are engaging in a particular task in eAssessment or cannot relate the task to what they are doing, then the metacognitive burden may become too large for them to cope. Similarly, it is important that academics understand what they are doing in eAssessment and why they are doing it.

Perceptions of eAssessment held in common by both academics and students may lead to positive learning situations and strengthen the bond between the students and academics. However, differences in perceptions held by students and academics may result in barriers to learning (section 2.4). Barriers to learning are not always visible and cannot always be controlled by students or academics. Understanding of perceived and actual barriers is important for academics to enable successful students' engagement in eAssessment.

The context for the research is within an Irish institute of technology and selected higher education establishments of similar academic standing. Section 2.3 examines the situation in Ireland for mathematics education relating to engineering, and the change in assessment experienced by students. The research occurred prior to the Covid-19 pandemic and a brief overview of engagement with eAssessment during that period is provided in chapter 6.

2.2 Student Voice

This review of literature begins with the focus of the research, 'the student voice'. The term 'student voice' has been chosen because it best describes my own understanding of the term in the plural as well as the singular. Student voice is described in the literature using variations of the grammar, however the meaning is contextualized to provide structural meaning (Canning, 2017) or dialogic meaning (Cook-Sather, 2006). Structural meaning is that which encompasses formal and informal structures in higher education and dialogic meaning is that which encompasses the rights, respects for, and listening to students.

Irrespective of meaning, students' voices have been reified as tokens to be gathered for measurement purposes (Hall, 2017) in the post-compulsory education sector via various media, fora, and government interventions. Using student voice for transformational purposes (Butler, Kane & Morshead, 2017) is not a primary concern in higher education. Student voice remains passive in higher education, even though it is powerful.

> Student perception is scarcely heard in research on technology implementation in education. (Zhou & Teo, 2017, p. 31)

My understanding of students' voice is

> to transform teaching and learning practice in schools through seeking to understand or to improve participation, teaching, and learning … by authorizing students' voices *(Butler, Kane & Morshead, 2017, p. 894)*

The danger associated with authorizing students' voice is the potential for its generalization and subsequent essentialization. The student voices within this research are framed within undergraduate engineering mathematics; authority may be lost outside of the context of the learning space. These voices may be negative, positive, or stereotypical, however by refusing to decontextualize the voices and maintaining them within their learning space, a discourse may develop.

2.2.1 Student Voice Context

Student voice and its associated agency is rarely discussed within the design of engineering programmes, where learning is traditionally a *prescribed pedagogy* of theoretical and practical consideration (Fielding, 2004a, p. 198). Promoting and enabling student voice through socio-constructive agency permits students to define the issues and topics – students are no longer mere objects to be analysed (Bergmark & Kostenius, 2018). Student voice has value, meaning and agency; students are not algorithmic parameters. Whether student or teacher initiated, dialogue is the agent for enhanced, connected discourse within communities of practice such as engineering mathematics (Fielding, 2004a; Wenger, 1998).

The contextual location of student voice in primary and post-primary school as listening to, valuing, communicating with, empowering and treating students as equal partners is in stark contrast to the literature for higher education (Seale, 2010). Hall (2017, p. 184) notes the paucity of *formal research into the concept of the student voice* where the concept of student voice in higher education is more closely aligned with quality assurance and professional development. Student voice in higher education is underdeveloped in relation to participation, equality and empowerment (Seale, 2010), and increasingly relegated due to the policy conflation of partnership and consumer status of students (Hall, 2017; Seale et al., 2015). The issue of listening and hearing is revealed within the definitions of student voice. Students' meta-cognitive activities are not being recognized through dialogue; student voice is being compartmentalized, e.g., disabled learners, disadvantaged learners. Compartmentalization raises the question as to who or what benefits from the typology (Freeman, 2016; Gourlay, 2015).

The growth in student voice literature since Seale's study (2010) is predominantly framed within the lens of institutional policy making (Canning, 2017; Freeman, 2016; Gourlay, 2015). Within the institutional policy frame, concepts such as engagement and participation are measurements of what is conducted in practice in response to government policies (Freeman, 2016). However, little consideration is given to those silent spaces of *…critical thinking, questioning and evaluation* (Freeman, 2016, p. 859). Student voice has been formalized with a new sense of power – not necessarily empowerment – to the potential detriment of the student in the institutional sense as a further means of control (Fielding, 2004b).

Descriptors of student voice depend on consultation with students – questions arise as to which students are selected and how? Educationally elite (Faulkner et al., 2016) and privileged (Fielding, 2004b) students do not represent the majority of students in this research; power relationships (Bahou, 2011) may be skewed depending on the perceptions of the actors. The skewed nature of the student voice is further influenced by bias in determining which voices are the most appropriate to listen to. The challenge is to filter the stentorian and listen to the voice of the student, silently situated, in the background (Fielding, 2004a). Taking account of the social situation of the student is necessary to hear the student because social practices relate to time and context (Groundwater-Smith & Mockler, 2016).

Groundwater-Smith and Mockler (2016) identified three key issues from their synthesis of 'student voice' literature relating to young people: power and authority, authentic engagement and ownership of initiatives. The synthesis highlights the progression of student voice from the position of the student as co-researcher (Bland & Atweh, 2007) through to peer-researcher (Kilpatrick, McCartan, McAlister & McKeown, 2007) or as partners (Seale, Gibson, Haynes & Potter, 2015). The position of the student as partner or peer-researcher adds value and a greater level of insight whilst researching the student voice. Students as peer-researchers is not without criticism due to a tendency by researchers to include their use at later stages in the process (Lobo, McCausland, Bates, Hallett, Donovan & Selvey, 2020) and the *unwillingness of professionals to listen to them* (Groundwater-Smith & Mockler, 2016, p. 169).

The balance of the power-relationship shifts from an adult/teacher perspective to a student perspective providing students with greater power; an agency unknown to, or rarely experienced by, students in the margins. Hall (2017) recognizes the processes of authentic engagement and ownership in progressive actions and doesn't dispute the synthesis by Groundwater-Smith and Mockler (2016), however there is recognition that overbearing government policies have consequences for the *position of student voice* (Hall, 2017, p. 186).

2.2.2 Student Voice and Engagement

In Ireland, the Higher Education Authority is responsible for governance, policy, and regulation of institutes of technology and universities. The Irish Higher Education Authority reifies engagement as a structural measurement of nine quantitative indicators from the annual Irish Survey of Student Engagement: higher order learning; reflective and integrative learning; quantitative reasoning; learning strategies; collaborative learning; student-faculty interaction; effective teaching practices; quality of interactions; and supportive environment. The challenge set by Cook-Sather (2006) to consider student voice, or engagement, from a human perspective and promote dialogue is not to the fore in Irish policy for higher education. Almost half of all first-year undergraduates in institutes of technology are categorized as below average or disadvantaged on the Irish Deprivation Index compared to one third for Irish Universities (HEA, 2020).

The hegemony of affluence in the Irish universities compared to institutes of technology creates a situation where the Fielding's (2004a) affluent stentorian tones make it more difficult to hear those *un-monied voices* within the overall system. Data for all students in Irish higher education is extracted from the single quantitative survey instrument outlined in the previous paragraph. Of note is the lack of human perspective through qualitative means and this lack of human perspective is supported by student-faculty interaction being ranked as the lowest engagement indicator (HEA, 2022). It is acceptable to use the data from national surveys to generalize, however the use of such findings to essentialize carries the danger of de-contextualizing the student responses (Butler, Kane & Morshead, 2017).

Engagement as a transformational factor in student voice requires a very different model to ensure the voice is not de-contextualized. Butler, Kane & Morshead (2017) describe a learning environment for compulsory school age pupils as a *safe space* containing an institutional safe space and a personal safe space. The institutional safe space is that typically experienced by students in the premises and guided by policies involving safeguarding, bullying, etc. The personal safe space is regarded by the student as a positive, relational, space where the student has ownership and freedom to transform. The safe space provides for disadvantaged or marginalized students to experience value through dialogue and constructive feedback raising the individual within the learning community of practice. Thus, the definition of student voice posited by Butler, Kane & Morshead (2017, p. 894) as *to transform teaching and learning practice in schools through seeking to understand or improve participation, teaching, and learning* is one which locates student engagement within a safe personal and institutional space.

Questions remain as to the theorization of student voice in engagement within Irish higher education institutions (Kahn, 2014). The framework outlined by Fielding (2004b), particularly the problems of 1) speaking for others, 2) getting heard and 3) speaking with others remain extant. Students as co-researchers (Cook-Sather, 2020a; Fielding, 2004b) or partner participants (Fielding, 2004b, p. 296) require contextual linkages in the pedagogy promoting awareness for intentional engagement. Disadvantaged students feel *underserved* and *undervalued* in the overall higher education schema (Cook-Sather, 2020a, p. 928). Students may express such feelings through psychographic traits, e.g., low self-efficacy, demonstrating a lack of agency, confidence, and empowerment.

Engagement as a reflexive factor, of individual and social meta-cognition is a complex variable (Archer, 2012). Students may take responsibility for learning in a restricted reflexive action depending on personal priorities or concerns. A sense of fractured reflexivity may also be present where a student is overwhelmed by a task. The fractured reflexive will not be able to construct a strategy to solve the task without deliberate external support or scaffolding (Kahn, 2014). Levels of reflexivity remain to be addressed in the models adopted for engagement where student voice is discussed (Flynn, 2021; Healey, Flint & Harrington, 2016). In the transition to higher education, students experience liminal periods as they depart from their backgrounds and are subsequently deprived from their normal dialogic partners. The absence of a traditional dialogic partner has potential to degrade responses to communication, within the distributed agency of higher education (Archer, 2012). Each higher education learning environment offers different characteristics and educators must consider the effects of the characteristics of the learning environment to optimize the effects of engagement (Kahn, 2014).

2.2.3 Student Voice and Dialogue

Dialogue is defined as a conversation between people or groups and forms the basis for communication. Student voice as a dialogue is based on the agency afforded by teachers (including academics, lecturers, and others in the profession of education). Teacher agency is the deliberate act(s) by teachers based on their own beliefs to support student agency through *pedagogical decisions and constraints; problem solving; and student choice and voice* (Moses et al., 2020, p. 215).

The evolution of our understanding of dialogue with students has taken place alongside a rapid growth of technology in education. Coomey and Stephenson (2001) considered design of online learning to comprise dialogue, control, support and involvement in their review. The extant situation for eAssessment remains broadly similar (O'Hagan, 2020). Whether the assessment design is synchronous, asynchronous or hybrid, the focus has been primarily on the product of the dialogue for formative or summative purposes; perhaps as a reflection of institutional expectations (Drumm, 2020).

The objective of dialogue in eAssessment, whether it is stated explicitly or not, is the sharing of information, strengths, and weaknesses. Good (2011) considered the understanding of the formative use of assessment to be a process and not a product if it was to have validity. Without veracity the process cannot be authentic and meaningful. Authentic eAssessment requires a sharing of responses from all parties, otherwise known as feedback (Rakoczy, Pinger, Hochweber, Klieme, Schutze & Besser, 2018; Shank, 2017; Narciss, Sosnovsky, Schnaubert, Andres, Eichelmann, Goguadze & Melis, 2014; Boud & Molloy, 2013; Black & Wiliam, 2009; Hattie & Timperley, 2007). Feedback is discussed in section 2.5.2 however, it is important that we are reminded of the importance of quality, timing, prior knowledge, goals, regulation and evaluation within the process (Good, 2011).

The process of eAssessment and feedback is a sharing process but there may be differences in perceptions between teachers and students (Jónsson et al., 2017). According to Jónsson, Smith and Geirsdóttir (2017) the effect of differences in perception result from a lack of shared dialogic language used within assessment, especially for feedback. Suggesting that teachers and students do not share a common language within assessment may be controversial, but it opens pathways for policy research and further study of the shared language used between teachers and students.

Within the processes of dialogue it is recognised that students are increasingly dissatisfied with feedback (Carless & Boud, 2018) and assessment (*The Future of Assessment: Five Principles, Five Targets for 2025*, 2020). JISC conducted their analysis and report on the Future of Assessment to address serious issues surrounding assessment in higher education and demonstrate that technology can help to automate some aspects of assessment. The report states that marking and feedback are suitable processes for automation however, such processes further remove the teacher from the student with a potential dilution of the dialogue (*The Future of Assessment: Five Principles, Five Targets for 2025*, 2020, p. 14).

2.2.4 Student Voice Agency

Student agency and empowerment isn't located in a vacuum, it is located in a flexible and adaptive nurturing learning environment (Cook-Sather, 2020b;

Vaughn, 2020). The higher education learning environment is a complex system of variables where the methodologies may be located as democratically uncertain (Fielding, 2004b). These locations are not necessarily spatial and are typically social, based on historical frameworks, where the disenfranchised may be disempowered. Agency per se is a partnership otherwise the danger of controlling a party is to diminish their role (Vaughn, 2020; Robertson, Brekenridge Padesky & Brock, 2020; Cook-Sather, 2018).

In hierarchical control lies the danger of homogenous accommodation of students as an undifferentiated group. Issues of race, social class, culture, etc., are attenuated in favour of the status quo. The focus of understanding may be lost, reciprocity in learning reduced, and students remain as objects (Cook-Sather, 2020a). Therefore, student and academic agency are relegated due to hierarchical control rather than promoted through dialogue (Cook-Sather, 2020a; Taylor & Robinson, 2009).

2.2.5 Metacognition to promote Student Voice

Being able to monitor and control cognitive ability and create an appropriate response or question is known generally as metacognition (Flavell, 1979). Although Flavell introduced the term metacognition, the area of study of cognitive development was initially explored by Piaget (1951), in the way children adapt through assimilation and accommodation, and was developed further through examination of social interaction (Vygotsky, 1978).

Vygotsky (1978) determined the development of behaviour as a cognitive growth cycle transforming *quantity into quality* (p19). Internal thought and reflection may be inferred from speech and activity and these concepts are enhanced through social interactivity in the production of higher order functionality. Of interest are the examination of mental capacity (p 86) and the myriad ways it may be displayed or inferred in different students receiving the same instruction. The gap between the actual developmental level and the potential development level is described by the term *Zone of Proximal Development*. The functions that exist but are not yet formed in any detail relating to maturity of thought and mental exercise, are hinted at leading to relationships with metacognition.

> … learning awakens a variety of internal development processes …
> (Vygotsky, 1978, p. 90)

Expanding on the concept of Piaget's stage theory of cognitive development in an exploration of memory skills in children, Flavell et al., (1970) considered the application of anticipation or rehearsal in recalling knowledge. The conclusions are unclear regarding an understanding of the range of memory states but hints at the beginnings of metacognition. Flavell develops the dialogue when he alludes to Piaget's formal operational stage in his question,

> That is, what adultlike knowledge and behavior might constitute the development target ...? (Flavell, 1979, p. 906)

Thus, the thought processes, or metacognition, of those other than children are considered worthy of exploration. Flavell (1979, p. 908) postulates that metacognition has four classes: (a) *metacognitive knowledge*, (b) *metacognitive experiences*, (c) *goals* (or tasks) and (d) *actions* (or strategies).

Focusing on the educational context, the *knowledge of cognition* and the *regulation of cognition* were highlighted as being the main components of metacognition (Brown, 1987). The empirical model proposed by Brown was later adapted and fine-tuned by Schraw (1998) again within an empirical, educational context by combining knowledge and regulation of cognition. Knowledge of cognition involves the sub-components of declarative knowledge, procedural knowledge, and conditional knowledge (Karaoglan Yilmaz, 2022; Schraw, 1998). *Declarative* knowledge refers to *knowing about* or *how to use* things. Examples include searching for headings, summaries, relating ideas, connecting ideas, and constructing themes. *Procedural* knowledge refers to knowing *when to use* something. Examples include prior reading before an unfamiliar task, reading slowly to aid comprehension and integrating material to form a deeper understanding. *Conditional* knowledge relates to knowing *why something is used*. Examples of conditional knowledge include providing a conceptual overview, activating prior knowledge to aid understanding within a new context, reducing memory loading through integration with prior material and organization into categories. Regulation of cognition involves the sub-components of planning, monitoring, and evaluating. *Planning* involves the identification of appropriate strategies, resources, and goal(s) to complete the task. *Monitoring* relates to self-awareness of the process in knowing what is being done, adapting methods or strategies if required, managing time, and ensuring that the task remains understood. *Evaluating* relates to self-appraisal regarding what is or is not working, are the goals still achievable, what would work better in future.

The sub-components are not always visible or readily understood by the student because it is not always possible for the student to articulate the activities in a meaningful manner. If students are not trained to regulate their cognitive activities they may not be fully conscious of the effect it has on their own learning (Boud & Molloy, 2013; Schraw, 1998). Shraw's view is that cognitive skills are encapsulated within domains or subject areas (Schraw, 1998, p. 116) whereas metacognitive skills span multiple domains (Veenman, van Hout-Wolters & Bernadette, 2006, p7). However, Sternberg (1998, p130) takes the view that Shraw is over optimistic and that metacognition does not span multiple domains in all circumstances, and expertise occurs only in a limited number of domains; Kelemen, Frost & Weaver III (2000) dispute the notion of a general metacognitive ability due to the lack of evidence of correlation between metacognitive accuracy and learning ability. However, agreement exists in terms of motivation and expertise: inefficient students may be motivated (see section 2.4.5) but lack the cognitive skills or have the cognitive skills and lack the motivation (Biggs, 1988); It is only when motivation and expertise are combined in a positive manner that excellence and efficiency may occur (Kirschner & van Merrienboer, 2008; Efklides, 2011).

Cognitive activity is a multi-faceted construct and develops within a socially interactive context (van Dinther et al., 2011). The various components of the mind develop at different times and stages depending on the learner and each learner will internalize their own experiences accordingly. Each student's cognitive state is different from everyone else, and this metacognitive awareness increases with age (Lockl & Schneider, 2006).

Not all learners are fully aware of their metacognition hence, a process of dialogue and meta-dialogue is required to further develop the necessary components

(Carless & Boud, 2018). The medium of metacognition and our understanding of emotions, beliefs, desires, thoughts, perceptions, and intentions, allows humans to consider the self-recursive nature of human language; self-recursiveness being the ability to be self-reflexive on dialogue. Therefore, it is possible to deceive or show respect and in so doing a meta-dialogue may be promoted (Hargens & Grau, 1994).

A meta-dialogue according to Hargens and Grau is not a dialogue about dialogue, rather a meta-dialogue is a shared socially constructed narrative or story. The understanding created by Hargens and Grau is reduced to a set of foci by Bereiter and Scardamalia (2016), as they set out to establish a set of 'good moves in knowledge dialogue', effectively limiting the scope of meta-dialogue to addressing a defined set of objects. The imposition of a set of defined objects on the dialogue is a fetter to thematic generation and limits the potential reflective codification of the discussion. Employing similar pre-determined foci as Bereiter and Scardamalia, an examination of teacher-student dialogue was conducted to establish an understanding of the productive classroom (Howe et al., 2019). A major outcome from the study of mathematics, science and reading classes, at age ten to eleven was related to mastery. For students participating extensively, their elaborations and querying of previous contributions were linked positively to curriculum mastery.

Shared narratives with students are contextually and culturally dependent as the narrative evolves through socio-construction and reflection. However, the process may be malformed if the reflective environment is less than optimal. The meta-dialogue occurs in a different cognitive space from standard feedback and may encompass more than one dialogue within the narrative. Therefore, a challenge exists for this 'different' or 'alternative' dialogue for academics and students (Sun & Trent, 2020). Sun & Trent (2020) allude to an alternative space through juxtaposition of experiences in dialogue to conceptualise learning. Although the juxtaposition identified by Sun & Trent is framed at PhD-level students it represents a paradigm shift in the pedagogical role of students within feedback. Undergraduate engineering students, in year 1, are described as being in a liminal phase (see section 2.2.2) as their narrative genesis is beginning to evolve. Altering the dialogue on assessment to include students sharing ideas and perceptions about its purpose and function may reduce negative affectances. In doing so, the students are empowered to take control and responsibility for learning.

The need to develop an alternative structure to support students' metacognition is in direct alignment with the need to avoid tensions in assessment for purposes of academics having been seen to have taken action (Freire, 1970). For shared dialogue to take place the words of all parties must be heard – students are not objects mediated by assessment. Teachers cannot simply impose their ideas on students otherwise the action of speech is not *transformed or humanized* (Freire, 1970, p. 89); the dialogic space must support mutual trust between teacher and student. Meta-dialogue is employed to reveal students' thinking, it is not a means of determining what knowledge has been deposited in the students' mind.

Student voice is only possible if students are aware of their own levels of cognitive ability (Bergmark & Kostenius, 2018; Cook-Sather, 2018b; J. K. Butler et al., 2017; Boud & Molloy, 2013; Kusurkar et al., 2012; Kirschner & van Merrienboer, 2008; Cook-Sather, 2006; Flavell, 2004; Schraw, 1998; A. Brown, 1987; Flavell, 1979). This section reveals why metacognition is an important dialogic component and is a major underlying factor to support student voice. Positive engagement within a student-academic meta-dialogue requires metacognitive confidence by the students and academics.

2.2.6 Actions and beliefs of academics to support student voice

A major factor in the students' transitional experience is the role of the educators; their teaching methods, expectations, beliefs, attitudes towards students, and understanding of how they can improve the transition for students (van Rooij et al., 2017a). A belief held by many educators towards barriers perceived, or experienced, in higher education is that the barriers are beyond their sphere of influence (Eickelmann & Vennemann, 2017; Goto & Martin, 2009). External barriers such as poor Internet bandwidth, pedagogical support outside of class, and lack of specific support programmes are generally considered by academics to be difficult to control. Internal factors are issues an academic may have control over such as, personal academics' beliefs about the use of ICT within the pedagogy, the willingness of academics to change practices, and desire to accommodate change (Reyes et al., 2017; KPolovie & Awusaku, 2016; Margaryan et al., 2011). Interventions by academics to support students in being autonomous and self-directed have been demonstrated to increase levels of intrinsic motivation and so reduce amotivation and aid retention (Baker, 2004).

A successful student - academic - institution nexus is fundamental in the transitional stage to the development of the students' sense of belonging as they move from the 'outsider' position to that of one where they feel involved (van Rooij et al., 2017a). The actions of academics within the unfamiliar setting of higher education may result in students relocating and remaining on the periphery of activities during the initial phases of first year due to students' feelings of anxiety and powerlessness. The role of the academic as the nexus between students and institutions may place burdens on the shoulders of the academics to adopt practices considered beyond the scope of the academics' roles. Institutional support is paramount to minimising the burdens on academics to allow academics' voices to be heard as they support students (Thompson, 2013).

The agency of the academic helps create conditions amenable to student empowerment and increased self-efficacy through setting appropriate levels of expectations for students (Schunk et al., 2014; Chickering & Gamson, 1987; Vroom & Deci, 1992). Sound pedagogical theories, in the transitional stages of higher education, and their appropriate design in learning are critical lynchpins within the nexus. However, the higher education space describes conflicting approaches conflating the confusion for academics (Radmehr & Drake, 2018). Performativist demands by national educational policies (Ball, 2003) and the constructivist desires of academics produces tensions in pedagogical design (Steffe & Gale, 1995). The result is an assimilation of knowledge approach rather than dynamic development in an active environment fostering self-mastery and self-regulatory processes (Hollis-Sawyer, 2011).

A less-than optimal curriculum design results from the inclusion of tensions leading to barriers in the educational experience (KPolovie & Awusaku, 2016). Academics are more likely to invest resources and persist – even when faced with barriers – if there is sufficient information to support them (Larionova et al., 2018). Motivational factors may be intrinsic, extrinsic, or both, with intrinsic being viewed as the most powerful factor (Bandura, 1977). The academics' own self-perception shapes their personal goals based on what they believe they can achieve. Academics' cognition and metacognitive skills are fundamental to understanding how barriers may be overcome and problems solved (Brubaker et al., 2017; van Dinther et al., 2011; Bandura, 1977).

The complexity of higher education learning spaces presents challenges and opportunities for academics in what can be described as an emotionally charged environment (Lehman, D'Mello & Graesser, 2012). Opportunities arise in the form of complex learning scenarios for academics to promote metacognitive activity in learners. Academics' awareness of the emotional and complex nature of the learning environment has to be considered in the context of the manner in which learners are accommodated within institutions (Hagerdorn, 2014). The manner by which an institution interacts with its learners through academics is a determining factor of success and belonging; the interaction between the learner and the institution via the academic is a factor in metacognitive activity (Kim et al., 2013).

The sense of belonging engenders the sense of community in both academic and student contexts (Cook-Sather, 2018a; van Rooij et al., 2017a; Ni Shuilleabhain et al., 2016; Wenger, 1998). Failure to perceive that one belongs to a community has potential for feelings of failure, this is especially true where online education is considered (Thomas, Herbert & Teras, 2014). The strategies employed by academics, to ensure a positive sense of belonging is promoted, are strongly related to the success or failure of students' perceptions and beliefs in belonging.

The importance of communication as a non-coerced dialogue between academics and students cannot be understated if learners are to become autonomous (Hartnett, 2012). Communication should be meaningful (Baartman & Prins, 2018), however it is not always explicitly stated in the academic curriculum apart from the mechanics of communication displayed by many formal feedback processes (Veenman, van Hout-Wolters & Afflerbach, 2006).

The predispositions and experiences of academics are a construction of beliefs, expectations and experiences arising from their own personal, social, cultural and professional histories and each academic will interpret events and interactions accordingly (Morgan & Watson, 2002). The processes by which academics' beliefs and their propensity to support the need for learners' belonging must be inferred or deduced by indirect means (Forbes & Gedera, 2019). Academics' beliefs and the nexus between emotions, personal values, and personal history are subjective. The lack of direct visibility of how academics' beliefs and perceptions affect the beliefs and perceptions of students is noted as is the lack of direct studies in this field (Rowe et al., 2015).

Realisation of optimum cognition in learners is reached when cognitive experiences resonate with students' personal experiences and internalized worldview (Thomas et al., 2014; Hughes, 2007). The gap between students and academics is evident in students' feelings of isolation and frustration, and perceived lack of activity by academics. Academics' discourse tends to be limited to the specific area of study, *the professional purpose* as being a nice way to get to know students in a professional capacity (Thomas, Herbert & Teras, 2014 p74). Academics and students are able to relate to the premise that presence *contributes to a sense of belonging* (Thomas, Herbert & Teras, 2014 p75).

The perspectives of students and academics reveals incongruency in perceptions and expectations of students and academics, and contradictions attributable to *teacher presence* (Forbes & Gedera, 2019 p2). Advice in the literature suggests that academics should attempt to envision the students' perspectives to reduce experienced divergencies (Salmon, 2002). This advice suggests that academics must become more aware of their presence in relation to students in the form of a learning partnership. Gaps or misunderstandings occur in the domain of learning where expectations by one or both parties are unclear within the learning design. Increased awareness, and gap reduction in perceptions, occurs when academics develop strategies that engage students; academic presence and valued students' voices are necessary components within the strategic design as is authenticity (Forbes & Gedera, 2019).

Communication is insufficient to engender belonging and academics must consider the role of metacommunication leading to meta-dialogue (section 2.2.5) to foster a shift in students' perceptions. Within the sphere of eAssessment, Hamalainen, Kiili and Smith (2017) offer an insight to how actions of academics may open up a safe space for students to present their voices through the appropriate mediation of technology. Pedagogical application of technology as a mediating factor recognizes the importance of Technology Enhanced Learning (TEL) in higher education, and locates both student and teacher within the process to support dialogic communication within eAssessment, to enhance the academic experience (Soares et al., 2020).

The use of TEL or digital learning is a factor affecting the actions and beliefs of academics. Transferring digital learning skills requires academics to be willing to embrace the technologies and integrate them into their teaching practices. Integration of digital learning skills into teaching practices rather than supplementing existing teaching materials is recognised for its difficulty as academics develop as facilitators (Guven & Gulbahar, 2020). Exposure to digital learning challenges academics' teaching, pedagogical and content knowledge (TPACK) as the knowledge becomes situated in a technology mediated environment. Such exposure has the potential to introduce tensions within the student-academic-institution nexus requiring the academic to adopt an additional position as a learning leader as opposed to that of learning designer (O'Hagan, 2020). The tensions generated are such that

> Transformation requires a rupture of the ordinary and this demands as much of teachers as it does of students. Indeed, it requires a transformation of what it means to be a student; what it means to be a teacher.
>
> Fielding (2004b, p. 296)

Academic agency is recognised in the literature as an under theorized area of agency (Li & Ruppar, 2021; Moses et al., 2020). Academic agency is strongly linked to student voice (Charteris & Smardon, 2019) and supports student agency (Vaughn, 2020), however academics should remain cognisant of their situated perspectives to ensure a pathway for deeper understanding (Hall, 2017; Fielding, 2004b, 2004a). Academic agency per se promotes a dialogic partnership otherwise there is no place for students to engage. Students will be disempowered by well-intentioned academics if the language isn't shared; it is not the actual content of the dialogue, rather it is the act of dialogue. The current structures in higher education don't support dialogical encounter (Hall, 2017).

Promotion of academic agency offers the power to relocate the pedagogy from didactic to dialogic; students and academics effectively embrace each other in the pedagogy. Student agency integrated with academic agency creates a person-centred learning space. The performativist (Hall, 2017; Fielding, 2004a) structures of higher education make the person-centred learning space difficult to develop, as external policy demands exert control and regress the pedagogy (Moses et al., 2020).

2.2.7 eAssessment as a medium for Student Voice

The role of assessment is paramount to the student voice (Beattie et al., 2018). Within the assessment process, the potential for dialogue is present between academics and students. The form of assessment reviewed is online assessment or eAssessment. It is necessary to understand the factors of eAssessment for students and academics.

Assessment is conducted to determine if learning is taking place or has taken place and may be formal or informal in nature. To claim knowledge of learning, the assessor must purport to claim knowledge of another human being without the ability to extract data directly from that human. Learning may only be judged by inference of the learned capacity of the subject under study. Learning (or learned capacity) may be evidenced in some appropriate manner such as writing, solving an equation, speaking, etc., and the link must exist to tie the claim of knowledge to the reality to which the learner lays claim to (Dearden, 1979).

The learned capabilities of the individual are evidenced in behaviour. Practical and physical skills such as juggling a ball are unambiguous in this respect, but evidence of intellectual learning is open to inferences that may be deemed more hazardous. The actions of the assessor of intellectual changes in behaviour are critical, and the assessor not only has to judge what is observed to be true but also what is fair to the learner.

> All but the simplest forms of assessment call for skilled judgement in the assessor.
>
> (Dearden, 1979, p 117)

Assessment is generally broken down into two elements; formative assessment and summative assessment (Torrance, 2012; Wiliam, 2011; Bennett, 2011; Wang, 2010; Bennett, 2009; Reece & Walker, 2003; Black & Wiliam, 1998). Formative assessment, also known as assessment *for* learning, is informal but central to teaching and learning. It is a practical requirement of teaching and learning to show how a learner or teacher is doing as a condition of intelligent choice and variation. Summative assessment, also known as assessment *of* learning, is formal and usually takes place at the end of a learning cycle providing a permanent record of achievement or behavioural change (Ras et al., 2015). Both forms of assessment have a presence online and play a major role in programme delivery, however, there is disagreement within the literature regarding the phraseology (Torrance, 2012; Bennett, 2011, p 7; Black & Wiliam, 1998). A possible differentiation of formative assessment and assessment for learning provides that

> Formative assessment informs the teacher about student progress, assessment for learning informs the student about their own learning
>
> (Ras et al., 2015, p 23)

Prior experiences (Hattie & Timperley, 2007) of the students entering higher education are significant in relation to how the student interacts with the teacher, other students, and the overall the learning experience (Gallimore & Stewart, 2014). Within the various manifestations of assessment, there is a variety of forces acting on the curriculum designer to ensure that the needs of professional organisations and accrediting bodies are considered within the pedagogical design (Torrance, 2012).

> …where assessment procedures and practices come completely to dominate the learning experience, and 'criteria compliance' comes to replace 'learning'.
>
> (Torrance, 2012, p. 329)

The dictated requirements of such professional organisations tend to produce behaviourist designs in terms of assessment and classroom interaction.

2.3 Engineering Mathematics Context

This section reviews the literature associated with engineering mathematics in Ireland and situates the knowledge in a wider context. The issues reviewed regarding engineering mathematics in this section are not unique to Ireland. The situation regarding mathematics as a major factor in higher education engineering programmes is described as well as the effects of mathematics education at secondary level. It is through eAssessment in engineering mathematics that the student voice is illuminated within this study. Mathematics and its associated subjects are fundamental elements of engineering education, and proficiency in the area is expected (Nguyen, 1998). Engineers are required to be analytical and be able to utilise their mathematical toolkit to solve problems that may be ill or well defined depending on the contextual situation of the engineer.

2.3.1 Mathematics context in Ireland

The primary contextual setting for the study is the mathematics programme common to first year of the BEng degrees in Building Services & Renewable Energy, Civil Engineering, Fire Safety Engineering, Mechanical Engineering, Electronic Engineering, and Computer Engineering, within an institute of technology in Ireland. All engineering students follow a common mathematics programme through years 1, 2 and 3 as accredited by the professional body Engineers Ireland for Associate Engineer level and approved by the Higher Education Authority (HEA) in Ireland. The students studying these programmes have a considerable diversity of backgrounds in relation to mathematics.

A lack of sufficient mathematical knowledge by Irish students is problematic for many students resulting in disengagement from higher education programmes, and ultimately failure to progress to later years of study (Bhaird et al., 2009; Kinnari, 2010; Gill, O'Donoghue, et al., 2010; Passmore et al., 2011; Gallimore & Stewart, 2014; Tempel & Neumann, 2014; McCraith, 2015; Prendergast et al., 2016). Deficiencies in mathematical knowledge (Gould, 2012, p. 44) extend beyond the students' immediate environment onto third-level institutions in the form of retention, progression, and self-efficacy; these issues are not unique to Ireland (Rylands & Coady, 2009; Kajander & Lovric, 2005) and are explored further in section 2.3.2. Mathematical skills on entry to higher education are considered to be of primary importance for students of science, technology, engineering, and mathematics, (Johnson & O'Keeffe, 2016; Croft et al., 2009) and it is important to remain cognizant of the changing student profile at third level (HEA, 2015). In

Ireland, there has been a general increase of 8% to 12% in the number of non-standard students while the increase experienced by this institute of technology reached a peak of 33% in 2015. The mismatch of mathematical skills and knowledge from secondary level schools and further education is being addressed, however the adult learner cohort also requires support to overcome negative perceptions of mathematics (Klinger, 2011a).

To address the issues raised by the lack of sufficient mathematics knowledge a Mathematics Learning centre was established in 2006 in this Institute; a move engaged in by many higher education institutes in Ireland between 2001 and 2006 (Gill, Mac An Bhaird, et al., 2010; Gallimore & Stewart, 2014; Ni Fhloinn, 2018). In addition to the development of Maths Support Centres, as they are now more commonly called, a new mathematics curriculum was introduced in Ireland in 2011 known as Project Maths to address shortcomings. Pope (2013) was commissioned by Ireland's National Council for Curriculum and Assessment to compare the Project Maths curriculum with experiences around the world. A subset of Pope's larger study was used, selecting Scotland, Finland, New Zealand, Singapore, and Massachusetts to examine upper secondary mathematics. The study revealed that the Project Maths curriculum has

> considerable commonality: problem solving, procedural competence relational understanding, positive dispositions, and analytical and critical thinking
> (Hodgen et al., 2013)

The only significant difference is that only Ireland has factual recall as an objective for mathematics education. Some differences exist where the overall curriculum at secondary level is wide (Ireland, Massachusetts, Finland and New Zealand) compared to where it is narrow and hence greater specialism can take place (Scotland and Singapore), however, these differences do not account for the lack of preparedness exhibited by many students (Gallimore & Stewart, 2014).

A barometer of mathematics preparedness in Ireland is the annual diagnostic test of first year students at University of Limerick. The test was first introduced in 1997 to investigate arithmetic, algebra, geometry, trigonometry, co-ordinate geometry, complex numbers, differentiation, integration, and modelling. The mean score has consistently dropped over the years from a mean score 59.3 (sd

16.5) to 50.8 (sd 17.7). The student body is no longer exclusively made up of school-leavers and now includes non-standard entry students. A suggestion has been made that the non-standard students perform poorly in the test, and this has a negative effect on performance at third level (Faulkner et al., 2010).

The education system in Ireland requires all students to attend compulsory education until completion of the Junior Certificate at age 15/16. The qualifications needed to enter third-level Higher Education – university or institute of technology – mean that students must remain in second-level education and complete the Leaving Certificate and/or the Higher Leaving Certificate at age 17/18. The Higher Leaving Certificate explores the curriculum to a greater depth than the Leaving Certificate. Entry to the level 7 Bachelor of Engineering programme in the institute of technology under study requires a student to have achieved minimum grade OD3 (a pass at Leaving Certificate level of between 40% and 50%) or better in mathematics (see figure 2.1 for the Irish National Framework of Qualifications). In contrast, entry to a Level 8 Bachelor of Engineering Honours Degree in Engineering at university requires a student to have obtained minimum grade H4 (60%) in mathematics at Higher Leaving Certificate.

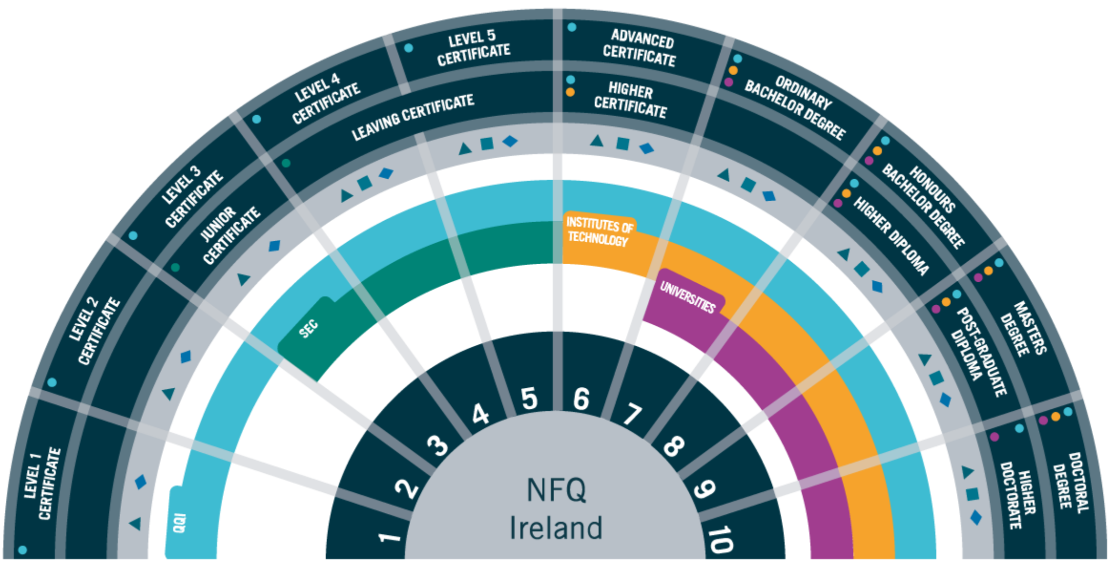

Figure 2.1 National Framework of Qualifications in Ireland (source: *Qualifications Frameworks - A European View*, n.d.)

Any student entering from a non-standard route and presenting alternative qualifications and/or experience may also participate in higher education programmes if their qualifications and/or experience are deemed appropriate. The Institute of Technology sector has been recognised as being significantly different from the University sector because of the high proportion of non-standard, and mature, students engaging with study opportunities in the Institute of Technology sector. Therefore, the type of student and students' mathematical ability are significantly different from the students researched within the extant literature (Prendergast & Treacy, 2017; Gould, 2012; Faulkner et al., 2010).

The engineering students in this study comprise a wide grouping of engineering disciplines however, they all share the same engineering mathematics syllabus. The programmes engaged in this study are accredited by the Irish professional engineering body Engineers Ireland at Technician Engineer level. The membership classification for Engineers Ireland at level 7 is the Associate Engineer. Some students may continue their studies on completion of the Level 7 programme to level 8, suitable for Chartered Engineer status.

2.3.2 The wider mathematics context

This section demonstrates that issues of mathematics in engineering are not restricted to Irish higher education. Gill et al (2010) observe that the transition from secondary to tertiary level education in Ireland is problematic in relation to mathematics, but this problem is not uniquely restricted to Ireland and not limited to the last decade (Gallimore & Stewart, 2014; Higgins et al., 2010; Kinnari, 2010; Radmehr & Drake, 2018; Hawkes & Savage, 2000; Rinneheimo, 2010). The *mathematics problem* (LMS, 1995) affects many students entering third-level education, with a lack of interest characterized by poor mathematical skills. The international context of the *mathematics problem* is a complex composition of different cultures, languages, curricula, societal needs, political, industrial, and commercial, landscapes.

The changing student profile leading to reduced homogeneity (Gallimore & Stewart, 2014) combined with the general reduction in mathematics abilities (Rylands & Coady, 2009), supports the claim that subjects studied in first-year undergraduate courses are not optimized to match the students' standards. An interesting observation by Saxe (cited in Shakerdge, 2016) is that of anxiety built up in secondary school because mathematics is used as a benchmark, whereas other subjects do not suffer in the same manner. There is disagreement as to the extent of the problem in different countries, however the *mathematics problem* is recognised as a major issue (Jerrim, 2018; Puri, 2018; Cole et al., 2014; Dobson, 2013; Horta, 2013; Smolentseva, 2013; Gomes et al., 2002).

2.3.3 Online Assessment (eAssessment) of engineering mathematics

Towards the end of the last Millennium, the presence of computers garnered greater acceptance within the population at large and within the world of education as a tool. This tool is now the subject of increasing scrutiny and in particular where assessment is made both *of* and *for* learning (Ras et al., 2015; Torrance, 2012). The literature surrounding learning per se is considerable; however, the literature surrounding learning within an online environment is slightly more restricted and less mature. The question as to what is meant by learning (Dijkstra, 2000), the learning process (Mehanna, 2004; Larreamendy-Joerns & Leinhardt, 2006), and its assessment (Condie & Livingston, 2007; Castellanos-Nieves et al., 2011; Gikandi et al., 2011; Redecker & Johannessen, 2013; Jordan, 2013; Narciss et al., 2014) within the online sphere is highly complex.

Robles and Braathen (2002) indicated that online assessment must be more than just testing and evaluating students; teachers should adapt their assessment activities to provide useful feedback, accountability, and opportunities to demonstrate quality. The pedagogical considerations of online feedback and assessment require attention to ensure impartiality and fairness to all students irrespective of impairment, race, colour, creed or gender, geographical location (Mehanna, 2004; Larreamendy-Joerns & Leinhardt, 2006). The facilitation of online assessment and feedback initially focused on written communication (Alexander & Boud, 2001; Coomey & Stephenson, 2001; Hattie & Timperley, 2007; Ras et al., 2015), and this has continued to be the greatest representation of learner engagement in an attempt to reveal knowledge, and meaningful, effective learning. However, Mehanna's (2004) examination of e-pedagogy revealed that the foundation for the approach to assessing learners online was not sound; supported by Condie & Livingston (2007) in relation to assessment of mixed ability groups.

Redecker and Johannessen (2013) conducted an extensive review of e-assessment to consider how Information and Communication Technologies (ICT) can support a shift in the pedagogy required to support evolving and potential e-assessment strategies. The evolution of ICT has given rise to a shift within society, and this is becoming reflected in education as the curricula adapt to changing needs of society. Using the SAMR model (Substitution - Augmentation - Modification - Redefinition) (Puentedura, 2013) it can be seen that e-assessment is moving from a computer-testing phase through to embedded assessment. Embedded assessment is the use of Learning Analytics to interpret a student's performance, predict future performance, and tailor the education to the individual student (Redecker & Johannessen, 2013, p. 81).

A system of interactivity (Ashton et al., 2006) was explored to mimic the assessment practices of a teacher by providing partial credit (Beevers et al., 1999) for attempts within a mathematics programme at secondary level through the use of steps (Jordan, 2013). It was noted that the assessment techniques of mathematics testing when moving from paper tests to computer-based testing required considerable redesign. The human marker can apply expert judgement when presented with a less than correct solution to a problem, and award partial credits for the attempt, in relation to learning goals achieved within the test; this element of the assessment process is important from a meta-cognitive aspect. The beliefs of the learner about their learning (Schneider & Artelt, 2010) and problem solving can act as important guides in the encoding and retrieval of mathematical material. Failure to award the learner has direct effect on the expectancy (Schunk et al., 2014; Vroom & Deci, 1992) of the learner, and if the valence (Weiner, 2010) of the action is perceived to be negative, the learner may not vary their behaviour in a positive manner. The learner may then shape their own behaviour in a stereotypically consistent manner as a result of the negative behavioural traits observed from the reduced expectancy; test anxiety and perceived deficiency in ability has the potential to undermine performance(Tempel & Neumann, 2014).

2.3.4 Feedback processes in engineering mathematics

Feedback in engineering mathematics is an opportunity to engage with students and to listen to the student voice. Listening to the student voice introduces empowerment to the students within the learning processes (Brooman et al., 2015).

The employment of feedback for the cognitive apprenticeship of the student becomes apparent through knowledge acquisition and mastery (Collins, Brown, & Newman, 1989, cited in Kirschner & van Merrienboer, 2008; Schneider & Artelt, 2010). The expert gradually releases the student by removing the support and scaffolding to increase the student's regulation skills and the student becomes central within the educational process.

Feedback information is necessary for an assessment to function in a formative manner and this area has undergone significant changes in understanding in the literature. The important element of feedback is the continuous flow of information to maintain the desired trajectory of the learning (Boud & Molloy, 2013). Feedback does not provide any benefit unless it can be acted upon by the receiver, namely the student (Wiliam, 2011). Feedback provides information relating to the gap in knowledge exposed by the assessment of the learning experience, but it is only considered to be feedback when it is used to alter the gap producing an observable change in behaviour (Ramaprasad, 1983). This form of feedback is aligned with the concepts of Weiner (1954) because it is more than just information

> When I communicate with another person, I impart a message to him, and when he communicates back with me he returns a related message, which contains information primarily accessible to him and not to me. When I control the actions of another person, I communicate a message to him and although this message is in the imperative mood, the technique of communication does not differ from that of a message of fact. Furthermore, if my control is to be effective I must take cognisance of any messages from him, which may indicate that the order is understood and has been obeyed.
>
> (Weiner, 1954, p. 16)

Weiner's belief that society can only be understood by the means of communication employed is also relevant to eAssessment however, it may be considered at variance with the construct of the information being about the gap (Bloom et al., 1971).

Information should not be about the gap but how to reduce it (Hattie & Timperley, 2007; Kirschner & Neelen, 2018). If the information fed back to the student provides details about how to reduce the gap it has the potential to affect future performance. Hence, it is important that the word feedback is used in the correct epistemic form to ensure that its status within the assessment process is not negated (Guasch et al., 2013; Kirschner & Neelen, 2018). Feedback should be considered chronologically as affecting future performance and not in the engineering sense of moving on a backward path; the three informative states of *Why* something is incorrect, *How* the error may be considered, and *What* may help solve the problem, are essential elements in the feedback (Shute, 2008; Torrance, 2012). The feedback process appears in a variety of manifestations (Bloom et al., 1971; Butler & Winne, 1995; Ramaprasad, 1983; Black & Wiliam, 1998; Hattie & Timperley, 2007; Shute, 2008; Black & Wiliam, 2009; Pachler et al., 2010; Bennett, 2011; Good, 2011; Torrance, 2012; Boud & Molloy, 2013; Guasch et al., 2013; Narciss et al., 2014; Hansen & Ringdal, 2018a; Kirschner & Neelen, 2018). However, within the debate surrounding its actual definition whilst remaining cognisant of the tensions present in the interpretations and definitions, Torrance (2012) concludes that there is a generally accepted commitment to the development of formative assessment as a valuable mechanism. This development moves Bloom's (1971) restrictive definition of formative assessment from curriculum goals to the pedagogic, hence encompassing not just the student but all actors in the schema.

Feedback when combined with a correctional view becomes intertwined with instruction and this combination becomes a form of new instruction (Hattie & Timperley, 2007). The process of reducing the gap is addressed by three questions (where is the learner going? where is the learner right now? and how does the learner get there?). The information provided to the student in the form of *Why*, *What*, and *How*, may be affective, cognitive or a combination. Affective feedback relates to the amount effort, performance, motivation or encouragement given to the student, usually it is short duration and specific to a point in time (Robles & Braathen, 2002). Cognitive feedback seeks to make the student engage in cognitive processes such as reconsidering an argument, restructuring an understanding or even considering an alternative strategy to solve a problem (Hattie & Timperley, 2007). The student is thus able to confirm, restructure, or negate information held in memory; the information may be cognitive, meta-cognitive, domain, or self, related. To be effective, the feedback must take place within a learning context and is sequenced to follow on from the instruction (Boud & Molloy, 2013). If the engineering model of feedback is employed then there must be at least one task, which demonstrates the learning gap and a follow up task to enable the student to demonstrate the change in behaviour. Yet, this approach is considered inefficient and lacking in epistemic integrity (Guasch et al., 2013).

The sequencing is understood and acted upon by academics, however, the student must be able to determine and understand the type of feedback received (Narciss et al., 2014). The student also needs to know what action to take when provided with diagnostic information about their performance (Boud & Molloy, 2013). For low-achievers, less-engaged students, or difficult to obtain outcomes, the process may require more than one cycle of feedback. Hence, the level of understanding by the learner as to what the feedback actually means becomes more important, otherwise the feedback cycle has the potential to negatively impact on the learning experience (Guasch et al., 2013). The process of feedback as a continuing cycle of dialogue between student and academic is fundamental to eAssessment.

If active learning is to be promoted, an alternative is required where feedback is no longer an overarching control mechanism but rather a facilitating mechanism. The role of the student moves into a central position when the student engages in active learning (Boud & Molloy, 2012, Narciss, 2014). There is an accepted perception that students entering higher education are accomplished learners – some even say elite (Faulkner et al., 2014) however, Boud & Molloy (2013, p. 705) demonstrated that this perception may be unfounded for a body of students particularly in relation to first year students.

> Students and teachers need to see feedback as a way of promoting learning through fostering active learners…feedback is… appreciating…acting…not a process that is done to students, by educators.
>
> (Boud & Molloy, 2013, p. 706)

The task of creating an active learning environment must provide consideration for space, gestures, questions, and cooperation. A major dimension within this structure is trust between all involved, to ensure that information sharing is progressed (Shank, 2017). Information sharing may be made at a level appropriate to the student and the ideal learning experience occurs when both student and academic seek answers to the same issues. The student needs to move in a continuum of learning, where the strategies for assessment for learning are tightly interwoven within the learning context, and with the learning content (Ras et al., 2015).

Aspiring towards the ideal model is good practice, however, many questions remain regarding the challenges of addressing the needs of mixed ability groups (Shank, 2017). Academics are expected to view the feedback from an individual perspective to personalise the learning experience. Effective students are expected to be autonomous, disciplined, controlled, and directed in their desire to attain their goals. Thus, it is possible to describe effective students as those who generate their own internal feedback and cognitive routines by means of self-regulation. By contrast, students may be described as less effective if they have reduced self-regulation strategies, fail to generate their own internal feedback and cognitive routines, and demonstrate high dependence on external support mechanisms such as academics for feedback. If the learning environment is not inclusive there is potential for creation of barriers for those students less able to mediate or regulate their own learning (Winne, 1982). Further evolution of these principles conducted by Shute (2008) places the onus on the academic to ensure the feedback is task-related and does not negatively impact on a student's self-esteem.

2.3.5 Metacognition within Engineering Mathematics

The language of engineering is mathematics where the conceptual and procedural domains are inextricably linked by application (Raveh et al., 2017). Understanding mathematics deeply indicates knowledge about mathematics, its relationship with like items, its relationship with different items, and how it links with other theories (Michener, 1978, p.377). Cognition describes these issues and relationships between them. Students with poor levels of cognition are not well placed to create the necessary cognitive relationships between concepts, procedures, and applications (Raveh et al., 2017).

There is a difference between knowing what to do and knowing why it is done, i.e., procedural knowledge vs. conceptual knowledge (Ní Shé et al., 2017b; Schraw, 1998; Skemp, 1976). The demarcation between the procedural and conceptual is not always obvious, depends on the number of linkages a learner may make in relation to other pieces of information connected to it, and may require iteration to establish the connection (Rittle-Johnson et al., 2015). Khiat's (2010) exploration of the literature reveals that some research does not agree with the idea that procedural proficiency in mathematics leads to greater conceptual understanding. Khiat (2010, p 1460) also laments the lack of literature on the engineering mathematics domain – the literature concentrates on the general mathematics domain. The lack of literature in the area makes it difficult to know the correct mechanisms and strategies for determining students' concerns within engineering mathematics. Understanding students' concerns requires analysis of the how perceptions manifest and are presented to students. The processes of cognition in engineering mathematics are not limited to the student base; academics make a significant contribution to the cognitive development of students.

Raveh, Trotskovsky and Sabag (2017) explored the linkages between mathematical understanding and engineering understanding in a qualitative study which revealed a gap in mathematical understanding in an undergraduate engineering programme. Engineering students were found to display knowledge of procedures and concepts but lacked knowledge of the application of mathematics. The detachment of application from procedure and concept reduces the sense a student may have of their self within the domain of engineering. Strong cognitive activity exists within a particular domain i.e., a domain that the learner understands (Veenman & Elshout, 1999). This may be regarded as where the learner is in their cognitive comfort zone. The learner will understand the principles governing a particular domain and interrelations between units of knowledge within that domain (Tall, 2008; Rittle-Johnson et al., 2015).

Procedural knowledge of rules, algorithms, procedures, symbols, and conceptual knowledge are necessary for engagement in problem-solving activities (Mayer & Wittrock, 2006). Authenticity in engineering mathematics education requires students to recognize not only the concepts and procedures required to solve a problem but also to recognize how a solution may be applied in practice (Sedelmaier & Landes, 2017; Wiley, n.d.). Without robust application of the mathematics the engineer may not be able to produce reliable and authentic solutions (Nguyen, 1998). There may be occasions where an engineer must extend outside the cognitive comfort zone. A holistic understanding is required beyond the heuristic approaches of simple procedural knowledge to engage in solution development for design problems (Nurrenbern & Pickering, 1987).

2.4 Barriers to learning in engineering mathematics

While attempting to access the student voice in higher education, there is evidence in the research literature that barriers to learning can produce a negative effect for many students. These barriers may be difficult for many students to navigate (Goto & Martin, 2009). The issue of barriers to learning has become more prevalent as the demographic composition of student types shifts to include more non-standard entry types, such as second-chance learners (Osam et al., 2017). Prediction of future behaviour by non-standard and standard entry types means that students need to be more aware of the types of barriers they will need to overcome (Boles & Whelan, 2017; Poon et al., 2014; Quaye & Harper, 2014).

Barriers or ‘difficulties’ as experienced or perceived by students are highly subjective views and reflect an incongruency between the *learner’s affective and cognitive characteristics* (Garland, 1993). The perceived barriers may vary according to cultural differences, social differences, and dispositional composition. The domains require separation to ascertain individual situational narratives to develop the life situation of students. Students' narratives are not always possible to determine within the highly prescribed learning environment of higher education, thus accessing deeply held personal knowledge is not straightforward. The manifestation of barriers forms a unique set of experiences for each student. The complexities of deeply held barrier perceptions may be masked by a façade (Garland, 1993); many barriers may be less visible to the students and not considered within the academic locus of control (Eickelmann & Vennemann, 2017).

2.4.1 Transitioning to higher education

The transition from secondary level to higher education occurs when the majority of students entering third-level are making the transition from childhood to adulthood (Van Laer & Elen, 2018). This transition can be described not only in terms of moving between phases of education but also in terms of self, such as the students' support networks (Pennington et al., 2017; Artino, 2010): transition from home to self-supporting in student accommodation; transition from peers at school to peers in higher education. Of note is transition to the model of andragogy – the teaching of adults as opposed to children - as the students become engaged in an alternative manner (Knowles et al., 2010). This may appear as a barrier where the lens is now on the students' abilities and learning independence (Van Rooij & Jansen, 2018; Pennington et al., 2017). Academic adjustment to higher education in the transition period may appear more confusing for students, who are less motivated to learn, are not sure of their academic goals, who minimise the efforts required to meet the demands of third-level, and/or are less than satisfied with the learning environment (Baker & Siryk, 1984). Possessing confidence to use skills and managing emotions are important for academic achievement (Galla & Wood, 2012, p.1145 cited in Tariq et al., 2013).

The pedagogy associated with students in their transition must accommodate the need to re-align the learners with the need to identify with the community of active learners (Wenger, 1998). A sense of non-belonging and uncertainty has potential to create barriers (Cook-Sather, 2018a). Active learners have a sense of their own learning and there is growing expectation by educational authorities that learners take greater responsibility for their own learning (Pachler et al., 2010; Wang, 2010; Gikandi et al., 2011).

Not all students enter third-level directly from secondary school and are typically described as “non-standard” (O’Sullivan et al., 2014), “non-traditional” (Eichelberger & Imler, 2016), “Adult” (Gill & O’Donoghue, 2014; Hagerdorn, 2014), “Second-chance” (Van Laer & Elen, 2018). Second-chance learners and non-standard learners are typically those who did not complete secondary school education. These students now wish to return to education due to issues such as isolation in the labour market or redetermination of personal aims. Those learners typically exist within lower socio-economic groups and dropped-out from education having had negative prior experiences leading to barriers they considered impossible to break down. Second-chance learners rarely enter higher education engineering programmes directly (Van Laer & Elen, 2018) although this statement may be refined by suggesting that it is common in Irish institutes of technology (CAO_d, 2015) if the students’ experiences and/or qualifications are acceptable.

Considering the context of transition in Ireland to higher education, the widening of access to encompass lower socio-economic groups, those with disabilities, and ethnic minority groups, as a result of government policy in Ireland (HEA, 2015; O’Reilly, 2008) is laudable. One academic perception is that it is no longer exclusively elite secondary school students who progress to higher education (Faulkner et al., 2014). It is not explicitly clear if this perception exists outside Ireland and without an accompanying definition the term ‘exclusively elite’ is ambiguous. To accommodate the required changes to the student profile entering higher education, the model of education must also be transformed to take account of the specific needs of these groups (Hagerdorn, 2014 ch.19). The move to widen access should be viewed in the context of students’ standards, i.e. the decline, on entry to higher education not just in Ireland (Faulkner et al., 2016; Kajander & Lovric, 2005). Although considered in a positive sense, there are links to the lowering of academic achievement leading to declining student progression and retention rates (Gill & O’Donoghue, 2014; Rylands & Coady, 2009). The findings of Rylands and Coady (2009) and Johnson and O’Keefe (2016) are balanced by those of other studies (Faulkner et al., 2014) where non-standard students perform at least as well as standard students.

Irrespective of entrance pathway, three quarters of students feel underprepared for university (Thomas, 2012) and feel underprepared for self-directed and unsupervised learning (Pennington et al., 2017). Preparedness and readiness for higher education is multi-faceted involving not just the learning processes (Frawley et al., 2017; Treacy & Faulkner, 2015; Faulkner et al., 2014; Conley, 2008). Expectations are also placed on the students by performance oriented higher education institutions (Ball, 2003). One such expectation is that of digital literacy and the mainstream media overhyped description of students as "digital natives" (Kirschner & De Bruyckere, 2017; Slechtova, 2015; Margaryan, Littlejohn, & Vojt, 2011; Prensky, 2001). The liminal (Van Laer & Elen, 2018; van Rooij et al., 2017a, 2017b; Pennington et al., 2017; Pampaka et al., 2016; Bowles et al., 2014; Rienties et al., 2012; Aspelmeier et al., 2012; Artino, 2010; R. W. Baker & Siryk, 1984) state of the transition may be conflated by misguided perceptions and expectations of both students and higher education professionals (Conley, 2008). The lack of integrated support by institution services compounds the confusion for all concerned (Brown & Feniser, 2018).

A smooth transition into third-level beyond standard induction (Pennington et al., 2017) is a desirable state for higher education institutions (Frawley et al., 2017; *Y1Feedback,* 2016; Conley, 2008), and may also be true for the career domain as integration within the new environment continues; non-progression rates are a cause for concern, suggesting challenges may be insurmountable for some students.

> The diverse student profile and academic preparedness of the new entrant cohort entering the institutes of technology is negatively impacting on the sector's overall progression rates
>
> (Frawley et al., 2017)

Some students may be confused when deciding which course to study as to what is meant by higher education, because the norm is for it to be based in a university. Looking outside Ireland within Europe, the United Kingdom being an exception (Scott, 2014), the higher education sector operates on a binary platform, i.e. research universities and universities of applied sciences/polytechnics/institutes of technology depending on country of study. The choice of higher education type and course may be a determining factor of success for many students. A major factor to be addressed by institutes of technology in Ireland is the requirement for all courses to demonstrate that a market exists for graduates as a result of their study (Regional Technical Colleges Act, 1992, s.5.); this stipulation does not apply to Irish universities. Therefore, retention (Johnson & O'Keeffe, 2016; van Rooij et al., 2017) is a key issue for institutes of technology to meet the demands of industry and the knowledge economy (Frawley et al., 2017 p.13; Fottrell et al., 2003). It has been suggested that issues relating retention and readiness to the higher education transition may be better addressed in secondary schools through greater preparation for students (Van Rooij & Jansen, 2018; Higgins et al., 2010). However, this approach is not agreeable to secondary school teachers and does not offer any means of support for non-traditional and second-chance students (Van Rooij & Jansen, 2018). Remediation has been deemed necessary in higher education to address the issues raised in particular domains, e.g. mathematics (O'Sullivan et al., 2014) and writing (Pajares, 2003). Irrespective of the locus of preparedness, a major factor affecting success and progression in higher education is motivation, or lack of (Baker, 2004). Any feelings of incompetence, stress, helplessness, or lack of being valued, may result in students not completing tasks or believing that outcomes of activities will not be as desired (Bandura, 1989; Dweck, 1986).

2.4.2 Higher education and technology enhanced learning

The educational pathways in higher education are somewhat different from the highly structured traditional classroom of secondary school. These pathways have been extended in higher education to include online learning, and online assessment. Some students may not have experienced Technology Enhanced Learning (TEL) prior to higher education (McCraith, 2015). TEL provides for alternative student experiences through blended learning and fully online learning.

> Blended learning is learning that happens in an instructional context [*sic*] which is characterized by a deliberate combination of online and classroom-based interventions to instigate and support learning. Learning happening in purely online or purely classroom-based instructional settings is excluded
>
> (Boelens et al., 2015)

Paramount to the overall process is the importance of the student experience, this is true today as it was when Alexander and Boud (2001) stated "*experience is the foundation of, and stimulus for, learning*". The situational context of the experience may have varied however, learning experiences are holistic, socially and culturally constructed, and influenced by the socio-emotional (Goto & Martin, 2009). TEL lies within the envelope of the learners' experiences in higher education with a subsequent expectation of students' skills in Information and Communication Technologies (ICT), Digital Literacy, Digital Citizenship and higher-order thinking (Topper, 2018). Proficiency in ICT, Digital Literacy, and Digital Citizenship, is often an assumed skillset of students (Eichelberger & Imler, 2016; Heerwegh et al., 2016) at variance with the reality of experience (Slechtova, 2015). Not all students are proficient in Digital Literacy on entry to higher education and their mastery of basic information technology skills is open to interpretation.

Students' ICT experiences in this transitional phase are heavily reliant on those garnered from secondary school. Internal factors affecting the students' beliefs play considerable roles in the students' successful integration into third level. These beliefs are subjective (negative or positive), considered "*true and important* " (Eickelmann & Vennemann, 2017) and may be highly complex in nature comprising cognitive, affective, and conative components. The evidence suggests dissonance in students' use of ICT at third level and provokes thought as to the way higher education treats ICT as an expected skillset (Eickelmann & Vennemann, 2017; Uukkivi et al., 2019).

The use of the term ICT requires clarification when associated with higher education. Apart from knowledge of the basic office suite, browsing the Internet, email and text messaging, and accessing social media, the students' ICT skillset is restricted (Henderson, Selwyn, & Aston, 2017; Kirschner & De Bruyckere, 2017; Slechtova, 2015). The digital literacy skills required to support the students' learning are not necessarily those required to engage in activities related to "*personal empowerment and entertainment*" (Kirschner & De Bruyckere, 2017, p. 136). Thus, an expectation by teachers that students have the requisite skills to engage in a meaningful manner may be misplaced (Margaryan et al., 2011;

Valtonen et al., 2011a). The subsequent 'noise' experienced by students resulting from exposure to an 'abundance' of information, media, communications tools, and domain specific tools, may overwhelm the student leading to an increase in tensions and risks to the education experience (Quinlan, 2017). The curriculum should consider the students' baggage' brought to higher education in conjunction with cognitive knowledge. The learning spaces (Marshalsey & Sclater, 2018) supporting psychosocial adjustment (Baker, 2004), TEL, affordances of the domain tools (Kirschner & De Bruyckere, 2017), and the learning environment must all be considered to minimise any detrimental effects on the learner during transition.

2.4.3 Situational Barriers in higher education

Situational barriers arise from learners' physical environment, access to learning materials, the availability of the intellectual community, peer support and the home situation. The transition to higher education creates an incongruent relationship with education for many learners (Corriveau & Bednarz, 2017). In addition to physical barriers, there is also a time barrier; course time may be underestimated in conjunction with course demands (Conley, 2008). The variable nature by which learners adjust and respond to these barriers may be related to their life experiences; determination of correct cognitive strategies is difficult in generalized situations (Eronen, Nurmi & Salmelo-Aro, 1998). Predicting future behaviour requires acknowledgement of the situational factors associated with the intended action. Academics may not apply sufficient consideration to situational barriers for students, either as students make the transition to higher education or as students encounter unfamiliar experiences, in order to accurately predict how the students will cope (Poon, Koehler & Buehler, 2014).

2.4.4 Institutional Barriers

On transition to higher education the presence of new learning methods, scheduling and pacing of courses, assessments and activities, require learners to respond and adjust their cognitive state (Conley, 2008). Institutional policies, practices, and procedures affect all learners. Changing learner demographics to include greater numbers of non-standard entry students has created additional barriers Institutions are slow to react to the needs (Osam, Bergman & Cumberland,

2017) of non-standard entry learners in the form of admissions, class scheduling, access to facilities, and learner support.

A common barrier is that of heavy assignment loading (Baker & Siryk, 1984) and associated feedback (Wiliam, 2011) being viewed as not meaningful. The weight of responsibility has moved to the student (Robles & Braathen, 2002), and there may be academic anxieties (Reyes, 1984; Jameson & Fusco, 2014; Tempel & Neumann, 2014) due to apparent lack of desirable academic characteristics or social anxieties based on fear of social interaction (Kamalou, Shaughnessy & Moscovitch, 2019) .

A major institutional barrier is the instructional design to support student learning (Phipps et al., 2018). Facilitation for writing, expression of thought, and interaction in a variety of locales depends on consistency of instruction and support. Where course content may be considered ambiguous or abstract, the learner may perceive the processes as lacking in authenticity based on learners' expectations of meaningful engagement.

2.4.5 Dispositional Barriers

Learners' disposition and motivation towards the learning environment may result from a variety of sources: desire to study (van Rooij, Jansen & van de Grift, 2017); professional aspirations (Brubaker, Shar & Sheppard, 2017); increased skillset and mastery (Dweck, 1986; Hansen & Ringdal, 2018b); achievement goals and goals orientation (Pekrun et al., 2009; Guo et al., 2015; Schunk et al., 2014). The nuances of disposition are complex and difficult to extract as individual factors. The approaches a learner takes to study, unlike learning style (Sirmaci, 2010) as contested by Kirschner (2017), and how the learner *plays the game* (Garland, 1993) of learning, are attributes related to *self* (Simon & Hastedt, 1999). Realization of the need to balance learning activities against other activities may not become visible to the learner leading to a sense being overwhelmed and poor performance in the learning domain(Baker, 2004). A lack of personal control due to the presence of extrinsic or intrinsic factors (Calder & Staw, 1975) affects self-confidence leading to a reduction in resilience (Duggan, Cowan & Cantley, 2017).

Learners with low academic achievements experience psychological barriers in the form of low ego and not having an academic sense of belonging (Pennington, Bates, Kaye & Bolam, 2017; van Rooij, Jansen & van de Grift, 2017). An incongruency in the nexus between a learner's cognitive and affective dispositions affects the learner's perceptions of the knowledge leading to a feeling of epistemological incompatibility with the course. The sense of incompatibility is particularly true for those expecting to continue gathering discrete knowledge instead of developing an understanding of the knowledge; barriers to progression quickly materialize when cognitive development of abstract concepts is expected in the form of pre-requisites for progression.

The potential to introduce dispositional barriers to learning is where academics introduce cognitively dissonant learning into the process. Cognitively dissonant learning has the potential to widen the gap between learners' expectations and those expected of the learners (Harmon-Jones et al., 2020). The appearance of cognitive dissonance in the assessment process without mediation exposes students having unsophisticated cognitive affordances, particularly those without the necessary expected pre-requisite knowledge. Barriers or 'difficulties' as experienced or perceived by students are highly subjective views and reflect an incongruency between the *learner's affective and cognitive characteristics* (Garland, 1993). In conjunction with the learners' self-efficacy as discussed in section 2.4.9, learners' implicit theories (Ackerman & Gross, 2018; Buckley, O'Connor, Seery, Hyland & Canty, 2018) have the potential to contribute to the perception of barriers. Implicit theories, i.e., the beliefs students have about their academic abilities, can lead to a wide variety of responses from students of all academic abilities. The notion of implicit theories building on the work of Dweck (1986), Bandura (1989) and Artino & Jones (2012) supports students' malleable and non-malleable beliefs, each of which may lead the student to perceive barriers to progress (Savoji, Niusha & Boreiri, 2013). The benefits intended by the dialogue, or communication process, between academics and students may be attenuated if students receive information in a non-supporting manner (Carless & Boud, 2018).

2.4.6 Perceptions within mathematics

Mathematics is an essential discipline for all engineers (Nguyen, 1998) to support comprehension and problem solving skills (Alves et al., 2016) to aid the analysis of problems and reach a solution. Perceptions about the role of mathematics shape the students' career choices (Gould, 2012) and the resultant attitude towards mathematics is a construct that determines how students may react in certain contexts (Hodges & Kim, 2013). If the student does not understand the role played by mathematics in their engineering career this may have negative outcomes. The issue of perception of mathematics in first year of study at third level is conflated by the students' preparation for higher education and the failure of schools to adequately prepare students for third level Treacy, Faulkner and Prendergast (2016) report that many students perceive a significant leap in teaching and learning as the students move to third level; there is a note of optimism in that non-standard students appear to improve their mathematical performances – more so than standard students. It is suggested that non-standard students' use of prior knowledge enables them to develop efficient coping strategies (Sanchiz et al., 2017). The improvement in mathematical performances is in contrast to earlier suggestions that the widening of access to include non-standard students increased the incidence of lower attainment in mathematics for undergraduates (Faulkner et al., 2010, 2014). A degree of caution is required regarding the levels of attainment due to a further decline in mathematics ability (Treacy & Faulkner, 2015b; Treacy et al., 2016; Prendergast et al., 2017; *Sustainable Development in the European Union*, 2017).

Students' perceptions are not the sole issue to be considered, Academics also have perceptions of the issues surrounding students (Ní Shé et al., 2017b). One such perception is the lack of enthusiasm by students to visit the library or seek textbooks whilst perceiving those students prefer to access lecturers' self-developed digital resources. The perception that students are "digital natives" is held by many lecturers in contrast with the findings in the literature (Kirschner & De Bruyckere, 2017). Evidence exists to show that students are not aware of most online support sites, supporting the evidence that students are not as digitally aware as many academics believe (Ní Shé et al., 2017b). Cultural subjective norms in secondary education conflated by media hype may be responsible for the conflicting beliefs and perceptions of TEL awareness prior to higher education. Understanding the role of perceptions requires analysis of the how perceptions manifest and are presented to students and academics.

2.4.7 Confidence within Engineering Mathematics

Confidence is considered to be an important construct of metacognitive experiences where feelings and judgements have a role in task knowledge, such as assessment (Efklides, 2006, 2008, 2011). Closely related to self-regulatory processes during learning, students' confidence beliefs affect their ability to produce a specific outcome (Flavell, 1979; Jiang & Kleitman, 2015).

The inference of confidence is open to interpretation and although related to self-efficacy, confidence does not define self-efficacy. Research conducted of first year undergraduate students revealed confidence is not necessarily matched by performance, and that students are not able to adequately explain their mismatched levels of confidence (Cleary et al., 2010). The mismatch between confidence and performance raises questions relating to the students' mathematical literacy and an observed lack of persistence in relation to challenging questions. A general study of academic success factors amongst first year university undergraduates found that academic adjustment was an important factor to consider when measuring how well a student engaged and performed (van Rooij, Jansen & van de Grift, 2017). Eichelberger and Imler (2016) found that traditional students are more confident in their technology skills than non-traditional but the levels of confidence were not matched in test scores. In the same study, it was discovered that the most problematic student group is traditional, over-confident, and unconcerned by lack of skills. These students realize too late that they lack the requisite skills to complete assignments on time (Eichelberger & Imler, 2016, p. 477).

2.4.8 Anxiety within Engineering Mathematics

Placing the onus on the student to be an active learner is especially true where online technology is concerned and raises the question as to whether academics have knowledge that the requirements of teaching facilitation and learning promotion are being met (Robles & Braathen, 2002). Academics' knowledge about students may be derogated in the quest for maximizing delivery potential, further increasing the role of negative, anxious, metacognitive experiences in students (Flavell, 1979; Schneider & Artelt, 2010). The construct of anxiety is defined as *evoking anxious or emotional reactions when performing a particular behavior* (Venkatesh, Morris, Davis, & Davis, 2003, p. 432). This construct can relate to any domain, including mathematics, and evidence points to a negative effect on test performance (Tempel & Neumann, 2014). Specific test scores may comprise multiple impairment sources and that examiners should be aware of such impairments; students experiencing stereotypical, or trait anxieties may display their anxieties in singular or complex modes.

Engineering mathematics assessments may be designed for written, or eAssessment modes; anxieties in the assessment process may be affected by domain identification (Peetsma & van der Veen, 2011; Sirejacob, Chenevotot-Quentin & Grugeon-Allys, 2017), mathematics anxiety (Bai et al., 2009; Jameson & Fusco, 2014; Alves et al., 2016; Maloney & Retanal, 2020), computer anxiety – within e-assessment (Bai, Wang, Pan & Frey, 2009; Cazan, Cocorada & Maican, 2016), test anxiety (Tempel & Neumann, 2014), and stereotype threat (Tempel & Neumann, 2014). The relationships between anxiety types are complex and may be moderated or augmented by students' dispositional factors (Garland, 1993).

The process of determination of an individual's learned in an academic setting is evidenced in the learner's behaviour capabilities. The actions of the assessor in the inference of learning cannot produce an absolute determination that the gap between learned capacity and behavioural evidence has been completely closed (Dearden, 1979). The resultant subjectivity of the process may be considered a source of tension and anxiety for the learner. Prejudice in academic judgements based on historical distributions, and their use in pre-determining success (Faulkner, Hannigan & Fitzmaurice, 2014), introduces fallacies (Dearden, 1979), which may result in false assumptions of learning. Students encountering such practices may have their sense of loss or injustice further reinforced leading to more deeply embedded feelings of anxiety.

2.4.9 Self-efficacy

Self-efficacy is a determining factor for the amount of effort and persistence that students will use when engaging with tasks (Bandura, 1977). A major component of metacognition (Bergmark & Kostenius, 2018; Cook-Sather, 2018a, 2020b; J. K. Butler et al., 2017; Boud & Molloy, 2013; Kusurkar et al., 2012; Kirschner & van Merrienboer, 2008; Cook-Sather, 2006; Flavell, 2004; A. Brown, 1987; Flavell, 1979; Bandura, 1977), self-efficacy belief determines how effectively a student will function to achieve desired levels of mastery (Artino, 2012).

The most powerful enactor of self-efficacy is the authentic mastery experience because it provides firm evidence that the student is capable of succeeding (Artino, 2012; Klinger, 2011b). Such mastery experiences should not be singular events but sustained to ensure the raised level of self-efficacy is established as a robust state. In interpreting their authentic mastery experiences, students can develop beliefs about their capability to perform in subsequent tasks; if self-efficacy is to grow, the success should not be viewed as easy. Social interaction and observation via vicarious experiences are known to promote growth of self-efficacy – conversely the vicarious experience may also negate the growth (Thomas, Herbert and Teras, 2014; Smith, 2013). Such experiences suggest trait-based outcomes and can be quickly lowered by failure.

Information, in an educational sense, is a major factor affecting self-efficacy, however if used on its own it only offers limited power in creating a robust sense of self-efficacy. Information in the form of feedback (section 2.3.4) is the most common form in higher education and it should be relevant, persuasive, evaluative and force students to think to be effective (Black & Wiliam, 1998). Students view academic staff as knowledgeable and reliable and if information received does not match this view this may negatively affect the students' own self-efficacy.

Self-reflection, or self-referent thinking, occurs when students evaluate and modify their thoughts and behaviours; this includes perceptions of self-efficacy. A student's perseverance is correlated with self-efficacy. A student with low self-efficacy will perceive tasks as being more difficult leading to a sense of failure and despair (Pajares, 1996). When considering the mediating factors shown to affect students' self-efficacy in higher education it is important to remain cognizant of the performativist model promoted by higher education and the tensions associated with designing a constructivist intervention within that environment (Ball, 2003). Subjective norms, of culture and self-efficacy, affect enjoyment and anxiety levels within higher education institutions; higher education institutions need to address these subjective norms to move students to higher levels of expectation. An intervention considered outside the social norm may negatively impact students' self-efficacy and so reduce the desired learning experience, therefore the pedagogical design must be sound and be aware of mastery, vicarious experiences, information flow and physiology/psychology (Abdullah & Ward, 2016; Ní Shé et al., 2017).

Self-efficacy is known to heavily influence motivation and cognition through the media of affectance of task interest, goals, and choices, and cognitive, metacognitive, and self-regulatory strategies. The self-efficacy of the student is a key mediating factor of human agency between determinants of competence (Lent et al., 1994). It is considered that the main sources of information that lead to a student's self-efficacy are: mastery experiences; vicarious experiences; information; physiological and psychological states (Schunk & Parajes, 2001; van Dinther et al., 2011). Duggan, Cowan and Cantley (2017) suggest that if students care about what they are learning and have belief their efforts will pay off whilst envisioning themselves on the correct path, they are more likely to demonstrate resilience. Such descriptions are appropriate for high-achievers; however, the authors do not address issues relating to low-to-medium achievers.

The multi-faceted construct of self-efficacy means that cognitive appraisals do not take place in isolation. A student will weigh and combine the contributions by the various factors such as difficulty of the task, what peers say, previous successes, and support required. The cultural aspects of the student and the learning environment may also play a role; the influences of culture may be collective or individual in nature (Schunk & Parajes, 2001). With all these factors influencing students' self-efficacy, it should be apparent that higher education establishments, in their endeavour to motivate and support, must consider self-efficacy as a competency to be developed. Thus, it is possible to influence students' self-efficacy within a higher education environment by means of appropriate intervention and design of the curriculum in the form of authenticity and relevance of instruction (Mitchell & McMillan, 2018).

Physiological, emotional and mood states, such as anxiety, stress, or illness can all be interpreted as signs of failure. A positive mood can enhance a person's self-efficacy, whereas a negative mood has the potential to dramatically reduce self-efficacy; a student may see anxiety as a weakness. Reduced self-efficacy beliefs affect the sense of belonging within a community and may result in a desire to leave the community (Ni Shuilleabhain et al., 2016). Major issues in engineering programmes are retention (Faulkner, Lane & Smith, 2016) and lack of belonging in the engineering domain (Duggan, Cowan & Cantley, 2017; Otel, Lungu & Costin, 2018). Retention and belonging are associated with self-efficacy, i.e. the cognitive judgement control of one's capacity to organize and execute given types of performance (Bandura, 1977, p. 194).

2.4.10 Motivation

Motivation depends on students' driving forces, or innate properties, developed through personal experiences, manifesting in the autonomous traits of students (Schunk et al., 2014). The students' cognitive state affects behaviours, motivational beliefs, and perceptions. When a student comments on the difficulty of a task, the comment reflects perceptions held based on a complex myriad of social, personal, and academic, concerns, and aspirations.

Motivational theories concentrating on the management of human capital (Vroom & Deci, 1992) based on functional perspectives do not explain why humans place values on their goals. As with Vroom and Deci's theories (1992), Weiner's (2010) approach focused on an algorithmic approach where it is believed that the greatest students' pride is achieved through success in the most difficult tasks. The algorithmic approach is considered important for motivating employees in the workplace, however in higher education this approach suggests commoditization of learning. The heterogenous nature of society makes it difficult to apply an algorithm to perception because perception cannot be quantified (Romdenh-Romluc, 2011). The expectation that an action will lead to a beneficial outcome moves motivational theory beyond function to the cognitive as seen in the theories of self-efficacy (Bandura, 1977). Therefore, motivation in educational terms is not a product of learning; motivation is a process in learning. Measurement of motivation is an indirect process and cannot be described as a product.

Expectancy-value theory is based on the relationships between effort, performance, outcome and result (Lunenburg, 2011; Vroom & Deci, 1992) and may be affected by: Self-efficacy; Goal difficulty; Perceived control. This theory is directly applicable to teaching where the teachers' expectations can influence the achievements of the learners. Teachers may establish different expectations for different students and treat those students accordingly. Educational theories of expectancy-value provide evidence that difficult assessments provide more information about the task than about the student (Schunk, Meece & Pintrich, 2014) yet the majority of the literature focuses on high goal appraisal (Guo et al., 2015; Lehman, D'Mello & Graesser, 2012; Pekrun, Elliot & Maier, 2009).

To achieve a level of expertise within a particular domain, such as engineering mathematics, the student must, be motivated and, have the cognitive skills necessary and, have certain metacognitive ability (Kirschner & van Merrienboer, 2008; Kusurkar et al., 2012). Motivation is an important factor in relation to metacognitive awareness when solving problems. A highly motivated and efficient learner will employ strategies appropriate to the problem in terms of quality and quantity (Lunenburg, 2011). A less motivated and inefficient learner will suffer from levels of dissociation determined by the context, e.g., being forced to study a subject to satisfy a parental desire. Students may have the ability and demonstrate this through excellence in tests but not have the motivation or lack ability but feel highly motivated because of false praise.

2.5 Summary and Knowledge Gap

This chapter sets out a review of the literature about student voice, metacognition and students voice, barriers to learning in engineering mathematics, eAssessment as a medium for student voice, the engineering mathematics context, and actions and beliefs of academics to support student voice. The aim of the chapter is to establish the available literature about the role of student voice and academic voice within the locale of engineering mathematics for first year students. The extant situation of mathematics education in Ireland was outlined to provide context for the research and to describe the issues faced by academics and students. Irish mathematics education issues were described in a global context using a sample of countries to provide an overall viewpoint.

On completion of this review stage, several knowledge gaps arise. First, the transition process to third-level engineering education is a complex determinating factor for success; Motivational factors are not fully understood by practitioners in the transition to third level. Tensions are evident regarding responsibility for the perceptions of students, and the motivation for student success particularly with the increase in non-standard entry students. The current state of Irish higher education is best described as in flux with confusion surrounding how best to address the needs of the modern student. Research in this area in the Irish context is limited and this is identified as a considerable knowledge gap to be addressed.

Second, the skills and competencies of students in a post-digital age are misrepresented by the consensus of the academic cohort through misguided perceptions of ICT ability, barriers, preparation for eAssessment and digital literacy. Facilitation of learning processes and products has introduced a broken link in teacher presence as experienced by students. The nexus of academic facilitation and students' ICT literacy introduces tensions in the process causing confusion, anxiety, and disproportionate responses at all levels with potential to affect students' self-efficacy and subsequent motivation.

Third, dialogue in assessment and e-assessment is treated as a mechanical component within feedback by academics, in which the dialogue may be reduced to the simple provision of a grade or short comment. Students require more than mechanical feedback if they are to fully understand the processes of learning and assessment. Academics' knowledge of students' expectations, the values the students place on tasks, the rewards gained, and effort required to gain those rewards, does not take place when teachers' actions and ideas are imposed on the student. Raising the communication between teacher and student to a meta-dialogue removes the mechanical aspects of the dialogue and provides both parties with an opportunity to better understand; meta-dialogue offers an opportunity to better infer the students' knowledge.

As far as the author is aware, most extant literature on mathematics at third level focuses on university students where motivational and psychographic factors are concerned, and not those entering institutes of technology or the equivalent. How the learning space may be activated to provide agency for the students' voice in the context of an institute of technology remains unanswered within the literature.

Chapter 3 – PHILOSOPHY, METHODOLOGY AND METHODS

Part A-Research Philosophy

This chapter describes the development of the research philosophy beginning with the reasons for selecting the core study approach. The theoretical underpinnings of the research design are considered and argued to provide a sound basis for the design of the research methodology and methods used. Meta-theoretical, ontological, and epistemological philosophical considerations are described, and the relationships between the layers are discussed. Theoretically framed within critical realism, phenomena of perception are brought to the fore within the dialogue between researcher and participants whilst maintaining the premise that students are not *objects* in a learning hierarchy (Taylor & Robinson, 2009, p. 165). The philosophical relationships are discussed in the first part of the chapter as the foundation for the research methodology.

3.1 Introduction

The determination of phenomena of perceptions within a natural sciences/empirical setting prompts thought as to how the perceptions should be articulated within the study. Difficulty lies in the determination of an appropriate approach within which it may be possible to analyse the perceptions of engineering students and lecturers; the philosophical debates relating to determination of seemingly irrational properties create tensions with the empirical world of natural science.

The underpinning philosophy of perception initially led me to engage in the research without first considering a hypothesis or an initial theory (Garrison & Macmillan, 1984; Ball, 1995). The theory-driven research approach described by Ball and Garrison & Macmillan is described by Gage (2009, p. 41) as the 'Prior-Theory-is-Indispensable Position' in the Galilean sense. Gage (2009, p. 42) offers an alternative position in the form of the 'Prior-Theory-is-Not-Indispensable Position' where the establishment of prior theory is not considered necessary, allowing for 'serendipity' within research. As a practicing engineering lecturer with industrial experience, I as the researcher am aware of the Galilean, empirical, tensions associated with a hypothesis-less study in the engineering domain. The initial underlying philosophy of perception within this research is therefore described as implicit and is not a Prior-Theory approach because it had not been explicitly formulated - opening the door to criticism from the empirical viewpoint in the early stages of this research study.

My personal philosophy is that a theory whether explicit or implicit is necessary to underpin any research study (Trafford & Leshem, 2008; Cohen et al., 2011; Bryman, 2016). The conceptual framework offered by socio-cognitive research is closely aligned to my own personal beliefs that learning does not occur in a vacuum and is a social event (Wenger, 1998). The observed phenomena of students prior to the research suggests an implicit theory involving rhetorical statements, and the discursive manner with which the statements are made, have meaning (Cohen et al., 2011; Braun & Clarke, 2013; Bryman, 2016).

3.1.1 Researcher's Role

The researcher occupies a pivotal position within the design and operationalization of the research study. The role of the researcher in the design of research instruments, the researcher's personal philosophical understandings, methodological beliefs, personal biases, moral and ethical values, and prejudices, all have the potential to affect the way the deeply held beliefs and perspectives of the participants are reported and analysed. Bias may be introduced at any stage in the research process; intentionally, insidiously, unintentionally, or sub-consciously. The threat posed by the researcher is addressed within the ethical application of the study. The action of the research and researcher is guided to a large extent by Kantian principles (Gaudet & Robert, 2018; Romdenh-Romluc, 2011) where human dignity is a moral absolute; the participants must be respected, free and informed with the right to anonymity, without fear of prejudice.

Qualitative research procedures may suffer researcher bias because the researcher is an instrument within the qualitative data gathering exercise. However, the researcher is also instrumental within the quantitative process with potential for bias. It is not possible to separate the researcher from the research process within the mixed methods model hence, the critical realist location of the ontology. Each person in the process may view or experience objects differently due to the location of their perception. The social construction of the knowledge allows a level of abstraction to be achieved allowing knowledge to be drawn from it (Bhaskar, 1998).

Reflexivity, ensuring transparency, at all stages in the process is not always easy, however situating the personal viewpoint of the researcher may allow others to achieve a greater understanding of the research, protocols, philosophies and analysis (Bourdieu, 2004). My personal role as an engineering lecturer and my location within the sphere of engineering is not the result of a linear education process. I excelled at mathematics and physics at secondary school but completely failed at the first A-level attempt; I was more interested in punk rock music because it was an alternative to the *Troubles* in Northern Ireland and as the first person in my family to study A-level I did not know what A-levels entailed. Subsequent reflection led to success at A-level at the next sitting and my pathway to engineering through Higher National Diploma. Enjoyment of systems and not just electronics led me to follow control systems through to honours degree equivalent and finally to master's degree. My industrial experience was in industrial project research and design in the garment industry. I enjoyed the application of control systems, statistical measurement, validation of machine designs, and training mechanics in the art of electronic fault finding. In parallel I consulted on industrial economic issues to the European Economic Council and managed several national and European research projects involving technology. During the delivery of training courses, I quickly became aware of the need to focus on the explicit needs of the trainee rather than what I thought they needed. Reflecting on the training course pedagogy, I struggled to understand why mathematics lecturers in engineering made the programmes so tough at times but provided little support to students. On entering my post as a lecturer in 1997 I had no knowledge of the Irish mathematics curriculum at second level; I naively believed the mathematics curriculum was the same as in Northern Ireland as in Republic of Ireland. Lecturing commitments were in the areas of computer electronics, computer systems, computer networking and programming for the first ten years until illness forced me to convalesce for six months. On return, I was asked to teach first year mathematics and engineering science because the subjects were major stumbling blocks in relation to retention. I examined the pedagogy in the two subjects and found them deficient in formative and summative assessment and addressed the problems – not without resistance.

My personal (individual) reflexive trajectory (Maton, 2003) - and hopefully not a narcissistic reflective approach - determines the need to maintain an open mind with regard to the first-year experience and to nurture the fragile student whilst establishing higher expectations for the more capable student. The personal voyage of discovery in this research has been enriched by publication of some of the research and the ensuing detailed pedagogical discourses with other academics. I have embarked on this journey with an open mind in as rigorous, fair, and honest manner as possible to better understand the students, and to use the results to improve the pedagogical model of engineering mathematics assessment. In doing so, I hope that students will grow to feel that engineering is an excellent career choice or that the students will accept their educational life lessons in a positive light.

3.2 Ontological and Epistemological Assumptions

The philosophical context of the importance of being raises the need to consider the epistemology (Bryman, 2016), and the ontology (Stahl, 2007a), of the research methodology (Braun & Clarke, 2013, p. 31) in conjunction with the ethical (Stahl, 2007a, p. 145) considerations of the research.

3.2.1 Ontological Assumptions

The relationship between the reality of interaction and the world and human interpretations and practices is described by the ontology (Braun & Clarke, 2013, p. 27). In essence, the question addressed by the ontology is whether the social reality is external to the social actors or something that people are in the process of creating (Cohen et al., 2011; Braun & Clarke, 2013; Bryman, 2016). To address this question it is necessary to consider the position of the study within the ontology continuum in relation to the perspective taken in this study, and the many variations between relativism and realism (Braun & Clarke, 2013, p. 26).

The philosophy of relativism holds that it is not possible to determine a single accessible thing that constitutes the meaning of a word (Cohen et al., 2011); reality is totally dependent on human interpretation and knowledge (Braun & Clarke, 2013). The opposite end of the continuum is described by the philosophy of realism, or the world as it is known. Realism assumes that objects exist independently and are not dependent on the person (Cohen et al., 2011). The absolute position is of a single truth (Braun & Clarke, 2013, p. 27) which may be understood through research.

The absolute of realism does not sit well within this research due to the temporal nature of the perceptions of students. If a single truth describes the knowledge, it is difficult to envision how perception can be malleable within the continuum of time. The absolute of relativism poses difficulty in that perceptions vary between actors in the study and so it is not possible to determine knowledge with absolute assuredness (Cromby & Nightingale, 1999 cited in Braun & Clarke, 2013, p. 27).

The nature of the research suggests that a less absolutist determination of the ontology is required to gain insight of the subjective, temporal, and socially variable knowledge. A philosophy permitting the necessary insight is critical realism, where it is acceptable to explore and describe a reality in which the research only gains partial access (Braun & Clarke, 2013).

The theory of reality, or being, is inextricably linked with the subsequent supporting doctrine, namely whether the doctrine is positivist or non-positivist (Stahl, 2007b). It is a necessity for the researcher to understand how the ontological doctrine aligns with the research epistemology and methodology, with associated ethical affordance. The positivist/non-positivist debate has potential to generate confusion and contradiction (Stahl, 2007b), however the location of the doctrine for the researcher is critical in the formation of the discourse; the resultant discourse *must be believable*.

3.2.2 Epistemological Assumptions

Stahl questions the philosophical syncretism of the critical realism-interpretivist nexus (2007b, p. 128) by arguing the case for mutual exclusivity between positivism and interpretivism, hence introducing difficulty for those wishing to mix ontologies. The logic of the argument is strong and cannot be ignored if interpretivism is only considered as an ontology; an epistemological position may be considered where critical realism is adopted as a meta-theory. The dichotomy of positivism -interpretivism is overcome in the epistemological sense (Braun & Clarke, 2013, p. 31) and allows the critical realist (Sorrell, 2018) to support quantitative and qualitative methods within the overall methodology in an ontologically and epistemologically sound design. The philosophical levels are defined within the syncretism and help to explain one another. The resultant implications for the research design are that empirical evidence may be gathered – not necessarily in an empiricist manner (Bryman, 2016, p. 20) – using several methods, and combined to determine an explanation, description or interpretation, of a particular social event or generative mechanism.

Access to generative mechanisms is not always achievable making the stratified layers within the social setting difficult to measure. Actors do not always have full knowledge of the generative mechanisms (Walsh & Evans, 2014) and knowledge of them is constructed as phenomena are uncovered. Thus, different actors observe and react to the same experience in different ways. A problem with accessing perceptions is that perceptions are not real, they do not have material possession but are constructed internally. In this sense, critical realism as an epistemology for the determination of perception in assessment of engineering mathematics may be located in the same frame as engineering ethics (Martin, 2020) where individual social practices cannot be studied in isolation.

3.2.3 Critical Realism

Critical realism as a philosophy is situated on the ontology continuum (Braun & Clarke, 2013) as a reflection on the premise that it is only possible to partially access a separate reality. The model adopted is based on the seminal works by Bhaskar (A Realist Theory of Science, 1975, cited in Archer et al., 1998) and claims to combine realism and relativism within a single philosophical envelope. The most important component within the philosophy of critical realism is that support for a *realist conception of science* is not dependent upon any implicit or explicit empirical assessment. The metaphysical nature of critical realism removes restrictions on location of the argument; social activities, agents, and actors, may be historically transient. The resultant philosophical conceptions may therefore lead to ontologically realist and epistemologically relativist conclusions; intransitive abstractions such as perception may now be explained.

Bhaskar (1998, p. 24) explores the meaning of perception and how it is in the form of independent occurrence of objects that the significance of perception may be located. The location of perception is central within this study as an intransitive object experienced by more than one person; each may view the object differently. It is in the movement between the discourse of perception to a more concrete abstraction that individuals may have to draw upon knowledge outside of the sphere of their initial perception (Sayer, 1998). The historically transient nature of critical realism offers support for variation in the typology, or dependencies, without affecting the logical tautology (Bhaskar, 1998).

Society, the interaction of those in society, the context of those in society, and individual self-determination, is poorly accounted for if individuals are described in solipsistic terms (Scott, 2005, p. 634). The individual is not described simply in terms of absolute quanta, or the sole quality of the individual as described by the naïve realistic or radical relativism, a middle ground is suggested in the form of critical realism.

A fundamental issue in my personal philosophy is that data must be authentic, and the truth of any statement or analysis must be considered a priority; this does not eliminate the genuine attempt by an individual to provide comment, even if the comment is not wholly truthful but limited by their experiences. The implied theory of critical realism although unknown to me as the researcher in the initial stages has become explicit; my own truth has become more visible. Reflecting on internal critique and the values placed on my research (Robinson, 2018), and updating knowledge in a looping manner (Hacking, 1999, p. 34) within the terms of reference of the study, allows modification to take place as new knowledge becomes available (the individual is always one step behind). Continual changes in society and our relationships endure because of historical understanding, only if acknowledgement is made of the temporal nature of such relationships. We may only make approximations and generalizations based on descriptions and explanations.

Critical realism philosophy lies on the relativism-realism continuum and exposes weaknesses in the absolute elements of the continuum to explain the *world* and the role of the *individual* in society. The absolutes of naïve realism or radical relativism are addressed by Pring (2000) as he develops an argument for their position in social science research. Vagueness of the language used by Pring is exposed by Scott's (2005, p. 639) critique and deconstruction of Pring's arguments, thus weakening the strength of the arguments. The decision by Pring to concentrate on comparison of only one form of extreme relativism with another form of extreme realism further weakens the argument. Social beliefs and interactions do not merely exist as epiphenomenal activities (Scott, 2005, p. 640); the interactions cannot simply be explained by self, other dimensions of social action also affect the experience. Separation of structure to the quantitative, and agency to the qualitative, without consideration for interwoven linkages is inappropriate. I argue that the two cannot be separated in this study, the nature of being supporting existence is affected by thought and unthought aspects of life (Romdenh-Romluc, 2011),and a methodology supporting critical realism must be adopted. The ontological and epistemological relationships are therefore dependent on historical settings and understandings of the world. The role of critical realism allows me to

> …prioritise social actors' descriptions of their experiences, projects and desires.
>
> (Scott, 2005, p. 644)

Quantitative reduction does not adequately describe the reification of society and social learning; the complete *histoire* of social learning cannot be fully understood through quantitative means alone. This is not an argument to say that the use of qualitative methodologies will lead to the sole truth, it is merely stating the ineffective application of a closed methodology within this setting.

The interplay of epistemology and ontology is crucial to the philosophical underpinning of a combined methodology involving qualitative and quantitative methods; the determination of a firm meta-theoretical explanation of the social world of engineering education is required. The transitory nature of society is captured within critical realism to account for *fallibility* and allow for adaption as society reveals new truths (Sayer, 1998, p. 134).

This research study seeks to understand the mis-framing of the student voice in the assessment of engineering mathematics. The process of understanding requires a framework providing value to the student voice beyond the empirical as the student constructs knowledge. Critical realism is described as a *both-and approach* (Danermark, 2003) involving realism and constructivism providing the necessary framework. The retroductive nature of critical realism permits the researcher to make inferences as students construct their versions of truth as *truth-like* (Danermark, 2003 Table 1), providing an emancipatory agency for the student voice (Haigh et al., 2019; Mingers, 2014; DeForge & Shaw, 2012). Of interest in the study are phenomena surrounding the generative mechanisms (Walsh & Evans, 2014) or social structures affecting students and academics. The axiology of critical realism lies in the exposure of new knowledge, raising self-awareness and self-consciousness, with potential to promote greater agency for the student voice.

3.2.3.1 Critical realism and the social context within engineering education

Critical realism as a meta-theory, framed within an ontology and epistemology, provides access to the strata of realities within open systems, where different accounts of activities may be posited to substantiate claims (Bhaskar & Lawson, 1998). It is argued that the external world, historical and social aspects all have validity in three ontological dimensions: the experiential, the independent and the generative (Danermark, 2003). The generative dimension is not always observable or realizable, it may originally be fuzzy or opaque and become more focused or visible (Behari-Leak, 2017; Blom & Morén, 2011). The independent dimension describes where reality exists independently of our knowledge of it. The experiential dimension describes where the world is experienced through experience of structures, culture, and agency (Behari-Leak, 2017, p. 488). The stratified ontological dimensions representing reality exist beyond the observable and are hierarchical. However, each level does not depend on the level below because each level has its own generative mechanisms.

eAssessment processes in engineering mathematics may be observed and experienced by all actors, however the third dimension of the real, generative, is where the *intangible* through *structure, culture and agency*, is situated (Wynn & Williams, 2012). Intangible factors include higher education structures such as institution, faculty, departments, national policies, professional bodies, and institutional committees. Additional, and no less hierarchical factors include social or cultural systems, where values and beliefs reside. Learning and teaching contextuality (Restad, 2019) is determined by the agency provided by the factors and is manifest in the cognitive properties of the actor (Sharar, 2018). Addressing the hierarchical levels and the social needs of students and academics situates assessment in a wider social context. Martin (2020) identifies the *failure to integrate the different levels into models for change* as an issue that has not been addressed in engineering education.

3.2.3.2 Abstraction and retroduction in critical realism

The search for a determination of the perceptions between students and academics is the target for this research. A difficulty with social systems is their open nature and lack of controlled conditions (Martin, 2020; Sayer, 1998). Inference of these perceptions is by means of narratives, and retroduction. The outcomes of the perceptions depend on the abstract nature of the mechanisms and contexts, requiring narratives to explore them within appropriate conceptual frameworks. The subsequent interpretation of the narratives provide a pathway to the determination of phenomena linking the empirical and real dimensions of the experienced reality (Danermark, 2003). The process of retroduction is the analysis of the narrative to identify a factor responsible for it, that helped produce it, or at least facilitated it (Bhaskar, 1998, p. 156). The sequences, or patterns, allow sense to be made of the wider context of the narrative abstraction where a retroductive mode of inference is required to form an argument (Danermark, 2003).

The focus of the argument relocates to a more holistic understanding of the perceptions of students and academics (Danermark, 2019). Relocation of the argument to the holistic requires access to structures, mechanisms, and contexts to produce an inferential outcome. The argument is situated within the social, political, historical, and value systems of the learning environment allowing critical realism to provide a gateway to a holistic determination. Truth, within the context of this study, is limited to the understanding and lived experiences of the students and academics and doesn't attempt to impose a sense that the world is understood in its entirety (Scott, 2005). Critical realism accepts the fallibility of human knowledge; this study seeks not to generalize, model, or validate laws, rather it seeks a deeper understanding.

3.2.3.3 Model of critical realism in this research

The ontological model of critical realism within this research contains three domain layers: real, actual, and empirical. It is necessary to identify the characteristics and actors present in each domain to support the analysis and interpretation of the relationships. The real domain encompasses the actual and empirical domains, and describes the generative mechanisms associated with policies affecting assessment at the individual, institutional and meta levels. The meta level in this sense is used to incorporate national, professional body and international policies for assessment. The actual domain describes individual, institutional, and meta level engagement with eAssessment. The innermost empirical describes the beliefs/values, understanding and attitudes of the individual, institutional and meta level actors towards eAssessment. The task of developing a truth-like and meaningful dialogue requires an appropriate supporting mechanism or system of mechanisms to allow inferences to be made.

3.2.4 Phenomenology

The philosophy of phenomenology offers the potential for depth within the study to explore narratives. The work of Edmund Husserl in his study of the philosophy of phenomenology led Husserl to consider the world as we experience it, or *Lebenswelt* (lived world) (Romdenh-Romluc, 2011, p. 12). The tensions between Galilean science and the non-naturalistic (transcendental) subjective require a modified philosophy to allow social experiences to be considered empirically. A rigor must be established through description which is acceptable to the empirical as well as the phenomenological.

The construction of viewpoints and considered opinion to develop an ontological status and its relation to the world – in this case the world of engineering mathematics – requires that *The world is inseparable from the subject …* (cited in Romdenh-Romluc, 2011, p. 104). Merleau-Ponty develops the work of Husserl to describe the lived, or experienced, world as a process of interactions through which *perceived things take shape or are constituted* (Romdenh-Romluc, 2011, p. 108). Merleau-Ponty considers the initial qualities of perception to be fuzzy and dependent on the habitual way the subject interacts; the quality of perception is not homogenous due to the heterogenous way society and culture affect how different experiences are perceived.

A person's awareness of the world is determined by the *pull* (Romdenh-Romluc, 2011, p. 127) experienced. The tension created by the pull is intangible and is the activity that allows the person to become aware of certain properties or indeed become aware of a perception. The pull describes the indeterminate sense a person may have but they cannot yet *put their finger on it*. The degree by which a person experiences the pull is unique to the person, as is the depth to which something is experienced by a person. Such activities do not occur in isolation due to the presence of other objects and humans, and concepts such as culture, society, and profession. The perception of something is affected by the context in which it is perceived and where engagement occurs with the world. Perceptions are expressed through meaningful thought from which others may better understand the process of sharing of life's experiences. Meaningful thought, or self-knowledge, is based on awareness of self, however it may not always be possible to establish the correct words to accurately describe this self-knowledge. Self-knowledge is subject to personal bias and as such cannot be employed indubitably. When such experiences are shared with others it is a requirement that the experiences be perceived as being qualitatively the same; with potential for reduction in the personal bias (Pronin, 2007).

The shaping or construction of a perception occurs within a temporal continuum, rather than a series of instants, where the past is *known* in an explicit sense and the future is implied through experience. This relationship between the temporal space and constructed ontology of the world determines how the person will perceive sense, interactions, and phenomena, with the world.

Phenomenology is the science of pure phenomena developed by Edmond Husserl as a means of exploring experience (Smith et al., 2009; Cohen et al., 2011; Bryman, 2016; Gaudet & Robert, 2018). This approach by Husserl was viewed as subversive and was heavily criticised because positivist logic was the accepted guiding philosophical layer for natural and social science studies (Gaudet & Robert, 2018). Experience is a subjective component of human nature requiring sensitivity as the researcher teases out a person's understanding of the experience (Gaudet & Robert, 2018; Cohen et al., 2011; Smith et al., 2009); I consider the potential for access to a rich seam of human realities as a driver for engagement in a phenomenological study.

The science of phenomenology is not without its critics. Cohen et al. criticize phenomenology due to the fallibility of experience and that objectivity may be lost (2011, p. 21). The perceptions, feelings, and understandings of the subject may be misguided or falsely interpreted. Layder (1994, cited in Cohen et al., 2011, p. 21) argues that the interpretation may be revealed through a lens with a very small sociological field of vision, with subsequent limitation on how the experience may be explained.

The literature gives the impression that certain authors have favourite phenomenological philosophers: Stahl (2007a) focuses on Heidegger; Cohen et al. (2011) focuses on Husserl; Bryman (2016) focuses on Schutz. Irrespective of these philosophical league structures the underlying premise of phenomenology is the human experience and the unearthing of the lived experience (Romdenh-Romluc, 2011; Gaudet & Robert, 2018).

In this section I outlined the philosophy of Merleau-Ponty as a development of Husserl's work, which situates the researcher and the participant, and both situations must be explicitly accounted for. Merleau-Ponty's philosophical stance separates my philosophical stance from Heidegger's interpretation of *lebenswelt* where the researcher's account is an interpretation of the lived world; the researcher's account isn't situated in the same space as the participant. Of particular importance to my own philosophical stance is the importance Merleau-Ponty places on physical affordances as well as logical or abstract affordances (Smith et al., 2009); I consider the weave of physical and cerebral interactions of the student within a technology enhanced mediated environment to be important and something that cannot be ignored.

3.3 Discussion

Research philosophy is a multi-faceted and multi-layered guiding component within the research study. The weave of linkages and dialogues between the philosophical layers is complex as would be expected when considering human interaction. The regional location of the research bounded by an overall socio-cognitive philosophy has generated many personal tensions and cognitive stress points. The study is set within the Galilean setting of engineering education requiring sensitivity in study design.

Teasing meaning between the philosophical layers to develop ontological and epistemological relationships was an important element in the research process. The philosophical layers could have been generated mechanically; however, it was considered imperative that any philosophical underpinning should resonate with my own personal philosophy. A resonant alignment of personal and research philosophies had the potential for enhanced personal engagement.

The arguments for the ontological and epistemological philosophies with a critical realism meta-theoretical underpinning have been established to address possible areas of criticism in terms of the subjective nature of perception. The location of critical realism as a meta-theory is vital for the support of interpretivism as an epistemology. The interpretation of the phenomena is vital as are the social and cultural relationships in the process of establishing a sense of being and belonging.

Alternatives to interpretivism were considered such as the absolutist position of radical constructivism or positivist philosophies, however these alternatives have been rejected as being not in alignment with my own philosophical understanding. The philosophical abstractions of socio cognition, critical realism and interpretivism create interwoven layers supporting the potential for a sound research methodology. The desire to access perceptions is a driver in this study and this may be achieved through phenomenology.

The philosophy of phenomenology to understand the lived heterogenous world allows meaning to be described. An appropriate tool or set of tools may now be employed to gain access to the descriptions of the lived world as experienced by the participants. My own personal bias is stated explicitly and will be repeated within the methodology and analysis of the research. The perceptions of assessment processes by students and academics will be explained within a generative explanation of the layers of reality experienced. A discussion of the need for change, and recommendations for change, will be made for made for enhancement of assessment processes and practices in engineering mathematics in Chapter 6.

Chapter 3 – Philosophy, Methodology and Methods

Part B-Research Methodology

This chapter establishes the methodological framework and the boundaries within which the methodology will support the overall socio-cognitive framework. The methodology will be discussed in greater detail in sections 3.6 to 3.13.

The theoretical framework requires a supporting social theoretical methodology to aid the identification and analysis of themes in a rigorous manner to provide a foundation for discussion. The research philosophy and methodology must be aligned and supportive of each other to permit the research questions to be addressed using appropriate techniques (Bryman, 2016; Cohen et al., 2011; Trafford & Leshem, 2008). The nature of the knowledge sought, and the context within which the locale of knowledge resides, are paramount parameters within the research philosophy suggesting a mixed methods study design.

3.4 Mixed Methods Methodological Framework

The aim of the study is to obtain the perspectives of the students and academics to identify areas that should be improved to enhance the learning experience. As a researcher-practitioner, I consider it to be imperative that the value and quality of the voice is brought to the fore, 1) to allow practitioners to engage with, and 2) to enhance the educational experiences of both students and academics.

The theoretical framework for the research has been identified as socio-cognitive supported by ontological and epistemological layers of critical realism. The strategic feature of this research study is the creation of new understandings of students' perceptions of assessment, and the localization of students' and academics' perceptions (Bryman, 2016; Creswell, 2014; Cohen et al., 2011) of assessment, as emergent themes (Braun & Clarke, 2013, p. 237) of online assessment of engineering mathematics.

The study does not seek to generalize the analysis through an exploratory study (Creswell, 2014, p. 71); neither does the study engage with any form of experimentation leading to interpretation, and no form of intervention was planned or expected to be undertaken. The nature of perception is such that it may be possible to ascertain if any form, or sense, of social injustice exists within the pedagogy, or operation, of the curriculum through analysis of the qualitative data. Knowledge formed through quantitative measurement of students' experiences of online engagement with engineering mathematics is integrated with the knowledge gained from interpretation of students' and academics' experiences. Quantitative and qualitative sample sizes may differ on condition that the data are mutually informing through an integrated design; bias must not be present towards any particular paradigm (Creswell & Plano Clark, 2018; Cohen et al., 2011). The mixed methods approach permits the different philosophies and epistemologies present within this research study to describe the data and construct explanations for the subsequent reasoning. The perceptions' phenomena are complex, a single method may result in a partial, or incomplete, and potentially misleading understanding of the problems. The *looseness* of the initial research must be catered for within the mixed methods and sufficiently manageable to generate a robust outcome within the timescale. The temporal dependence and subjective nature of the study does not lend itself towards experimentation.

The analysis seeks to explore a discourse of the research questions. Outcomes of the research questions will be addressed and expatiated within the discussion. Replication of the data is not possible within this mixed-methods study because of the idiographic nature of the qualitative analysis. The methodology underlying this study includes the methods and analysis as seen in figure 3.1.

Figure 3.1 displays the two-stage convergent mixed methods design strategy involving the collection of qualitative and quantitative data and initial analysis: stage one is in Ireland; stage two involves Ireland, Estonia, Finland, Poland, Portugal, Romania, and Russia, building on the outputs from stage one. Figure 3.2 displays the Gantt chart for the planning of each element within the methodology in sections 3.6, 3.7 and 3.8. The findings from the overall study will form the basis for discussion in Chapter 6.

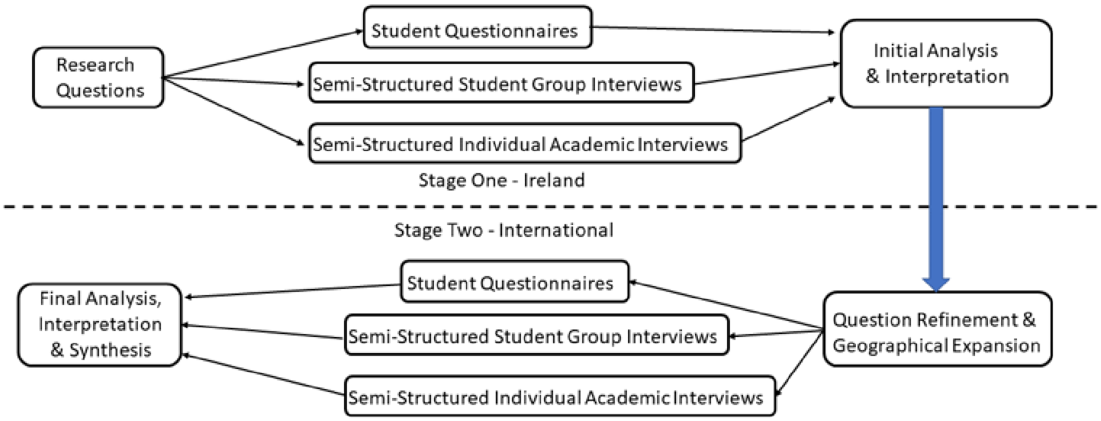

Figure 3.1: Two-stage convergent mixed methods design

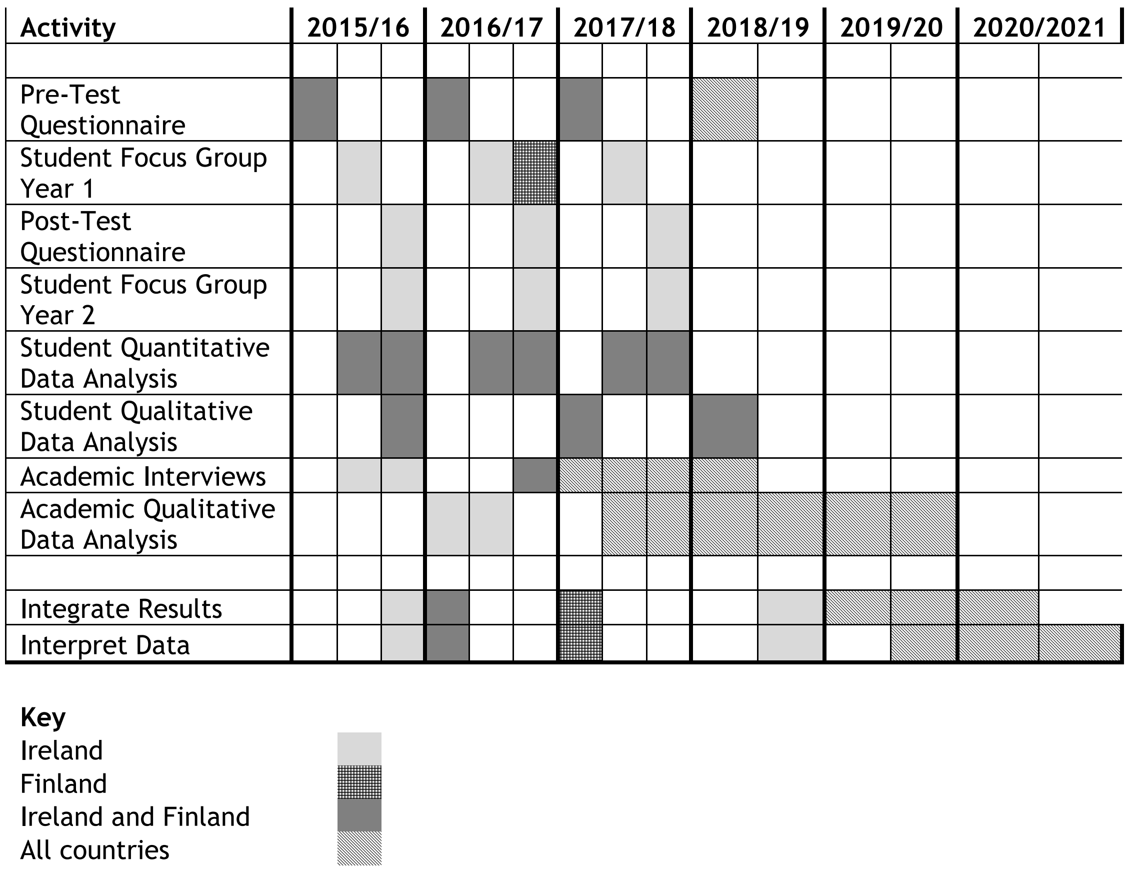

Figure 3.2: Data Collection and Analysis Gantt Chart

3.5 Interpretative Phenomenological Analysis of Qualitative Data

Perceptions of disconnects, barriers, values, expectations, and instrumentality within an intensive technology mediated environment, the associated understanding of those perceptions and the complex web they weave, are highly subjective components. Determination of valuable output requires a voice to be given to the participants to generate new knowledge in an area where a paucity of literature exists (Gould, 2012). Additional value is added to the knowledge base through the agency provided by the academics' voice.

Phenomenological analysis is informed through phenomenology, hermeneutics and idiographic study of individuals, events, or facts, and establishes a focus for further study through analysis of observed phenomena. Thus, the boundaries of the study are defined, and the range of diversity revealed based on the population studied (Smith et al., 2009).

To minimize the effects of any pre-judgments of the researcher the study uses the Interpretative Phenomenological Analysis (IPA) (Symeonides & Childs, 2015; Smith et al., 2009) technique of qualitative enquiry. The phenomenological approach is an idiographic exploration of experiences in the participants' own terms particularly where these experiences have a large significance. Experiences of major significance are considered to lead to reflection on the significance of what is happening. These experiences may be bounded and discrete or may continue for significant lengths of time and the researcher makes sense of them by means of hermeneutics. The interpretation is second order in that the experience is interpreted via the account described by the learner. The researcher is critical within this approach as the main instrument in obtaining the knowledge.

The potential for tensions with participants cannot be understated where the researcher is located as a pivot in the data gathering process. The researcher must remain cognizant of their role in the process and how data was generated because of the intervention. It is important that as far as possible, the participants can express their concerns and make claims on their own terms. The generation of a safe space where participants may engage without fear requires a high degree of open-mindedness on the part of the researcher (Smith et al., 2009, p. 42).

3.6 Stage one Data Collection Methodologies

Stage one of the process is designed to gather quantitative and qualitative data from Irish students over two academic years to form a baseline for Stage two.

The intent behind the integrated convergent design (Creswell, 2014, p. 78) is to obtain, and compare, perspectives of the students' perceptions of assessment practices and perceptions of barriers to learning. The qualitative sample sizes described in more detail in table 3.2, section 3.11, are by necessity smaller than the sample size in the quantitative design, restrictions on time and physical resourcing limit the options on larger samples for the qualitative design. The qualitative data obtained through semi-structured interviews, provides an alternative narrative to the outputs from the quantitative survey instrument data.

3.6.1 Stage One Quantitative Instrument

A survey questionnaire is selected as the most appropriate instrument for the collection of data from the larger student population. The survey instrument is administered to the whole student population where the foci are on perceptions, barriers, and general feelings towards mathematics assessment. Such constructs are generally subjective and highly dependent on individual circumstance, so a causal relationship is not sought.

Exploring subjective issues that may make students feel uncomfortable and interpreting the responses is a sensitive process and requires an ethical approach to minimise any detrimental or negative personal effects. The qualitative transactions involve mixed gender where possible without compromising the safety, or magnification of the role of any minority gender. To ensure synchronic reliability, qualitative data is gathered within a relatively short time scale of the survey instrument (Cohen et al., 2011, p. 196).

The purpose of the Stage One phase in table 3.1 is to address initial questions by means of a pre-test questionnaire to be issued immediately before the first eAssessment for Irish students. Issues addressed by the survey instrument are: 1) Barriers to learning and support in overcoming them; 2) Confidence using online assessment systems for mathematics; 3) Gender profile, age range, and mathematics qualifications range; 4) Feelings using online assessment in mathematics. The initial analysis and findings from the survey responses will form the framework for the findings and will inform the questions for the qualitative semi-structured interview instrument. Tight connection between the instruments is important to ensure integration of the data. The sample population in the quantitative instrument is significantly larger than the sample for the qualitative instrument because whole class groups of at least thirty students are invited to participate. A second study (Post-test Questionnaire) using a similar survey instrument is designed to be conducted after the first eAssessment to test if any significant changes have occurred within the responses. The same student class groups are used in the second study to ensure comparability of responses.

3.6.2 Stage One Qualitative Instrument

The qualitative instrument is a semi-structured interview of individuals and groups where sampling is based on convenience because the participants are available to the researcher within timetabled hours. The interviews are therefore time bounded and take place within familiar settings. The phenomenological output will permit dialogue to establish a baseline of the status of on-line assessment of engineering mathematics of first year students in engineering. The semi-structured approach will be utilised to ensure that all topics and issues to be covered are specified in advance and that all interviewees are asked the same basic questions to ensure comparability of responses. The language of the questions must be easily understood by the respondents to ensure natural responses. Semi-structured interviews of individual academics will be operationalized to enable the perspectives of academics to be considered in relation to students' issues. These academics' interviews are programmed to begin after initial analysis of the semi-structured student group interviews and continue throughout stage one and stage two to fit in with free time for academics.

The core questions of perception of assessment of engineering mathematics and online assessment of engineering mathematics are addressed within the qualitative instruments. Semi-structured interviews focus on the core questions whilst providing scope for the participants to explore their thoughts and feelings.

The interview enquiry is designed around open questions to give the individual students the chance to reveal their perceptions using their own language and colloquialisms without fear (Agee, 2009). All interviews were recorded using a video recorder and an audio recorder as backup. The video recorder lens was aimed away to ensure that no faces appeared, and participants could not be identified visually. The process of recoding audio permits the researcher to focus solely on the interview process with subsequent transcription of the interview at a later stage. The interviews are time bounded, restricting the potential for unstructured interviewing to maintain a focus on the core questions. A highly structured interview does not lend itself to exploration by the participants; they may wish to expand and explore somewhat but the tight structure does not permit this aspect. An interview protocol – see Appendix 1 - was developed in advance of the semi-structured interview with students to ensure the enquiry process was pre-determined with the focus on perceptions. The interview protocol is not totally rigid and is sufficiently flexible to accommodate adaption of issues raised by participants if a hegemonic issue arises. The survey design adopts a non-probability convenience sample approach integrated within the mixed methods study design in table 3.1 (Bryman, 2016, p. 187; Cohen et al., 2011, p. 155).

3.6.2.1 Student Qualitative Instrument

Sampling for participation in semi-structured focus group interview activity is non-probabilistic and is based on convenience as determined by the availability of participants to the researcher. The student sample group in year one, semester one, is limited to an invited maximum of eight students in each session and is drawn from a group of available participants within a standard timetabled session. The student sample group in year two is limited to eight students in semester four, is non-probabilistic and self-selecting; they make themselves available during a lunch time session. The interview activities utilise a semi-structured, standardised open-question approach. The first-year student group interview activity is timed to take place after the first questionnaire has been operationalized and immediately after the first online assessment exercise. The second-year student group discussion activity takes place at the beginning of semester four to allow them time to reflect on their experiences within year two. A standardised open-ended approach is utilised to ensure that all topics and issues to be covered are specified in advance and that all interviewees are asked the same basic questions to ensure comparability of responses. Student identities within the discussion group processes are coded to ensure anonymity. The interviews are video recorded, but steps are taken to ensure that faces and student names cannot be determined.

3.6.2.2 Academic Qualitative Instrument

The study involves engineering mathematics lecturers. Each lecturer participates with consent in an individual anonymized semi-structured video interview and is asked the same questions to allow comparisons to be made. Prior to the lecturer interviews an analysis of the student questionnaires is designed to be conducted to establish main thematic areas for consideration. The selected thematic areas are deduced from the completed student questionnaires using the combination of responses to open and closed questions. The lecturer interview questions are formed around the following thematic areas: Training and Preparation for online assessment, Perceptions of student confidence for online assessment, Perceptions and knowledge of barriers for optimal online assessment.

3.6.3 Stage One Research Time Frame

The time frame in table 3.1 for each activity displays the total time taken by each activity and these may overlap with other activities over a period of fifteen months.

Data Type	Procedures	Products	Overall Time
Quantitative Data Collection	- Select 1st year engineering mathematics students - Survey measures: Gender, Educational attainment, experiences of online testing, support, training, and confidence	- Numerical item scores - Open responses to good and bad experiences	6 months
Qualitative Data Collection	- Sample from 1st year engineering mathematics students - Semi-structured interviews	- Transcripts	9 months
Qualitative Data Collection	- Sample from 2nd year engineering mathematics students -	- Transcripts	9 months
Qualitative Data Collection	- Sample from academics in institution -	- Transcripts	9 months
Quantitative Data Analysis	- Descriptive statistics - Comparisons - Associations	- Means, - Standard Deviations, - Significances - Effect size	3 months
Qualitative Data Analysis	- Determination of utterances - Coding for thematic analysis	- 8 major themes	3 months
Merge Results	- Crosstabulation between quantitative variables and qualitative themes	- Relationships between qualitative themes and quantitative variables - Comparison matrix	3 months
Interpretation	- Analysis of relationships and comparisons	- Discussion	3 months

Table 3.1 Stage One Time Frame Overview

3.6.4 Stage One Study Sample

Stage One of this study concentrates on students studying Bachelor of Engineering programmes in Electronic, Mechanical, Fire Safety and Building Services Engineering at level 7 of the National Framework of Qualifications in Ireland – see Chapter 2 figure 2.1.

Sampling for quantitative purposes is by invitation to the student body in first year of study in any Bachelor of Engineering programme. Sampling for qualitative purposes is by invitation and convenience within a timetabled session. The students are all engaged in engineering mathematics, and this nexus provides the homogeneity required to enable a narrative to be constructed leading to improved understanding of perceptions. Sampling of academics was by invitation to all academics involved in engineering mathematics.

3.7 Stage Two Data Collection Methodologies

The initial intention of stage one of the convergent design, through integration of data and initial analysis, was to form a case study from which to refine the questions within a second case study of students entering year one of engineering. Discussions with academics in higher education institutions outside Ireland gave rise to a redesign of stage two and an extended purpose. Engineering mathematics lecturers in European universities of applied sciences and polytechnics enquired about the possibility of extending the participant groupings to include students and academics outside Ireland.

The stage two study design, in table 3.2, accommodates students and academics in seven countries. The complexity of such a study, given issues such as language, culture, timing, and data sensitivity, cannot be understated where the study is conducted by a single researcher. Stage two was made possible by a network of academics, developed through Erasmus and other networking activities, making themselves available to support the operationalization of the data gathering instruments.

The language used in this study is English, however not all students in stage two are fluent English speakers. To ensure that all students understood the questions and responses were aligned with the research it was decided that translations of questions and responses would be made used. The quantitative instruments were translated to Portuguese, Romanian, Estonian, Polish, and Russian, by the supporting network of academics and their respective institutions and tested for accuracy. Students in Finland completed the quantitative instruments within an English language communication module and gained credits within the module.

Interviews were designed to take place in Finland with a group of English-speaking year one engineering students in the presence of an independent interpreter to provide support. The qualitative instrument was used with academics in Portugal, United Kingdom, Finland, Romania, and Russia. All participating academics lecture mathematics for engineering and were fluent English speakers. Data collection for quantitative and qualitative information took place consecutively to fit in with availability of students and academics. Analysis, merging, and interpretation was designed to follow successively. Semi-structured interviews were conducted using remote video conferencing or face-to-face interviews depending on the ability of the researcher to travel at times of availability of the academic participants.

3.7.1 Stage Two Research Time Frame

The time frame in table 3.2 for each activity displays the total time taken by each activity and these may overlap with other activities over a period of thirty months.

Data Type	Procedures	Products	Overall Time
Quantitative Questions	- Translation from English to Estonian, Polish, Romanian, Russian - Establish Google Forms for administration of questionnaires	- Questionnaires in local language where necessary	3 months
Quantitative Data Collection	- Select 1st year engineering mathematics students - Survey measures: Gender, Educational attainment, experiences of online testing, support, training, and confidence	- Numerical item scores - Open responses to good and bad experiences	18 months
Qualitative Data Collection	- Sample from Irish 1st year engineering mathematics students - Sample from Finnish 1st year engineering mathematics students - Semi-structured interviews	- Transcripts	24 months
Qualitative Data Collection	- Sample from Irish 2nd year engineering mathematics students - Semi-structured interviews	- Transcripts	24 months
Qualitative Data Collection	- Sample from academics in institutions - Semi-structured interviews	- Transcripts	24 months
Quantitative Data Analysis	- Descriptive statistics - Comparisons - Associations	- Means, - Standard Deviations, - Significances - Effect size	6 months
Qualitative Data Analysis	- Determination of utterances - Coding for thematic analysis	- 8 major themes	6 months
Merge Results	- Crosstabulation between quantitative variables and qualitative themes	- Relationships between qualitative themes and quantitative variables - Comparison matrix	6 months
Interpretation	- Analysis of relationships and comparisons	- Discussion	6 months

Table 3.2 Stage Two Time Frame Overview

3.7.2 Study Sample

Homogeneity of the population being researched is paramount in the extension of the study to ensure consistency in reporting and analysis, i.e., all students are studying engineering mathematics and all participant academics teach engineering mathematics. The non-probabilistic student population samples selected in Finland, Russia, Romania, Poland, Portugal, Estonia, and Ireland were selected entirely based on access to the participants within the established network of academics. All students are in higher education engineering degree programmes, studying at the equivalent of level seven of the Irish National Qualifications Framework – Figure 2.1. Equivalence has been determined through the EU Bologna process using International Standard Classification of Education (ISCED) (Drennan, 2018) reference mapping.

Selection of academics in Portugal, United Kingdom, Finland, Romania, and Russia was determined through availability of English-speaking engineering mathematics lecturers. All academic participants in Stage Two of the research study have experience of having used e-assessment with their students and are fluent English speakers.

3.7.3 Stage Two Quantitative Instrument

The purpose of the Stage Two quantitative phase is to expand the exploration of the initial questions on the background information gained from the Irish context to a wider population. The pre-test survey instrument used in Stage One was redesigned for Stage Two to accommodate design issues arising from Stage One, to enable easier translation from English to Estonian, Polish, Portuguese, Romanian, and Russian, and to enable delivery using Google Forms. Issues addressed by the survey instrument are: 1) Barriers to learning and support in overcoming them; 2) Confidence using online assessment systems for mathematics; 3) Gender profile, age range, and mathematics qualifications range; 4) Feelings using online assessment in mathematics. The quantitative instrument is translated as appropriate to the local language as necessary and tested for accuracy prior to release. The analysis and findings from the survey responses form the framework for the findings and integrate with the responses for the qualitative semi-structured interview instrument. The sample population in the quantitative instrument (estimated at n=500) is significantly larger than the sample for the qualitative instrument.

3.7.4 Stage Two Qualitative Instrument

3.7.4.1 Student Qualitative Instrument

Sampling for participation in semi-structured interview group activity is non-probabilistic and is based on convenience as determined by the availability of learners to the researcher. The Finnish student sample group in year 1, semester 2, is not self-selecting and is drawn from a group of available participants of engineering students in Finland during an Erasmus international teacher exchange week. The student group activities utilise a semi-structured, standardised open-question approach. The semi-structured question list was forwarded to Finnish engineering mathematics lecturers and English Language lecturers for testing. It was agreed that a neutral academic translator would assist during the semi-structured interview if required to reduce stress among the participants.

3.7.4.2 Academic Qualitative Instrument

The study involves mathematics lecturers; those who could participate by video conference and those who could meet for a face-to-face interview. Prior to the interviews the semi-structured question list was sent to the participants to allow them to prepare and clarify any questions. Each lecturer participates with consent in an individual anonymized semi-structured video interview and is asked the same questions to allow comparisons to be made. Irish and international academics were invited to discuss the same selected thematic areas as deduced from the completed student questionnaires using the combination of responses to open and closed questions in Stage One. The lecturer interview questions are formed around the following thematic areas: Training and Preparation for online assessment, perceptions of student confidence for online assessment, perceptions and knowledge of barriers for optimal online assessment.

3.8 Data Analysis

3.8.1 Quantitative Instruments

Analysis of the questionnaire is conducted using a combination of Excel and SPSS. Numerical codes (see Appendix 2) are developed for the multiple choice and Likert scale questions and entered initially into Excel to produce graphical outputs and simple statistical analysis. The Excel spreadsheets are then transferred to SPSS for in-depth analysis.

Apart from the basic descriptive statistical outputs of mean, median, mode and, dispersion, the main thrust of the quantitative analysis lies around the relationships between the variables. Causality is not an element of the outputs due to the cross-sectional design of the study. The Likert questions are multiple-item measures and are tested for relationships between participants and countries.

3.8.2 Qualitative Instruments

Qualitative semi-structured and questionnaire open response data are transcribed and double checked for accuracy. A manual coding schema (Ryan & Bernard, 2003) developed from the questionnaires in the initial phase of analysis allows themes to be explored in the face-to-face group and remote video interviews. For open question responses, the level of granularity for the analysis is determined to be an utterance rather than individual words. An utterance could be part of a sentence or even a complete sentence. To reduce the complexity the same utterance could not be awarded an additional code – all utterances are considered unique within this research. The code selected to represent the utterance will not change until a succeeding utterance, response, or phrase requires an alternative code. Initial analysis resulting in a significant number of sub-themes is then re-analysed to determine the topology of the Quote/Sub-Theme/Main-theme tree – See Appendix 4. The main themes are then selected to maintain the context of the research.

Data analysis is conducted in three phases to generate the contextual thematic outputs of the phenomena. Phase one uses an open coding approach to examine and analyse the unique students' utterances in the questionnaire open responses. The resultant codex comprises twenty-eight individual codes (See table A4-1 in Appendix 4). The codex of utterances is taken forward to the analysis of the first student interviews within a heuristic framework to test the individual codes through a second order analysis as prompted by the individual cases. The resultant cross case analysis (Smith et al., 2009, p. 166) adds strength to the provisional code outputs. The idiographic nature of IPA is upheld by this approach as each individual case contributes to the refined analysis. The students are experiential experts, and the flexible inductive nature of IPA permits the students to bring personal experiences to the core of the research. The codex analysis is found to be representative of eight main themes, the eight themes are in table A4-2 in Appendix 4.

Phase two of the coding process involves testing the eight themes with a group of second-year undergraduate engineering students. Analysis of the discourse takes the research to a higher theoretical level where the socio-cognitive epistemology becomes more apparent. The axial coding conducted in phase one satisfies the desire to be consistent and semi-structured whilst allowing the students' voices to be heard; analysis of the discourse suggests that the coding is in alignment with the discourse.

Phase three of the coding process is based on the patterns and themes of phases one and two. Semi-structured interviews with academic staff are based on the phase two thematic patterns and codes. The phenomena were observed from the analysis based on the eight-theme codex in Appendix 4, table A4-2.

3.9 Quality Considerations

Judgement of the subsequent research, the research design, and analysis, making sense of the process, and the consequent discourse, is dependent on the quality of the process. The field of mixed methods is still maturing (Creswell, 2014) and a specific quality standard is not yet operational. However, the lack of a particular quality standard does not mitigate the responsibility for the researcher to employ as robust a protocol, or set of protocols, to maximize the credibility and reliability of the research (Cohen et al., 2011).

The quality of the process is limited by any weaknesses present in the design; the most visible weakness is the role of a single researcher to conduct, engage with, analyse, and report on the research. At all stages the researcher has attempted to minimise human bias, to be consistent in the approach and to maintain an open-mind, in the framing of the perspectives of the participants (Braun & Clarke, 2013).

The use of mixed methods to triangulate (Cohen et al., 2011) and integrate data creates a robustness in the data and aligns with the researcher's own moral code. The participants' voices are the primary sources of the richness, depth, honesty, and range, of answers; without the student voice there is no narrative of worth, and the researcher is indebted to the participants for the quality of analysis. When considering the students' voices the researcher is intimately aware of the power relationship with the participants. The researcher must endeavour to mimic the professional relationship and clarify all ambiguities and protect the participants from any damaging or adverse effects of the study (Gaudet & Robert, 2018).

3.9.1 Validity

The validity of the research, or the legitimization of the research is strengthened through application of appropriate techniques within the design of the research (Cohen et al., 2011). Validity is obtained through honest representation of the material transactions present within the qualitative discourses and the quantitative analysis. The validity of the exercise is reduced if the philosophical, epistemological, and methodological beliefs are not supportive, leading to conflicting rhetoric in analysis. The research process is time-bound and certain activities must take place according to the academic calendars of the participating organisations. It was not the intention of the research to determine a representative statement for all first-year engineering students in Ireland and further afield. Rather, the research aimed to identify thematic perceptions for purposes of discussion and generate a better understanding of student voice in eAssessment of engineering mathematics.

The foci of the qualitative instruments are strongly integrated with the foci of the quantitative instruments, and clarity of measures made transparent to participants. External validity, or the relationship of the study in a general sense, is purposely limited to the participating organisations due to the limitations of engagement by a single researcher. Any relationship between the research and the validity of the research to the real world in terms of ecological validity is exposed through dissemination of analyses and extra-discourse with non-participating academics. Real world validity is a manifestation of the context of the subsequent and emergent discourse of the research; the qualitative instruments may take place within an artificial arena, however real-world issues are engaged with and reported on.

A major component to be considered within the survey design is bias and ensuring that the sample population should be free from bias. Bias has been at the fore of all decisions made within the process and cannot be eliminated within the design; it is a statistical design weakness of this research, but the researcher considers it a strength from a personal standpoint because the researcher wants to bring the students voice to the fore. The design is biased because the design draws on participants who have a personal contact with the researcher as well as students who relate to the researcher's network of professional contacts. It cannot be stated the responses and opinions expressed in the data analysis are without bias. The level of connection between the participants and the researcher means that the survey must be conducted as an overt and transparent activity without any prejudice towards the participants.

3.9.2 Reliability

The results and their repeatability are dependent on the quality of the instruments and the procedures adopted in the research design. Reliability or the possibility of producing the same results using the same instruments and techniques by different researchers is not strictly possible in the context of this research study (Creswell, 2014; Braun & Clarke, 2013; Cohen et al., 2011). Cohen et al (2011) suggest that the research be conducted with similar participant groups in similar contexts, however the fluidity of demographics and degree programmes offered may not always make this possible. Braun and Clarke (2013) are of the opinion that for the qualitative components (extrapolated to include mixed methods) reliability is not appropriate. The researcher considers the truthfulness, honesty or dependability of the methods and instruments to have more meaning in the context of this study. Reliability may be established within the quantitative element, but the experiences of the participants and researcher are not constant and may vary across the qualitative phase. Therefore, Creswell's guide to ensure a robust set of design criteria is paramount. The guiding criteria establish a protocol for the purpose, design, sampling, collection, analysis, and justification of the process (2014, p. 106 table 9.1).

3.9.3 Generalizability

Generalization requires an alternative philosophical paradigm to underpin the research(Gould, 2012). Firestone (1993) argues that generalization may be possible for the qualitative outputs if the research is underpinned by an appropriate theoretical extrapolation of the sample. This research is framed by philosophical arguments that honesty, rather than extrapolating and fitting to a consensus, is paramount. Extrapolation of the sample to the population of engineering students is not appropriate in this instance because the sample does not accurately reflect the population.

The sample size is not large, but neither is it insignificant when the integrated data set is considered. The perspectives of the students and academics within the identified areas and resultant analysis are not expected to be generalized. The participants have been sought because it is considered by the researcher that they are good sources of information, and will aid the advancement of the research goals due to their locale within the domain of engineering mathematics (Braun & Clarke, 2013).

3.10 Ethical Considerations

Ethics and ethical considerations must be integrated into the complete research process and adherence to ethics should not be seen as meeting the minimum requirements (Braun & Clarke, 2013). The research study is primarily focused on students in engineering mathematics and, before any institutional ethical considerations are made, the researcher is aware that the subjects are humans. The research practices and protocols informing the research ethics require cognizance of the fragility of the researcher-participant relationship. The gathering of data must be achieved through a process based on the integrity of the researcher.

All participants, stakeholders, and participating organisations must be informed about the purpose of the research. It is necessary to seek the informed consent of all participants without any form of deception, maintain confidentiality, securely store, and protect any data, provide the right without fear of prejudice or risk to withdraw at any stage, and be honest in all reporting of the research results. The benefits of the research must be considered in terms of the benefits to the participants, the researcher, the wider academic community, and the community at large. Offsetting the benefits are the costs of participation in the form of time, personal contribution, possible embarrassment, and fear of retribution. The ethical dilemmas facing the researcher must always retain the welfare of the participants as the focus.

The research has been guided by the ethical and moral compass of the researcher in conjunction with the institutional ethical guidelines and protocols of the supporting institutions.

3.10.1 Survey Information Document

All students in the survey were provided with a Participant Information Sheet to inform them that the purpose of the survey was to obtain an insight into eAssessment of mathematics within the School of Engineering and that it was an integral component within this research study. Students were informed why they had been selected and that all participation was voluntary without prejudice. All responses would be treated anonymously and stored in a secure area. Information regarding further ethical queries was provided if students wished to explore this issue further. A copy of the Participant information sheet is in Appendix 1.

3.10.2 Participant Consent Form

Prior to administering the survey each student received a consent form. The consent form sought confirmation that the participant information sheet had been received and any outstanding questions addressed. In addition, the form brought the voluntary nature of the exercise to the attention of the students, and finally the students were asked to sign and date the consent form. Participants were reminded that they could withdraw at any stage in the process. A copy of the Consent Form is in Appendix 1.

3.10.3 Ethical Approval

In advance of any contact with students regarding the research it was necessary to obtain ethical approval for the process. Ethical approval within this research was obtained at three levels: Letterkenny Institute of Technology; University of Glasgow; and Oulu University of Applied Sciences. Ethical approval was not sought in Estonia, Poland, Portugal, Romania, or Russia because it is currently not a requirement, however all participants were invited to avail of consent forms and information sheets along with statements of data confidentiality. The process involved the identification of risks, confidentially, impartiality, dissemination, consent, funding, and information requirements. A copy of all ethics documents is in Appendix 1.

3.11 Sample Sizes

A description of the institutions selected to participate in the research is provided in Appendix 1. A summary of the samples employed are provided in table 3.3.

Country	Student Pre-test Questionnaire	Student Post-test Questionnaire	Student Interview 1st Year	Student Interview 2nd Year	Academic Interview
Estonia	72	-	-	-	1
Finland	96	-	5	-	2
Ireland	161	126	33	14	6
Poland	68	-	-	-	-
Portugal	103	-	-	-	2
Romania	53	-	-	-	1
Russia	56	-	-	-	3
United Kingdom	-	-	-	-	1
Total	601	126	38	14	16

Table 3.3 Sample sizes per institution

3.12 Questionnaire Design

The application of a questionnaire is generally viewed as the prime mechanism for gathering data from a large population where the focus is on obtaining opinions with the purpose of generating statistical data to provide answers for sub-questions 1, 2, 3 and 4 (Cohen et al., 2011, p. 128). Data relating to the perceptions held by students regarding assessment processes of engineering mathematics in a variety of geographical locales and their subsequent emerging issues will be gathered and presented in a manner suitable for further analysis.

Considerations to be made within the questionnaire design include time required to complete the questionnaire, relationships between questions, clarity of research questions, mechanisms for questionnaire administration, and analysis of responses. The survey uses a non-probability convenience sample approach with students in standard timetabled class sessions and online. The survey in Stage One was conducted in class with the Irish Students. The survey in Stage Two was administered online using Google Forms. The research questions were divided into the following sections:

1. General participant data
    a. Gender
    b. Highest level of education attainment prior to third level study
2. Prior experiences of computer-based testing
    a. Good/bad experiences
    b. Reason for not having prior experience if applicable
3. Support and training
    a. Use of general computer systems
    b. Use of Virtual Learning Environment
    c. Computer-based Quizzes
    d. Answering mathematical Computer-based Quizzes
4. Extant experiences of using computer-based testing
    a. Confidence
    b. Preparation
    c. Barriers experienced
    d. Experience using mathematical quizzes

The pre-test questionnaire underwent several iterations prior to administration. A pilot questionnaire was tested with several engineering colleagues and a sample of students. Issues such as clarity, ease of understanding, and time to complete and collect responses were considered. To ensure the time limit could be achieved the number and types of questions were reduced. Responses to general participant data are tick-box type. Prior good/bad experiences of computer-based testing are open questions. The reason for not having any computer-based testing experience prior to third level if applicable is also included as an open question. Questions relating to support, training and extant experiences are Likert based ranging from "none" to "a great deal". This design approach allows both quantitative and qualitative data to be gathered within a single survey instrument and is deemed to be the most efficient use of the survey instrument. A copy of the questionnaire is included in Appendix 1. Students' responses, comments and perceptions are used to guide the semi-structured interview questions for students and academics based around perceptions of academic background, prior experiences, support and training, confidence, preparation, and barriers.

3.12.1 Participant Information

As stated earlier, the survey design is that of a non-probability convenience sample. The sample does not seek to generalize to the wider population; however, the opportunity is present to explore the sample demographics. Therefore, questions relating to gender and academic attainment are sought to support the descriptive discourse of the sample; gender balance within engineering education and the engineering profession is an issue of concern (Engineers Ireland, 2018).

3.12.2 Prior experiences of computer-based testing

The routes taken by students to reach third level within the institute of technology are recognised as being non-standard for approximately thirty percent of students in the School of Engineering. Discussions with colleagues in the participating research network have provided anecdotal evidence that a similar situation exists in other universities of applied sciences. The computer-based testing experiences of students prior to their first year of engineering cannot be assumed to be homogenous given that up to one third may have been in non-educational settings.

Access to knowledge of the extent to which students have prior experience and the type of experience is valuable for the pedagogical design of eAssessment.

Students are requested to state if they have any experience of computer-based testing. If the student states ‘yes’, they are prompted to describe the main things they find good and/or bad about their experiences. If the student states ‘no’ they are prompted to describe why they have not experienced computer-based testing prior to third level education. These open questions provide an opportunity for the students to describe their past experiences and may be compared with perceptions held by academics.

3.12.3 Support and training

The manner and levels of students’ engagement while accessing their mathematics eAssessments depends on factors such as training, support, and past experiences. Knowledge of the heterogenous nature of past experiences, ICT literacy and self-efficacy within the first-year engineering mathematics groups is necessary to ensure maximum inclusion. A five-point Likert scale was developed, where: 1 = none; 2 = very little; 3 = a moderate amount; 4 = quite a lot; and 5 = a very great deal. Students were asked to rate the support and training they received in the first few weeks of their first-year undergraduate study in engineering mathematics in terms of: General use of computer systems and applications; use of the Virtual Learning Environment; use of quizzes and eAssessments within the Virtual Learning Environment; and answering mathematics type computer-based quizzes.

3.12.4 Experiences using computer-based tests

In addition to how students are supported and trained to use computer-based tests for engineering mathematics, it is necessary to establish if the students consider themselves to be adequately prepared. Assumptions have been made regarding the abilities of students to successfully engage online, and the presence of high bandwidth Internet access in certain locations may be distorting the views of academics. To ascertain if the assumptions are true a five-point Likert scale was developed, where: 1 = none; 2 = very little; 3 = a moderate amount; 4 = quite a lot; and 5 = a very great deal. Students were asked to rate their levels of confidence using computer-based tests and their levels of perceived preparation. The students were asked to rate the number of computer-based quizzes they had already completed by this stage and to identify if they had experienced anything that placed a barrier in the way of the online engagement.

3.12.5 Operation of Questionnaires

3.12.5.1 *Stage One: Ireland*

The questionnaire was delivered in paper format in standard timetabled class sessions. The time allocated to each class session is limited to sixty minutes and the prime function is delivery of the curriculum. The time allocated to the administration of the survey was limited to twenty minutes to ensure that standard class activities did not suffer undue disruption.

3.12.5.2 Stage Two: Estonia, Finland, Ireland, Poland, Portugal, Romania, and Russia

In Stage Two, the research sample was expanded to widen the evidence base with subsequent changes in time frame (see Table 3.2). The questionnaire was reorganised to make it suitable for online format using Google forms. The reason for using online operationalization was primarily because the academics who kindly offered their support made this request. The questions were translated into Russian, Estonian, and Romanian and checked for language stability after initial pilot tests – Finland, Poland and Portugal used the original English version. Students were provided with anonymous online access to the survey and could only be identified by country.

3.12.5.3 Post-test Questionnaire Ireland

A reduced version of the pre-test questionnaire was designed to be administered immediately following the first eAssessment for the Irish students. A major concern with the post-test questionnaire was survey fatigue because the researcher was aware of a significant number of institution related surveys being conducted at the same time. Therefore, the questionnaire was simplified to accommodate the students. The post-test questionnaire was not administered outside Ireland to reduce the administrative burden on the participant institutions.

The time allocated to the administration of the survey was limited to twenty minutes to ensure that standard class activities did not suffer undue disruption. The research questions were divided into the following sections:

1. General participant data
    a. Gender
    b. Standard or non-standard entry to third level
2. Good and bad experiences of using computer-based testing
3. Confidence
4. Preparedness
5. Barriers

The post-test questionnaire underwent one iteration prior to administration. A pilot questionnaire was tested with a sample of students to explore issues such as clarity, ease of understanding, and time to complete and collect responses. No changes to the pilot were required for the post-test questionnaire. Responses to general participant data are tick-box type. Open questions were used to gather comments regarding students' perceptions and experiences of computer-based tests for mathematics during the first semester. Questions relating to confidence, preparedness and barriers are Likert based with the scale ranging from "none" to "a very great deal". This design approach allows both quantitative and qualitative data to be gathered within a single survey instrument and is deemed to be the most efficient use of the survey instrument. A copy of the questionnaire is included in Appendix 1. The design philosophy of the post-test questionnaire is to allow comparison of the students' responses in the questionnaire with the interpretation of the year one engineering student group interview and with comments made within the open responses to the pre-test questionnaire. Students' responses, comments, and perceptions will also be used in to guide the semi-structured interview questions for academics based around perceptions of academic background, prior experiences, support and training, and confidence, preparation, and barriers.

3.12.5.4 Good and bad perceptions of computer-based tests

Students engaging with the survey do so at the beginning of semester two in year one of their undergraduate study. All participants had an opportunity to engage with computer-based testing of mathematics for both formative and summative purposes during semester one in engineering mathematics. Two open questions are asked using a prompt format to minimise the need for students to engage in analysis of the question to elicit informative answers:

1. The main thing I find good about computer-based tests is …
2. The main thing I find bad about computer-based tests is …

The open questions allow the students to expand on what they now view as good or bad issues relating to eAssessment.

3.12.5.5 Feelings of confidence, preparedness, and barriers

The manner and levels of students' engagement while accessing their mathematics eAssessments depends on factors such as ICT literacy, self-efficacy, and past experiences. Knowledge of how students feel immediately following their first eAssessment regarding their levels of confidence, preparation, and barriers may provide information about any shifts in perceptions held. A five-point Likert scale was developed, where: 1 = none; 2 = very little; 3 = a moderate amount; 4 = quite a lot; and 5 = a very great deal. Students were asked to rate the support and training they received in the first few weeks of their first-year undergraduate study in engineering mathematics in terms of: General use of computer systems and applications; use of the Virtual Learning Environment; use of quizzes and assessments within the Virtual Learning Environment; and answering mathematics type computer-based quizzes.

3.12.5.6 Experiences using computer-based tests

In addition to how students are supported and trained to use computer-based tests for engineering mathematics, it is necessary to establish if the students consider themselves to be adequately prepared. Assumptions have been made regarding the abilities of students to successfully engage online, and the presence of high bandwidth Internet access in certain locations may be distorting the views of academics. To ascertain if the assumptions are true a five-point Likert scale was developed, where: 1 = none; 2 = very little; 3 = a moderate amount; 4 = quite a lot; and 5 = a very great deal. Students were asked to rate their levels of confidence using computer-based tests and their levels of perceived preparation. The students were asked to rate the number of computer-based quizzes they had already completed by this stage and to identify if they had experienced anything that placed a barrier in the way of the online engagement.

3.12.5.7 Administration of Questionnaires

The purpose of the questionnaire document was to gather data from engineering students in their first year of undergraduate study. The data is required to enhance the knowledge and understanding of the salient issues experienced by students as they engage online with the assessment of mathematics. Students were not offered any incentives to complete the questionnaire apart from the satisfaction of knowing that they were contributing to potential improvements in teaching within engineering. The pre-test survey was to be administered in Ireland, Estonia, Finland, Poland, Portugal, Romania, and Russia whilst the post-test questionnaire would only be administered in Ireland. The English language used on the pre-test questionnaire deliberately avoided any abstruse language to ensure it was acceptable to all students and translations to local language were available if necessary. The pre-test questionnaires were designed to be administered in week three before the first eAssessment to take place in semester one week four. It was decided in advance that the researcher would not identify individuals. After collection, each questionnaire was identified by a number and date to support coding and entry in SPSS. All responses from the online questionnaires were coded according to the codex in Appendix 4.

3.13 Interview Design

Within the overall mixed method design the integration of qualitative and quantitative data is paramount to meet the philosophical requirements of the research (Bryman, 2016; Creswell, 2014; Cohen et al., 2011). Interviews with students and academic staff are designed to operate based on analysis of the comments and closed responses made by students in the pre-test questionnaire. The interviews are semi-structured using standardized open-ended questioning (Braun & Clarke, 2013). The semi-structured interview is designed to address questions relating to confidence, barriers, support, and training, whilst also providing space for students to engage in tangential discourses.

A semi-structured interview guide was developed from the initial analysis of the outputs from the pre-test questionnaire; a copy is provided in Appendix 1. The guide is sufficiently loose to permit leeway within the discussion. The flexibility of the semi-structured design frames the questioning, and students may feel free to explore additional issues they wish to bring to the attention of the researcher.

The combined role of lecturer and researcher is subject to tensions with participants, and this may affect the individual and group dynamic. The bias is additive along with the power relationship held by the lecturer. Each interview is preceded by brief dialogue regarding the Hawthorne effect to minimise the potential for changes in behaviour. All participants receive a guarantee that what is said in the interview remains in the interview.

3.13.1 Student Interviews

Based on convenience, the interviews with students are designed to function as group interviews with between six and eight students in each group during spare class periods. Two sets of group interviews were planned for stage one of the research study; group one comprises semester-one students and group two is a group of year-two semester-three or semester-four students. The purpose of group one is to gather data in week seven immediately following the first official summative online mathematics assessment in semester one. The purpose of group two is to gather data from students having progressed through to year two of undergraduate study. The interview with group two is designed to take place in year-two at a time convenient to students and researcher. The timing for the group two interview allows students time to reflect on their first and second-year mathematics activities, and to discuss these reflections in line with the comments made by group one. The ideal situation would be to have a representative spectrum of students engaging with the interview process. The gender balance within the student sample is not representative and students were invited to form a group for participation; a weakness in the methodology is the lack of randomness of participants. It is not possible to state if those participating hold extreme or representative views, however the most important consideration is providing a voice to the students.

3.13.2 Academic Staff Interviews

The impact of academic staff on the experiences of students cannot be underestimated within the realm of assessment as the assessor attempts to discover and give justice to learning (Dearden, 1979). The phenomenon of experiential interplay and the subsequent frameworks of belief held by students and academics is an aspect of interest in sub-question 2 (Driver et al., 1994). The adjustment of learning to reduce inconsistencies in beliefs may be difficult to achieve if academics are not aware of students' beliefs or ideas.

Assessment techniques, pedagogical reasoning, beliefs, and perceptions held by academic staff are of interest to address sub-question 2. Semi-structured interviews were planned with academic staff in stage one to operate during the mid-section of semester two. The timing of the academic interviews was designed to permit initial analysis and reflection of the interview with student group two to take place in advance (Noon, 2018). The sampling used to select suitable academic staff was purposive to enable comparisons to be made regarding beliefs, perceptions and methods used in teaching mathematics. A schedule of individual interviews was constructed to match availability of staff members with responsibility for teaching mathematics. The schedule included members of staff who used eAssessment methods and members of staff who used traditional classroom methods. The outcomes are not generalizable nor considered representative of the wider population of academic staff; the primary concern was the acquisition of in-depth expert knowledge.

3.13.3 Administration of Interviews

A protocol and guide was developed to maximize consistency between semi-structured interviews (Braun & Clarke, 2013) – see Appendix 1. A list of questions was developed using the interpreted themes from the initial data in the pre-test questionnaire. All interviews were designed to be conducted using face-to-face techniques in a convenient but familiar setting to minimise stress. Face-to-face interviews were considered unfeasible for most international academic staff, these interviews were held using online video conferencing and recording techniques. The interview protocol and guide were designed to support the research by utilizing similar questioning in each interview where possible.

The time-slots available for interviews limited the interviews to one hour maximum. Salient questions were addressed at the beginning of each interview followed by less structured discourse.

Chapter 4 – QUANTITATIVE RESULTS

This chapter presents the results of the questionnaires answered by first-year higher education students studying engineering mathematics. The purpose of the questionnaires is to aid the answering of research sub-questions 1 and 3.

Chapter 3 section 3.2.3 discusses the critical realism model of perceptions with reference to three domains: empirical domain, actual domain, and real domain. The questionnaires support answering the two research sub-questions in the empirical domain and the actual domain. The empirical and actual layers of the critical realism ontological model are contextually linked (Blom & Morén, 2011). The empirical observations from the questionnaires provide an evidential base for an understanding of the generative mechanisms in the real domain.

The perceptions of the students affect the students' relationships with engineering mathematics and the findings are presented in more detail in sections 4.1, 4.2, 4.3, 4.4, and 4.5.

Quantitative Results – Stage One

The research question of Irish students' perceptions of assessment as an emerging issue of online assessment is the focal point of this stage in the research. Anecdotal evidence of educational alignment was gathered in the years prior to the research study and the evidence gathered in Stage One provides an evidence base to qualify the anecdotal findings. The quantitative analysis in Stage one addresses and provides a baseline for research sub-question one.

The questionnaire responses contain a mixture of dichotomous, ordinal, and nominal data types and many responses are Likert categorical. Quantitative analysis of relationships was conducted using the following tests as appropriate:

1) Tests of variance
   a. Chi Square (test for statistically significant differences to determine if the variables are independent of each other) (Cohen, Mannion & Morrison, 2011)

b. T-Test (test of two means to determine if they are equal, data is continuous) (Cohen, Mannion & Morrison, 2011)

c. ANOVA (test of three or more group means where a significant result shows that at least one pair of group means is statistically significantly different) (Cohen, Mannion & Morrison, 2011)

d. Welch ANOVA (test for equal means between populations where group variances are different) (Cohen, Mannion & Morrison, 2011)

2) Analysis of regression

a. Ordinal logistic regression (used to predict and explain the relationship between one dependent variable containing multiple categories and two or more independent variables) (Cohen, Mannion & Morrison, 2011; Tabachnick & Fidell, 2013)

3) Non-parametric

a. Mann Whitney (test to determine if there is a difference between the dependent variable for two independent groups, data is ordinal) (Cohen, Mannion & Morrison, 2011; Dinneen & Blakesley, 1973)

b. Kruskal-Wallis (ANOVA to compare mean ranks for more than two groups) (Cohen, Mannion & Morrison, 2011)

4.1 Pre-test Questionnaire

The pre-test questionnaire was designed to request information to provide background information in questions 1 and 2 to establish a baseline for the student responses and these are detailed in section 4.1.1.

4.1.1 General Participant Profile

The purpose of this general section was to determine if significant differences existed between Irish student groups in the years 2015/16 and 2016/17 prior to engaging with the respective qualitative components for each group. Large differences would not enable sensible discourse, veracity, and inter-student relationships to be evaluated.

4.1.1.1 Test 1: Male/Female Proportions

Question: Students were invited to state their gender as male or female

A purposively selected sample of n=119 (n=67 in academic year 2015/16, n= 52 in academic year 2016/17) Irish engineering students participated in the stage one Pre-test survey, comprising n=114 male students and n=5 female students. An ideal sample would contain the same number of participants in each year group however, the values are sufficiently close without upsetting statistical validity. Analysis is conducted for n=111 due to failure to complete questions by n=8 students – the students did not wish to proceed with participation.

The students were randomly assigned to year of study and male/female. At the conclusion it was not possible to calculate proportions because female participants were at the minimum frequency (n=5) requirements for a chi^2 test for homogeneity. Figure 4.1 displays the male to female proportions.

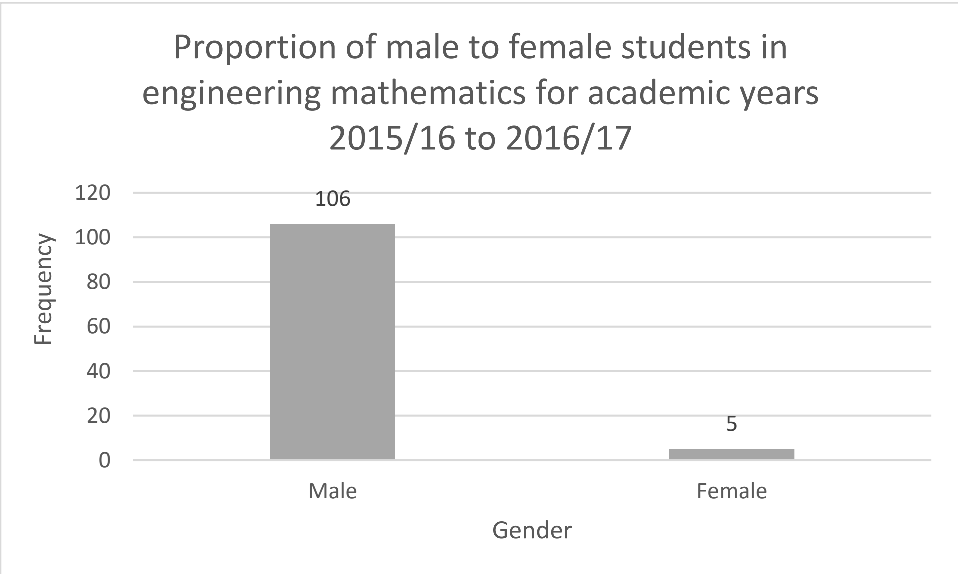

Figure 4.1 Proportion of male students to female students in First Year Engineering 2015/16 and 2016/17

4.1.1.2 Test 2: Academic Entry Profile

The veracity of the students' voices representing the students I am familiar with is supported by comparison of the distributions in figure 4.2a and figure 4.2b. The student profile in the Irish institute of technology was relatively stable for three years during the study. On this basis a baseline was established for comparative and relationship purposes with students in similar higher educational settings.

Question: Is there a difference in academic entry profile of first-year engineering student groups between the students in the Irish institute of technology prior to the research in the academic years 2012/13, 2013/14 and 2014/15 and those engaging with the research in the academic years 2015/16 and 2016/17?

Students were asked to answer this question by selecting the most appropriate CAO score range from a choice of <100, 101 to 200, 201 to 300, 301 to 400, 401 to 500, >500 and non-CAO. Students entering first year from a non-standard route such as mature entry were asked to select non-CAO. Distributions as assessed by a visual inspection were similar. Median and mean academic entry profile scores were controlled by removing non-standard academic profiles, the resultant distributions remained similar. The CAO scores used in Ireland are described in chapter two section 2.6.1.

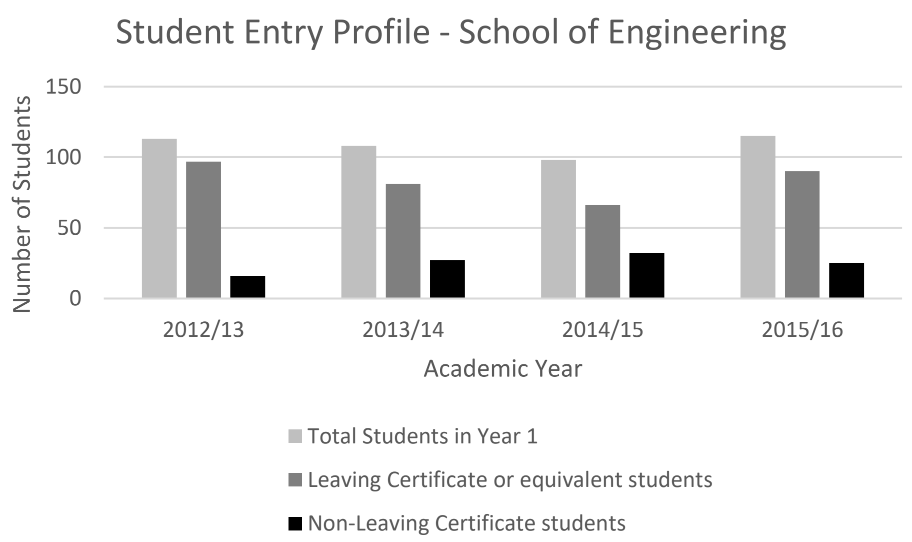

Figure 4.2a First Year Engineering Student Entry Type Profile prior to the study Academic Years 2012/13, 2013/14 and 2014/15

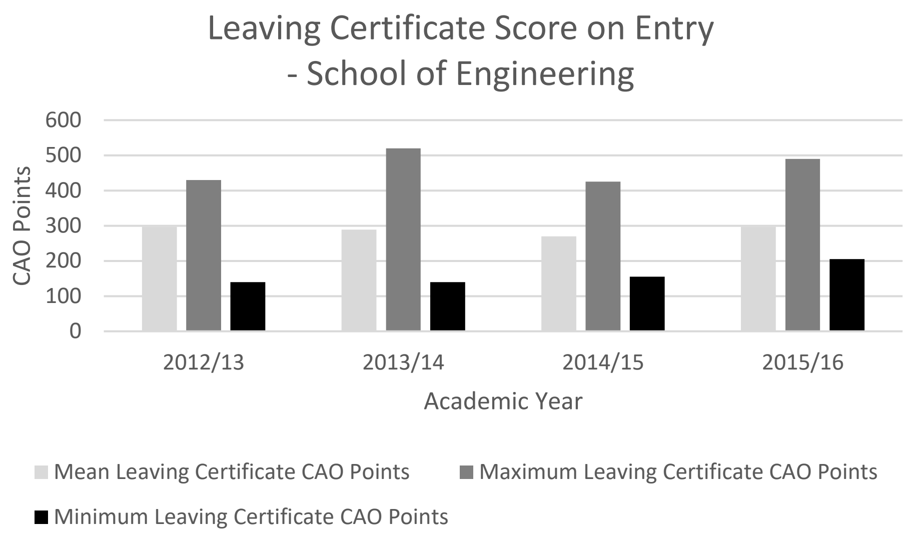

Figure 4.2b First Year Engineering Student CAO Leaving Certificate points prior to the study Academic Years 2012/13, 2013/14 and 2014/15

Data for academic years 2015/16 and 2016/17 was analysed to examine the profile of the Leaving Certificate scores of each student on entry and is presented in Figure 4.3. The profile is in line with expectation.

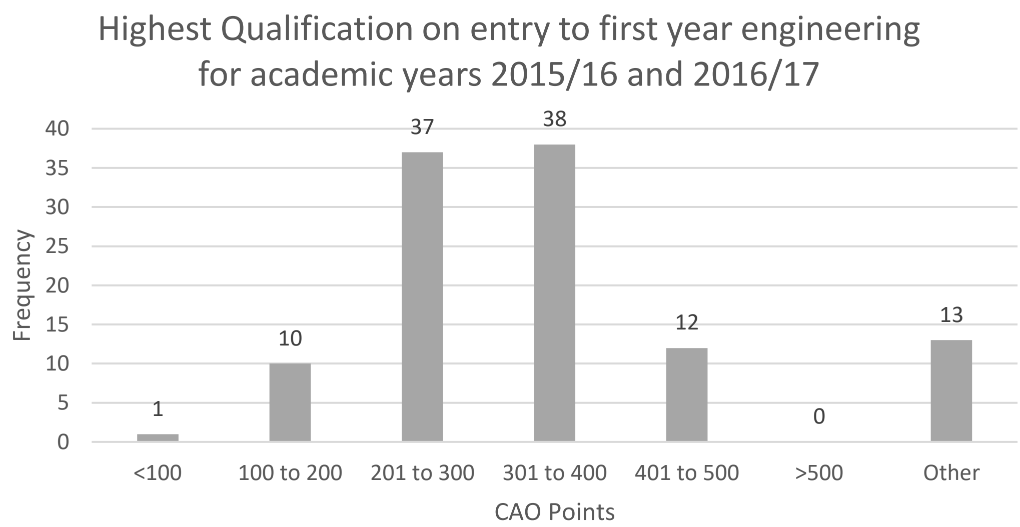

Figure 4.3 First Year Engineering Student Profile 2015/16 to 2016/17

4.1.2 Test 3: Prior Experiences of eAssessment

Question: Students were asked if they had any prior experiences of having conducted any form of eAssessment before entering first year engineering, where the reply was Yes or No.

The responses are displayed in figure 4.4 and show a significant quantity of students in each year group report no experience of any form of eAssessment prior to entry to higher education. This finding reflects the situation in Ireland in the years before the beginning of the Covid-19 pandemic. Few secondary schools in Ireland engaged with eAssessment prior to the Covid-19 pandemic. The majority of eAssessment experiences relate to the Irish students having conducted online driving licence application theory tests as stated in the open responses to the questionnaire.

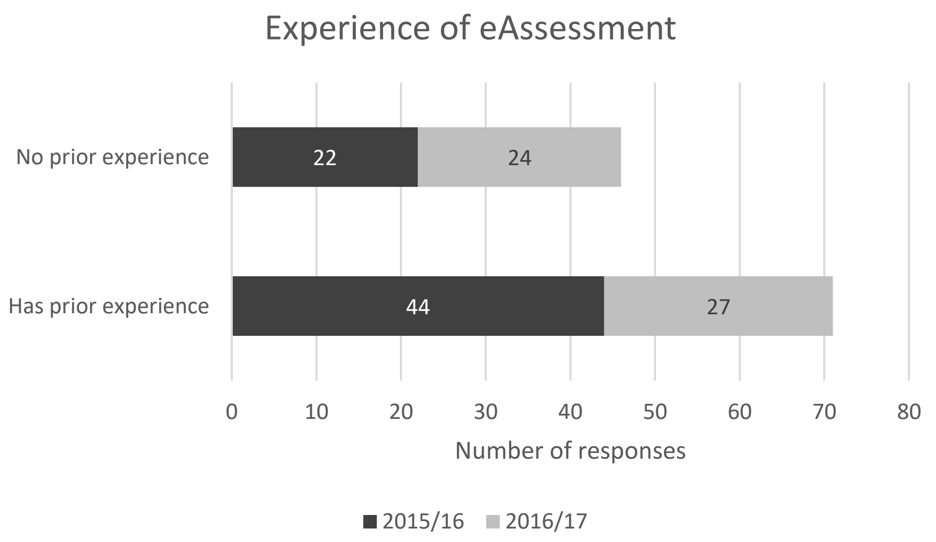

Figure 4.4 First Year Engineering Student Profile 2015/16 to 2016/17

Based on the dichotomous question of prior experience where the coding is yes = 1 and no = 2, an independent-samples t-test was run, because the group means are being compared for a dichotomous question, to determine if there were statistically significant differences in having experience of eAssessment prior to the first mathematics eAssessment between year groups 2015/16 and 2016/17. The reported eAssessment for year group 2015/16 was less (1.33 ± 0.475) than year group 2016/17 (1.50 ± 0.505). There is homogeneity of variances as assessed by Levene's test for equality of variances (p=0.015). The result is not statistically significant -0.167(95% CI, -0.348 to 0.146), t(114)=-1.821, p=0.071. See Appendix 2, table A2-1.

The mean value of 1.33 for academic year 2015/16 is lower than the mean of 1.50 for academic year 2016/17 but is not statistically significantly different. The quantity of students reporting no experience of eAssessment in both years is relatively stable, but it does demonstrate that academics need to be aware of this in the initial stages of semester one. Accepting that the differences between year groups 2015/16 and 2016/17 are not significant statistically the remaining analysis of the pre-test questionnaire is conducted by combining the year groups.

4.1.3 Test 4: Perceptions of Training and Support for general computer systems

Question: What are the reported perceptions of training and support for general computer systems, of first-year engineering student groups in an Irish institute of technology? Students were asked to provide their perception of the level of training and support the School of Engineering had provided regarding general computer systems and their applications.

The responses vary considerably for perceptions of the amount of training received in the use of general computer systems within the course of study and most notable is 27% do not relate the training received to be transferrable between subjects. Students do not necessarily relate training and support in different subjects and may not be able to understand the need for skills to be transferrable between subjects studied.

The bar chart for test 4 in figure 4.5 displays a large spread of responses. See Appendix 2, table A2-2.

Questions 4 to 10 were based on a five-point Likert scale, where: 1=none, 2 = very little, 3 = moderate, 4=quite a few, and 5 = a great deal.

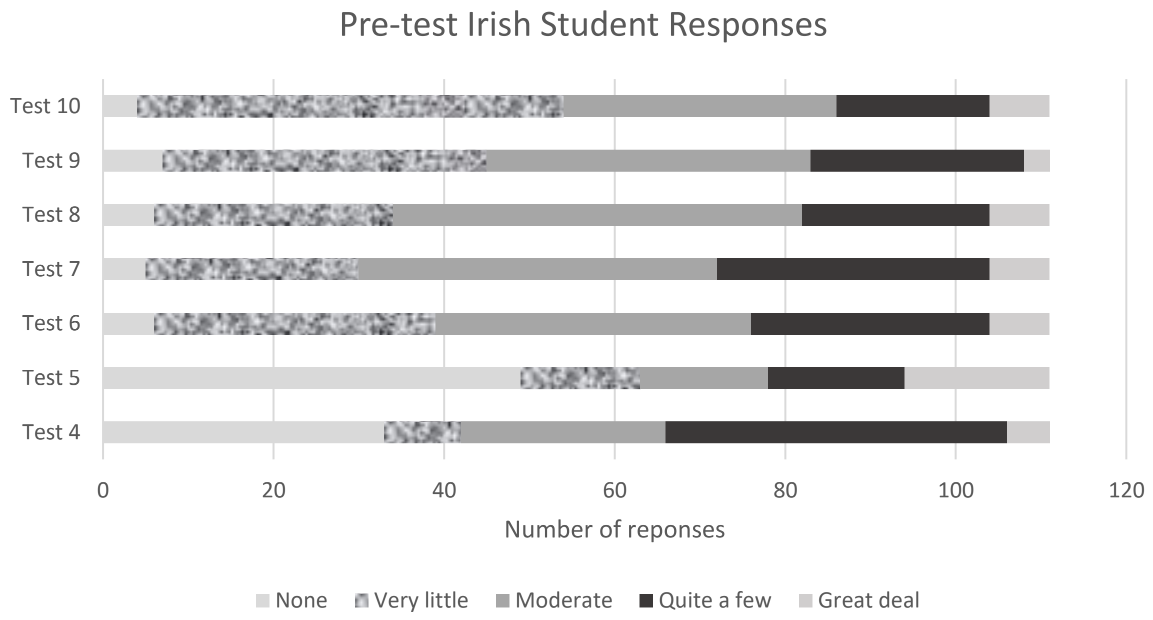

Figure 4.5 First Year engineering student self-reporting of perceptions completed prior to first mathematics eAssessment

4.1.4 Test 5: Perceptions of Training and Support for use of learning management systems

Question: What are the reported perceptions of training and support for the use of learning management systems, of first-year engineering student groups in an Irish institute of technology? Students were asked to provide their perception of the level of training and support the School of Engineering had provided regarding the use of the Blackboard learning management system.

The reported perception by 44% of students in figure 4.5 that they received no training and support in the use of virtual management systems is unexpected. The results for training and support on the use of general computer systems reveals a large proportion of students do not recognize the digital tools employed. All students receive training in the use of the Blackboard learning management system during their first week of term in semester one in the School of Engineering. The language used during the training may not be immediately recognized by students. See Appendix 2, table A2-2.

4.1.5 Test 6: Perceptions of training for eAssessment

Question: What are the reported perceptions of the training received for eAssessment, of first-year engineering student groups in an Irish institute of technology? Students were asked to provide their perception of the level of training and support the School of Engineering had provided regarding the use of computer-based quizzes within the Blackboard learning management system.

All eAssessment is conducted through the virtual management system, 5.4% report in figure 4.5 they did not receive any training for eAssessment, and 34% stated they received very little training for eAssessment compared to 44% reporting no training on the virtual learning environment. Students are presented with a series of practice eAssessments, and a significant minority do not avail of the opportunity to explore the practice tasks in practice. The incongruency of this difference suggests a variation in the degree of understanding by first year students about the digital tools in use. See Appendix 2, table A2-2.

4.1.6 Test 7: Perceptions of Confidence for eAssessment of Mathematics

Question: What are the reported perceptions of confidence for eAssessment of mathematics, of first-year engineering student groups in an Irish institute of technology? Students were asked to rate their levels of confidence.

The students report their confidence at engaging with eAssessment as shown in figure 4.5. Students reporting no confidence to very little confidence account for 27% of the participants. This finding is not unexpected when the findings from tests 4, 5, and 6 are considered. Examination of the student profile shows that 77% of the students have CAO scores less than 400. The average mathematics score for students entering the School of Engineering is CAO C3/D1 at ordinary level representing a grade score between 50% and 59%. These scores are considerably lower than for students entering a four-year honours degree in engineering where a minimum CAO H3 at higher level is expected. See Appendix 2, table A2-2.

4.1.7 Test 8: Perceptions of Preparation for eAssessment of Mathematics

Question: What are the reported perceptions of preparation for eAssessment of mathematics, of first-year engineering student groups in an Irish institute of technology? Students were asked how well prepared they were for engaging with eAssessment within the Blackboard learning management system.

The distribution in figure 4.5 is like the distribution for test 6 (training for eAssessment). 31% of students report very little, or no training received for mathematics eAssessment compared to 35 % for general eAssessment training in test 6. The degree of understanding of the meanings of training and preparation should be considered. Students might be equating the amount of training received with their perception of preparation. The degree of confusion in students' minds as to their own sense of preparation is paramount in this sense because they are still establishing their own relationships with the new education regime of higher education. See Appendix 2, table A2-2.

4.1.8 Test 9: Perceptions of Barriers to eAssessment of Mathematics

Question: What are the reported perceptions of barriers to eAssessment of mathematics, of first-year engineering student groups in an Irish institute of technology? Students were asked to provide their perception of barriers experienced that might hamper their engagement with eAssessment within the Blackboard learning management system.

Referring to figure 4.5, 60% of students believe they will experience a moderate amount to a great deal of barriers to eAssessment and only 6% believe they will not experience any barriers. Most students believe they will experience less than a moderate number of barriers. See Appendix 2, table A2-2. The barriers experienced are explored in depth in Chapter 5 and summarized as: poor internet availability, sharing bandwidth at home, limited access to suitable computer equipment, and distractions at home.

4.1.9 Test 10: Perceptions of Quantity of eAssessments of Mathematics

Question: What are the reported perceptions of the quantity of eAssessment of mathematics, of first-year engineering student groups in an Irish institute of technology? Students were asked to provide their perception of the quantity of eAssessments they have engaged with.

4% of students in figure 4.5 report that they had not completed any eAssessment activity, and 45% of students report very little eAssessment activity of mathematics prior to the first mathematics eAssessment in the first year of their engineering studies. The distribution is skewed towards students reporting they have experienced eAssessment. The high level of skewing may be a result of misunderstanding the role of the practice eAssessment opportunities, and students not linking the practice as part of their preparation and training. Some students may have preferred to access a larger bank of practice eAssessments, hence the dominant reporting of very little eAssessment. See Appendix 2, table A2-2.

4.2 Post-Test Questionnaire

The purpose of the post-test survey was to determine if students' perceptions and experiences had changed after their first summative eAssessment for mathematics; performance values are not under consideration. All Irish students had engaged with summative eAssessment in week four of semester one.

Study sizes differ (n = 111, pre-test) and (n=104, post-test). The difference is due to students' attrition for a variety of reasons outside the scope of this research and may not be related to mathematics. The quantity of non-standard entry students remained stable (n=13). The post-test survey addresses issues of confidence, preparation and barriers using a six-point Likert scale for tests 11 to 16. A six-point scale ensured that students were not presented with a definite central rank; this approach forced the students to think about their response before selecting a rank.

Comparison of students' perceptions of confidence in, preparation for, and barriers experienced for, eAssessment of mathematics is made between the pre-test and post-test survey responses. The pre-test survey uses a five-point Likert scale, and the post-test survey uses a six-point Likert scale. To conduct the comparison using Mann Whitney U tests it was necessary to convert the six-point scale to an equivalent five-point scale by combining scores for Likert values 3 and 4. The 6-point mapping to 5-point Likert scale is provided in table A2-3, Appendix A2. The six-point Likert scale questions were based on: 1=none, 2 = very little, 3 = moderate, 4=quite a lot, 5 = a great deal, and 6 = a very great deal, unless otherwise identified.

4.2.1 Test 11: Perceptions of post-test confidence in eAssessment

Question: What are the reported perceptions of students' confidence while engaging eAssessment of mathematics, of first-year engineering student groups in an Irish institute of technology, after having completed a summative eAssessment? Students were asked to rate their level of confidence having engaged with a mathematics eAssessment using a 6-point Likert scale.

A shift in confidence levels is evidenced when the graph in figure 4.6 is examined visually and compared with the graph for Test 7 in figure 4.5. Of note is that zero students reported having no confidence after having engaged with the eAssessment. Students received their grades immediately on completion with targeted feedback to help them gauge their performance. Some students display better understanding of the processes however, the action of entering results was problematic for those who did not participate in the practice eAssessments. The practice eAssessments were designed to allow students a safe space to practise entering results in the correct format. See Appendix 2, table A2-4 for the data. Further analysis of the shift in confidence levels is conducted in section 4.2.4, Test 14 to determine if the shift in confidence is statistically significant.

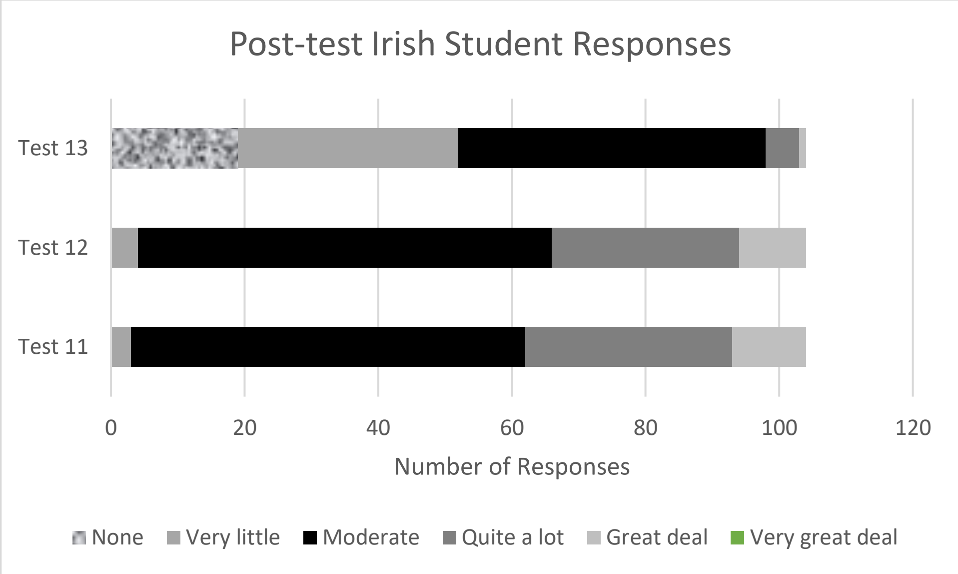

Figure 4.6 First Year engineering student self-reporting of perceptions having completed the first mathematics eAssessment

4.2.2 Test 12: Perceptions of post-test preparation for eAssessment

Question: What are the reported perceptions of students' preparation for engaging eAssessment of mathematics, of first-year engineering student groups in an Irish institute of technology, after having completed a summative eAssessment? Students were asked to rate their levels of preparation having engaged with a mathematics eAssessment using a 6-point Likert scale.

The levels of students' perception of preparation for eAssessment having conducted their first eAssessment are displayed in figure 4.6. A shift in perception of preparation from the pre-test questionnaire (test 8) is evidenced where zero students now report having no preparation. It is interesting to note this perception because six students reported no preparation in the pre-test questionnaire. This finding could result from students not fully understanding the meaning of preparation for the pre-test questionnaire and confusing preparation with training and support. See Appendix 2, table A2-4 for the data. To determine if the change in perception levels for preparation are statistically significant further analysis is conducted in section 4.2.5 Test 15.

4.2.3 Test 13: Perceptions of barriers experienced in eAssessment

Question: What are the reported perceptions of barriers experienced by students engaging eAssessment of mathematics, of first-year engineering student groups in an Irish institute of technology, after having completed a summative eAssessment? Students were asked to rate the barriers experienced while engaging with a mathematics eAssessment using a 6-point Likert scale.

Having conducted the first eAssessment, students were able to report on their experiences of barriers encountered, see figure 4.6. Students no longer reported the perception that they would experience a great many barriers to the eAssessment however, 49% report experiencing moderate amount to quite a lot of barriers. The actual barriers encountered are explored in greater depth in Chapter 5, where the qualitative responses are examined. See Appendix 2, table A2-4 for the data. Further analysis is conducted in section 4.2.6, Test 16 to determine if the reported students' perceptions of barriers between pre-test and post-test questionnaires is statistically significant.

4.2.4 Test 14: Differences between students' perceptions of confidence pre-test and post-test

Question: Is there a difference in Irish students' perceptions of confidence in eAssessment of mathematics in the first semester of undergraduate engineering having completed their first eAssessment in mathematics?

A one-way ANOVA was conducted, because the two groups are categorized into two or more categories, to determine if Irish students experience and change perceptions of confidence whilst engaging with eAssessment having received training and support and engaging with their first mathematics eAssessment. Participants were classified into two groups: pre-test (n=111) and post-test (n=104). See Appendix 2, table A2-5 for complete data.

Confidence score, in table 4.2, increased statistically significantly from a pre-test low moderate score to a high moderate post-test score. The one-way ANOVA provides evidence that the students experienced a positive shift in confidence levels having completed their first eAssessment in engineering mathematics.

Chapter 2 discusses issues affecting students entering higher education and the liminal effects that the change in pedagogy can have on students. This finding demonstrates that with appropriate planning it is possible to support the students during the liminal stages of semester one. Having experienced eAssessment in mathematics for the first time the students can judge their performance and receive timely feedback on their work. Students with low self-esteem and high levels of mathematics anxiety are studying in classes where some students have high levels of self-esteem and low mathematics anxiety. The opportunity to engage with mathematics in a safe and low-pressure environment may have helped to provide a boost in confidence.

Test	Mean	Standard Deviation
Pre-test	3.09	0.960
Post-test	3.48	0.723
ANOVA	$F(1,220) = 11.280$, $p<0.001$, $\eta^2=0.54$	

Table 4.2 Comparison of changes in perception of confidence during years 2015/16 to 2016/17

4.2.5 Test 15: Differences between students' perceptions of preparation pre-test and post-test

Question: Is there a difference in Irish students' perceptions of preparation for eAssessment of mathematics in the first semester of undergraduate engineering having completed their first eAssessment in mathematics?

A one-way ANOVA was conducted to determine if Irish students experience and change perceptions of preparation for engagement with eAssessment having received training and support and engaging with their first mathematics eAssessment. Participants were classified into two groups: pre-test (n=111) and post-test (n=104). See Appendix 2, table A2-5 for complete data.

Preparation score, in table 4.3, increased statistically significantly from a pre-test very little score to a medium moderate post-test score. The statistical significance of this test provides evidence that perceptions of preparation have changed because of their engagement with the first eAssessment in mathematics. The students may have confused their understanding of preparation with the training and support received in the weeks leading up to the eAssessment. Preparation is subjective as some students may consider themselves more prepared than others given that they have encountered the exact same pedagogical design. The issue of preparation is explored further in Chapter 5 as part of the qualitative research.

Test	Mean	Standard Deviation
Pre-test	2.96	0.968
Post-test	3.42	0.720
ANOVA	$F(1,220)=16.750$, $p<0.001$, $\eta^2=0.52$	

Table 4.3 Comparison of changes in perception of preparation during years 2015/16 to 2016/17

4.2.6 Test 16: Differences between students' perceptions of barriers experienced pre-test and post-test

Question: Is there a difference in Irish students' perceptions of barriers experienced in eAssessment of mathematics in the first semester of undergraduate engineering having completed their first eAssessment in mathematics?

A one-way ANOVA was conducted to determine if Irish students experience and change perceptions of barriers whilst engaging with eAssessment having received training and support and engaging with their first mathematics eAssessment. Participants were classified into two groups: pre-test (n=111) and post-test (n=104). See Appendix 2, table A2-5 for complete data.

Perception of barriers score, in table 4.4, decreased statistically significantly from a high pre-test score of very little to a low post-test score of very little. The students are more confident in the post-test responses compared to the pre-test responses and report a slight decrease in perceived barriers. The improved perceptions of preparation are consistent with expectations given that students would have engaged several times between pre-test and post-test. The reasons for the decrease in students' perceptions of barriers result from the actual experiences of the eAssessment process. Access to appropriate technology on-campus and off-campus removed some of the students' anticipated barriers. Barrier issues are explored further in Chapter 5 within the qualitative research.

Test	Mean	Standard Deviation
Pre-test	2.80	0.935
Post-test	2.38	0.874
ANOVA	$F(1,218) = 11.615$, $p<0.001$, $\eta^2=0.51$	

Table 4.4 Comparison of changes in perception of barriers during years 2015/16 to 2016/17

4.3 *Stage One Results Overview*

The salient phenomena associated with students' quantitative responses relate to confidence, preparation, and barriers to eAssessment. These phenomena are not mutually exclusive and do not exist in isolation, they are intertwined with expectancy and self-efficacy cognitive factors. The phenomena of confidence, preparation and barriers are explored further in section 4.5 and the cognitive factors of expectancy and self-efficacy are explored further in section 4.5.6. Confidence, preparation, barriers, expectancy, and self-efficacy are explored qualitatively in Chapter 5.

Many responses in the pre-test survey report no prior experience of online assessment and yet they are expected to be able to cope (Kirschner & De Bruyckere, 2017). The quantitative responses underline the Irish gender imbalance as an issue for the engineering profession in Ireland. The heavily skewed gender balance towards male students is repeated in other countries, but not all (see figure 4.7, section 4.5.1.1).

Prior experiences of computer-based testing, training and support for online assessment, preparation for online assessment and barriers to engagement online reveal issues to be considered for programme planners in Irish higher education institutions. During the preparatory and training stages prior to the first online assessment Irish students were provided with access to several training quizzes.

The initial stages of undergraduate education create dissonances, and the ability of students to adapt their learning within a mathematics eAssessment environment is linked to the students' sense of self-concept (Sax et al., 2015). Personal competencies are not yet developed for the new environment; motivation, emotions and performance expectations are linked to prior experiences, and these are explored in Chapter 5. The evidence at this juncture is sufficient to proceed with expansion of the evidence base.

Quantitative Results – Stage Two

The research problem of Irish students' perceptions of assessment as an emerging issue of online assessment was the focal point of this research study in Stage One. The anecdotal evidence of educational alignment gathered in the years prior to the research study involving partner institutions suggests that evidence gathered in Stage One doesn't just apply to Irish students. Expansion of the research to other geographic locales permits the research study to address students' perceptions in other locales. Data gathered in stage one provides the necessary nexus with the anecdotal evidence to create firm foundations for the research in the second stage. Therefore, the quantitative analysis in Stage Two addresses and provides a baseline for research sub-question three.

The participating countries in Stage Two were Estonia, Finland, Ireland, Poland, Portugal, Romania, and Russia. A comparative analysis between Irish students and Finnish students responding to the pre-test questionnaire in years 2015/16 and 2016/17 is provided in section 4.4. The Irish and Finnish comparative analysis was conducted prior to the full comparative analysis, with the introduction of a modified questionnaire, by students in all participating countries in year 2017/18 in section 4.5.

4.4 Comparative Analysis between Irish and Finish Students during years 2015/16 and 2016/17

The five-point Likert scale questions were based on: 1=none, 2 = very little, 3 = moderate, 4=quite a few, and 5 = a great deal, unless otherwise identified.

4.4.1 Test 17: Male/Female Proportions

Question: Is there a difference in male/female proportions of first-year engineering student groups between an Irish institute of technology and a Finnish university of applied sciences? Students were invited to state their gender as male or female.

Two hundred and thirty students (see table 4.5) from Finland (n=111) and Ireland (n=119) participated in the pre-test questionnaire. (114) 96% of students in Ireland and (106) 96% of students in Finland reported as male. Due to the small sample size of females (n = 10), Fishers exact test was run producing no statistically significant difference in proportions of 0.003, p=1.000 between the Irish and Finnish groups. See Appendix A2 table A2-6A.

The test for proportions demonstrates the similarity in male to female proportions in the Irish and Finnish student engineering classes.

Country	Male	Female
Ireland	114	5
Finland	106	5

Table 4.5 Male/Female students studying engineering during years 2015/16 to 2016/17

4.4.2 Test 18: Academic Entry Profile

Question: Is there a difference in academic entry profile of first-year engineering student groups between an Irish institute of technology and a Finnish university of applied sciences?

The academic profiles of Irish and Finnish students were mapped using the ISCED classification system (*International Standard Classification of Education (ISCED)*, 2015) to establish cross-comparability between the two education systems. It is not possible to accurately map the academic entry profiles of non-standard entry students. Non-standard entry students present alternative qualifications such as recognized prior learning or experiences. It was therefore necessary to control the comparison by removing the non-standard entries.

A Mann-Whitney U test for two hundred and thirty students was run to determine if differences occur between the academic entry profiles of Irish and Finnish students. Distributions as assessed by a visual inspection were similar. The resultant distributions for standard entry students were similar, therefore the medians are reported in table 4.6. The differences in standard entry qualifications between Ireland and Finland were not statistically significantly different with identical median qualifications at 3.000, p=0.254. See Appendix A2, table A2-6B for full data.

Test	Median Score		Mean Score		Mann-Whitney, U	Standardised test statistic, z	Asymptotic sig (2-sided test), p	Cases included	Cases excluded	Statistically Significant
	Ireland	Finland	Ireland	Finland						
18	3.000	3.000	-	-	1771	142	88	142	88	No
19	-	-	1.4034	1.1892	5190	230	0	230	0	Yes
20	-	-	3.0932	4.0818	9743	228	2	228	2	Yes
21	-	-	2.9492	3.2636	7655	226	4	226	4	Yes
22	3.000	3.000	-	-	5938	226	4	226	4	No
23	3.000	3.000	-	-	6929.5	228	2	228	2	No

Table 4.6 Comparisons between Irish and Finnish engineering students during academic years 2015/16 to 2016/17

A median value of 3.000 represents a median entry qualification at the top end of the range 201 to 300 points for the Irish CAO points system and for the equivalent Finnish Matriculation system. The similarities between the countries for entry qualification are in line with expectation and allow further comparisons to be conducted.

4.4.2 Test 19: Prior Experiences of eAssessment

Question: Is there a difference in the prior experiences of eAssessment, of first-year engineering student groups, between an Irish institute of technology and a Finnish university of applied sciences? Students were asked if they had any prior experiences of having conducted any form of eAssessment before entering first year engineering, where the reply was a dichotomous Yes or No response.

A Mann-Whitney U test of two hundred and thirty students was run to determine if there were differences in prior experiences of eAssessment between Irish and Finnish students. Responses from all students (standard-entry and non-standard entry) are considered. Distributions of prior experience scores for Irish and Finnish students were not similar, as assessed by visual inspection, therefore the means are reported in table 4.6. See Appendix 2, table A2-6C for full data. The Finnish students reported statistically significantly lower prior experience levels than the Irish students. This difference may be explained by the higher ratio of non-standard entry students entering engineering in the Finnish University. Non-standard entry students report a lower exposure to eAssessment prior to higher education.

4.4.3 Test 20: Perceptions of Confidence for eAssessment of Mathematics

Question: Is there a difference in the perceptions of confidence when engaged with eAssessment, of first-year engineering student groups, between an Irish institute of technology and a Finnish university of applied sciences? Students were asked to rate their levels of confidence.

The question was based on a five-point Likert scale, where: 1=none, 2 = very little, 3 = moderate, 4=quite a few, and 5 = a great deal.

A Mann-Whitney U test was run to determine if there were differences in perceived confidence with eAssessment between Irish and Finnish students. Distributions of perceived confidence scores differed as assessed by visual inspection, hence the mean scores are reported in table 4.6. Mean perceived confidence scores were statistically significantly higher in Finland (4.0818) than in Ireland (3.0932). See Appendix A2 table A2-6D for full data.

Even though Finnish students reported less exposure to eAssessment than Irish students prior to higher education (see Test 19) there is a statistically significant difference in perceptions of confidence to engage with eAssessment. The Finnish student body has a significant number of non-standard entry students (n=72), such as mature students, compared to the Irish student body (n=16). The non-standard entry students may be basing their perceptions of confidence on their life experiences.

4.4.4 Test 21: Perceptions of Preparation for eAssessment of Mathematics

Question: Is there a difference in the perceptions of preparation when engaged with eAssessment, of first-year engineering student groups, between an Irish institute of technology and a Finnish university of applied sciences? Students were asked to provide their perception of how well prepared they were for engaging with eAssessment within their respective institutions.

A Mann-Whitney U test was run to determine if there were differences in perceived preparation for eAssessment of mathematics between Irish and Finnish students. Distributions of perceived preparation scores were not similar as assessed by visual inspection hence, the mean scores are reported in table 4.6. See Appendix A2 table A2-6E for full data. The mean scores were statistically significantly different and Finnish students reported higher perception levels of preparation (3.2636) than Irish students (2.9492).

In Stage One section 4.1.7 many Irish students reported low levels of preparation for eAssessment, and this level of perception continues when compared with the Finnish students. Misunderstanding the meaning of preparation and conflating this with training and support may be culturally aligned.

4.4.5 Test 22: Perceptions of Barriers to eAssessment of Mathematics

Question: Is there a difference in the perceptions of barriers when engaged with eAssessment, of first-year engineering student groups, between an Irish institute of technology and a Finnish university of applied sciences? Students were asked to provide their perception of barriers experienced that might hamper their engagement with eAssessment.

A Mann-Whitney U test was run to determine if there were differences in perceived barriers for eAssessment of mathematics between Irish and Finnish students. Distributions of perceived barrier scores were similar as assessed by visual inspection hence the median scores are reported in table 4.6. The median perceived barrier scores for Irish students (3.000) and Finnish students (3.000), were not statistically significantly different, p=0.344. See Appendix A2 table A2-6F for full data.

Finnish students report higher levels of confidence (Test 20) and preparation (Test 21), however the Finnish students' perceptions of barriers to eAssessment are not statistically significantly different from Irish students' perceptions of barriers at this stage in semester one. The issue of barriers is explored further in the qualitative responses in Chapter 5 and reveals differences in students' perceptions and those of academics.

4.4.6 Test 23: Perceptions of Quantity of eAssessments of Mathematics

Question: Is there a difference in the perceptions of the quantity of eAssessments of mathematics, of first-year engineering student groups, between an Irish institute of technology and a Finnish university of applied sciences? Students were asked to provide their perception of the quantity of eAssessments they have engaged with.

A Mann-Whitney U test was run to determine if there were differences in perceptions of the number of eAssessments that Irish and Finnish students had engaged with. The distributions were inspected visually and noted to be similar hence, the median scores are reported in table 4.6. The median perceived barrier scores for Irish students (3.000) and Finnish students (3.000), were not statistically significantly different, p=0.354. See Appendix A2 table A2-6G for full data.

A median score of 3.000 represents a moderate quantity of eAssessment engaged with. The eAssessments at this stage are typically formative and for purposes of practice and preparation as well as gaining experience. The skills and competencies developed within the practice tests are not limited to mathematics but include the use of syntax, entry of answers to the correct level of accuracy, and use of their respective institutions' Learning Management Systems.

4.4.7 Test 24: Perceptions of Training and Support for eAssessment of Mathematics

Question: Is there a difference in the perceptions of training and support for eAssessment, of first-year engineering student groups, between an Irish institute of technology and a Finnish university of applied sciences? Students were asked to rank their perceptions of training and support received in general computer systems, using learning management systems, and for eAssessment.

A composite score, in the range 4 to 20, capturing all training and support questions was created by adding the students' responses from the following questions:

1. What is your perception of the level of training and support regarding general computer systems and their applications? Answer range 1 to 5
2. What is your perception of the level of training and support regarding the use of the learning management system? Answer range 1 to 5
3. What is your perception of the level of training and support regarding eAssessment? Answer range 1 to 5
4. What is your perception of the level of training and support regarding mathematics eAssessment? Answer range 1 to 5

A Mann-Whitney U test was run to determine if there were differences in the composite Training and Support score between Irish and Finnish students. Some students (n=6) were excluded from the test because they failed to provide responses. Distributions of the Training and Support scores for Ireland and Finland were not similar as assessed by visual inspection, it is not possible to report the median scores and mean rank scores are reported instead. Composite Training and Support scores for Irish students and Finnish students were not statistically different, U=7851, z=2.610, p=0.009. See Appendix A2 table A2-6H for full data.

Country	Mean Rank
Ireland	12.66
Finland	14.05

Table 4.7 Comparisons of perceptions of training and support for mathematics eAssessment between Irish and Finnish engineering students during academic years 2015/16 to 2016/17

The students' perceptions are that training and support in the first month of semester one in Finland is higher than for students in Ireland. The significance of this finding is reflected in the higher levels of confidence and preparation reported by Finnish students in tests 20 and 21. The result of this test provides pointers for Irish academics to be more aware of the needs of students, and to be cognizant of the low levels of confidence in the training and support received that Irish students exhibit.

4.5 Comparative Analysis between Students studying in Estonia, Finland, Ireland, Portugal, Poland, Romania, and Russia during year 2017/18 using a pre-test questionnaire

To locate the situation in Ireland regarding students' experiences of mathematics eAssessment, Estonian, Finnish, Irish, Polish, Portuguese, Romanian and Russian students were asked prior to conducting an eAssessment about perceptions they had during semester one while studying engineering in higher education. Table 4.8 displays a breakdown of number of participants per country and their reported gender. Gender is displayed quantitatively as well as in percentage format. Students were invited to respond to two dichotomous questions for participant gender and prior experience of eAssessment, ten Likert scale questions for perceptions of their first year in engineering mathematics, and four questions for perceptions on their overall first year engineering programme.

Country	Participants	Male		Female	
		Number	Percentage	Number	Percentage
Estonia	72	56	78%	16	22%
Finland	97	82	85%	15	15%
Ireland	50	45	90%	5	10%
Poland	68	34	50%	34	50%
Portugal	103	50	49%	53	51%
Romania	53	36	68%	17	32%
Russia	56	25	45%	31	55%

Table 4.8 Country and gender participation during academic year 2017/18

4.5.1 General Participant Profile

The purpose of this general section was to determine if significant differences existed, within the groups' characteristics, between student groups prior to engaging with the qualitative components reported in Chapter 5. If the differences were too large it would not be possible for sensible discourse, veracity, and inter-student relationships to be evaluated. Table 4.8 displays the overall participation by country and contains a breakdown of the number of males and females participating. The number of participants per country is not equal, however the statistical tests selected for the analysis are sufficiently robust to take these differences in numbers into account.

4.5.1.1 Test 25: Male/Female Proportions

Question: What is the male to female ratio of first-year engineering student groups in a selection of international higher education institutions?

The bar chart in figure 4.7 (See Appendix 2, table A2-7 for data) displays the first-year engineering student male/female profiles for each participating country. The proportion of males to females differ in stark contrast between two groups

Estonia/Finland/Ireland and Poland/Portugal/Romania/Russia. The proportions are highly skewed making individual country comparisons for male and female perceptions difficult. Therefore, any tests involving males and females as independent variables are reported for the total sample and not for individual countries.

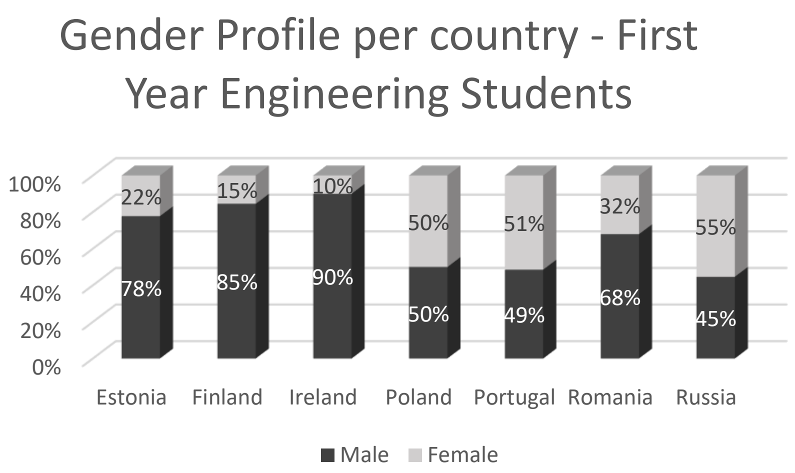

Figure 4.7 First Year engineering student male/female profile

4.5.2 Engaging with eAssessment

This section explores the differences if any between the self-reported perceptions of Irish students and students studying in other countries in their perceptions of eAssessment.

4.5.2.1 Test 26: Prior Experience of eAssessment

Question: Are there any significant differences between Ireland and the other countries regarding self-reported prior experiences of eAssessment? Students were asked the dichotomous question “Before studying your current higher education programme, did you have any experience(s) of Computer Based Tests?”

The dichotomous answers were Yes (1) and No (2).

A cumulative odds ordinal regression with proportional odds was run to determine the effect of country of study and having experience of eAssessment prior to the first mathematics eAssessment in first year of engineering studies. A cumulative odds regression test was required because a comparison is being made between two multi-categorical variables.

The salient SPSS outputs are in Appendix 2, table A2-8. Table 4.9 summarizes the results and demonstrates that Estonian, Finnish, Polish, Portugal, Romanian, and Russian students all reported statistically significant results of having more eAssessment experience than Ireland prior to studying engineering. The reference country is Ireland. The final model statistically significantly predicted the dependent variables over and above the intercept-only model, $x^2(6) = 45.736$, $p<0.001$. Thus, the data provides evidence that Irish students are at a disadvantage compared to their counterparts in the other countries due to their lack of experience with eAssessment prior to entering higher education. The significance at $p<0.001$ demonstrates that this is a highly significant result

Country	Odds of not having prior eAssessment experience	Wald x^2	p-value	Statistically Significant
Estonia	0.066(95% CI, 0.027 to 0.161)	$x^2(1) = 35.397$	P<0.001	Yes
Finland	0.148(95% CI, 0.006 to 0.330)	$x^2(1) = 21.647$	P<0.001	Yes
Poland	0.155(95% CI, 0.066 to 0.361)	$x^2(1) = 18.590$	P<0.001	Yes
Portugal	0.179(95% CI, 0.081 to 0.397)	$x^2(1) = 17.926$	P<0.001	Yes
Romania	0.203(95% CI, 0.086 to 0.482)	$x^2(1) = 13.048$	P<0.001	Yes
Russia	0.061(95% CI, 0.023 to 0.159)	$x^2(1) = 32.807$	P<0.001	Yes

Table 4.9 First Year engineering student prior experience of eAssessment

4.5.2.2 Test 27: Confidence engaging with eAssessment

Question: Are there any significant differences between Ireland and the other countries regarding self-reported confidence levels engaging with eAssessment? Students were asked “This question is about feelings of confidence that you now have in relation to being assessed using eAssessment. In your opinion, you feel that your confidence is:”

This question was based on a six-point Likert scale, where: 1=very low, 2 = low, 3 = moderate, 4=above moderate, 5 = high, and 6 = very high.

A cumulative odds ordinal regression with proportional odds was run to determine the effect of country of study and self-reported confidence levels engaging with eAssessment prior to the first mathematics eAssessment in first year of engineering studies. The salient SPSS outputs are in Appendix 2, table A2-9. The statistically significant test was operated as a single run using Ireland as the reference country, Wald $x^2(6) = 18.420$, $p = 0.005$. A single run does not result in the overall omnibus statistical test in the parameters table of outputs and multiple runs are required using each country as reference to establish the complete relationships. Table 4.10 summarizes the results and demonstrates that Portuguese, Romanian, and Russian students all reported statistically significant results of having less confidence regarding eAssessment experience prior to their first mathematics eAssessment compared to Ireland.

Of interest is the evidence provided in test 20 that Finnish students in the years 2015/16 and 2016/17 were more confident than Irish students, yet in 2017/18 the Finnish students didn't report greater confidence. The reason for the change in reported confidence is not known.

Country	Odds of higher self-reported confidence in eAssessment and confidence levels	Wald x^2	p-value	Statistically significant
Estonia	0.600(95% CI 0.313 to 1.150)	$x^2(1) = 2.365$	p=0.124	no
Finland	0.752(95% CI 0.407 to 1.392)	$x^2(1) = 0.822$	p=0.365	no
Poland	0.563(95% CI 0.292 to 1.088)	$x^2(1) = 2.922$	p=0.087	no
Portugal	0.429(95% CI 0.233 to 0.790)	$x^2(1) = 7.378$	p=0.0007	yes
Romania	0.388(95% CI 0.196 to 0.769)	$x^2(1) = 7.361$	p=0.0007	yes
Russia	0.296(95% CI 0.148 to 0.592)	$x^2(1) = 11.857$	$p<0.001$	yes

Table 4.10 First Year engineering student confidence while engaging with eAssessment

4.5.2.3 Test 28: Preparation for engaging with eAssessment

Question: Are there any significant differences between Ireland and the other countries regarding self-reported preparation levels for engaging with eAssessment? Students were asked “This question is about feelings of preparedness that you now have in relation to being assessed using Computer Based Tests. In your opinion, you feel that your level of preparedness is:”

This question was based on a six-point Likert scale, where: 1=very low, 2 = low, 3 = moderate, 4=above moderate, 5 = high, and 6 = very high.

A cumulative odds ordinal regression with proportional odds was run to determine the effect of country of study and self-reported preparedness levels engaging with eAssessment prior to the first mathematics eAssessment in first year of engineering studies. The salient SPSS outputs are in Appendix 2 table A2-10. The statistically significant test was operated as a single run using Ireland as the reference country, Wald $x^2(6)$ =19.629, p = 0.003. A single run does not result in the overall omnibus statistical test in the parameters table of outputs. Table 4.11 summarizes the results and demonstrates that Polish, Romanian, and Russian students all reported statistically significant results of having lower preparation regarding eAssessment experience prior to their first mathematics eAssessment. This test was designed to ascertain if students’ perception of preparation for eAssessment could be determined. Perception of preparation is subjective and affected by many factors such as self-study, training and support, confidence in the subject and self-efficacy.

Country	Odds of higher self-reported preparation for eAssessment experience and confidence levels	Wald x^2	p-value	Statistically Significant
Estonia	0.603(95% CI, 0.315 to 1.154)	$x^2(1)$ =0.123	P=0.726	No
Finland	0.755(95% CI, 0.408 to 1.395)	$x^2(1)$ =0.363	P=0.547	No
Poland	0.566(95% CI, 0.293 to 1.092)	$x^2(1)$ =4.368	P=0.037	Yes
Portugal	0.431(95% CI, 0.234 to 0.794)	$x^2(1)$ =3.167	P=0.075	No
Romania	0.431(95% CI, 0.234 to 0.794)	$x^2(1)$ =6.488	P=0.011	Yes
Russia	0.299(95% CI, 0.150 to 0.596)	$x^2(1)$ =5.536	P=0.019	Yes

Table 4.11 First Year engineering student preparation for eAssessment

4.5.3 Mathematical ability and confidence in mathematics

This section explores the differences if any between the self-reported perceptions of Irish students and students studying in other countries in relation to how they perceive their abilities in mathematics prior to entering higher education.

4.5.3.1 Test 29: Self-reported mathematics abilities prior to higher education

Question: Are there any significant differences between students in Ireland and the other countries regarding self-reported mathematics abilities prior to studying engineering in higher education? Students were asked "This question relates to the personal feelings you had about mathematics before your higher education programme. How would you have described your abilities in mathematics?"

This question was based on a six-point Likert scale, where: 1= poor, 2 = below average, 3 = average, 4=above average, 5 = good, and 6 = very good.

A cumulative odds ordinal regression with proportional odds was run to determine the effect of country of study and self-reported mathematics abilities prior to entering first year of engineering studies. The salient SPSS outputs are in Appendix 2 table A2-12. The test was operated as a single run using Ireland as the reference country and reported no statistically significant differences between the Estonian, Finnish, Portuguese, and Romanian students, Wald $x^2(6) = 36.711$, $p < 0.001$. The differences are statistically significant for Polish and Russian students where students report higher levels of mathematics ability compared to Irish students. A single run does not result in the overall omnibus statistical test in the parameters table of outputs. Table 4.12 summarizes the results.

Country	Odds of higher self-reported mathematics ability levels prior to higher education	Wald x^2	p-value	Statistically Significant
Estonia	0.805(95% CI, 0.422 to 1.536)	$x^2(1) = 0.434$	P=0.510	No
Finland	0.859(95% CI, 0.466 to 1.582)	$x^2(1) = 0.238$	P=0.625	No
Poland	1.990(95% CI, 1.033 to 3.835)	$x^2(1) = 4.226$	P=0.040	Yes
Portugal	0.972(95% CI, 0.531 to 1.778)	$x^2(1) = 0.009$	P=0.926	No
Romania	1.052(95% CI, 0.535 to 2.069)	$x^2(1) = 0.022$	P=0.883	No
Russia	3.992(95% CI, 1.988 to 8.016)	$x^2(1) = 15.147$	P<0.001	Yes

Table 4.12 Students' self-reported mathematics ability per prior to higher education per country

4.5.3.2 Test 30: Self-reported current mathematics abilities in first year of higher education

Question: Are there any significant differences between students in Ireland and the other countries regarding current self-reported mathematics abilities while studying first year of an engineering degree in higher education? Students were asked "This question relates to your personal feelings about mathematics now that you are in higher education. In your opinion, your feel that you are:"

This question was based on a six-point Likert scale, where: 1= poor, 2 = below average, 3 = average, 4=above average, 5 = good, and 6 = very good.

A cumulative odds ordinal regression with proportional odds was run to determine the effect of country of study and self-reported mathematics abilities during first year of engineering studies. The salient SPSS outputs are in Appendix 2 table A2-13. The test was operated as a single run using Ireland as the reference country and reported no statistically significant differences between the Estonian, Finnish, Polish, Portuguese, Romanian, and Russian students, Wald $x^2(6) = 2.740$, $p = 0.841$, compared to Irish students. A single run does not result in the overall omnibus statistical test in the parameters table of outputs. Table 4.13 summarizes the results.

Country	Odds of higher self-reported current mathematics ability levels	Wald x^2	p-value	Statistically Significant
Estonia	1.181(95% CI, 0.617 to 2.259)	$x^2(1) = 0.252$	P=0.615	No
Finland	1.056(95% CI, 0.572 to 1.949)	$x^2(1) = 0.030$	P=0.863	No
Poland	0.768(95% CI, 0.398 to 1.482)	$x^2(1) = 0.619$	P=0.431	No
Portugal	0.962(95% CI, 0.524 to 1.767)	$x^2(1) = 0.015$	P=0.902	No
Romania	1.178(95% CI, 0.597 to 2.325)	$x^2(1) = 0.223$	P=0.637	No
Russia	0.941(95% CI, 0.474 to 1.869)	$x^2(1) = 0.030$	P=0.863	No

Table 4.13 First Year engineering student self-reported current mathematics abilities in first year engineering

4.5.3.3 Test 31: Self-reported confidence levels that students will complete their current mathematics programme

Question: Are there any significant differences between students in Ireland and the other countries regarding current self-reported confidence levels that students will successfully complete their mathematics programme? Students were asked “This question relates to your feelings of confidence in successfully completing the mathematics component of your higher education programme. In your opinion, the possibility of completing the mathematics component is:”

This question was based on a six-point Likert scale, where: 1= poor, 2 = below average, 3 = average, 4=above average, 5 = good, and 6 = very good.

A cumulative odds ordinal regression with proportional odds was run to determine the effect of country of study and self-reported confidence that students will successfully complete their mathematics programme in first year of engineering studies. The salient SPSS outputs are in Appendix 2 table A2-14. The test was operated as a single run using Ireland as the reference country and reported statistically significant differences between the Estonian, Finnish, Polish, Portuguese, Romanian, and Russian students, Wald $x^2(6) = 33.679$, $p < 0.001$, compared to Irish students. A single run does not result in the overall omnibus statistical test in the parameters table of outputs. Table 4.14 summarizes the results.

Tests 29 and 30 show that Irish students are in general alignment with students in Estonia, Finland, Portugal, and Romania regarding perceptions of their mathematics abilities. However, the results of asking if students will successfully complete their current mathematics modules are striking. Relative to Ireland all countries report statistically significantly that they are much less confident that they will successfully complete their mathematics module.

Country	Odds of higher self-reported confidence in levels to complete the mathematics programme	Wald x^2	p-value	Statistically Significant
Estonia	0.473(95% CI, 0.246 to 0.911)	$x^2(1) = 5.019$	P=0.025	Yes
Finland	0.447(95% CI, 0.240 to 0.831)	$x^2(1) = 6.481$	P=0.011	Yes
Poland	0.149(95% CI, 0.076 to 0.294)	$x^2(1) = 30.323$	P<0.001	Yes
Portugal	0.447(95% CI, 0.242 to 0.827)	$x^2(1) = 6.578$	P=0.010	Yes
Romania	0.318(95% CI, 0.160 to 0.632)	$x^2(1) = 10.656$	P=0.001	Yes
Russia	0.431(95% CI, 0.216 to 0.860)	$x^2(1) = 5.694$	P=0.017	Yes

Table 4.14 First Year engineering student self-reported mathematics confidence levels in first year engineering

4.5.4 Amount of work and the rewards in mathematics

This section explores the differences if any between the self-reported perceptions of Irish students and students studying in other countries in relation to how they perceive the amount of work required to successfully complete their programme of mathematics and their perceptions of the rewards for that work. This section provides data to support the psychographic comparisons in section 4.5.6.

4.5.4.1 Test 32: Self-reported perceptions of the amount of work in mathematics

Question: Are there any significant differences between students in Ireland and the other countries regarding self-reported amounts of work required to complete their mathematics assignments? Students were asked "This question relates to the amount of work you need to put into mathematics assignments. The amount of work that you need to put into mathematics assignments is:"

This question was based on a six-point Likert scale, where: 1= very little, 2 = little, 3 = less than I should do, 4 = about right, 5 = a bit much, and 6 = too much.

A cumulative odds ordinal regression with proportional odds was run to determine the effect of country of study and self-reported amount of work required to successfully complete their mathematics programme in first year of engineering studies. The salient SPSS outputs are in Appendix 2 table A2-15. The test was operated as a single run using Ireland as the reference country and reported statistically significant differences between the Finnish, Portuguese, and Russian students, Wald $x^2(6) = 38.220$, $p < 0.001$, compared to Irish students. A single run does not result in the overall omnibus statistical test in the parameters table of outputs. Table 4.15 summarizes the results.

All countries reported higher levels of work required to complete mathematics assignments compared to Ireland. The perceptions of students in Portugal, Russia and Finland are that they are much more likely to say they have more work to complete mathematics assignments than Irish students.

Country	Odds of high self-reported perception levels of the amount of work in mathematics	Wald x^2	p-value	Statistically Significant
Estonia	1.309(95% CI, 0.670 to 2.536)	$x^2(1)$ =0.635	P=0.426	No
Finland	2.659(95% CI, 1.413 to 5.007)	$x^2(1)$ =9.180	P=0.002	Yes
Poland	1.557(95% CI, 0.796 to 3.045)	$x^2(1)$ =1.670	P=0.196	No
Portugal	4.440(95% CI, 2.356 to 8.365)	$x^2(1)$ =21.267	P<0.001	Yes
Romania	1.442(95% CI, 0.720 to 2.889)	$x^2(1)$ =1.068	P=0.301	No
Russia	3.848(95% CI, 1.890 to 7.836)	$x^2(1)$ =13.801	P<0.001	Yes

Table 4.15 First Year engineering student perceptions of amount of work involved completing mathematics assignments in first year engineering

4.5.4.2 Test 33: Self-reported perceptions of learning mathematics

Question: Are there any significant differences between students in Ireland and the other countries regarding self-reported perceptions of learning mathematics? Students were asked "This question relates to how well you think you can learn mathematics. Do you feel that learning mathematics is:"

This question was based on a six-point Likert scale, where: 1= very difficult, 2 = difficult, 3 = a bit of a struggle, 4 = alright, 5 = quite easy, and 6 = very easy.

A cumulative odds ordinal regression with proportional odds was run to determine the effect of country of study and self-reported perceptions of how difficult it is to learn mathematics in first year of engineering studies. The salient SPSS outputs are in Appendix 2 table A2-16. Ireland was the reference country and reported statistically significant differences between the Estonian, and Romanian students, Wald $x^2(6) = 55.889$, $p < 0.001$, compared to Irish students. A single run does not result in the overall omnibus statistical test in the parameters table of outputs. Table 4.16 summarizes the results.

Estonian and Romanian are almost four times more likely to say that learning mathematics in higher education is very easy than Irish students. Russian students are the least likely to say that learning mathematics is very easy, and the other countries report similar perceptions to Ireland.

Country	Odds of higher self-reported perception levels of learning mathematics	Wald x^2	p-value	Statistically Significant
Estonia	3.531(95% CI, 1.828 to 6.823)	$x^2(1) = 14.094$	P<0.001	Yes
Finland	1.222(95% CI, 0.661 to 2.260)	$x^2(1) = 0.408$	P=0.523	No
Poland	0.967(95% CI, 0.501 to 1.867)	$x^2(1) = 0.010$	P=0.920	No
Portugal	1.061(95% CI, 0.577 to 1.950)	$x^2(1) = 0.037$	P=0.848	No
Romania	3.899(95% CI, 1.953 to 7.782)	$x^2(1) = 14.889$	P<0.001	Yes
Russia	0.522(95% CI, 0.262 to 1.041)	$x^2(1) = 3.403$	P=0.065	No

Table 4.16 First Year engineering student perceptions of how difficult it is to learn mathematics in first year engineering

4.5.4.3 Test 34: Self-reported perceptions of Rewards for effort in mathematics

Question: Are there any significant differences between students in Ireland and the other countries regarding self-reported perceptions of the rewards received for studying mathematics? Students were asked “The reward you receive for the amount of work you need to put into mathematics assignments is:”

This question was based on a six-point Likert scale, where: 1= very little, 2 = little, 3 = a bit less than it should be, 4 = about right, 5 = a bit much, and 6 = too much.

A cumulative odds ordinal regression with proportional odds was run to determine the effect of country of study and self-reported perceptions of rewards for efforts in learning mathematics in first year of engineering studies. The salient SPSS outputs are in Appendix 2 table A2-17. The test was operated as a single run using Ireland as the reference country and reported statistically significant differences between the Estonian, Finnish, Polish and Portuguese students, Wald $x^2(6) = 28.244$, $p < 0.001$, compared to Irish students. A single run does not result in the overall omnibus statistical test in the parameters table of outputs. Table 4.17 summarizes the results.

Irish students are approximately twice as likely to report higher rewards than Estonian, Finnish, Polish, and Portuguese students. The perceptions of Romanian and Russian students are almost identical to Irish students for rewards.

Country	Odds of higher self-reported perception levels of the rewards for effort in mathematics	Wald x^2	p-value	Statistically Significant
Estonia	0.504(95% CI, 0.255 to 0.999)	$x^2(1)$ =3.857	P=0.050	Yes
Finland	0.414(95% CI, 0.217 to 0.792)	$x^2(1)$ =7.116	P=0.008	Yes
Poland	0.328(95% CI, 0.164 to 0.654)	$x^2(1)$ =9.997	P=0.002	Yes
Portugal	0.473(95% CI, 0.249 to 0.898)	$x^2(1)$ =5.248	P=0.022	Yes
Romania	1.296(95% CI, 0.635 to 2.646)	$x^2(1)$ =0.508	P=0.476	No
Russia	0.979(95% CI, 0.476 to 2.011)	$x^2(1)$ =0.003	P=0.953	No

Table 4.17 First Year engineering student perceptions of how difficult it is to learn mathematics in first year engineering

4.5.4.4 Test 35: Self-reported perceptions of mathematics instructors' awareness

Question: Are there any significant differences between students in Ireland and the other countries regarding self-reported perceptions of awareness of mathematics instructors towards students' mathematics abilities? Students were asked "This question relates to your perceptions about your mathematics instructor(s). The awareness of the mathematics instructor(s) of your mathematical abilities is:"

This question was based on a six-point Likert scale, where: 1= very poor, 2 = poor, 3 = not good, 4 = good, 5 = very good, and 6 = excellent.

A cumulative odds ordinal regression with proportional odds was run to determine the effect of country of study and self-reported perceptions of the awareness of students' mathematics abilities by mathematics instructors in first year of engineering studies. The salient SPSS outputs are in Appendix 2 table A2-18. The test was operated as a single run using Ireland as the reference country and reported statistically significant differences between Portuguese students, Wald $x^2(6) = 27.074$, $p < 0.001$, compared to Irish students. A single run does not result in the overall omnibus statistical test in the parameters table of outputs. Table 4.18 summarizes the results.

Portuguese students are approximately twice as likely as Irish students to report that mathematics instructors have excellent awareness of their abilities. This perception by Portuguese students suggests that even though they feel less likely to obtain high rewards (see test 33) their instructors are very aware of their abilities. Students in Estonia, Finland, Romania, and Russia are less likely than Irish students to have perceptions of excellent instructor awareness.

Country	Odds of higher self-reported perception levels of mathematics instructors' awareness of abilities	Wald x^2	p-value	Statistically Significant
Estonia	0.713(95% CI, 0.362 to 1.405)	$x^2(1) = 0.955$	P=0.328	No
Finland	0.631(95% CI, 0.332 to 1.200)	$x^2(1) = 1.970$	P=0.160	No
Poland	1.407(95% CI, 0.708 to 2.795)	$x^2(1) = 0.950$	P=0.330	No
Portugal	1.932(95% CI, 1.023 to 3.650)	$x^2(1) = 4.120$	P=0.042	Yes
Romania	0.609(95% CI, 0.299 to 1.239)	$x^2(1) = 1.873$	P=0.171	No
Russia	0.713(95% CI, 0.348 to 1.461)	$x^2(1) = 0.852$	P=0.356	No

Table 4.18 First Year engineering student perceptions of instructors' awareness

4.5.5 Self-reporting of students' perceptions of first year engineering studies in general

This section explores the differences if any between the self-reported perceptions of Irish students and students studying in other countries in relation to their perceptions of the first year of their respective engineering studies.

4.5.5.1 Test 36: Self-reported students' perceptions of confidence to complete first year of studies

Question: Are there any significant differences between students in Ireland and the other countries regarding self-reported perceptions of their confidence in being able to complete the first year of engineering studies? Students were asked "This question relates to how you think you will successfully complete your current study programme. Completing the whole programme will be:"

This question was based on a six-point Likert scale, where: 1= very difficult, 2 = difficult, 3 = a bit of a struggle, 4 = alright, 5 = quite easy, and 6 = very easy.

A cumulative odds ordinal regression with proportional odds was run to determine the effect of country of study and self-reported perceptions of students' confidence to complete their first year of engineering studies. The salient SPSS outputs are in Appendix 2 table A2-19. The test was operated as a single run using Ireland as the reference country and reported statistically significant differences between Estonian, Finnish, Polish, Portuguese, and Romanian students, Wald $x^2(6) = 31.299$, $p < 0.001$, compared to Irish students. A single run does not result in the overall omnibus statistical test in the parameters table of outputs. Table 4.19 summarizes the results.

Country	Odds of higher self-reported perception levels of confidence to complete the first year of the programme	Wald x^2	p-value	Statistically Significant
Estonia	2.192(95% CI, 1.121 to 4.288)	$x^2(1) = 5.262$	P=0.022	Yes
Finland	2.183(95% CI, 1.158 to 4.117)	$x^2(1) = 5.823$	P=0.016	Yes
Poland	2.694(95% CI, 1.362 to 5.327)	$x^2(1) = 8.116$	P=0.004	Yes
Portugal	2.830(95% CI, 1.505 to 5.322)	$x^2(1) = 10.426$	P=0.001	Yes
Romania	3.043(95% CI, 1.499 to 6.178)	$x^2(1) = 9.484$	P=0.002	Yes
Russia	0.714(95% CI, 0.353 to 1.442)	$x^2(1) = 0.883$	P=0.337	No

Table 4.19 First Year engineering student perceptions of confidence to complete first year engineering

The findings in test 31 show that Irish students are twice as confident of completing the current mathematics programme compared to all the other countries. However, test 35 reveals that Russian students are the only group with the perception that they are less likely than Irish students to complete the overall programme of studies in first year engineering.

4.5.5.2 Test 37: Self-reported students' perceptions of amount of work for assignments in first year engineering

Question: Are there any significant differences between students in Ireland and the other countries regarding self-reported perceptions of the amount of work in first year of engineering studies? Students were asked "You feel that the amount of work you need to put into assignments within your programme of study is:

This question was based on a six-point Likert scale, where: 1= very little, 2 = little, 3 = I should put in more work, 4 = about right, 5 = a bit much, and 6 = too much.

A cumulative odds ordinal regression with proportional odds was run to determine the effect of country of study and self-reported students' perceptions of the amount of work required to complete their first year of engineering studies. The salient SPSS outputs are in Appendix 2 table A2-20. The test was operated as a single run using Ireland as the reference country and reported statistically significant differences between Romanian students, Wald $x^2(6) = 24.783$, $p < 0.001$, compared to Irish students. A single run does not result in the overall omnibus statistical test in the parameters table of outputs. Table 4.20 summarizes the results.

Country	Odds of higher self-reported perception levels of the amount of work required to complete assignments in first year engineering	Wald x^2	p-value	Statistically Significant
Estonia	1.230(95% CI, 0.630 to 2.403)	$x^2(1)$ =0.367	P=0.545	No
Finland	1.109(95% CI, 0.589 to 2.089)	$x^2(1)$ =0.103	P=0.749	No
Poland	0.679(95% CI, 0.345 to 1.336)	$x^2(1)$ =1.257	P=0.262	No
Portugal	1.534(95% CI, 0.818 to 2.874)	$x^2(1)$ =1.781	P=0.182	No
Romania	2.628(95% CI, 1.298 to 5.320)	$x^2(1)$ =7.206	P=0.007	Yes
Russia	0.627(95% CI, 0.309 to 1.271)	$x^2(1)$ =1.675	P=0.196	No

Table 4.20 First Year engineering student perceptions of the amount of work in first year engineering

All countries with exception of Romania reported differences in perceptions of the amount for work as being not statistically significant from Ireland. Romanian students were more than twice as likely as Irish students to report that the amount of work required to complete assignments was too much. Russian and Polish students were only approximately two-thirds as likely as Irish students to believe the amount of work required was too much. 46.2% of students reported that the amount of work was 'about right'.

4.5.5.3 Test 38: Self-reported students' perceptions of rewards for work done to complete assignments in first year engineering

Question: Are there any significant differences between students in Ireland and the other countries regarding self-reported perceptions of the rewards for work done in first year of engineering studies?

This question was based on a six-point Likert scale, where: 1= very little, 2 = little, 3 = I should put in more work, 4 = about right, 5 = a bit much, and 6 = too much.

A cumulative odds ordinal regression with proportional odds was run to determine the effect of country of study and self-reported students' perceptions of the rewards for work done to complete assignments in their first year of engineering studies. The salient SPSS outputs are in Appendix 2 table A2-21. The test was operated as a single run using Ireland as the reference country and reported statistically significant differences between Romanian students, Wald $x^2(6) = 24.783$, $p < 0.001$, compared to Irish students. A single run does not result in the overall omnibus statistical test in the parameters table of outputs. Table 4.21 summarizes the results.

All countries with exception of Romania reported differences in perceptions of the rewards for work as being not statistically significant. Romanian students were more than twice as likely as Irish students to report that the rewards for completing assignments was too much. Russian and Polish students were only approximately two-thirds as likely as Irish students to believe the rewards were too much. 62.5% of students believe the rewards are 'about right' and providing evidence of pedagogical alignment with students' perceptions.

Country	Odds of higher self-reported perceptions levels of rewards for completing assignments in first year engineering	Wald x^2	p-value	Statistically Significant
Estonia	1.117(95% CI, 0.537 to 2.326)	$x^2(1)$ =0.088	P=0.767	No
Finland	0.811(95% CI, 0.407 to 1.617)	$x^2(1)$ =0.354	P=0.552	No
Poland	0.547(95% CI, 0.263 to 1.135)	$x^2(1)$ =2.623	P=0.105	No
Portugal	1.032(95% CI, 0.520 to 2.049)	$x^2(1)$ =0.008	P=0.928	No
Romania	1.158(95% CI, 0.537 to 2.499)	$x^2(1)$ =0.140	P=0.709	No
Russia	3.604(95% CI, 1.664 to 7.803)	$x^2(1)$ =10.577	P=0.001	Yes

Table 4.21 First Year engineering student perceptions of the rewards for work done in first year engineering

4.5.5.4 Test 39: Self-reported students' perceptions of programme instructor's awareness

Question: Are there any significant differences between students in Ireland and the other countries regarding self-reported perceptions of the programme instructors' awareness of the students' abilities in first year of engineering studies?

This question was based on a six-point Likert scale, where: 1= very poor, 2 = poor, 3 = not good, 4 = good, 5 = very good, and 6 = excellent.

A cumulative odds ordinal regression with proportional odds was run to determine the effect of country of study and self-reported students' perceptions of the rewards for work done to complete their first year of engineering studies. The salient SPSS outputs are in Appendix 2 table A2-22. The test was operated as a single run using Ireland as the reference country and did not report any statistically significant differences between students, Wald $x^2(6) = 12.031$, p =0.061, compared to Irish students. A single run does not result in the overall omnibus statistical test in the parameters table of outputs. Table 4.22 summarizes the results.

62.1% of students reported perceptions that instructor awareness of the abilities of students was good. The perceptions do not differ statistically significantly between countries. This finding closely aligns with test 36 for work required and test 37 for rewards.

Country	Odds of higher self-reported perception levels of instructors' awareness in all subjects	Wald x^2	p-value	Statistically Significant
Estonia	0.785(95% CI, 0.389 to 1.622)	$x^2(1)$ =0.514	P=0.514	No
Finland	0.575(95% CI, 0.290 to 1.141)	$x^2(1)$ =0.114	P=0.114	No
Poland	0.866(95% CI, 0.416 to 1.804)	$x^2(1)$ =0.701	P=0.701	No
Portugal	1.135(95% CI, 0.576 to 2.238)	$x^2(1)$ =0.133	P=0.715	No
Romania	0.588(95% CI, 0.275 to 1.253)	$x^2(1)$ =1.893	P=0.169	No
Russia	1.463(95% CI, 0.681 to 0.953)	$x^2(1)$ =0.953	P=0.329	No

Table 4.22 First Year engineering student perceptions of the awareness of students' abilities by programme instructors in first year engineering

4.5.6 Self-reporting of students' psychographic perceptions of first year engineering studies

This section explores the differences if any between the self-reported psychographic perceptions for all students studying mathematics in relation to their perceptions of the first year of their respective engineering studies. Tests 17 to 38 used Irish student responses as the reference to support an understanding of the perceptions held by students in other countries. Test 39 to 41 examine the perceptions of all the students on a per country basis to provide an insight to perceptions between the countries.

4.5.6.1 Test 40: Self-reported students' perceptions of mathematics expectancy

Question: Are there any significant differences in self-reported perceptions of mathematics expectancy in the first year of engineering studies based on country of study?

Expectancy as a true measure is a complex mix of cultural beliefs, self-beliefs, social perceptions, interpretation of experiences, goals, expectations, achievements, and task value (Schunk et al., 2014). This questionnaire is designed to consider perceptions based on task value resulting from the difference between the work done to complete a mathematics assignment and the rewards received for that assignment.

The expectancy score is calculated using Mathematics Rewards score (Test 33) – Mathematics Work Done score (Test 32), in this case the rewards and work done are for mathematics assignments. Mathematics Rewards score is in the range 1(very little) to 6 (too much), and Mathematics Work Done score is in the range 1(very little) to 6 (too much).

A Kruskal-Wallis test was conducted, because the data is non-parametric, to determine if there were differences in the mathematics expectancy scores between countries. The scores range from Rewards << work done (score -6) through Rewards = work done (score 0) to Rewards >> work done (score +6). Distributions of mathematics expectancy were not similar for all groups, as assessed by visual inspection of the boxplot in figure 4.8. The null hypothesis that the distributions of programme expectancy are similar for all groups was rejected because $p<0.05$ as found in Appendix 2 table A2-23, this finding is supported by visual inspection of the boxplot in figure 4.8. Rejection of the null hypothesis means that it is not possible to use the median scores for each group, it is only possible to say one or more groups' scores are higher or lower than another groups (Vargha & Delaney, 1998). The boxplot in figure 4.8 shows that Irish, Portuguese, and Russian students reported perceptions that the rewards were slightly less than the amount of work required. Estonian, Finnish, and Polish students reported perceptions that the rewards were slightly more than the amount of work required. Romanian students reported a neutral perception that the rewards matched the work required. The overall mean mathematics expectancy score (0.159) provides evidence of slightly positive expectancy in figure 4.9.

Mathematics expectancy scores were statistically significantly different between five country pairs $x^2(6) = 32.916$, $p<0.001$. Pairwise comparisons were performed and a Bonferroni correction for multiple comparisons was made with statistical significance accepted at the $p<0.00025$ level. Table 4.23 displays the mean rank mathematics expectancy scores for all countries and indicates those country pairings with statistically significant differences from the post hoc analysis. The salient SPSS outputs are contained in Appendix 2 table A2-23.

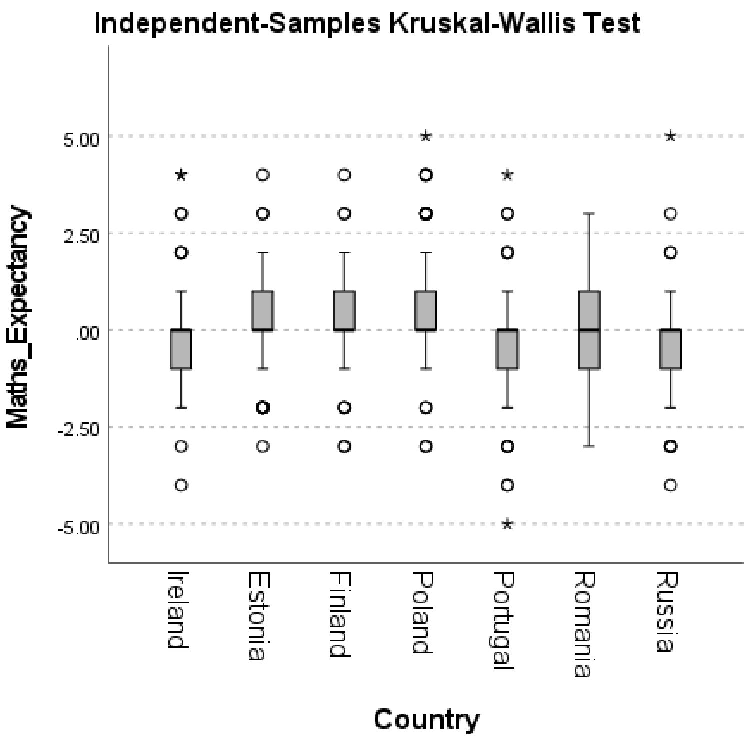

Figure 4.8 Distribution box plots for mathematics expectancy per country

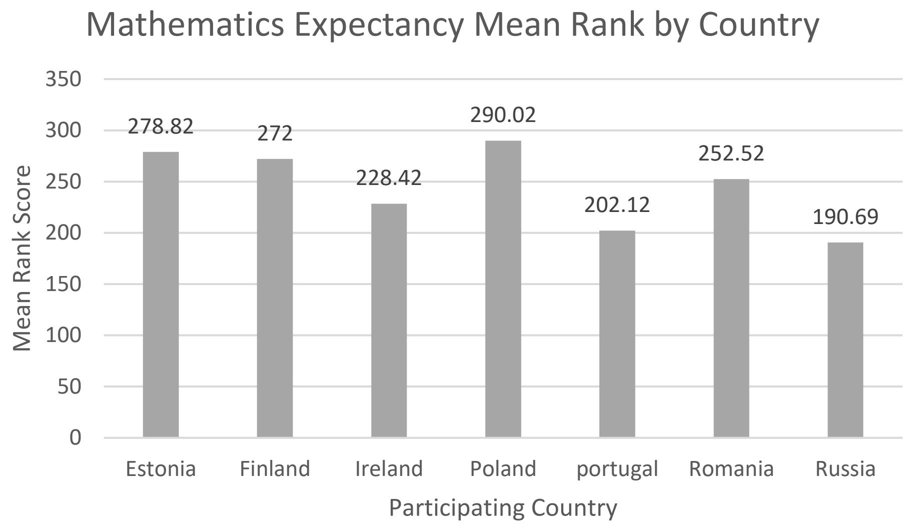

Figure 4.9 Mean rank mathematics expectancy scores for first year engineering students per country in academic year 2017/2018

Country	Estonia	Finland	Ireland	Poland	Portugal	Romania	Russia
Estonia	-	x	x	x	p=0.022	x	p=0.007
Finland	x	-	x	x	x	x	p=0.041
Ireland	x	x	-	x	x	x	x
Poland	x	x	x	-	p=0.003	x	p=0.001
Portugal	p=0.022	x	x	p=0.003	-	x	x
Romania	x	x	x	x	x	-	x
Russia	p=0.007	p=0.041	x	p=0.001	x	x	-

(x denotes difference between pair is not statistically significant)

Table 4.23 Comparisons between countries for first year engineering student perceptions of mathematics expectancy in first year engineering

4.5.6.2 Test 41: Self-reported students' perceptions of first year programme expectancy

Question: Are there any significant differences in self-reported perceptions of expectancy for the complete programme of study in the first year of engineering studies based on country of study?

The expectancy score is calculated using Programme Rewards score (Test 36) – Programme Work Done score (Test 37), in this case the rewards and work done are for all assessments encountered so far during first year. Programme Rewards score is in the range 1(very little) to 6 (too much), and Programme Work Done score is in the range 1(very little) to 6 (too much).

A Kruskal-Wallis test was conducted to determine if there were differences in the programme expectancy scores (figure 4.11) between countries that differed according to expectancy. The scores range from Rewards << work done (score -6) through Rewards = work done (score 0) to Rewards >> work done (score +6). The null hypothesis that the distributions of programme expectancy are similar for all groups was rejected because $p<0.05$ as found in Appendix 2 table A2-24, this finding is supported by visual inspection of the boxplot in figure 4.10. Rejection of the null hypothesis means that it is not possible to use the median scores for each group, it is only possible to say one or more groups' scores are higher or lower than another groups (Vargha & Delaney, 1998).

The boxplot in figure 4.10 shows the perceptions of Irish and Romanian students regarding programme expectancy are slightly less negative than for mathematics expectancy. Estonian, Polish, and Portuguese students' perceptions of programme expectancy are slightly positive, although some Portuguese students have very negative perceptions of programme expectancy. Finnish and Russian students' perceptions of programme expectancy are spread evenly around a neutral score. The overall mean programme expectancy score (0.03) provides evidence that many students believe the rewards match the work done in the first-year programme. The salient SPSS outputs are contained in Appendix 2 table A2-24.

Programme expectancy scores were statistically significantly different between the different countries $x^2(6) =31.069$, $p<0.001$. Pairwise comparisons were performed and a Bonferroni correction for multiple comparisons (Dunn, 1964) was made with statistical significance accepted at the $p<0.00025$ level. Table 4.24 displays the mean rank programme expectancy scores for all countries and indicates those country pairings with statistically significant differences from the post hoc analysis. Romania reported statistically significant differences with Estonia, Finland, Ireland, Poland, and Portugal, but not Russia.

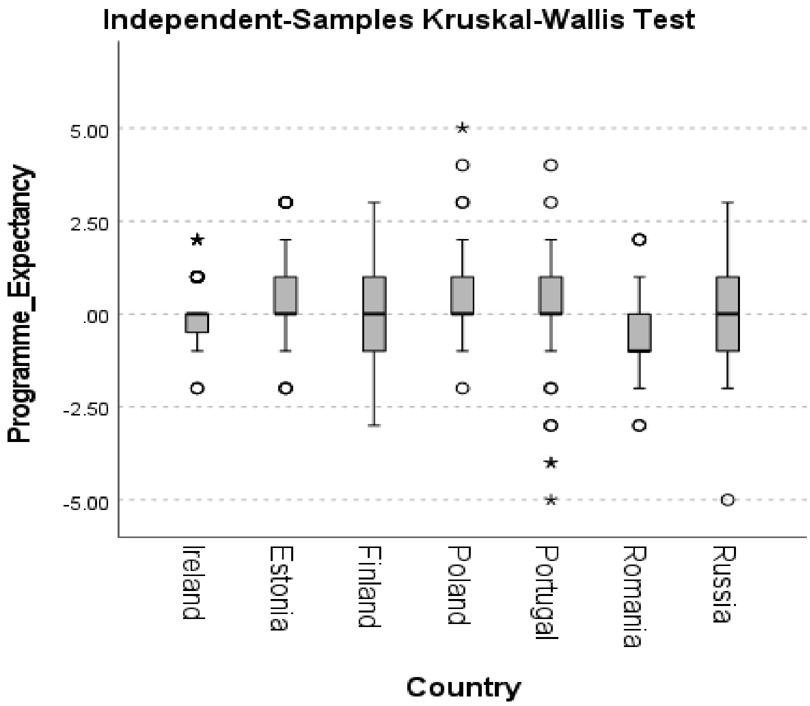

Figure 4.10 Distribution box plots for programme expectancy per country

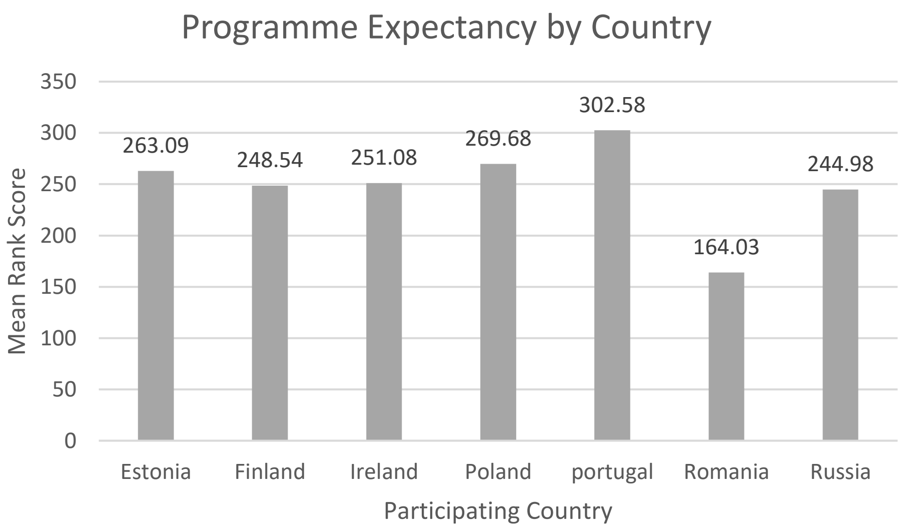

Figure 4.11 Programme expectancy scores for first year engineering students in academic year 2017/2018

Country	Estonia	Finland	Ireland	Poland	Portugal	Romania	Russia
Estonia	-	x	x	x	x	p<0.001	x
Finland	x	-	x	x	x	p=0.015	x
Ireland	x	x	-	x	x	p=0.009	x
Poland	x	x	x	-	x	p<0.001	x
Portugal	x	x	x	x	-	p<0.001	x
Romania	p<0.001	p=0.015	p=0.009	p<0.001	p<0.001	-	x
Russia	x	x	x	x	x	x	-

(x denotes difference between pair is not statistically significant)

Table 4.24 First Year engineering student perceptions of expectancy for first year engineering

4.5.6.3 Test 42: Self-reported students' mathematics self-efficacy

Question: Are there any significant differences in self-reported perceptions of mathematics self-efficacy in the first year of engineering studies based on country of study?

Self-efficacy relates to the students' personal judgements as they determine the course(s) of action required to achieve a certain level of performance (Schunk et al., 2014). The motivational foundation established by self-efficacy is vital for students to persist and engage with their engineering studies. A measure of mathematics self-efficacy was determined using the questionnaire responses as Self-Efficacy score = prior mathematics ability (Test 29) + current mathematics ability (Test 30) + confidence to complete mathematics programme (Test 31) + beliefs in learning mathematics (Test 32) + awareness of the mathematics instructors. Each variable has a range 1 to 6, hence the Self-efficacy score will have a possible range from minimum 5 to maximum 30.

A one-way Welch ANOVA was conducted, due to unequal group variances, to determine if students' self-reported mathematics self-efficacy was different per country. Participants (n=504) were classified into seven groups: Estonia (n=72), Finland (n=97), Ireland (n=50), Poland (n=68), Portugal (n=103), Romania (n=58), and Russia (n=56). The data was normally distributed, see boxplot in figure 4.12a, for each group as assessed by Shapiro-Wilk (p>0.05); but Levene's test of homogeneity reported heterogeneity of variances (p=0.002). Data is presented in table 4.25 and the salient SPSS outputs are contained in Appendix 2 table A2-25.

The boxplot in figure 4.12a shows the perceptions of Irish and Romanian students regarding programme expectancy are slightly less negative than for mathematics expectancy. Estonian, Polish, and Portuguese students' perceptions of programme self-efficacy are slightly positive, although some Portuguese students have very negative perceptions. Finnish and Russian students' perceptions of programme self-efficacy are spread evenly around a neutral score. The overall mean programme expectancy score (0.03) provides evidence that many students believe the rewards match the work done in the first-year programme.

Mathematics self-efficacy mean score in figure 4.12b increased from Finland to Estonia to Poland to Romania to Portugal to Russia to Ireland, in that order, but the differences between countries were not statistically significant, Welch's F(6, 0.502) = 48.270, p = 0.807.

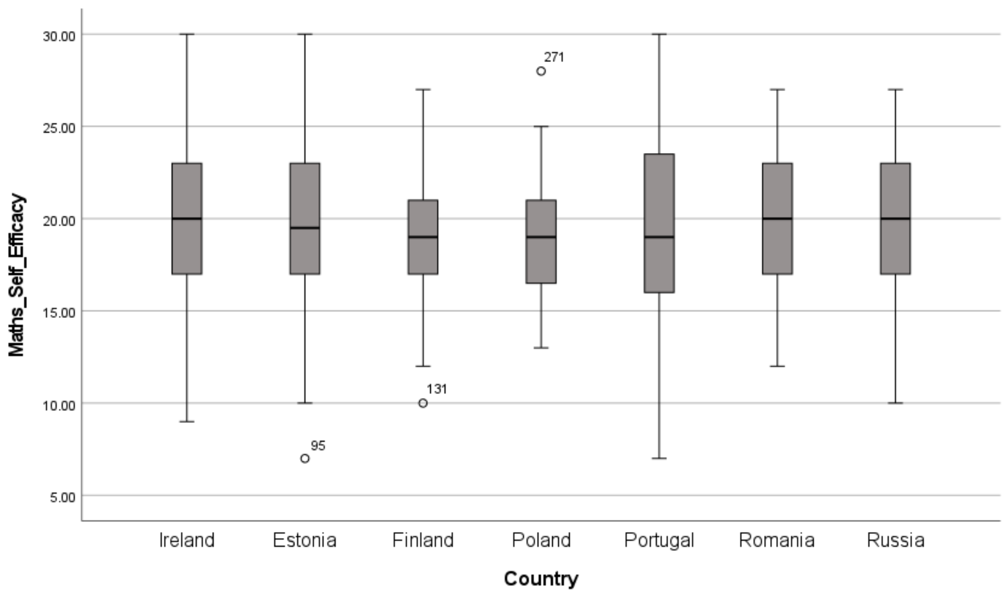

Figure 4.12a Box Plots of Mathematics Self-efficacy comparisons per country

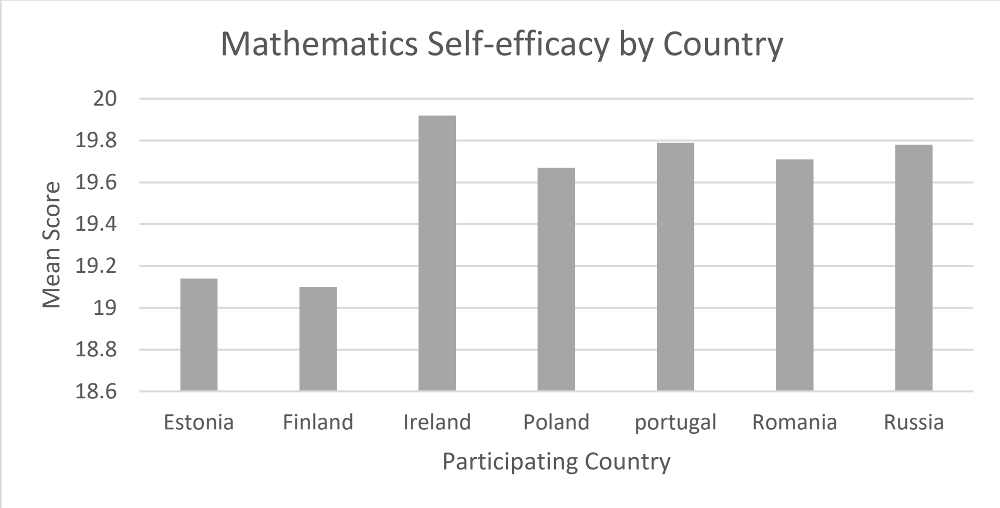

Figure 4.12b Mean Score Mathematics Self-efficacy comparisons per country

Country	Mean	Standard Deviation
Estonia	19.14	3.35
Finland	19.10	3.31
Ireland	19.92	4.42
Poland	19.67	4.58
Portugal	19.79	3.75
Romania	19.71	4.04
Russia	19.78	4.34

Table 4.25 Mean Scores for students' mathematics self-efficacy per country

4.5.7 Self-reporting of students' perceptions of barriers experienced in first year engineering studies

This section explores the differences if any between the self-reported perceptions for all students studying mathematics in relation to barriers experienced during eAssessment in the first year of their respective engineering studies. Tests 26 to 41 explore how students engage with eAssessment as a process in the first year of study. Test 42 explores the barriers experienced, if any, by the students.

4.5.7.1 Test 43: Self-reported students' perceptions of barriers experienced

Question: Are there any significant differences in self-reported perceptions of barriers experienced in eAssessment in the first year of engineering studies based on country of study? Students were asked "This question is about perceptions of barriers experienced in relation to being assessed using eAssessment. The number of barriers or things that get in the way of your participation in eAssessment is best described as:"

This question was based on a six-point Likert scale, where: 1=none, 2 = low, 3 = some, 4 = moderate amount, 5 = many, and 6 = too many.

A cumulative odds ordinal regression with proportional odds was run to determine the effect of country of study and self-reported barriers experienced engaging with eAssessment prior to the first mathematics eAssessment in first year of engineering studies. The salient SPSS outputs are in Appendix 2 table A2-11. The statistically significant test was operated as a single run using Ireland as the reference country, Wald $x^2(6) = 53.946$, $p = 0.006$. A single run does not result in the overall omnibus statistical test in the parameters table of outputs. Table 4.26 summarizes the results and demonstrates that Polish, Portuguese, Romanian, and Russian students all reported statistically significant results of perceiving higher barriers regarding their eAssessment experience prior to their first mathematics eAssessment. This test was designed to ascertain if students' perception of barriers experienced for eAssessment could be determined.

Country	Odds of higher self-reported barriers to eAssessment and confidence levels	Wald x^2	p-value	Statistically significant
Estonia	0.828(95% CI 0.432 to 1.588)	$x^2(1) = 0.322$	p=0.570	no
Finland	0.479(95% CI 0.258 to 0.891)	$x^2(1) = 5.396$	p=0.020	yes
Poland	2.746(95% CI 1.417 to 5.323)	$x^2(1) = 8.948$	p=0.003	yes
Portugal	1.979(95% CI 1.075 to 3.644)	$x^2(1) = 4.803$	p=0.028	yes
Romania	1.988(95% CI 1.005 to 3.934)	$x^2(1) = 3.893$	p=0.048	yes
Russia	2.107(95% CI 1.059 to 4.195)	$x^2(1) = 4.504$	p=0.034	yes

Table 4.26 Barriers to eAssessment comparisons per country

4.6 Summary

In response to the first research sub-question regarding by students of assessment processes in engineering mathematics in an Irish institute of technology, there is evidence in the quantitative data to conclude that:

1. Students' perceptions of barriers decrease as they gain experience of engaging with the assessment processes.
2. Students' perceptions of the preparation for assessment increases with experience of engaging with the assessment process.
3. Students' perceptions of their confidence to engage with assessment increases with experience of the assessment process.
4. Students' motivational factors such as self-efficacy and expectancy influence success.

The students are undertaking eAssessment during a liminal phase in higher education and their responses to questions regarding training and support demonstrate some levels of confusion about the meaning of training and support; this confusion suggests an inability by some students to relate transferrable knowledge and skills to different aspects of assessment.

The self-reported qualifications on entry to first year engineering at the institute of technology are as expected from analysis of student intakes prior to the study – see Appendix 2, table A2-26. There is considerable variability in mathematics skills and knowledge in the student cohort with potential for highly negative experiences during eAssessment. The variability in mathematics skills and knowledge, as reflected in the qualifications on entry to first year, is evidenced in the students' perceptions of the quantity of eAssessments conducted prior to the first mathematics eAssessment. Some students have experienced a great many eAssessments whereas some have reported no eAssessments. This profile reflects the reported experiences of students prior to higher education in Ireland, where large inconsistencies exist in mathematics.

The second research sub-question was addressed by gathering data from Finnish students in parallel to the Irish students during the first two years of the study, and subsequently expanding the process to include data from students in Estonia, Poland, Portugal, Romania, and Russia.

The academic profile of Finnish students from a university of applied sciences partly mirrors that of the Irish institute of technology. Finnish students reported greater exposure to eAssessment prior to entry to higher education whilst the

Finnish students' perceptions of training and support were like the Irish students. Yet, the Finnish students' higher levels of prior eAssessment experiences do not reflect in higher perceptions of confidence and preparation for eAssessment. It is noteworthy that Finnish students' perceptions of barriers to eAssessment are like those of Irish students. This may be explained by the greater quantity of practice eAssessments experienced by the Irish students during the first four weeks of semester one compared to the Finnish students.

Estonia, Finland, Poland, Portugal, Romania, and Russia reported higher levels of eAssessment experience prior to entering higher education than Ireland, although only Portugal, Romania, and Russia reported higher levels of confidence in eAssessment than Ireland. These results are reflected in the higher levels of preparation for eAssessment.

Self-reported mathematics ability is subjective and is affected by factors to be explored through qualitative study. Another subjective element within the study is the reporting of confidence. Irish students reported significantly lower levels of confidence in completing their mathematics studies compared to Estonian, Finnish, Polish, Portuguese, Romanian, and Russian students. The reported levels of Irish students' perceptions of confidence are very similar to their perceptions of the amount of work experienced in higher education. Students' confidence in mathematics is difficult to quantify objectively except when validated by performance values. This issue is explored in Chapter Two and students with high levels of mathematics confidence do not necessarily remain confident when they enter higher education and experience alternative assessment and teaching methodologies.

The results for self-reported perceptions of learning mathematics appears to conflict with levels of confidence as evidenced by Finnish, Polish, Portuguese, and Romanian students reporting similar levels of perceptions of learning mathematics to Irish students.

Irish, Romanian, and Russian students report lower perception levels of rewards for work done than Estonian, Finnish, Polish, and Portuguese students. The task value of lower returns for work done affects motivation and may be linked to lower levels of Irish students' confidence, although it doesn't explain the perceptions of rewards by Romanian and Russian students. Russian students believe expectation of success is matched to the performance derived from the work done. Romanian students experience difficulties in viewing success due to lower expectations.

Perceptions of students' levels of confidence to complete the first year of engineering studies are mirrored by perceptions of confidence to complete their mathematics programme. Of interest is the difference in the students' perceptions of the amount of work in the overall first year compared to that for mathematics. The difference may be explained by curriculum design in each country, and this result is very similar to the perceptions of rewards for work done.

Students' psychography is an important factor for motivation and success. Irish students report higher levels of expectancy for mathematics than the other participants, but these levels are not reflected in expectancy for the overall programme. Expectancy levels vary compared to Ireland for the other participating countries with Poland, Portugal and Russia displaying significant differences.

There were no statistically significant differences between countries for self-efficacy in mathematics. This result is complex because it relates to so many factors involving cultural and social perceptions as well as those related to the respective institutions.

Chapter 5 – QUALITATIVE RESULTS

In Chapter Four the results of the quantitative phase were outlined, and this chapter explores the qualitative perspective on issues encountered by first year engineering students and academics within the domain of engineering mathematics assessment. The research sub-questions are explored using the methodology set out in figure 3.2. The design methodology is provided in Appendix 3. This chapter addresses the qualitative results through the thematic outputs of the interpretative phenomenological analysis to aid the answering of research sub-questions 1 to 5.

Student qualitative data comprises the responses to open questions in pre-test and post-test questionnaires, and comments made within semi-structured group interviews, but it was not possible to establish semi-structured student interviews in Estonia, Poland, Portugal, Romania, and Russia due to language issues.

Stage 1. Pre-test questionnaire open questions as follows:

If the student responded to question 3 that they had prior experience of computer-based tests they were invited to answer question 4.

Question 4. The main things I find good or bad about computer-based tests are:

If the student responded to question 3 that they did not have prior experience of computer-based tests they were invited to answer question 5.

Question 5 I do not have experience of computer-based tests because

Stage 2. Post-test questionnaire open questions as follows:

Question 3. The main thing(s) I find good about computer-based tests are

Question 4. The main thing(s) I find bad about computer-based tests are

The open responses are short, typically one sentence in length. The pre-test questionnaire was the first opportunity for many Irish and Finnish students to express thoughts on their education focusing on online assessment of mathematics. The open responses by the Finnish students were provided in English as a second language hence, it may have been difficult for some of the Finnish students to express their true thoughts.

Semi-structured first year student group interviews were conducted shortly after completion of the first eAssessment for engineering mathematics. The initial design methodology concentrated on first-year engineering students, however the results obtained from the open responses revealed interesting perceptions resulting in an expansion of the qualitative data collection to include group interviews by Irish students in their second year of study. The reason for the inclusion of second year students was to explore any reflective changes since the first-year experience.

Academic staff data was gathered from semi-structured interviews with individual academic staff and some groups of academic staff responsible for the design and delivery of engineering mathematics programmes. Academic staff data was gathered in Ireland, Northern Ireland, Estonia, Finland, Portugal, Romania, and Russia, using face-to-face interviews where possible and by video conference if face-to-face was not possible within the period of the research. All interviews were conducted in English and all participants were fluent in English to avoid misunderstandings.

The underlying theoretical perspective of this research is critical realism where priority lies with the students' voices, experiences, and desires. Academic voices are sought, to provide context for the students' educational situation to provide the best explanations for the overall interpretation. Idiographic interpretation of individual student open responses, semi-structured student group interviews, and semi-structured academic interviews was developed using the codex in table 5.1 and compared across and within cases. The responses and comments made by the students and academics are windows to their internal emotions and allow the inquiry to be situated within the assessment processes of engineering mathematics. The subsequent pluralist situation of beliefs, emotions, and intuitions within engineering mathematics presents a danger of reductive oversimplification to obtain a form of clarity which may not exist. Linkages exist between, within, and across, all cases explored as part of the discourse creating a complex structure with unpredictable outcomes. Therefore, a degree of flexibility in interpretation is deliberately used to accommodate the complex and inaccessible realities experienced by all participants; the qualitative research is not weakened, it is strengthened. As the researcher and a lecturer in a unique position of power I am aware of students' fears of exposing their beliefs, desires, experiences, and perceptions. The critical realism focus, within a socio-cognitive epistemology, is on genuinely held perceptions whether they be true or false.

Within-case or vertical analysis using manual coding revealed twenty-eight codes on the first iteration, see table 5.1 (Sub-theme Code column). Two further iterative passes integrated the twenty-eight codes to nine thematic codes (Salient Thematic Code column); one code was reserved for no response or information deemed not relevant. The second stage within this analysis used a cross-case or horizontal approach to allow the students' voices to be considered as members of a shared community of practice with academics. Students have the identifier "S_xx_year_country" for a survey open response or "S_xx_year_G(I or F)" for a semi-structured interview response (I = Ireland, F = Finland), and academics have the identifier "ACxx" to ensure individuals cannot be identified.

The application of cross-case analysis allows the thematic outputs to be considered as shared phenomena within the group. The analysis provides evidence that students have internalized perceptions of the environment within which they are studying. It is not simply that something is good or bad; they are aware of incongruencies. Two primary cognitive domains of Self-efficacy and Expectancy became visible during the cross-case analysis, see table 5.1 cognitive domain column, to be discussed at the end of the chapter. The qualitative results are presented through the eight codes representing the following interpreted salient themes:

1. Confidence - coded as CONF
2. Experiences – coded as EXP
3. Barriers – coded as BARR
4. Assessment – coded as AMNT

5. Perceptions - coded as PCPT
6. Feedback - coded as FBCK
7. Training and Support - coded as TRST
8. Preparation - coded as PREP

Sub-Theme Description	Sub-Theme Title	Sub-Theme Code	Salient Thematic Code	Cognitive Domain
The subject described the activity or process easy to use without much cognitive loading. This resulted in a positive sense of self-efficacy	Ease of Use	EOU	CONF	Self-Efficacy
Sub-Theme Description	**Sub-Theme Title**	**Sub-Theme Code**	**Salient Thematic Code**	**Cognitive Domain**
The subject described the activity or process as difficult leading to a lack of confidence. This lack of confidence results in negative self-efficacy.	Lack of Confidence	LOC	CONF	Self-Efficacy
The subject expresses a sense of anxiety about the issue. This feeling leads to a negative sense of self-efficacy	Feelings of Anxiety	FOA	CONF	Self-Efficacy
The subject expresses a sense of anxiety regarding mathematics issues. This leads to a negative sense of self-efficacy.	Mathematics Anxiety	MA	CONF	Self-Efficacy
The subject is confident with the issue discussed. The subject has a positive sense of self-efficacy.	Confident in Use	CIU	CONF	Self-Efficacy
The subject feels that the issue being examined has led to a reduction in stress. This reduction in stress is considered to lead to a positive sense of self-efficacy.	Ease of Stress	EOS	CONF	Self-Efficacy
The subject is discussing the preparations they have underwent prior to e-Assessment. The relationship with Expectancy may be positive, negative, or neutral.	Prepare for e-Assessment	PFE	PREP	Expectancy

The subject is discussing the preparations they have underwent prior to non eAssessment. The relationship with Expectancy may be positive, negative, or neutral.	Prepare for Assessment	PFA	PREP	Expectancy
The subject considers the training undergone prior to the activity as being insufficient. This leads to a negative sense of Expectancy.	Lack of Training	LOT	TRST	Expectancy
Sub-Theme Description	**Sub-Theme Title**	**Sub-Theme Code**	**Salient Thematic Code**	**Cognitive Domain**
The subject considers the training undergone prior to the activity as being sufficient. This leads to a positive sense of Expectancy.	Sufficient Training	ST	TRST	Expectancy
The subject is discussing their experiences of eAssessment. The relationship with self-efficacy may be positive, negative, or neutral.	Experience of e-Assessment	EOE	EXP	Self-Efficacy
The subject is discussing their experiences of Assessment. The relationship with self-efficacy may be positive, negative, or neutral.	Experience of Assessment	EOA	EXP	Self-Efficacy
The subject is discussing the type of assessment they engage with. The relationship with Expectancy may be positive, negative, or neutral.	Type of Assessment	TOA	AMNT	Expectancy
The comments or utterances are not considered relevant to the study.	Not Relevant	NR	NR	
The subject is discussing an issue relating to cognitive development. The relationship with Expectancy may be positive, negative, or neutral.	Cognitive Development	CD	AMNT	Self-Efficacy

Sub-Theme Description	Sub-Theme Title	Sub-Theme Code	Salient Thematic Code	Cognitive Domain
The subject is discussing the environment in which the assessment takes places. The relationship with Expectancy may be positive, negative, or neutral.	Assessment Environment	AE	AMNT	Expectancy
The subject is discussing the length of the assessment that they engaged with. The relationship with Expectancy may be positive, negative, or neutral.	Length of Assessment	LOA	AMNT	Expectancy
Sub-Theme Description	**Sub-Theme Title**	**Sub-Theme Code**	**Salient Thematic Code**	**Cognitive Domain**
The subject is discussing the type of eAssessment they engaged with. The relationship with Expectancy may be positive, negative, or neutral.	Type of e-Assessment	TOE	AMNT	Expectancy
The subject is discussing any obstacles encountered or distractions that may occur leading to some form of perceived or actual barrier to learning. The experience leads to a negative sense of self-efficacy.	Distractions/Obstacles	DO	BARR	Self-Efficacy
The subject considers that the amount of value placed on the work done for an assessment had little or no value. This is a barrier to learning leading to a sense of negative expectancy.	No Value for work done	NVW	BARR	Expectancy
The subject indicated that accessing resources was problematic. This is a barrier to learning leading to a negative sense of self-efficacy.	No Access to resources	ATR	BARR	Self-Efficacy
The subject obtained feedback from assessment exercises and considered the feedback to be useful. The usefulness of the feedback is considered to lead to a positive sense of self-efficacy.	Feedback is Useful	FIU	FBCK	Self-Efficacy

The subject obtained feedback from assessment exercises but did not consider the feedback to be useful. The lack of usefulness of the feedback is considered to lead to a negative sense of self-efficacy	Feedback is not Useful	FNU	FBCK	Self-Efficacy
The subject is discussing their experience of feedback. The resulting effect on self-efficacy may be be positive, negative, or neutral.	Experience of Feedback	EOF	FBCK	Self-Efficacy
Sub-Theme Description	**Sub-Theme Title**	**Sub-Theme Code**	**Salient Thematic Code**	**Cognitive Domain**
The subject is discussing an issue and now feels that the learning situation has improved because of the activity. This leads to a positive sense of self-efficacy.	Feeling better about things	FBA	PCPT	Self-Efficacy
The subject is discussing the perceived confidence of other subjects or making judgements about their confidence. The result may be a positive, negative, or neutral sense of self-efficacy.	Perception of Confidence	POC	PCPT	Self-Efficacy
The subject is discussing the perceived experience of other subjects or making judgements about their experience. The result may be a positive, negative, or neutral sense of self-efficacy.	Perception of Experience	POE	PCPT	Self-Efficacy
The subject is discussing the support needs that they believe affects or are required by other subjects. The result may be a positive, negative, or neutral sense of self-efficacy.	Perception of Support Needs	PSN	PCPT	Self-Efficacy
The subject is discussing anxieties that they witness or perceive in other subjects. This leads to the sense of a negative self-efficacy in the subject.	Perception of Anxiety	POA	PCPT	Self-Efficacy
The comments or utterances are not	Not Relevant	NR	NR	

considered relevant to the study.				

Table 5.1 Codex for interpretation

5.1 Confidence

Confidence in relation to students' performance during assessment is difficult to explain or describe by the participant, and interpretation is highly subjective. Examination of the accounts uncovers a mix of positive and negative responses. Academic's adjusting to student confidence and performance is evident as they monitor students' performance.

5.1.1 Students' perceptions of confidence

The students' narrative reveals an organic growth in confidence using eAssessment and self-confidence as they move through first year to second year. Initial feelings are mixed and somewhat contradictory ranging from low confidence through to high confidence. Confidence is not limited to self; it also relates to the eAssessment process.

> *I don't really like it at all…With the computer it doesn't feel like anything, so I dislike them a lot…It needs motivation online.* S_2_2017_GF
>
> *I am a stupid construction worker* S_4_2017_GF
>
> *I was nervous, very anxious but that is me, I was incredibly frightened* S_4_2015_GI

Frustration and emotional helplessness epitomise many such comments by some students in the early stages of eAssessment. Some students have knowledge of IT but prefer to use pen and paper because mistakes can be rectified easily. Other students without prior IT knowledge report very low confidence levels not only in themselves but also in the processes of eAssessment. Mathematics anxiety and test anxiety are factors that can be hidden during eAssessment of mathematics and are not always made visible by students. Such comments do not summarize the full student corpus and are balanced by positive sentiments of confidence.

> *I think it is great because there is lots of revisions, so it sticks in your head. For me it is pretty easy because I went to high school so everything you have was there already.* S_5_2017_GF

Definitely more confident! With the practice tests I got used to the way they worked S_22_2016_GI

Here the students' comments align with those made by academics and their beliefs that students are digital natives. High levels of confidence in IT and prior knowledge of similar types of assessment are accepted as to how students' confidence should appear, but as demonstrated this is not always true. Mixed emotions about confidence in eAssessment appear in neutral or qualified responses.

…I would feel confident but if it is time limited you feel more pressure because you need to break up the questions. S_3_2015_GI

Student S_3_2015_GI qualifies the discussion on confidence by placing boundaries relating to the mechanics of the eAssessment. These boundaries also apply to time-limited assessments in general, self-confidence is related to pressures felt meeting assessment requirements.

Growth in confidence linked to other psychographic affectances associated with students' studies in mathematics takes place at different rates for individual students. The methodologies applied by academics are intrinsically linked within the structure of the overall programme. Students' progress from first year mathematics confidence is described through experiential emotions of tiredness, frustration, and confusion.

I expected second year to be the same format but it isn't… It's like learning to walk again. S_7_2016_GI2

The discourse reveals contradictory comments and feelings relating to confidence resulting from transferring to different pedagogical methodologies not only in mathematics but across the programme of study. The narrative appears as one of pressure to study for assessment at the expense of other activities

5.1.2 Academics' perceptions of student confidence

Academics were invited to discuss their perceptions of students' confidence while engaging with assessment in mathematics. Responses in relation to the lack of willingness by students to attend tutorial classes are viewed as being related to negative confidence levels

there is a history of "I am no good at maths" AC2
there is a fear of it, AC4
…because they may be less confident. AC6
It is common for them to be unconfident because it is like a culture… they are scared! AC10

Negative aspects of students' confidence in terms of fear or anxiety are visible to some academics when considering assessment, but this may also not be visible to the students, such as the comment above by AC2. Such comments suggest that because some students do not consider themselves good at mathematics, they automatically avoid the stress and trauma of subjecting themselves to further pain. Personal students' experiences prior to higher education are evident through such comments and can negatively affect students' motivation.

They are not motivated. AC2

Here, academic AC2 perceives a lack of motivation but doesn't reflect on the causes or effects within the processes under the academic's control.

AC10 addresses the lack of students' confidence and willingness to participate through being forced to teach by institutional tradition using a didactic approach as in a secondary school. This academic reflected on the extant practices in teaching mathematics and its assessment. The pedagogy was subsequently modified to be more inclusive and engaging, to offer reward for work done and to match students' expectations and abilities.

I was a failure…it is harder for them [the students] to pay attention … it is harder for those who are older. AC10

Academic AC10 is displaying awareness of the student body as a non-homogenous group. Traditional and non-traditional students display different characteristics because of their own lived-world experiences and AC10 acknowledges this factor. Awareness of students lacking confidence is evidentially entwined with performance expectations within the academic discourse, and the resultant redesign has helped to reduce the fear and anxiety whilst helping with performance improvement. The positive nature of such comments addressing assessment anxiety demonstrated that some students are not confident in high stake examination situations, and removing the pressure helps improve their perception of confidence.

The discourse on perceptions of students' positive confidence levels in eAssessment is closely linked with the belief that students are digital natives. Students are considered by some academics to be more online savvy than some academics and this perception creates a false impression of student confidence

> *They are more savvy online than me!* *AC3*
> *… they are very confident,* *AC1*

This perception provides a crutch for the academic because IT skills are confused with confidence in the early stages of the process. Such sentiments are mirrored by AC2, AC14 and AC15. Another perception is created through the analysis of incoming student grades.

> *When they come to our university we know their marks from their exams … On the basis of these details we can build expectations about their future.* *AC13*

Here, the belief becomes an expectation prior to any engagement online. The emotions such as fear and anxiety are enveloped in the expectation based on grades rather than personal knowledge.

5.2 Experiences

Experiences of eAssessment are not limited to those on campus or teaching quality and methods. As with confidence, experiences are subjective and form a mix of highly individual emotions and group emotions.

5.2.1 Students' experiences of eAssessment

Reference is made to the issue of 'poor handwriting' as being problematic in handwritten assessments, with eAssessment seen as a mechanism for overcoming this issue.

No ambiguity caused by bad handwriting S_15_2016_I

and

Teacher doesn't have to mind about bad handwriting. S_75_2016_F
Good thing is that I don't need to write on paper. S_75_2015_I

Students report a positive experience where they prefer to type answers rather than write on paper. These comments are not universal, especially where students lack experience of using computers. Such students are typically from, but not limited to, non-standard entry or vocational schools. Also, some students demonstrate awareness of the world in which they live by referring to the desire to minimize their use of paper.

The presence of metacognitive reflection on eAssessment is revealed through emotional descriptions of students' experiences. There is a sense that the students are aware of the presence of new forms of engagement with assessment and they are attempting to regulate their strategies and approaches with eAssessment.

I think computer tests are bad because there are only marks for right and no marks for in between S_17_2015_I

However, this student qualifies the negative response by providing a positive emotional description of the experience as

They allow faster completion S_17_2015_I

Experiences of prior educational situations are described by some to support the stressful factors that eAssessment can place on a student. Lack of experience of IT equipment for standard school leavers is mentioned as an issue as well as for non-standard entry students.

When I was at school, we didn't have a lot of experience working with computers S_32_2015_I
We haven't had any tests on computer S_100_2015_F
We never done computer tests in secondary school. Only time was for my car and bike licences S_10_2016_I

When faced with unfamiliar technology and assessment techniques the task value of the eAssessment may be considered beyond the scope of the student leading to demotivating affectances. Both Irish and Finnish students refer to the stability and speed of access to the test environment and the lack of use of paper as both negative and positive perceptions. Awareness of negative experiences of eAssessment by students is offset by the positive experiences of their peers. Negative experiences appear to be balanced by associated positive comments demonstrating a multi-layered aspect to students' perceptions of their experiences in eAssessment.

> *I found it beneficial because there was no pressure from an exam room environment. I was more comfortable in my own space* S_33_2015_I

Here the experience is seen as positive for this student because the student can engage outside the standard classroom for assessment. The student situated in the familiar surroundings of home doesn't feel pressure from other students. The sense of inadequacy felt by a student when another student completes an assessment quickly in the classroom is removed from the situation. Other similar distractions are also removed allowing the student to relax.

5.2.2 Academics' experiences of eAssessment

Lived experiences carry across all themes for academics and students, and academics' experiences have the potential to impact heavily on students due to their position of privilege within the institution. The dialogue with academics uncovered a wide range of experiences from extremely good through to dislike of eAssessment. The experiences are not uniform in terms of length of time spent on eAssessment ranging from almost zero time through to more than a decade. Some have generated a momentum and are committed to eAssessment whilst one has just begun to consider its use in teaching. The academic with very little experience of eAssessment was asked if any consideration had been given to eAssessment

> *No, I haven't but I have talked to lecturers who have taken online assessment…I think maybe I should look at it, even if not for maths but maybe for other subjects* AC4

Lack of reflection on teaching procedures and practices aligned with a degree of conservativism and unwillingness by this academic to explore new avenues is linked to comments made by some students as to why they were not experiencing a positive relationship with mathematics.

As already discussed in section 5.1.2, academics are aware of incoming students' grades. The grades of students in this research are not typically in the upper realms and their mathematics grades vary considerably. An underlying assumption alluded to in the dialogues about students' experiences is that

> *They are coming into 3rd level with a pre-judgment about maths.* AC2

The comment by AC2 about the students' pre-judgement about maths is unsupported in the academic's dialogue by any explanation or evidence as to the basis of this perception, displaying a subjective opinion rather than an objective fact. Students do carry their experiences about performance in mathematics from secondary school, however not all students have negatively pre-disposed experiences.

Academics' eAssessment experiences are mixed and reflect the students' experiences. One academic describes the experience of eAssessment as problematic

> *I also have a big problem and maybe that is my fault because I do not understand everything* AC7

Here, academic AC7 highlights issues with technical pedagogical knowledge and how it affects the teaching. The eAssessment tools available in the university are difficult to use. Relocating to the position of student to try and visualize how a student would be affected by unwieldy tools in eAssessment has highlighted issues for the academic. Diminished control and agency using difficult tools negating the experiences of the academic have distressed this academic. However, reflection on the potential for eAssessment is evident in

> *I do not like it and will wait until I see a tool that works easily for me* AC7

Another academic (AC9) reflected on experiences of eAssessment and related to diminished agency through lack of understanding of how eAssessment could be embedded in the pedagogy. This academic sought institutional support and advice leading to a complete redesign of assessment with help from an instructional designer. This academic explored the tools and question types to minimize gender bias and to improve the uptake of assessment exercises. Improved student experiences were paramount to aid the development of students' reflective processes

> *For them to reflect is not an easy task. They feel almost as if it makes them look weak in front of their peers* *AC9*

Other academics relating more positive experiences of eAssessment and greater confidence using the tools available to them have expanded the institutional tools to include tools available to students in their daily use.

> *Social networking allow communication with students to maybe solve things if they do not understand something.* *AC13*
> *Google, Google classroom* *AC10*

The desire to provide agency to the students within their eAssessment experiences highlights the academics' metacognitive activities although they are not extrinsically expressed. AC2, AC5, AC6, AC7, AC8, AC9, AC10, AC11, AC12, AC13, AC14, AC15, and AC16 demonstrate reflection, strategizing, evaluation, and feedback within their dialogues.

5.3 Barriers

Perceptions of barriers to learning throughout the first two years of study are analysed. There is evidence that barrier types are not constant across the first year and second year. Perceived barriers evolve as students develop an improved cognition of their role and position within the learning continuum. The perceptions of barriers may be physical or psychological in nature.

5.3.1 Students' perceptions of barriers in eAssessment

First year Irish students did not dwell on barriers associated with their mathematical abilities within the group interviews, rather they explored physical and emotional barriers within the narrative.

Access to good and stable Internet off-campus and most typically in the home environment is vital by students. The remote geographical home locations of many students in mountainous or wooded regions gives rise to problems of gaining good Internet connections in both Ireland and Finland.

> *I have bad Internet at home, I can't access Blackboard or anything like that.*
> *S_3_2017_GI*

The Internet connection may also be stable and good for access to learning materials and eAssessment if the student is the only person depending on the connection. Multiple shared connections are evident resulting in lowered bandwidth and greater potential for connection timeouts.

An unexpected response from student S_8_2015_GI unveiled a misconception held by me that all students had access to computers at home. Similar comments were made in the Finnish student group interview causing a similar reaction to mine by the Finnish academic. Indeed, the gap in expectations between Finnish students and academics was revealed when the student complained about poor Internet due to the location of a student's home within the forest – the academics observing the conversation found this information difficult to believe. Surrounded by information technology in higher education and many academics also having similar information technology equipment at home relocates the academic away from the students' experiences.

> *I don't have a computer at home, so I don't have Internet access.* *S_8_2015_GI*

Digital poverty, as a barrier, is a stigma that students do not discuss openly, especially by mature students. Some students use mobile phones to access learning materials and eAssessments and complain that material is not formatted correctly to allow them to interact without extended scrolling.

Not all barrier comments are related to the physical or the negative aspects of eAssessment. Psychological barriers are also experienced by students relating to eAssessment. Anxiety may be offset by students relating to the new environment and discovering they are under less pressure depending on the design of the assessment environment.

> *It is a lot more laid back because you can do it at your own pace and stuff. If it is a written test in the classroom, you see other people leaving early and that makes you anxious.* *S_6_2017_GI*
>
> *I stay more focused when I am using pencil and paper because I don't like the Internet, but the computer is good at right and wrong questions. It is the only thing that computers are good at! But not much more.* *S_4_2017_GF*

The lack of familiarity with eAssessment tools and processes has potential to induce anxiety and stress as barriers to learning. Anxiety caused by forced engagement with eAssessment is perceived as a barrier by some Finnish students. Even with access to computers at home not all students are comfortable. Some students display a degree of hostility to a non-paper environment and one student addresses the issue head-on

> *We have been using pencil and paper since caveman days. Why do we need to change now?* *S_4_2017_GF*

The question by S_4_2017_GF reveals this student, and others, is not comfortable engaging in the new environment and is resistant to using the digital tools. The student doesn't dwell on the subject, and it is not possible to determine whether the reasoning is because of a conservative nature or due to a poor experience.

Second year students evolved the narrative beyond engagement with eAssessment whilst focusing on lack of feedback as the primary barrier to learning. This factor meshes with the theme of feedback; the context here is that poor feedback is a barrier to learning.

> *We probably won't get feedback because the assignment is so close to Christmas*
> *S_5_2017_GI2*

The comment by S_5_2017_GI2 was agreed on by all Irish second year students as a source of disgruntlement affecting their ability to reflect and strategize in a timely manner.

> *There is a lot of stress and frustration this year.* *S_4_2017_GI2*

Anxiety and stress were to the fore in second year as all students in the group interviews discussed their frustrations, anxieties, and feelings of stress at the lack of feedback, as summarized by S_4_2017_GI2. Assessment design in second year is significantly different from first year mathematics. In first year, the eAssessments are divided into logical blocks and split across the semester. In second year, all topics are combined in a single end of semester assessment making it difficult for students to determine their progress accurately.

5.3.2 Academics' perceptions of barriers to eAssessment

Relocation and privileged access are taken for granted and this subjective norm causes unintentional barriers because the academics do not experience them. Barriers experienced by students in the form of situational barriers are generally overlooked by the academics apart from access to learning materials via the institutions' learning management systems

> *Students are enrolled here on a 9.30am to 5.30pm course with Internet facilities available within the college during that time. I don't consider it to be a valid excuse.* *AC1*

Academic AC1 believes that any problems outside campus can be overcome during free time on campus. The assumption made is that computers within the institute will be available to the students on an ad hoc basis and that students' time is genuinely free from other tasks.

Some academics, AC2, AC3, AC8, AC10, AC14 and AC15, feel that institutional barriers caused by new learning methods using online technologies are outside their control. The tools and systems are available for students to use, and it is one of the students' tasks to work out how best to use the tools and systems. This barrier overlaps with the themes of experience and training and support with considerable enmeshment. Only two academics discussed the role of supporting students to overcome institutional barriers. The first academic displays an integrated approach to course design and delivery.

> *We have technical specialists who work with teachers, work out the course, then we have methodologists, people who provide support for students' learning.* AC11

The second academic believed that active intervention was not required, unless to meet a statutory requirement such as disability.

> *Unless they have some particular learning difficulty.* AC2

Active intervention as a strategic pedagogical component is not evident in many of the academic interviews. The preferred option is to remain passive during the process suggesting a failure to locate the presence of the teacher within the learning cycles.

Several academics discussed their declarative and conditional knowledge within the repertoire and revealed a lack of such knowledge in the domain of online assessment.

> *I can't see how you could examine that on Blackboard.* AC4

This example by AC4 reveals a lack of understanding of the technology used by the academic for eAssessment and is demonstrated within this academic's course design as a supplemental approach. The technology is not embedded within the pedagogy to support assessment, rather it is supplementally located to meet institutional requirements. Applying technology for eAssessment has the potential to unintentionally introduce barriers due to academic's lack of understanding of the processes. This issue is cross-thematic and appears in the feedback and assessment themes.

Higher order cognitive concepts are contained within the narrative as academics engage with problem solving and incongruencies in pedagogy to make the learning experiences for students more meaningful.

> *It is very important to us to change the environment…they become the owner of the knowledge.* AC14

However, even within higher order narratives outlined by AC14 it is evident that not all academics such as AC13 are fully aware of the barriers experienced by students.

> *Maybe they have such problems and will just do their homework here (on campus), no students have spoken to me about that.* AC13

Comments such as that by AC13 provide evidence of a gap between expectations held by academics and the reality of students' experiences of barriers.

5.4 Forms of Assessment

Assessment in all its forms is a priority for all students and academics. The transition from secondary school or the workplace to higher education is a known area of trauma and disturbance to be grappled with by students in the initial stages of first year. The assessment experience is not uniform for all students and academics.

5.4.1 Students' perceptions of eAssessment and Assessment

Reflection on the assessment methods experienced in secondary school was noted by the Irish students, where rote learning has been identified as problematic and negatively affected confidence. Student S_23_2015_I describes a perplexed situation in the transition to higher education assessment approaches.

> *Each new test may have questions worded differently to what was asked previously so my score is badly affected.* S_23_2015_I

Assessment questions where the wording of the questions alter very little with time supports rote learning for such questions. Rote learning in secondary school affects inquiry and leads some students to feel that all questions and question types follow a standard protocol. The use of alternative questioning in higher education appears to be a source of dilemma for some students adding to their frustrations.

By contrast, some students discovered that it was possible to enjoy a more relaxed approach to assessment because they could complete eAssessments in a relaxed environment.

> *I found it beneficial because there was no pressure from an exam room environment. I was more confident and comfortable in my own space* S_34_2015_I

> *I think computer-based tests are good because it relieves a bit of stress and pressure because you are not in a big group. When I did tests in secondary school I used to panic because we all did the test in one classroom. When I do it in the comfort of my own home I tend to not panic as much.* S_28_2016_I

The ability to undertake an assessment or eAssessment in the home relieves the pressure experienced from peer participation in the classroom or examination hall. Here, as with student S_28_2016_I, the stress is evident as the students do not experience the actions of other students within their home environment. Students leaving or entering the assessment environment can disturb other students, thus creating less than optimal assessment conditions for some.

The narratives also mentioned the manner of conducting assessments in class through the learning management system and completing the assessment in the home environment.

> *We do some in class and some that we don't have time to. We are supposed to do them at home. I don't always do them! When they put layer upon layer the assessments where we have to know several things and they are like hard, we will help each other.* S_3_2017_GF

Student S_3_2017_GF is demonstrating the ability to operate in a blended design by continuing to use the learning management system in the home environment. In this example, the student is reflecting on the difficulties experienced within the assessment, and either supporting or seeking support from peers. This strategic approach allows students to communicate with one another to address difficulties experienced within the eAssessment.

The eAssessment strategy in year one is designed to aid the students' preparation for further study. Multiple, alternative, and non-high stake, opportunities in first year to engage with eAssessment methodologies and practices provide students with a safe environment to explore, reflect and assess their strategies. A more stressful alternative form of assessment is employed in year two for Irish students, however the alternative form is seen by the lecturer as beneficial because students can demonstrate their processes more easily than through eAssessment. First-year study was perceived to be less stressful.

> *I think for second year it is more stressful* S_1_2017_GI2

> *First year seemed more relaxed and enjoyable … we are putting stuff off now to do assessments, … there is so much more stress.* S_4_2017_GI2

Here, the students are demonstrating they have reflected on their experiences of assessment processes in the first two years of higher education. Likes and dislikes are to the fore along with explanations as to why the students have these feelings.

> *Both years should have a similar layout or approach.* S_5_2017_GI2

The different forms of assessment employed by academics is perceived by students to affect their beliefs in their confidence leading to a degree of anxiety. The overlap and intermeshing of themes is evident within the discussions on assessment processes in all its forms.

The language employed is representative of the vocabulary and grammar available to the students. Lack of high-level, peer, or family, social interaction does not provide foundation for reflexive discourse. However, the language is honest

> *If I gave it to somebody else to do for me, I would be in "deep shit" in the exam.* S_8_2015_GI

Awareness of the situation in which the students find themselves is evident in the comment by S_8_2015_GI. Conducting eAssessments and other forms of assessment is fundamental to progress, demonstration of, and acquisition of knowledge. It is clear from this statement that the student is aware that not personally engaging with the process is detrimental to progression within the mathematics programme.

The narrative is dominated by unfavourable comments on assessment tinged with frustration with some of the eAssessment processes. The narrative reveals that diminished eAssessment experiences are leading to a failure to enhance students' sense of belonging resulting in a negative contribution to conditional knowledge. A concern within the students' comments is the lack of opportunity for self-regulation resulting from another meshed thematic issue of feedback, feedback is not perceived by students to be integral to eAssessment when only correct answers provide rewards and the work conducted by the student is not considered.

> *The computer is good with right and wrong questions. It is the only thing the computer is good at. But not much more!* S_4_2017_GF
> *Computers are total morons; you get it wrong even for a simple grammatical error.* S_72_2015_F

Feedback and performance through access to grades are conflated within the comments for eAssessment. Students are not sufficiently adept at identifying the components of assessment in the early stages of the eAssessment experience. The comments by S_4_2017_GF and S_72_2015_F are not unique within the corpus and reflect the comments of many students.

5.4.2 Academics' perceptions of eAssessment and Assessment

Academics' perceptions are mirrored in their reflections on what is loosely termed 'student engagement'. Academics are tying student engagement to performance i.e., meeting institutional requirements rather than considering the broader social environment of learning situated by the students. Use of eAssessment removes some academics from the locale of the student, with the perception that eAssessment tools are outside of the academics' domain of control. A sense of laissez-faire is detected relieving some academics of responsibility to the students.

> *I find with Blackboard that they don't engage; I suppose I should be concerned.* AC3

AC3 describes the use of eAssessment as supplemental within the planning and design of the eAssessment and hasn't yet fully integrated eAssessment into the process. This academic perceives the eAssessment technique as located in the actual domain, outside of the empirical domain experienced by the students. The generative mechanisms available through eAssessment are not linking correctly and this is evident through the afterthought that it is a matter for concern.

Another academic (AC2) perception relates students' engagement in eAssessment to personal ownership and expands the ownership to include the student group. The students are being generalized as a homogenous group where the individual is no longer visible, the person is no longer considered a valid entity unless actively operating within the standards and expectations of the academic. Reflections on individual ownership or engagement by students is not evident within the academics' narrative

> *The student body has to learn to engage and take ownership.* AC2

In contrast, some academics are very aware of the social learning environment and have taken action to address deficiencies in their own pedagogy. Assessment programmes have been redesigned, sometimes at personal risk of facing the ire of colleagues.

> *I had to teach it the same way my professor told me. He considers the ability of students has decreased and are not worthy of his patience. The students feel this! I was a complete failure because it was so hard for them [students] to focus…It's hard for some of my students … After the failure I changed it.* AC10

Visibility of students and students' struggles to actively operate within higher education are alluded to by AC10, almost in a pastoral sense akin to secondary school. Responsibility is accepted, with new techniques and methodologies employed to support the students.

5.5 Feedback

Feedback is closely related to eAssessment and forms an integral component of eAssessment. The role of feedback is critical to allow students to develop and realign strategies and tactics to enable them to engage fully within the learning process. Feedback must be correctly employed otherwise the eAssessment process may negate and disadvantage, or reduce, the future potential of the student.

5.5.1 Students' perceptions of Feedback in eAssessment and Assessment

Within-case and cross-case analysis revealed that students can experience considerable pressure during the eAssessment process. This pressure has the potential to create substantial and negative feelings in students. The process of feedback is mentioned regularly within the corpus as being generally lacking, or misunderstood, for many students. First-year students focus mainly on the marks or grades obtained from the assessment. Performance is conflated with feedback through a lack of understanding of the meaning of feedback. However, it is strongly evidenced within the student corpus that the work of the student is often not considered, such as the comment by S_17_2015_I, and that only the answer is the important part. This belief strengthens the connections between performance and feedback.

> *I think computer-based tests are bad because there are only marks for right and no marks for in between.* *S_17_2015_I*

Feedback available through the learning management systems is general and not individualized. The students are observing grades and receiving comments from the eAssessment system. These comments do not consider partial workings or partial credits and this fact is being noted by students as detrimental.

It is expected that learning engineering mathematics will become more difficult as the levels of abstraction increase in later years of study in higher education. A greater understanding of the role of feedback within the assessment process is evidenced through second year students, e.g., S_1_2016_G2. The levels of abstraction are not considered to be the issues affecting learning, rather it is the type or lack of feedback that causes most angst.

> *In maths year 1 we got good feedback.* *S_1_2016_G2*

Rather than a simple descriptive comment, the students expanded by an injunctive exploration through their understanding of the feedback process.

> There are no comments that come back after the test. You get your percentage back and that's it for the assignment. S_5_2016_G2

> Personally, I prefer the assessments from 1st year. You had a lot of online assessments … they were more easy to get your head around. Sometimes, if you are looking at a blank page and a lot of questions, well for me anyway, I get mixed up and I lose my train of thought… Also with it being on Blackboard, once it is marked, your mark is there for you to see. Whereas this year we were given a mark but that was it. There was no other way of seeing the solutions to know where you went right or got it wrong. S_1_2016_G2

Pressure in relation to feedback in second year is contributing to a negative sense of expectancy with potential to reduce students' self-efficacy. Here, the theme of feedback is enmeshed with expectancy and self-efficacy. Students are attempting to rationalize their cognition through their experiences to help them cope with perceived threats in the form of poor feedback experiences.

Feedback is the primary form of eAssessment communication with students within the academics' repertoire. Feedback is determined as a multimodal affordance utilising a variety of techniques, from the simple provision of a mark through to a personal discussion with the student. The comment by S_1_2016_G2 is not universal for all students and cannot be in any way generalized. Feedback processes and methodologies differ depending on academic and/or institution. Academics give insight to a myriad of feedback techniques ranging from the minimal to in-depth personal.

5.5.2 Academics' perceptions of Feedback in eAssessment and Assessment

Academics AC1, AC2, AC3 and AC4 provide minimal feedback to students. These academics were asked to explain their feedback methodologies and the reasoning behind them. However, the replies were scant with a hint of self-embarrassment partly because of inadequate teaching qualifications. The need for academics to hold teaching qualifications is not universal with many institutions regarding the primary professional degree as the basis for employment. The opportunity to support and motivate is lost and this is noticed extensively by students. The inability to determine what tactics and strategies are required to tackle eAssessments resulting from minimal feedback has potential to demotivate and frustrate students.

> *I give them a mark, but they have to work out which questions they got wrong.*
>
> *AC3*

AC5 prefers traditional pen and paper assessments and is aware of the difficulties providing the correct feedback through eAssessment tools. AC5 has reflected on the use of eAssessment for mathematics and prefers pen and paper for feedback because

> *There is also an element about the nature of feedback that you can give students. Right and wrong isn't essentially, necessarily, the feedback you want to give them.* AC5

In a manner analogous to AC5, AC6 and AC7 request students to provide scanned copies of solutions to ensure that individual feedback is provided to students. The workload is extended by this mechanism, but the benefit is for the students to be able to understand exactly how they performed and to strategize how they might improve.

AC8, AC10, AC11, AC12, AC13, AC14, AC15 and AC16 all engage with students online to provide timely feedback responses. The format of online engagement is dependent on the learning environment used within the institution. Some academics use internal email, chat and discussion forums, others use social media, and some use a mix of internal and external communication tools. The variety of tools used to communicate is maximised to ensure that students have an opportunity to communicate with the academic. Teacher presence during remote learning situations is critical to success.

> *I created it based on their feedback…I like to give partial credit … in the panic of a maths test a student might write 3 instead of 8 for example.* AC8

One important aspect of teacher presence is providing value for student contributions as seen by AC8 reflecting on feedback from students to help redesign the approach taken to providing feedback to students. The students are elevated to co-creators of knowledge by this process.

AC9 reflected on the eAssessment design within first year undergraduate mathematics and took advice from instructional designers to address deficiencies in feedback and the students' understanding of the feedback process. AC7 considers the early stages within the first semester to be crucial in the process of alleviating fears; many students display anxieties when studying mathematics, particularly mature students. The discourse provides connections to reflective thoughts by some academic practitioners as they operate within the noisy teaching environment of higher education.

5.6 Training and Support mechanisms for eAssessment

The processes of eAssessment and Assessment within higher education are increasingly taking place within managed learning systems. This statement is not true for all higher education institutions, however even those not employing such systems utilize internet style access to support students and academics. Formal or informal access to learning and assessment materials within higher education requires students and academics to be cognizant of the tools and how they may be optimally employed.

5.6.1 Students' perceptions of Training and Support in eAssessment and Assessment

The discourse on training and support for eAssessment took place during the student group interviews. The responses are mixed and demonstrate the wide range of perceptions held by the students. Training and support in this context include training for the correct use of the learning management system to access course materials and to conduct eAssessments. The training processes may be conducted at an institutional level for all students or by individual academics as appropriate. Support for students is typically a vague area crossing the boundaries of technical support and educational support.

The Finnish and Irish students use different learning management systems, namely Moodle and Blackboard. This section of the analysis concentrates on the students' general perceptions of training and support for eAssessment and not issues specific to each learning management system.

A conversation between some students, during a focus group for first year students, reveals the different perceptions held about the training received from the academic to ensure the students had the necessary knowledge to access the eAssessment. A series of practice tests were created where students could test their knowledge and skills and gain experience prior to a graded eAssessment.

> *Nobody showed us how to use the system* S_24_2016_GI
> *There were practice tests* S_25_2016_GI
> *Is that where we were shown* S_24_2016_GI
> *I just worked through the practice tests first to get a feel for it* S_25_2016_GI
> *Everything was fine* S_18_2016_GI
> *Nobody showed us how to use the tests. It was assumed that we knew how to use the computers and use all of it. Nobody walked us through any of it*
> S_24_2016_GI

Here, there is evidence of the width of perceptions. A student is convinced that the system had not been demonstrated and was left feeling adrift, yet other students perceived the training differently.

> *You weren't clawing around when it came to the test. You weren't looking at anything that was brand new. You had seen the question types and you had an idea how to do them.* S_3_2016_GI

Students appreciate the training and support provided if it supports their expectations of the summative eAssessment. Students can attempt practice tests and quizzes in relative comfort on their own or with support from peers or the academic.

> *Well, if I had any problems with the practice test I could look up the answer and figure out where I went wrong in my logic. And then I knew I could email you [the lecturer] for additional help with anything I could have done wrong on the next test.* S_8_2016_GI

Feedback as a support mechanism is not specifically mentioned by the students within the practice tests. Yet, as a component of assessment support this enmeshed theme is vital, to support students in their adjustment to eAssessment, to provide opportunities for reflection, to develop strategies and tactics, construct knowledge, to motivate, and adjust expectations. Students discussed grades and marks obtained within the practice tests but did not expand on the feedback received with those grades or marks.

5.6.2 Academics' perceptions of Training and Support in eAssessment and Assessment

Not all Irish or Finnish students have prior experience of the eAssessment methods used in higher education but are expected to engage fully from the beginning of first year. An example of this is given where academic AC2 was asked if training was provided, and the reply was

> *No! Definitely not!* *AC2*

This academic's privileged position is like the positions of AC14 and AC15. Given that they are aware of the range of mixed abilities within the class the comments are in stark contrast to the comments by AC8 and AC16. Some academics such as AC1, AC3, AC6, AC11, AC12, and AC13 provide support only if a student requests it.

> *I assume no knowledge.* *AC8*
> *Some students from vocational schools require training and support* *AC16*

The discourse involving academics AC4 and AC5 doesn't mention training and support because they don't conduct eAssessments.

Training programmes in the form of practice quizzes have been established by all the participating countries engaging with eAssessment. The training programmes appear to alleviate the fear of mathematics, especially by mature learners, and to help the students settle down. Practice quizzes are used as a means of training students while providing the students with an opportunity to engage with assessment as learning. Students displaying high levels of confidence and high levels of digital literacy don't require as much training and support and those with less digital literacy competencies. The notion of good academic practice is evident in the use of multiple assessment types available for practice including multiple choice, open response, calculated entry, and use of video. Academics dropping into the practice sessions can provide support through direct communication with struggling students, or by providing exemplars to the class. This form of online engagement by the academic maintains the presence of the teacher and maintains students' motivation to learn. However, AC1, AC2 and AC3 do not drop in on the practice tests because they consider this to be the students' responsibility. Full training and support on the institutions' online systems is assumed by all the academics to be the responsibility of their respective institutions. Here, the actual domain is expected to provide explicit support for those in the empirical domain.

5.7 Preparation

Preparation as a theme separates the student or academic from training and support. However, the difference between preparation and that of training and support may be succinct and there may be an overlap of the two themes. Preparation reveals the thoughts of students and academics, not just in terms of the interaction with eAssessment and assessment, as they reflect and process information and learning materials. Preparation as a subjective belief cannot be ascertained in absolute terms.

5.7.1 Students' perceptions of preparation for eAssessment and Assessment

Each student's belief of their preparation is based on unique affectances and these affectances may or may not be visible to the student or the academic. The students' discourse concentrated on how they used the practice tests and support offered by academics.

> *Practice was very handy, the practice tests, yeah! Helped me figure out where I might go wrong when answering it.* *S_3_2017_GI*

Such encouraging students' sentiments by some students are not atypical but do not explicitly reveal preparation for the first-year assessment within engineering. Students are framed by multiple identities on entry to higher education and do not realise these identities are not visible to others. Systemic preparation practices from secondary school are ingrained at this early stage and difficult to shift psychologically.

> *In between questions I am googling say quadratics or looking at my notes and then going back to doing it. Is it okay to use those things?* *S_2_2015_GI*

Student S_2_2015_GI has prepared for the summative eAssessment by conducting the practice tests and revising the course material. But the preparation is not complete, and gaps appear in the student's knowledge during the summative eAssessment and the student is seeking to gain knowledge. Asking if it is acceptable to continue developing knowledge during a summative assessment reveals an interesting dilemma for the student and academic regarding practices.

The nuances for success within the educational space are acknowledged primarily through performance. Some students consider themselves to be outsiders in the liminal phase during the beginning of first year and do not yet identify with the engineering profession. The perception of preparation for eAssessment in engineering mathematics is negative for some and affects confidence. The following comment by S_4_2017_GF exposes a deep-rooted fear and perception that the student is not yet prepared for the engineering profession.

> *I am a stupid construction worker.* *S_4_2017_GF*

A possible aspect of male Finnish culture is the lack of discourse with peers or society about feelings. S_4_2017_GF doesn't feel prepared to enter the engineering profession because of a perception of stupidity. A Finnish male engineering student making such a comment is extremely rare. He may have felt comfortable in the environment or was at the point where he felt there was a need to call for help. The rest of the students in the interview were initially shocked but quickly rallied to inform the student that he wasn't stupid.

Realisation that preparation is more than simply engaging in rote learning affects students' instrumentality beliefs. Evolution of students' cognition is demonstrated as the discourse on issues of eAssessment moves beyond practice tests in year one. Students adjust their learning strategies as they develop a sense of belonging within the learning space and achieve their expectations. Practices developed in secondary school are honed and adjusted within the new learning space as students gain experience through practice.

5.7.2 Academics' perceptions of preparation for eAssessment and Assessment

Preparation is perceived to involve an element of trust in the academic(s) deciding the students' rewards. A mixture of pedagogies, such as by AC10, employed in the form of pre-recorded video lectures, practical tests, quizzing and gamification, is common between the individual narratives in the academic interviews to ensure students are engaged and motivated.

> *Facilitation of online interaction and let them use their imagination to do abstract work* *AC10*

The notion of preparation is designed into the learning programme through teacher presence to facilitate the students in their preparation for assessment. Students are provided with a physical and temporal learning space to allow them to explore and experiment within the learning programme. Preparation of students through teacher presence to create a supportive learning environment is perceived by AC10, AC12, and AC16 to be crucial for success.

> *When they need to learn we should give them opportunities to learn… give them the platform, the environment…for lifelong learning.* *AC12*

Transforming the learning environment to be conducive to supporting not only those students who struggle but also those who excel is fundamental. This transformation undertaken by the interviewees is not viewed lightly, and to support the requirement for successful pedagogical design an inclusive fully integrated and supportive teaching approach is required. The role of higher education to prepare students within the community and society is to the fore.

5.8 Other Perceptions

Perceptions in higher education are highly individual and subjective. The perceptions held by individuals, whether student or academic, are the result of a mix of factors such as culture, previous experiences, support of peers and family, and knowledge of education processes. This theme is a general net to catch relevant perceptions, mentioned in the interviews and open comments, that couldn't be directly attributed to the other themes. This section may contain overlapping comments made by students and academics deemed relevant to one or more or the other themes. This theme demonstrates the messiness of incomplete statements or utterances that appear to be fuzzy in the minds of those participating in the research.

5.8.1 Students' perceptions of eAssessment and Assessment processes

Students perceive conflicting tasks can disrupt their participatory desires and goals. These conflicts are not included in their repertoires as excuses for self-inaction, the opposite appears to be the case for them providing an opportunity to make their voices heard. Vocalization of beliefs within a limited pedagogical grammar is to be expected because the students are only at the beginning of their higher education experience. However, it is possible to determine deeply held perceptions of the eAssessment process from the discourse. Positive and negative perceptions are encountered with corresponding influences on beliefs. Perceptions can affect self-esteem, identity, and the relationship with the domain of engineering mathematics and indeed the programme of study. Such affectances can lead to some students excelling or choosing to avoid mathematics.

> *But maybe it doesn't give a true portrait of what we know in maths S_2_2015_GI*

The perception expressed by S_2_2015_GI is not localized to Ireland and raises questions about what academics should do in such situations. It isn't known if students expressing such beliefs excel in engineering mathematics or avoid difficult situations because there was no way of tracing the responses. However, such expressions of belief are indicators that students are reflecting on the methodologies within engineering mathematics and attempting to strategize their responses and actions. Some students hold very negative perceptions about eAssessment.

> *I feel sometimes, Oh God, not again!* S_3_2017_GF

This perception by S_3_2017_GF appears to be strongly held by some students and further discussion revealed that eAssessment is viewed as just another way of lightening the workload for academics. The strength of tone used gives an insight to the way students perceive eAssessment methodologies when the methodology is not made clear to the students. The overwhelming frustration of S_3_2017_GI is evident, and palpable, producing the perception that eAssessment is faulty in the eyes of some students. Overcoming such perceptions is difficult for academics when faced with large class groups, and such perceptions may remain invisible if not expressed within an open and safe environment.

5.8.2 Academics' perceptions of eAssessment and Assessment processes

Functional aspects of teaching and eAssessment methods are perceived by many of the academics to be understood de facto by students, as is students' access to resources. Academic perceptions, e.g., AC1, that students have full access to teaching resources, stable communications, and appropriate equipment off campus contrasts the reality of some students' situations. Students consider limited access to equipment, etc., as a barrier to learning, see section 5.3.1 leading to fear and anxiety.

> *I don't think they have any fears, …, I don't consider it to be a valid excuse. AC1*

Students' frustrations are caused by inability to download materials and access eAssessments in a timely fashion, leading to demotivation and generating anxiety. Lack of understanding of these issues because of the invisibility of the problems is not perceived to lie in some academics' domain of control.

To support the mechanics of online assessment and teaching, the students have an expectation for training and preparation, but this aspect is notably absent or skimmed over within the academics' rhetoric. Most Irish academics do not perceive training and support as a core component within the curriculum and leave this to other staff within the institution. A misperception is evident (AC3) whereby students are considered digitally literate on entry to third level and don't need support in this area. The resultant negative affectances from this relocation of training and support produces a liminal state for students. The subjective task value of eAssessment is diminished, hence the expectancy of the process is also diminished, see section 5.9.2.

> *I don't sit down with them and show them. I assume that most students have a computer at home and Internet access so they can get online and do a test. AC3*

Some academics perceive that certain types of school do not provide the necessary tools for students to develop their digital literacy skills. Awareness of gaps in students' digital literacy is demonstrated for example

> *Some of my students from small country or vocational schools may not have full access to digital tools.* AC16

The narrative involving non-Irish academics demonstrates a mixed awareness relating to off campus issues, AC8, AC10, and AC11 demonstrate similar awareness to AC16. Awareness of society outside the institution comes through in the narrative revealing knowledge and understanding of student digital literacy problems. One academic (AC15) has never made enquiries from the students revealing mis-placed perceptions about student confidence, see section 5.1.2, yet

> *We don't know, it is fine. How can I tell levels of confidence? I think the engagement gives them motivation and motivation gives confidence.* AC15

Relocating responsibility for eAssessment decisions from academics to the students provides impetus for belief that issues such as access and digital literacy are functions outside the control of academics. Reducing teacher presence decreases students' awareness thus mitigating clarity in the learning partnership. However, such academic perceptions within the learning environment are not shared by all. Academics' reflection on practice and experiences is a core component of the professional in practice. Reflective and evaluative narratives such as that by AC7 are situated as minority narratives within mainly descriptive discourses focused on the mechanics of eAssessment.

> *I think the students will not like it, through reflection on their own abilities I do not like it.* AC7

AC7 makes a rare academic comment about perceived students' abilities and limited ICT literacy skills because of their own self-reflective practice. Self-reflective perception comments are limited within the discourse of the remaining academic participants.

5.9 Cognitive Domain

The ‘mechanics’ of eAssessment within the pedagogical design are evident in all academics’ comments. However, students’ metacognitive comments are not balanced by all participating academics. The absence of metacognitive rhetoric by some academics is not evidence that those academics are not aware of this factor, the absence may be a manifestation of unknown factors within the timing of the interviews. However, academic awareness of psychographic affordances, such as self-efficacy and expectancy, within the learning and assessment processes are important factors for students. Arising from the interpretations of the eight themes, two additional themes became apparent i.e., self-efficacy and expectancy

5.9.1 Self-efficacy

Motivation during eAssessment is a broad framework affected by the beliefs about capabilities within the domain being assessed. How students seek knowledge and are challenged by academics in the students’ efforts to learn, is dependent on the students’ psychographic affordances. The environmental situation is important to all within the assessment process and can be affected by many variables, some outside the control of students and academics. One such variable affecting motivation is self-efficacy.

5.9.1.1 Students’ relationships with Self-efficacy

Self-efficacy is inextricably linked to students’ success of the students in first year of higher education, as is the sense of mastery carried from second-level education. Students were asked to describe their experiences of engineering mathematics eAssessment and to provide reasons why they may not have experienced eAssessment prior to higher education. A typical response by S_86_2015_F was

> *In my previous school we did all tests on paper.* *S_86_2015_F*

Students without prior experience of eAssessment did not have the opportunity to develop mastery in eAssessment prior to higher education. Students with, and without, prior experience of computer-based testing revealed a mixed sense of self-efficacy relating to their confidence. The statements relating to self-efficacy were interpreted and can be represented by comments such as

Usually quick to complete, but I don't think they help me learn much. S_18_2015_I

This thread of thought demonstrates pragmatism about the difficulties affecting students' confidence. Mature students mentioned barriers such as having to cope with children and the lack of access to appropriate equipment, whereas other students mentioned other barriers affecting self-efficacy such as studying within the family home. The realization of self-participation involves cognitive costs as students develop their perceptions of community; academics supporting the students' and peers supporting each other.

Students' experience prior to higher education is not limited to secondary school, it is a complex social and cultural mix. Non-standard entry students such as mature students carry many life experiences that are called upon to help them grasp difficult or confusing issues. However, there are occasions when such life experiences negatively impact the student. The following quote is used again to highlight the way that some mature students view themselves in higher education.

I am a stupid construction worker S_4_2016_F

S_4_2016_F is a mature student and did not have any prior experience of eAssessment having left vocational school to work in a trade many years before entering engineering. This student's IT skills were being acquired in parallel with engagement in eAssessment forming a perception of additional workload. Low self-esteem is evident, and the energy required by the student to make this statement cannot be underestimated. Simply informing such students about expectations in higher education is not sufficient to make such students aware of task value. This highlights the struggle of such students to obtain a holistic view of their location in the actual domain.

Self-efficacy is considered an important contributing factor towards the students' sense of belonging in their education and chosen profession. An attempt to make sense of students' belonging is constructed by their experiences and their worldview. A specific self-efficacy target questionnaire was not deployed in this study; however, it is possible to ascertain indicators of self-efficacy from evidence relating to confidence and performance.

Interpretation of the semi-structured student group interviews reveals a more positive preponderance to belonging within the eAssessment domain, with the Irish students compared to the Finnish students. It is too simple to quote the positive, neutral, and negative responses without further exploration of the reasons why Finnish responses are more negative. The Finnish comments aren't based solely on mathematics experiences

> With the writing tests, sometimes they are done on the computer but mathematics part is hard. *S_4_2017_GF*

The Finnish students experience most eAssessment outside of mathematics in the first semester of first year unlike the Irish students. Negative self-efficacy is evident, but no explanation is provided as to how this may be overcome.

The sentiments of first-year students evolve in a similar manner to the sentiments interpreted for expectancy (see section 5.9.2) as Irish students locate their cognition of the assessment process into the second year of study. Within the semi-structured focus group interview with second-year students the negative perceptions of the value and effort of their work are dominant within the narrative.

> *There was no way of seeing the solutions to know where you went right or wrong.*
> *S_1_2017_GI2*

The shift towards negative expectancy in second year is affecting the self-efficacy of second-year Irish students towards mathematics. Second-year Irish students do not find the feedback process to be useful. Reflection on the construction and affirmation of knowledge is necessary for students to gauge their position relative to their learning goals. Students expect to be able to gauge their performance against model solutions in conjunction with constructive performance feedback. This component appears to be missing.

5.9.1.2 Academics' relationships with students' self-efficacy

Academics' perceptions reveal some dispositional beliefs that students are not capable of engaging at a high level. The comment by AC5 below is the result of long-term reflection on the use of eAssessment for engineering mathematics. This academic uses eAssessment in mathematics at post-graduate level but doesn't consider the process of eAssessment to be applicable in the early years of undergraduate teaching.

> *Requires a very capable student … in a constrained time frame.* *AC5*

Mentioning capability within constrained time frames by AC5 points to additional stresses and pressures placed on students by eAssessment. Time is recognised as an additional stressor by academics affecting student psychographic components. Students do not learn at the same rate and the wide mix of mathematical abilities inserts tensions into the teaching process.

Academic awareness of students' self-concept and attempts to accommodate this issue through inclusive assessment design, is perceived to be the most efficient strategy. AC10 expresses the difficulties experienced by students as a combination of students' beliefs and abilities tied in with the paradigm of teaching employed by the academic.

> *It is hard for some of our students, maybe those who are older and come just for the degree because they work. If they don't see where the theory is used, where the theoretical notations are used in practical applications, it is hard for them to assimilate.* *AC10*

The students' sense of belonging within engineering is related to teacher presence and value being given to students' voice; it is not always possible to access the students' voice within the class environment. Relocation of responsibility for providing a voice to the students through email is known to be insufficient. Accommodating students' belonging and participation by communicating synchronously online are perceived to be useful mechanisms for demonstrating acceptance of responsibility by academics. The learning management system and external tools are used as an attempt to accommodate students and maintain a presence. Allowing use of social networks to communicate with students helps solve things within a highly regulated institutional system where all actions are tracked and monitored.

> *Some social networks allow communicate with students so maybe solve things if they do not understand something.* *AC13*

Support for students is recorded within the narrative by several academics – AC1, AC2, AC3, AC8, AC14, AC15, and AC16 - where students are encouraged to engage with practice tests to develop their digital skills to improve students' opportunities positive experiences.

5.9.2 Expectancy

Expectancy, and its effect on motivation, depends on the circumstances preceding an event, and provides guidance in the form of cognitive antecedents to the student. Processing the cognitive antecedents informs the student about the amount of effort required to achieve a certain level of performance and reward. Negative perceptions of expectancy have the potential to lead to attenuation of performance. Instrumentality leading to negative valence values can affect long term perceptions of tasks. Negative valence is evident in comments by the students in relation to the way automated grading systems operate. Experience has shown the students that it is not always possible to obtain attempt marks and that any mistake in the final answer will result in zero marks being awarded. Positive perceptions of expectancy are also evident within the corpus resulting in increased self-esteem and confidence.

5.9.2.1 Students' relationships with Expectancy

Examination of comments by Finnish first-year students reveals a general negative sense of expectancy. The negativity stems from a belief that computers do not award the same value for work and effort as when a teacher personally grades an assessment. The eAssessment user experience appears to be negating the overall learning experience for Finnish students leading to a reduction in the expectation of success

You might not get the points from a question because of a typo that the system can't detect. S_76_2015_F

Similar sentiments of negative expectancy are also reflected in some comments by Irish students.

They definitely don't reflect where someone is at in regards the academics of the subject. Two similar choices can cause doubt for the student. Multiple choice type answers can be either a little easy or too vague. S_13_2016_I

Sentiments are conveyed where this issue is perceived to be a considerable barrier resulting in a negative valence. Positive valence occurs where a student expects a positive result or outcome, i.e., the effort is instrumental in achieving the outcome. A feel-good sense showing the student's interest in eAssessment is witnessed in

Nicer and more appealing than written tests. S_24_2015_I

The assessment method is viewed as a bonus to achieving the reward. It was noted that the assessment method appealed to some students' worldview as a means of saving paper. It is interesting to note the dominance of a perception of neutral expectancy from the students' statements.

We can do them any time or at any place. There is no anxious wait for results and if you miss the test date for a legitimate reason it can easily be done on the internet. S_29_2016_I

The students' perception of neutral expectancy is that balance, in the work required versus rewards given, has been achieved.

Examination of Irish students' comments reveals a significant decline in positive expectancy comments as they move from first year to second year in Ireland, whilst negative expectancy comments remain at a similar level. Second year Irish students appear to be indifferent, and more neutral, towards their perceptions of expectancy experiences as they encounter alternative forms and quantities of assessment.

The coursework hasn't been finished that the assessment is on. That is why it is taking so long to do it. *S_9_2016_GI2*

There are no comments that come back after the test. You get your percentage back and that's it. *S_11_2016_GI2*

The students struggle to cope with assessment demands in second year. Second-year students reflecting on their first-year experiences note that eAssessment was more relaxed compared to second year assessment.

I just think that any assignments in maths in year 1 we got good feedback. You knew where you were going wrong whereas in year 2 there is no such feedback.
S_7_2016_GI2

It is not possible for second-year students to determine if their expectancy goals are in alignment with expectations. Students are struggling to develop schemas supporting short-term and long-term goals.

The online was good. You could choose to do a few questions per day, and you could tell if you were on the right track. In year 2 we are getting questions from six weeks ago and you can't tell if you are right or wrong. You don't remember mistakes you made six weeks ago. S_3_2016_GI2

The inability to structure supportive schemas reduces the students' achievement related choices generating vagueness in determination of performance

5.9.2.2 Academics' relationships with students' expectancy

Expectancy as a personal and socio-cultural motivating factor for students within this research enters the academic discourse in the form of achievement. The academics' narratives don't mention students' affectation, previous experiences, or achievements. The consensus within the narratives is that students are a homogenous group for the purpose of performance and achievement. Some academics relate attendance with performance reward, whilst others identify performance with the terminal examination (AC5). Expectation of success is aligned with achievement-related performance.

It is important that the students are well lined up in terms of what their final assessment is. *AC5*

Instructional misalignment can cause confusion within eAssessment reducing the utility value of the task. The act of re-alignment usually takes place towards the final assessment. However, workload is recognised as an issue facing academics dealing with large classes, and academics identify with the problem of justified awards for students' work done. Students' work is skimmed quickly by the academic whilst stating that too many marks can't be given because of a feeling that too many students copy. Awareness of the psychographic component of expectancy in relation to eAssessment of mathematics is evident within the discourse

> *They will do all their calculations and have just made a silly mistake. I don't feel it is fair to give them no marks for that. So, I find with online versions you can't do that effectively.* *AC7*

In all the academic interviews there is a desire to give value and justified reward to the students' efforts. Realization of expectancy within the pedagogy and subsequent successful inclusion within engineering programmes places demands on academics. Interpretation of the issues of teaching during transitional phases, between traditional assessment and eAssessment, revealed tensions with more conservative teaching methods. The students' sense of belonging within the engineering profession may be quite vague in the early undergraduate years and affects the ability for many students to assimilate and relate to their world.

5.10 Interpretative Overview

The themes of confidence, feedback, and assessment dominate the narrative for eAssessment in engineering mathematics. Students initially reflect on training and support until they become familiar with the tools i.e., the students have developed their digital literacy competencies sufficiently to cope. Students' perceptions of barriers to eAssessment change as they develop strategies to cope with the challenges experienced.

Academics' perceptions align with some students' perceptions regarding confidence within the early stages of the higher education experience in relation to performance results, whereas many students concentrate on teaching quality and methods. However, it is also noted that considerable misalignment between perceptions held by the academics and students is also visible.

The analysis and interpretation within the qualitative research study placed a lens on the students' experiences resulting in thematic outputs of self-efficacy and expectancy. The data provides evidence relating to students' perceptions of eAssessment and academics' concerns and perceptions, thus allowing the research sub-questions to be addressed.

It is not necessary, in all countries participating in this research, for higher education academics to have gained teaching qualifications. For some participating academics the primary concern is to meet national, institutional, and professional body requirements. Without an understanding of the role assessment plays within the teaching process it is difficult to envision how an academic can develop a greater understanding of achievement behaviours and perceptions. Academics need to be aware from the academic's own personal worldview as well as from the students' perspectives.

Chapter 6 – SYNTHESIS AND DISCUSSION

But my words, like silent raindrops fell
And echoed in the wells, of silence.
(Simon and Garfunkel, The Sound of Silence, 1965)

6.1 Introduction

This chapter synthesizes and discusses the results from the quantitative data in Chapter 4 and the interpretation of the qualitative data in Chapter 5 to provide evidence for the gap between perceptions held by students and those held by academics as students engage in eAssessment of engineering mathematics. In Chapter 4, students shared their thoughts quantitatively on aspects of eAssessment of engineering mathematics and in relation to their overall studies in the first year of engineering. In Chapter 5, students and academics shared their thoughts qualitatively about eAssessment for engineering mathematics. The integration and synthesis of the data from this mixed methods approach helps address the main research problem: *There appears to be a significant mismatch between students' perceptions of assessment processes in engineering mathematics and those of academics that raises issues in relation to secondary to tertiary education transition, digital skills readiness, and assessment related dialogue.*

The chapter comprises three parts. The first part comprises Section 6.2 and presents a synthesis of the quantitative results from Chapter 4 and qualitative interpretations from Chapter 5. This section examines linkages between the results and interpretation of the emerging themes. The second part comprises Section 6.3 to discuss the synthesis findings. Section 6.4 forms the third part where the implications of the discussion are applied to the five research sub-questions whilst remaining cognizant of the relevant literature.

6.2 Synthesis

In this section, the research findings reveal mismatches between the perceptions held by students and those held by academics regarding eAssessment principles, practices, and policies for engineering mathematics. However, the findings also reveal areas of convergence between perceptions of students and academics. The thematic issues are situated within a complex weave that is difficult to deconstruct for both students and academics due to cultural, societal, professional dispositions and local/national/international variables.

Commonality (Pelgrum & Plomp, 2008) allows for a meta-study of variables in the investigation. Commonality was determined by examination of the engineering mathematics programmes in the participating institutions to ensure sufficient convergence within the participating engineering mathematics programmes prior to the start of the research. The outcomes may be influenced by external factors such as culture and different curricula. Therefore, cognizance was maintained to these possibilities and variables when conducting the analysis. From the outset, it was realised that informal settings are extremely difficult to analyse such as with the case of students' access to the Internet off-campus. An attempt was made within the study to highlight any salient issues involving informal settings however, it is not possible to validate the complete truth of the interpretation.

The research was conducted based on the main research problem identified in section 6.1. To explore the affectances of the students' and academics' perceptions within eAssessment of engineering mathematics, the main research problem was deconstructed through the five research sub-questions. The resultant outputs are discussed in sections 6.2.1, 6.2.2 and 6.2.3.

6.2.1 Perceptions of preparation for eAssessment and potential barriers to eAssessment

This section brings together the relevant qualitative themes of Barriers, Preparation, Training and Support, Confidence, Assessment, and Self-efficacy in Chapter 5 and the results from the quantitative test group analyses in Chapter 4 for Barriers, Background, Preparation, Assessment, Confidence, and Training and Support. The purpose is to provide an insight into students' and academics' perceptions of preparation for and potential barriers to eAssessment in engineering mathematics. The evidence uncovered from the findings and interpretations within this research study demonstrate that although there are mismatches, between the perceptions held by students and academics, in the first year of higher education within engineering mathematics, there are also some areas of congruency.

It is difficult for some students to relate to the eAssessment process because they do not have sufficient experience of eAssessment prior to entering higher education. Student narratives relating to traditional forms of assessment and eAssessment display degrees of confusion for the majority. Such confusion is based on students' prior experiences, typically from secondary school, where many students are coached to provide expected responses. An area of dissonance, within the qualitative data, for students is the use of formative eAssessment within the planned delivery of engineering mathematics. Students display a grade centric approach to their work resulting from their experiences to prior higher education. Students misunderstand formative eAssessment in the liminal disruptive phases of first year engineering mathematics. Misunderstanding of formative eAssessment, as a factor in the preparation for eAssessment, by students results in students not developing sufficient metacognitive strategies. Students in the first year of undergraduate study rely on their ICT skills, competencies, and experiences, from second-level education or other locales. Many students do not realise that additional literacies are required to successfully engage with eAssessment, and some students describe their experiences of eAssessment as confusing and impersonal. Those students revealing an understanding of formative eAssessment can relate their metacognitive strategies to the eAssessment process and overcome any misgivings they may have about their learning space. Assessment methods and practices in higher education are designed to require critical thinking and greater self-regulation. Liminality in early stages of higher education adds to student dissonances resulting in potential dissatisfaction if not addressed at the module, programme, and institution levels accordingly. Academics are aware of disruption and confusion amongst students in the early stages of first year study, but many consider this issue to be outside their control and remit. Adoptive supportive strategies to enable students to overcome their fears and frustrations are required when dealing with eAssessment. The supportive strategies display convergence with, and understanding of, the situation for students. Awareness of students' perceptions demonstrates that such perceptions are not taken for granted and are accommodated within the academics' planning and operationalization of engineering mathematics eAssessment.

The tasks undertaken do not always appear to be authentic to students and related to the profession of engineering. Students do not demonstrate full awareness of the linkages between concept, theory, and application in the early stages. The act of engaging with eAssessment off-campus is troublesome for those students with families to support, having poor Internet connections, and a lack of digital tools at their disposal. The barriers experienced and perceived by students do not provide evidence of low engagement in eAssessment but add to the sense of frustration felt, contributing to a lack of confidence in the eAssessment process.

When asked in advance of the first eAssessment, many Irish and Finnish students expected to experience some barriers. The barriers expected included access to computers off-campus, Internet issues, and anxiety about conducting eAssessments for the first time. On completion of the first eAssessment, fewer students reported reduced barriers, but anxiety for some students in the process increased. The positive sense garnered after the first eAssessment is further evidenced through the narratives of Irish second-year engineering students from their focus groups. A statistically significant reduction in perceived barriers provides evidence of a positive shift in perception from their first year eAssessment engagement; students were now able to relate to the formative preparational strategies in their first year. Similar evidence of perceived barriers is displayed in the quantitative analysis of the combined Estonian, Finnish, Irish, Polish, Portuguese, Romanian, and Russian, first-year students.

Some students demonstrate within the qualitative data that barriers continue to exist through digital paucity. I use the phrase 'digital paucity' to describe a paucity of access to required technology, lack of digital knowledge and poor digital infrastructure off-campus. Digital paucity resulting from situational barriers is a difficult issue for some academics to digest – it is at variance with the academics' experiences. However, some academics reported awareness of this issue and had developed plans to mitigate the effects of digital paucity.

Perceptions of barriers by students and academics are evidenced through subjective and empirical characteristics within the qualitative and quantitative data. Barriers are perceived through beliefs and cognition within the empirical domain and experienced through engagement processes in the actual domain. Situational, institutional, and dispositional barriers are experienced by all students and are overcome by resilient, successful students. Key to overcoming such barriers is the learning environment – situational and institutional. Dispositional barriers such as mismatched epistemological stances do not become clear until students *speak up*. If academics do not hear the students' voices, it is very difficult to address epistemological barriers. The qualitative data reveals that not all academics attempt to address such barriers.

The learning environment in this research is bounded by eAssessment in engineering mathematics. The quantitative and qualitative data shows that all students reported perceptions of barriers, as they engage in this learning environment. Exposure to multiple communication and domain tools in a short space of time has the potential to create unforeseen barriers hence, students require temporal and spatial allowances to allow them to self-regulate. An assumption made by some academic participants, within the qualitative narratives, is that students are digital natives and proficient in digital skills. Any difficulties or barriers experienced are therefore not considered to be of concern to those academics.

6.2.2 Expectations, Values, Reward, and Effort

This section integrates aspects of the qualitative themes of Preparation, Barriers, Training and Support, Experiences, Confidence, Assessment, and Expectancy from Chapter 5 and the results from the quantitative data analyses for Background, Training and Support, Confidence, Preparation, Quantity of Work, and Awareness in Chapter 4 to provide an insight into students' and academics' perceptions of expectations, values, reward, and effort when engaging with eAssessment in engineering mathematics. Expectations, values, reward, and effort as a group provide information about the expectancy values held by the students.

From the findings of this research, evidence is provided for the significance of how students and academics differ in their expectations in eAssessment. Students expect that when engaging with eAssessment they will have access to 'results' without having to wait. The results or grades are the driving forces for the engagement resulting from prior experiences, but few students realise the importance of personalized or group feedback or the need for dialogue. Students' expectations of eAssessment tools are that answers are provided, and results generated. However, many students do not develop in-depth knowledge of the eAssessment tools due to external pressures to meet the total course workload. Academics do not provide evidence for knowledge of external pressures when planning the workload for students. External pressures are not considered the responsibility of the academics as they strive to deliver their planned learning. The qualitative interview data indicates that most academics have unrealistic expectations of students' knowledge, skills, and competencies for the use of eAssessment tools in the early stages of higher education. Poorly motivated students, already feeling internal pressures due to heightened levels of mathematics anxiety, when confronted with unfamiliar tools perceive they cannot approach the academic for support. Also, the expectations held by academics can mean that students are extremely reluctant to approach academics because of cultural and societal issues.

Feedback as a critical component within the eAssessment process must be understood by both students and academics in the form of feedback literacy. The promotion of feedback literacy is not evident within the narratives of all academics. There is potential for misuse of feedback through diminished cognition of the role, factors, and affectances, of feedback for students. The role played by academics is critical. The data reveals incoherences and gaps in academic procedures and practices if feedback is not treated with the respect deserved. Students' narratives do not link the Why, How, and What, informative states presenting a perception that the feedback processes are not fully understood. There may be reasoning for the omission of feedback process within the narratives however, this analysis can only be conducted on the comments offered.

Value is added to the learning process through forward development in formative assessment as a pedagogical design goal within an inclusive dialogue between all actors. Meta-dialogue as a socio-cognitive and constructive affordance offers potential for teaching mathematics with embedded feedback processes however, the difficulties in implementing a Meta-dialogue are not to be underestimated. Affective feedback is not always present within eAssessment and is completely missing in some academic instances. Diminution of the affective reduces motivation and may eliminate the encouragement needed by students with low levels of self-esteem.

The opportunity for students to engage in cognitive feedback processes is diminished if students are not provided with temporal and spatial affordances within the pedagogy. Students require time and space to reflect and self-regulate within any learning environment. Thus, effort by students becomes misaligned resulting in false expectation of the task. The context of eAssessment is such that teacher presence is less visible within the spatial affordances of the students, or indeed the academic. Teacher presence needs to be considered as some academics leave feedback in the form of generalized comments embedded within their respective Learning Management Systems.

6.2.3 Motivational emotions and self-regulation

This section draws together aspects of the qualitative themes of Preparation, Barriers, Confidence, Experiences, Assessment, Self-efficacy, and Expectancy in Chapter 5 and the results from the quantitative test group in Chapter 4 analyses for Quantity of Work, Awareness, Preparation, Confidence, Training and Support, Barriers, and Background, to provide an insight into students' and academics' perceptions of motivational emotions and self-regulation during eAssessment in engineering mathematics.

Self-efficacy is a significant influencing factor towards the students' sense of belonging in engineering. The effect of prior or pre-existing attributes as factors of self-efficacy and the subsequent students' awareness of learning are in evidence from the data. Interaction with academics and the higher education institution means that students do not exist in isolation, however a point of demarcation appears to exist from some academics' viewpoints regarding how aware they must be of the students' prior or extant attributes.

Students' comments from the survey open responses and semi-structured interviews over a period of two years, were mainly positive in relation to self-efficacy regarding eAssessment of mathematics. There appears to be evidence that academics are also aware of the students' self-efficacy where just over half of academic comments on self-efficacy were positive. It is encouraging to analyse an academic's narrative where they recognize the presence of barriers to learning and provide support for students to overcome those barriers.

The flip side is also evident, an academic responded in the negative when asked about any concerns they may have in the knowledge that students had no prior experience of eAssessment. Self-efficacy is not supported when academics do not engage the reflective metacognitive affectances of feedback. Constructive feedback supports students' self-efficacy and yet not all academics engage in metacognitive activities with students.

Statistically, the quantitative surveys reported no significant differences between the participating countries for the determination of students' self-efficacy. The qualitative semi-structured interviews provided a valuable insight into students' perceptions of eAssessment organisation and execution of tasks. Finnish students' dialogues were heavily skewed towards a negative sense of self-efficacy and revealed very strong negative feelings towards eAssessment, which may result from the institutional tools used for eAssessment. Entry of mathematical formulae and symbols is not straightforward for many students, and it is very easy to make mistakes resulting in zero scoring for the effort. Students do not feel well prepared to use the mathematics eAssessment tools leading to frustration. Irish first-year students displayed a more positive sense of self-efficacy, however this positive effect diminished dramatically in the second year of study. Perceptions of decreased intrinsic motivation leading to reduced perceptions of self-efficacy from lack of useful feedback and assessments, lead to a growing disconnect with experiences in mathematics.

The role of some engineering mathematics academics has evolved with the affordances of the new learning technologies to that of distanced facilitation as evidenced within the qualitative interview data. Teaching and learning are not discrete activities; the learning process is organic where students need to communicate and share with the academic. Students' self-efficacy cannot be determined and enhanced if there is perceived distance between students and academics. The learning context is moving out of the fixed spatial and temporal domain to that of an interactive, supportive shared domain in consultation with the student and not just within the higher education environment. Technology involved in eAssessment is mediator, tool and tutor, idea resource and repository, support, and trainer. Failure by academics to involve in, engage, and reimagine the learning space, results in diminished understanding of students' behaviours, reduced metacognitive activities, and attenuation of students' self-efficacy.

Motivational expectancy resulting from perceptions held by students whilst engaging with eAssessment in engineering mathematics, is in evidence from the quantitative and qualitative data. Expectancy-value theory, framed as an expansion of the psychology of eAssessment introduces self-concept (or perceived ability) to the assessment model, is reflected in the data as a combination of perceived emotion, reward for effort, mathematics abilities, and instructor awareness.

Strong levels of students' emotions are evident depending on the students' individual circumstances. Cognitive engagement in the form of cognitive, metacognitive, and self-regulatory strategies, vary within and across cases. Therefore, it is not possible to determine a single factor or variable that determines students' perception of success. Emotions, reflection on effort required, perceived awareness of instructors, and sense of belonging, vary by country but not all variables are statistically illuminating when considered individually. Quantitative analysis was conducted to determine if any between-country relationships existed in relation to expectancy in eAssessment of engineering mathematics. This analysis concluded that perceptions of expectancy are quite similar for all the participating countries irrespective of social or cultural differences.

6.3. Discussion

Three significant phenomena emerged from the synthesis in section 6.2 relating to eAssessment of engineering mathematics as: preparation for eAssessment and barriers to eAssessment; expectations, values, reward, and effort; motivational emotions and self-regulation. This section discusses the knowledge of the phenomena from the synthesis in section 6.2 in the form of three findings. Tensions and similarities between participating students and academics are explored.

6.3.1 Knowledge of students' perceptions of their preparation for eAssessment, and potential barriers to eAssessment, aids academics' understanding of student behaviours.

A significant finding transpiring from the research is that, irrespective of the locale of study, not all engineering mathematics academics consider the impact of students' perceptions of eAssessment developed prior to third level education, nor are they guided by students' experiences during the liminal phases of the first semester in higher education. The research literature in Chapter 2 provides evidence that the students' transitional stage into third-level education is not always smooth (Van Laer & Elen, 2018; Van Rooij et al., 2018; Pennington et al., 2017). First-year students typically enter third-level education from secondary education pathways, although a significant minority now enter from alternative pathways (see Chapter 2, section 2.1), with an institutional expectation that students will integrate without a need for institutional change (Van Laer & Elen, 2018; Eichelberger & Imler, 2016; Gill & O'Donoghue, 2014; Hagerdorn, 2014). The challenges created by the complex learning spaces, within higher education, are compounded by an increased learner diversity profile affected by the considerable variety of subjectivity, perceptions and attitudes displayed by individual academics (Rowe et al., 2015). Attitudes of academics are a major factor affecting students according to the theory of planned behaviour (Preston, 2000 cited in Cox, 2012). Academics' subjective behaviour in eAssessment appears as a significant affectance in the relationship between the e-learning abilities of academics and the perceived value of e-learning to students' learning.

The literature places an emphasis on the higher education student as the independent learner with proven cognitive and metacognitive strategies (Schneider & Artelt, 2010; Robles & Braathen, 2002), however this emphasis may in itself create barriers to progress because many students do not possess the necessary skills to be declared as independent (Margaryan et al., 2011; Valtonen et al., 2011b). The skills-base necessary to be considered independent within a domain of study is not limited to knowledge and competencies of the domain. Post-digital rhetoric in relation to education, demands embedded technology within the pedagogical practices of, and models adopted by, academics and the subsequent shaping of the education core (Knox, 2019). The emphasis on digital technologies has implications for techno-cultural-human relationships where gaps in perceptions are evident. Gaps within the epistemology create pedagogical dissonances affecting the alignment of the learning processes, and educators must remain vigilant to the needs of learners (Czerniewicz, 2018).

Failure to maximize the learning opportunity afforded by technology mediation generates a confusing vista for students affecting motivation, confidence, and self-efficacy. Academics engaging with pedagogically sound technology mediation practices report positive results where eAssessment occurs. Knowledge of limiting factors affecting students is vital to ensure that diverse learner groups are accommodated within the learning process, however this is not always the case. An example of limiting factors reported that approximately half of first-year university engineering students in a study of students in the United Kingdom and Portugal could not identify what e-learning tools they were using (Munoz-Escalona et al., 2019). Carless and Boud (2018) introduce *Feedback Literacy* as an important affectance of assessment, and low levels of feedback literacy within eAssessment tools are considered to form barriers to learning. The confusion surrounding technology mediation in education is not limited to Ireland as evidenced in the literature.

The sense of belonging is a major psychographic factor associated with the students' academic identity as well as the students' social identity (Pennington et al., 2017). Hagerdorn (2014) argues that academics and educational institutions must become aware of the emotional and complex nature of the learning environment, and how learners can be accommodated within this space. Interaction between students and the education institution is a determining factor in the students' sense of belonging; it is a defining metacognitive factor. The community within which the students are situated includes academics (Wenger, 1998); there must be dialogue between students and academics otherwise academics cannot locate, situate and trace students' behaviours.

6.3.2 Academics' knowledge of students' expectations and values regarding justified rewards and effort during eAssessment allows academics and students to align students' expectations.

The second significant finding places a lens on the roles of students' expectation and expected reward within an eAssessment environment. The domain of eAssessment is growing in maturity in the area of mathematics (Narciss et al., 2014; Jordan, 2013; C. Sangwin, 2012) with the suggestion of greater availability of eAssessment technologies to academics and students. The literature paints a positive perspective of eAssessment for rapid feedback (Lamberti et al., 2014; Hamilton, 2009), formative assessment (Tempelaar et al., 2012), and online quizzing (Jordan, 2013), although the manner of accessing the feedback is unsatisfactory in many cases (Carless & Boud, 2018). Referring to Chapter 2, students with low levels of mathematics proficiency (Gill, Mac An Bhaird, et al., 2010; Kinnari, 2010), high levels of mathematics anxiety (Alves et al., 2016; Tempel & Neumann, 2014; Bai et al., 2009), and low levels of feedback literacy may determine that the reward from success is not worth the effort required to achieve it. These issues are not unique to Ireland and difficulties are being experienced by students and academics in many countries (Gill, Mac An Bhaird, et al., 2010).

Maloney and Retanal (2020) provide evidence of a cognitive link between mathematics anxiety (Jameson & Fusco, 2014) and reducing the students' need to enjoy the effort in solving problems. Metacognitive growth is demonstrated through changes in perceptions of feedback within the qualitative data showing low levels of feedback literacy at the beginning of undergraduate study and moving to higher levels of literacy by the time students reach mid-way in their second year. However, evidence in the students' focus group discourse demonstrates that students report unacceptable mathematics anxiety levels in their second year of study. Underperformance is reflected by the students' failure in addressing the connections between concepts, applications and theory in engineering mathematics (Raveh et al., 2017). The ultimate aim of students gaining a productive disposition (Kinnari, 2010) through procedural fluency and adaptive reasoning (Tall, 2008) creates tensions for academics in eAssessment oriented pedagogies.

The notion of cognitive growth in mathematics is not new, however it has been difficult to determine a model supporting cognitive growth in mathematics within a technology mediated learning environment in the literature (Tall, 2008). Mayes and de Freitas (2007) allude to the problems associated with modelling for e-learning where modelling is viewed is an enhancement of existing pedagogical models, the evidence to argue otherwise is scant within the extant literature and the works of Salmon (2012, 2002) are still relevant.

A dissonance is generated in the literature because it is also known that not all students are aware of the eAssessment tools used (Munoz-Escalona et al., 2019), and there is a conflict with academics' assumption of students' digital competencies (Kirschner & De Bruyckere, 2017; Ilomaki et al., 2016; Zhong, 2011). The perceived ease of use of external affordances of eAssessment helps determine a person's attitude towards using a system (Davis et al., 1989). External attributes associated with eAssessment systems are important mechanisms as students attempt to describe their levels of interaction, and the discourse provides evidence that perceived usefulness of eAssessment is not always present in the students' behaviours and perceptions. Similarly, some academics also display low levels of perceived usefulness of eAssessment as a beneficial affordance in the pedagogy.

eAssessment offers the potential for increased variety in assessment. It can enable students to check their levels of understanding on a range of topics and they may have repeated opportunities for practice. Students' discourse in the focus group interviews supports the perceived benefits of repeated opportunities, as well as the experiences of being able to make mistakes in private, thus boosting perceived confidence (Jordan, 2013). A particular issue raised by the students and some academics, is the use of symbolic notation within computer algebra systems, and through direct entry in an eAssessment exercise (Sangwin & Köcher, 2016; Abramovich, 2014; Sangwin, 2012).

The process of developing behaviour as a growth cycle is not passive and eAssessment tools are used in engineering mathematics to demonstrate *practical intelligence* (Vygotsky, 1978). In parallel, students perform within a socially interactive setting, to transform their behaviours using appropriate mathematical language converging towards logical reasoning through the solution of problems. Students carry their own mathematical experiences and attainments on to higher education and the pedagogical model must accommodate appropriate *zones of proximal development*. Academics should inculcate an awakening of the processes of internal development through interaction with peers and institutions. Thus, an internalization of the developmental processes may ultimately lead to achievement of learning, and a productive disposition towards mathematics.

6.3.3 Students' motivational emotions in complex learning environments involving eAssessment are major contributors to students' self-regulation

Learning in complex environments, such as higher education, creates a normal flip-flop effect between positive and negative emotions (Lehman et al., 2012). The flip-flop effect is evident within the students' narratives where some express delight in progress and others struggle while solving mathematical problems. Human mediators can adapt the learning process in face-to-face learning environments by varying cognitive states and adjusting affective constructs. Thus, students are aroused and motivational intensity increases (Schunk et al., 2014). It is more difficult to replicate the adaptive process within eAssessment. Students' self-reactions motivate, giving belief that progress is taking place towards a satisfactory goal reward. The affordance of self-reaction affects self-efficacy in a constructive manner, similarly there is potential to demotivate if negative self-reaction is a student's trait. It is believed that a negative self-reaction doesn't result in decreased motivation if students feel they can improve.

Students' mathematics ability prior to third level is an area of concern in the literature, and this issue is not limited to Ireland (See Chapter 2, sections 2.2 and 2.6). The only countries in the research reporting statistically significant differences in self-reported mathematics abilities with Ireland were Poland and Russia (see Chapter 4, table 4.12). Discussion with Polish and Russian academics, during the post-qualitative analysis phase, revealed significant social and cultural pressures on Russian and Polish students to perform strongly in mathematics. The mathematics abilities of Polish and Russian students are not poorer than Irish students. The motivational effects of socio-geographical pressures appear to be providing evidence as strong influencing factors to improve mathematics ability. Participating academics in Poland and Russia have very strong perceptions that their respective students must display high levels of mathematical competency.

The research opportunities to explore motivation by gender were limited in this study. The very low number of females participating in Ireland, Estonia, and Finland, compared to Poland, Portugal, and Russia, rendered across country comparisons invalid. A combined overall test was conducted revealing statistically significant evidence that female students self-reported higher levels of expectancy compared to males. Whilst interesting, within this study it is not possible to draw any conclusions from these statistics. The inability to compare gender and motivation across countries was disappointing.

Students shared a range of beliefs and values regarding eAssessment. Some students found that eAssessment was a more relaxing method of completing tasks, and this was balanced by a similar number who found eAssessment to be frustrating, bothersome and difficult (Henderson et al., 2017). Of particular interest is the relationship between first year and second year students. First year students were more positive in relation to assessment than second year students, and second year students were more neutral tending towards the negative than first year students. It is possible to view this movement as a negative affectance for students, or it may be a demonstration of metacognitive maturity as students learn to reflect on their situation and location within engineering mathematics.

The action of self-reaction combined with instruction received from academics can promote motivation. The academics' instruction in the form of eAssessment feedback are an integral component within the cyclic self-regulation phase. To aid my understanding of this process, I have adapted Zimmerman's cyclic model (Schunk et al., 2014, p. 179 Figure 4) for high achievers to accommodate low-to-average achievers, and the inconsistent nature of academic feedback. The evidence supporting this adaptation is provided within the students' and academics' narratives and the adaptation is shown in Figure 6.1. In this adapted model, academic feedback is an external affectance representing the knowledge of the academic. Academics' knowledge lies outside the control of the student, and is not always present, as witnessed through the interpretations of students' and academics' utterances in the study.

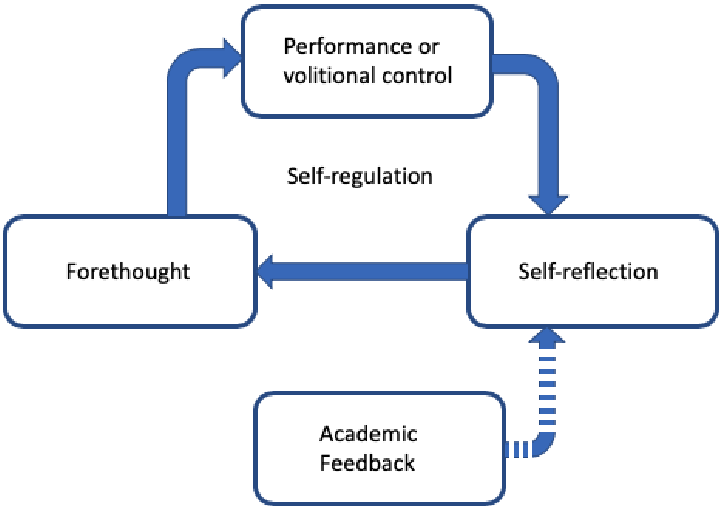

Figure 6.1 Modified Self-regulation incorporating feedback

An eAssessment environment may, or may not, incorporate human interaction in the mediation of learning depending on whether the learning environment is fully online or blended (Lehman et al., 2012). Pekrun, Elliot and Maier (2009) concluded that there is a *benefit to attending to both students' goals and emotions in structured learning environments*. Referring to Figure 6.1, the importance of academic feedback in the support of students' goals and emotions is clearly visible. However, academic feedback is not always visible to the students.

Students' emotions within a technology mediated eAssessment environment are visible within the interpretations of the data. However, there is no evidence within the interpretations that academics adopt structured approaches to supporting student emotions. The lack of a structured emotional support for students may contribute to existing levels of amotivation (Baker, 2004) and exacerbate negative intrinsic motivation (Goto & Martin, 2009). Intrinsic and extrinsic motivational goals of students may provide sufficient meaning for those with positive sense of self-concept (Priess-Groben & Hyde, 2017); a personal belief that action will produce a particular result (Bandura, 1977). This study provides evidence that not all students can be described as highly motivated with a positive outlook. The manner by which students acquire, deploy, and transfer skills and knowledge, is affected by motivational processes (Dweck, 1986). Each student presents a different lebenswelt (Husserl cited in Romdenh-Romluc, 2011, p. 12) or *personal history* of experiences, and each student should be accommodated within the mediation of learning.

6.4 Implications of the findings

Three phenomena are presented in section 6.3 as the pivotal findings. The first is the preparation for eAssessment and potential barriers to eAssessment, and how students would benefit from greater understanding by academics. The second is the effect of students' values of engaging in eAssessment on motivation, belonging and self-belief, and the embedded role of academics within the process. The third phenomena of motivation due to external feedback mechanisms is the combination of extrinsic and intrinsic affectances relating to students' behaviours. These phenomena are the guiding factors providing answers to the five sub-questions.

6.4.1 Research Sub-Question 1

To develop a full portrait of the students' perceptions of assessment in higher education it is necessary to gain an insight into prior assessment experiences as contributing factors. Students were asked if they had experience of eAssessment prior to higher education. Experiences of eAssessment, or the lack of, contribute to how a student may perceive eAssessment exercises in engineering-mathematics.

In stage one, it was found that non-standard entry Irish students were less likely to have prior experience of eAssessment compared to standard entry students. Post-test survey responses suggest a programme of preparation and training for eAssessment in the liminal stage of semester one has potential to overcome perceived deficiencies in students' digital literacies, skills, and competencies. The preparatory and engagement stages must be supported by an eAssessment process based on sound pedagogical guidelines.

A major pedagogical factor in higher education is the feedback process. The construct of feedback literacy and the need to ensure that students understand the processes of assessment and feedback is necessary (Carless & Boud, 2018). Many students associate feedback with grades, and there may be a sense of grade entitlement (Ackerman & Gross, 2018). An issue arising from the sense of grade entitlement is the possibility of grade inflation if students are viewed simply as customers in higher education. Academics should be aware of the students' dispositions to awards for effort, and gain an understanding of underlying implicit theories, or students' beliefs, in the learning and assessment processes (Garland, 1993).

Perceived barriers experienced by students are not only associated with dispositional barriers such as motivation. Additional barriers are in evidence within the interpretation and analysis in the form of institutional barriers and situational barriers. Students may be pre-disposed to overcoming the perceived barriers or they may struggle in the challenge. Indeed, some students may consider the struggle to be invalid, depending on their situational experiences (Rowe et al., 2015). Evidence in the students' narrative also points towards epistemological barriers that are perceived to form barriers to students' successful participation. Such barriers are subjective in their nature and may be discipline specific, conflation within congruencies in assessment and feedback has the potential to further reduce and hinder progress.

Feedback literacy (Carless & Boud, 2018) is a *meta-dialogue* between academics and students, with a lens on the processes and strategies of assessment rather than the product of assessment. Failure by academics to engage the meta-dialogue leads to an encumbrance and subsequent dissonances experienced by students. Evidence within the second-year Irish students' narratives demonstrates an evolution of awareness of assessment processes. Students perceive that they can relate to the need for multiple engagements within assessment as they reflect on their assessment experiences.

Irish students provided evidence that they are more likely not to have prior experience of eAssessment compared to other countries in the study. It was anticipated in the student interviews that this would manifest as a specifically local issue. However, interpretation of the students' discourse revealed that even though other countries reported greater levels of eAssessment experiences prior to third level, the perceptions held by all students were quite similar.

First year Irish engineering students concentrated on Internet access and digital skills as the main barriers, but these diminished by second year, where the greatest barrier was poor feedback from academics. Irish students were very quick to mention poor Internet access and lack of computer facilities at home as significant barriers. The geographic location of the participating Irish institution means that the main student catchment area is hilly and remote with poor Internet access, although the situation is slowly being addressed through Irish government actions.

6.4.2 Research Sub-Question 2

Rowe, Fitness and Wood (2015) provide evidence that students and academics have different and conflicting perspectives on the learning process, and that many student-academic interactions cannot be commented on through *theory alone*. A complex weave of emotions, behaviours, cognition, and learning experiences of both parties affects the learning environment.

The academic narratives in this study reveal a significant concentration on learning as a product of assessment and reduces, or ignores, the emotional and behavioural aspects of learning (Rowe et al., 2015; Schunk et al., 2014; Pekrun et al., 2009). Many academic perceptions of assessment do not prioritize the effects of positive or negative emotions held by students or recognize that human-human engagement involves emotions on both sides.

Assessment – especially formative assessment – is a process of learning, and not merely an object of learning (Good, 2011). Comments by academics that they are not responsible for, or have no knowledge of, external factors in the form of emotions, dispositions, prior experiences, and cognitive behaviours, reveal a discontinuity in the assessment process resulting in tensions with students. A mix of perceptions and concerns regarding eAssessment are evident within the discourse and interpretations as another source of tensions in the process. Conflicting approaches to eAssessment in engineering mathematics by academics give rise to tensions in the student-academic relationship. The tensions are evident in eAssessment as an integral component in technology mediated learning and manifest in the form of dissonances. There is growing emphasis on teaching higher-order thinking skills in the curricula of higher education institutions, but existing institutional and social tensions pressure academics to measure lower-order skills to meet demands (Hoogland & Tout, 2018).

Interpretation of the phenomena within the academics' narratives reflects for example the literature for research universities, however the Irish institution participating in this study is an institute of technology, whose core role is not research oriented. There is evidence to state that the rhetoric of academics closely reflects the expectations of higher education in general. A phenomenon present within the study of academic behaviours matches the literature, where *problems and solutions are rarely based on a rational analysis* of assessment within the curriculum and pedagogical design (Bearman et al., 2017). Few academics proffered metacognitive reasoning for choices of assessment and subsequent assessment design. Design within eAssessment or any assessment exercise should not simply be to *make the job of grading easier*. Rhetoric of this nature suggests that the student is not a prime motivating factor for design with consequential downgrading of the perceived status of the student within the learning process. The purpose of the assessments employed by several academics was not elaborated beyond the mechanics of the exercise (Postareff et al., 2012), however this deficiency was balanced by other academics who engaged in a manner suggesting high levels of assessment literacy (Price et al., 2011). Inconsistencies in assessment between purpose and practice are an issue that students struggle to deal with, academics appear to be unaware of this problem as reflected in the comments by both students and academics. What academics are expected to do and what they actually do is not always correlated in practice.

A disturbing misplaced Irish academic perception is students' access to appropriate technologies to engage with eAssessment. The Irish academic proffered solution is that facilities exist on campus if they don't exist at home. This perception creates barriers to learning because it does not accommodate the individual experiences of students. Students may not be able to access on-campus technologies at times suitable to their needs.

As stated in this section, the participating academics often perceive themselves to be powerless when asked about students' intrinsic motivational factors and are more interested in extrinsic factors. The perception that academics can only affect extrinsic factors through establishing specific goals is misguided because intrinsic motivational factors (Calder & Staw, 1975) are important for student belonging; teacher presence provides a means by which the gap in perception may be narrowed. The increased use of technology as a mediating factor in learning has led to greater use of the term autonomy, and the perception that students should be autonomous in a digital world. However, students entering non-research universities are not necessarily autonomous by nature or experience and yet a phenomenon of the research reveals a lack of desire by academics to inculcate autonomy through the pedagogy.

6.4.3 Research Sub-Question 3

The issues faced by students of similar academic standing in the other participating countries are remarkably like those faced by Irish students. Taking into account the variety of programme designs, with engineering mathematics at the core, the perceptions of instrumental genesis (Tabach, 2021; Tamborg, 2021; Clark-Wilson & Hoyles, 2019) remain the same in the early stages of higher education. Knowledge of students by academics is acknowledged by the students in the form of awareness of mathematical abilities but less is known about students' personal orientations. The participating academics in each of the countries in the study typically appear not to attempt to gain access to knowledge about individual student personal orientations towards engineering mathematics. Traditional students perceive a distancing factor is introduced in higher education moving the academics further from the students compared to secondary or vocational school. Non-traditional students perceive similar distancing from academics resulting in the establishment of dispositional barriers. A student perception is conjectured that society approves the academic distancing and removal to support autonomy.

The profile of students entering engineering mathematics in higher education in the selected countries differs based on the circumstances presented within each country. Geographic location was not a statistically significant factor in the perceived levels of abilities. This result provides an interesting insight to how students have a perceived sense of awareness of their abilities in third level in relation to their programme of study.

Statistical evidence, within this research, shows that perceptions of confidence vary across the participating countries, but it cannot be stated with any confidence that these variations do not change. Confidence is related to personal orientation and prior experiences with societal expectations playing a large role. Hence, the students' perceptions of confidence may also reflect that which is expected of them aligned with the students' perceived abilities in mathematics. However, culture and society in different countries are not homogeneous and evidence demonstrates that students display fear in sharing personal orientations. Many participating students reported high levels of prior eAssessment experiences, but this was not mirrored by an increased sense of enjoyment, or engagement, in the experience compared to Irish students.

6.4.4 Research Sub-Question 4

Determination of academics' perceptions in different geographic locales, is a highly desirable aspect of the research to aid an academic understanding of potential issues that may arise through student and academic mobility. Perceptions were not expected to be homogenous across the samples due to differences in language, culture, educational experiences, and societal expectations.

Perceptions of academics' pedagogical, content and technology knowledge gaps are provided within the students' narratives, supporting the findings by Clark-Wilson and Hoyes (2019) that the epistemic value of technology supporting eAssessment must be acknowledged within the processes of higher education mathematics education. However, not all academics demonstrate awareness of the lack of preparation for digital literacy creating an unintentional barrier to learning. Students are not fully prepared for eAssessment in higher education and the academics' narratives support the literature through the rhetoric of expectations in the belief that students are digitally literate (Munoz-Escalona et al., 2019).

There is a need for meta-dialogue between academics and students to explore strategies, necessary to mitigate the reduced perceptions of enjoyment and engagement, in third-level eAssessment; the meta-dialogue should not be restricted to entry preparation (Carless & Boud, 2018; Hargens & Grau, 1994). Evidence in the study provides pointers to psychographic components of self-efficacy, belonging, expectancy and motivation, where a meta-dialogue is essential for students' full understanding of eAssessment to mitigate perceived barriers to learning. Meta-dialogue is missing in all the participating academic perceptions.

Determination of what academics consider to be barriers to learning within the qualitative data provided evidence of a gap between the perceptions of students and those of academics depending on year of study. Finnish academics experienced severe discomfort during the focus group interview with Finnish students. The Finnish academics' perceptions of access to digital resources off-campus were not as expected; this phenomenon provides strong evidence of misplaced academic perceptions towards resource access by students.

Self-judgements of competence and motivation to overcome negative perceptions, and to reinforce positive perceptions of academics, are heavily influenced by the academics' self-efficacy (Bandura, 1977). The nexus of self-efficacy with motivation forms a powerful agent as the academic seeks to support students to achieve successful levels of mastery and competence. Cognitive appraisals by academics do not occur in isolation from factors such as expectancy and perceived barriers. The perceptions of academics and the degree by which they create interventions in eAssessment are mixed within the discourse. Failure to mitigate the negative effects of background socio-environmental influences by continuing negative interactions through poor feedback practices has potential to reduce students' self-efficacy (Eickelmann & Vennemann, 2017). Mitigation of negative factors may be achieved through sound feedback design and the establishment of a dialogue with the students (Carless & Boud, 2018; Rakoczy et al., 2018; Boud & Molloy, 2013; D. L. Butler & Winne, 1995; Ramaprasad, 1983). There is evidence that some of the participating academics perceive a need to mitigate any negative factors through tailored support, but this is not the perception of all the participating academics.

6.4.5 Research Sub-Question 5

Presentation of students' perceptions of eAssessment to academics provides an opportunity for students and academics to open a reflective dialogue or to develop a meta-dialogue (Hargens & Grau, 1994). A meta-dialogue offers the potential to reflect within a socio-constructivist ontology of critical realism; the students' voices are heard within the same socio-cognitive arena as the academics' voices (Palincsar & Brown, 1987). The meta-dialogue acknowledges the nexus between students and academics as a constructive component in metacognition and motivation.

Referring to Eccles' theoretical model of expectancy-value (Figure 1, Schunk et al., 2014, p. 58), an integral component of the model is students' perceptions for the setting of goals and effective schemas, and the students' affective reactions and memories. It is recognised that *it is only students who can act to improve their learning* by developing their tacit knowledge (Carless & Boud, 2018). A prime agent within the process of improving student learning is the academic environment, where academics are the main actors and points of contact with students. An argument is made for shared and individual interpretations of the co-construction of knowledge, thus the process of perceptions in eAssessment becomes a dialogue between students and academics (Carless & Boud, 2018; Palincsar & Brown, 1987).

Students, through experiencing a meaningful dialogue with peers and academics, can utilise their tacit knowledge to make sense of the strategic processes in eAssessment. Reflection on past and current experiences, adjustment to the third-level transition, and the introduction of eAssessment, develops capacities in judgement making (Banister, 2020). Sharing reflective comments with academics enables a dialogue requiring openness from both parties. Academics can allay fears, construct a safe learning environment, make judgements on the students' reflective situations and engage meta-cognitively (Ajjawi et al., 2013). Enablement of a dialogue between academics and students is prototypical, facilitative, and empowering for students. Post-interview analysis and discussion with academics revealed such dialogue is atypical and uncommon in their experience.

As a prototypical process, the realization by academics of a greater understanding of eAssessment processes aids students in their understanding of their locale and situation within a programme of study. Facilitation of the meta-dialogue enables students to elaborate fear, anxiety, joy, motivation, and barriers to academics. Students' tacit knowledge becomes more visible to the academics, allowing a process to begin, whereby feedback literacy of both students and academics is improved. Unfortunately, as elicited by Forbes and Gedera (2019), a lack of teacher presence whilst students are online may lead to misinterpretations by both academics and students. The need for academics to make themselves available for discussion is not yet common practice.

The onus remains on the students to engage with academics, their programme of study, and learning environment, to improve their meta-cognitive skills. However, this process cannot take place in a vacuum due to the complex socio-perceptions and socio-interactions expected by humans. The role of the academic is vital in providing a guiding pathway by which the students may remain on the learning path (Henderson, Ryan & Phillips 2019). As an enabling agent, academics can discuss the nature of feedback as opposed to discussing specific activity feedback.

A positive attitude towards feedback, improving feedback literacy, and constructing an understanding of feedback cycles, provides a vehicle by which students better understand the locale and situation of academics in the learning process (Malecka, Boud & Carless, 2020). Enablement of students as valued partners in learning through repeated experiences provides a safe space, in which students can gradually accept and acquire expertise (Zhu & Carless, 2018). Developing capacity for further metacognitive activity through discourse allows students to better make sense of the processes to enhance the individual and collective sense of belonging in the community of engineering mathematics practice.

The prototype of meta-dialogue has implications for academics as well as students (Cook-Sather, 2015). Successful engagement is achieved through programmes designed to support the dialogue (Sun & Trent, 2020). The dialogue cannot take place within individual subjects of study, the dialogue should be embedded in the curriculum and acted on by all academics involved with the students. True value and veracity of the process cannot be established if the process is experienced within a single subject and other subjects adopt alternative techniques (Hargens & Grau, 1994).

The relocation of eAssessment in the students' mind reflects the metacognitive process of instrumental genesis (Rabardel, 2002). Students interact with eAssessment and subsequently manipulate and transform eAssessment as an artifact into a meaningful instrument. The orchestration of eAssessment within a technology mediated environment depends on activities by students and teachers (Trouche, 2004). The orchestration defines the intention and systematic organisation of assessment within the learning environment. Orchestration of eAssessment is characterized by the academic and, unless there is a standardised design, confusion may be introduced as students attempt to rationalize each design. Thus, the outcome is dependent on the system of rules, the community or society; the design situates the students with eAssessment (Engeström et al., 1999). Considerable variety in assessment design within a programme has potential to upset the students' epistemic functions as they attempt to engage in heuristic functions. The location of confusing instrumentation is considered by students to reduce their pragmatic functionality, leading to discontent.

6.5 COVID-19 Pandemic

The outbreak of the COVID-19 pandemic occurred after this research was completed. Schools and universities had to close across the world forcing a move from primarily face-to-face teaching to an exclusively online learning format. The research literature in Chapter 2 provides evidence for the many issues faced by students and academics engaging in an online learning format prior to COVID-19. The literature researching the effects of online learning and the issues generated by COVID-19 supports the literature in Chapter 2. Mental health of students and academics was brought to the foreground (Baltà-Salvador et al., 2021). Emotions began to surface as an issue of high value when trying to understand online learning. A major outcome in the literature is the role of communication between students and academics, but it will be many years before the impact of COVID-19 on education is fully known (Blaskó, da Costa & Schnepf, 2022).

The hype surrounding online learning prior to COVID-19 became a distraction for many higher education institutions and was accepted as being strategically important. However, instead of planned learning using trained academics, a process of emergency remote teaching was adopted by educational institutions worldwide (Alonso-García et al., 2021). Educational institution management viewed emergency remote teaching as a satisfying mechanism for dealing with the operational management complexities they faced. Serious gaps in students' and academics' knowledge, skills, and digital readiness were exposed by the emergency remote teaching approach (Trust & Whalen, 2020).

Chapter 7 – CONCLUSION

This study set out to conceptualise, explore and investigate students' and academics' perceptions of eAssessment within undergraduate engineering mathematics in the early years of Irish, Estonian, Finnish, Polish, Portuguese, Romanian and Russian higher education institutions. The study addressed the following issues relating to eAssessment of engineering mathematics:

- Conceptualisation of students' and academics' perceptions
- Exploration of students' and academics' perceptions in different geographic locales
- Relationships between students' and academics' perceptions

The motivation for the study was the serendipitous discovery of students' voices in an Irish institute of technology, and the realisation that many students' voices remain unheard within the noise of narratives associated with them.

The findings of the study add to the body of literature providing new insights into the perceptions held by students and academics in relation to eAssessment in first-year undergraduate study of engineering mathematics. New knowledge has been added in the form of three pivotal findings. The first is knowledge of students' perceptions of their preparation for eAssessment, and potential barriers to eAssessment, aids academics' understanding of student behaviours. The second is academics' knowledge of students' expectations and values regarding justified rewards and effort during eAssessment allows academics and students to align students' expectations. The third is that students' motivational emotions in complex learning environments involving eAssessment are major contributors to students' self-regulation.

The three findings have implications for academics and institutions seeking to improve students' learning experiences, and to reduce perceived and actual barriers to learning. The findings are recognition of the importance of support provided by academics and institutions to students in the initial and subsequent phases of learning in higher education. The findings also provide evidence that greater awareness of eAssessment processes by both students and academics provides for an improved learning experience.

7.1 Contribution to Knowledge

This research was inspired by anecdotal observations, about dissatisfaction experienced by students while engaging in eAssessment in engineering mathematics. Supporting research literature to address this dissatisfaction proved difficult to obtain.

The contributions to research knowledge gained from this study are focused on three findings and these are:

1. Knowledge of students' perceptions of their preparation for eAssessment, and potential barriers to eAssessment, aids academics' understanding of student behaviours.

2. Academics' knowledge of students' expectations and values regarding justified rewards and effort during eAssessment allows academics and students to align students' expectations.

3. Students' motivational emotions in complex learning environments involving eAssessment are major contributors to students' self-regulation.

7.1.1 Knowledge of students' perceptions of their preparation for eAssessment, and potential barriers to eAssessment, aids academics' understanding of student behaviours

Consideration of students' perceptions of eAssessment gained prior to third level education is not given by all academics. Students' perceptions of eAssessment whilst studying in the early stages of higher education are similarly not considered by all academics, even though it is known that these early stages have potential to cause confusion and frustration amongst students.

The demographics of the student intake have been changing to include a significant minority of non-standard entry students. A lack of awareness of the needs of non-standard entry students by academics can lead to distancing of non-standard students because they perceive themselves as not worthy within the engineering education domain.

The assessment process resides within a complex learning space and this learning space can form institutional, situational, and dispositional barriers to learning for students from both standard and non-standard entry types.

Independent and autonomous learner modes are emphasised within the research literature however, not all students in the early stages of higher education perceive they have sufficient levels of preparation for, and cognition of, the metacognitive strategies required to become independent or autonomous within the engineering mathematics domain in higher education.

Academics demand, or at least expect, students be cognizant of the processes of engineering mathematics within the higher education learning environment. The levels of expectation shape the teaching and assessment processes, and a gap exists between the students' beliefs of teaching and assessment of engineering mathematics and those held by academics. This gap in beliefs results in learning dissonances as students and academics are not in alignment regarding facilitation of needs.

Tensions resulting from different perceptions of eAssessment are experienced by both academics and students. The socio-cultural fabric of the learning space has potential to unravel if the tensions and differences in perceptions are not addressed through dialogue. Self-efficacy is diminished by failure to engage positively within the medium where technology is a mediator. Diminished mediation within the learning environment negatively affects the sense of belonging held by students. Academics need to play a central role to ensure policies, practices and procedures mitigate the tensions caused by eAssessment.

Otherwise, it is not possible for academics to develop an understanding of students' behaviours in eAssessment.

7.1.2 Academics' knowledge of students' expectations and values regarding justified rewards and effort during eAssessment allows academics and students to align students' expectations

An important factor within the eAssessment environment is the expected reward for effort. It is evident that some students have unrealistically high expectations for effort, whilst other students display low expectations, based on prior experiences. Mitigation of unrealistic expectations is conducted by improving the feedback literacy and dialogue of both academics and students. Emphasis on performance as measured through grades enhances the unrealistic expectations of some students because foundational and tacit knowledge are not explored through grades alone. Dialogue is necessary to establish knowledge gained, learning, and tensions resulting from eAssessment.

Failure by academics to engage in dialogue with students for rewards, effort, achievement, and goals leads to increased levels of student anxiety. Mathematics anxiety is evidenced in the students' narratives resulting from dialogical failure by academics. Therefore, the ability to link concepts, theory, and application of mathematics to solve engineering problems is broken for some students resulting in negative mathematical dispositions.

Cognitive growth cannot be determined if students do not know why their efforts do not match realistic rewards. The perceived usefulness of eAssessment is not always present in both academic and student discourses. The dissonances resulting from perceived lack of usefulness affects how students perceive the levels of enjoyment, attainment, and utility of the tasks within eAssessment, because the purpose of the eAssessment is clouded by misinterpretation of the eAssessment tools.

Realistic alignment of perceptions for rewards and effort is not obtained through unidirectional communication from academics to students. Students and academics are enmeshed within a complex socio-cognitive network in the higher education learning sphere. Communication must involve true dialogue between all parties to expose tensions within the eAssessment process. Through social and learning interactions, anxieties can be attenuated as the grammar of engineering mathematics is developed cognitively.

The heterogenous higher education learning environment means that dialogue between students and academics must be pitched at the individual, group, and institutional levels. Such dialogue to encourage internalization of development processes is only possible if academics are aware of, and have objective input to, policies, practices, and procedures supporting dialogue within their respective institutions.

7.1.3 Students' motivational emotions in complex learning environments involving eAssessment are major contributors to students' self-regulation

Students display a wide range of emotions whilst engaging with eAssessment. Experiences prior to higher education leads to a variety of perceptions regarding assessment processes employed within engineering mathematics. Skills acquisition and metacognitive strategies demonstrated by students are indicators of students' self-efficacy. Students' self-efficacy is not homogenous within any group and is affected by the affordances of academics, parental, peer, and social interactions.

The cues derived by students from internal and external affordances are indicators for performance, and ultimately the students' sense of belonging in engineering mathematics. Poor performance may be mitigated if academics provide objective and targeted information to ensure students modify their metacognitive strategies, such as intensifying effort or altering task approaches.

A major tension for academics as they strive to mitigate poor students' performance, or indeed ensure students continue to achieve their goals, is the lack of an appropriate model for eAssessment. The failure within the research literature to provide appropriate models for eAssessment for the enhancement of students' cognitive growth is noted. The lack of a suitable model for eAssessment in engineering mathematics is a demotivating factor for some academics because they don't have anything to use as a benchmark.

Change in students' behaviours is evidenced within the narratives of the Irish second year students as a direct result of a change in the academic feedback process. A lack of dialogue and feedback can produce a demotivating influence for many students. This change in behaviour results from the affordances displayed by the academic as it affects the students' self-regulation due to self-reflection. Performance of students is affected by the affordances of academics and students do not have any control over this external influence.

The influence of students' emotions within the eAssessment environment has potential to generate tensions with academics in the engineering mathematics domain. Students' emotions are not perceived by academics to be an integral motivating component of eAssessment. Academics perceive emotion to be an extrinsic factor over which they have no control. The resulting dissonances created by this academic perception and failure to embed emotion as a motivational factor in the design, planning, and execution of eAssessment has potential to negatively affect student motivation.

Not all students can be described as highly motivated as they enter the higher education sphere, and their intrinsic motivational goals may be poorly established. Acquisition, transfer, and deployment of knowledge and skills are affected by the motivational processes. If academics are not aware of the motivational processes, it becomes extremely difficult for students with low intrinsic motivation to modify their personal dispositions to enhance their self-regulatory skills.

7.2 Research Study Limitations

Several limitations within the study have been identified: the study was conducted solely within the domain of engineering mathematics; there is an identifiable relationship between the researcher and the participants; interpretation of qualitative data; methodological limitations of the two-stage convergent design; veracity of semi-structured interviews.

7.2.1 Engineering Mathematics Environment

A potential limitation to developing an understanding of academics' perceptions may be a result of conducting the study solely within the engineering mathematics environment. The perceptions of students and academics may vary outside of engineering mathematics, but those areas are outside my domain of understanding. It may be that mathematics teachers in other educational domains adopt different approaches to eAssessment of mathematics within their curricula. Future studies could expand the scope of the research to include other domains to determine if alternative approaches to mathematics eAssessment are utilised. This could be addressed by engaging with other researchers in mathematics in higher education to support a larger scale study.

7.2.2 Relationship between Researcher and Participants

Whilst every opportunity was taken to be objective within the research there is an explicit relationship between the researcher and many of the participants. The researcher has identified (Chapter 3, section 3.10) the threat posed to students, either consciously or sub-consciously, through the position of power as their mathematics lecturer. The researcher also has a professional relationship with many of the academics, and there is the danger of a degree of subjectivity and judgement occurring when interpreting their narratives. Conscious at all stages to maintain the human dignity of all participants, to respect their opinions, ensure their right to anonymity, and to interpret without prejudice, the researcher is aware that bias will form part of the interpretation.

To minimise the subjective bias inherent in the process a future study should engage independent interpretation of all qualitative and quantitative processes. Interviews would be conducted using trained researchers identified as not having any professional or personal relationship with participants.

7.2.3 Interpretation of Qualitative Data

Interpretation of qualitative data is a subjective process because the researcher is embedded in the process, with an identified vested interest in the outputs. It is not possible to generate a fully objective interpretation when engaging in phenomenological techniques. The level of bias may be reduced if an independent interpreter is used in this stage, however as a single researcher this mechanism was not possible. A protocol for qualitative analysis was developed and adhered to throughout the process. Interviews were recorded without any facial images, although the student and academic participants were known to me. Participants were allocated unique codes without revealing names during analysis and interpretation. The qualitative data protocol was used for student open survey responses as well as semi-structured interviews with students and academics. Anonymous recording of student interviews and anonymity in open responses removed the ability to cross check responses between interviews and open responses. The resultant inability to cross check has reduced the quality of the qualitative data interpretation.

7.2.4 Methodological Limitations of the Two-stage Convergent Design

The two-stage convergent design is an adaptation, for this research study, of the single convergent design process and tested for the first time that the researcher is aware of. The convergent design is an established methodology requiring tight integration, and interaction, of quantitative and qualitative data gathering and analysis. The first stage of the process was designed and operated mainly as expected, however the required interpretation process took longer than designed because of the pilot programme experience. The pilot programme was conducted in a relaxed atmosphere at the end of a semester without any incumbent activities to cause interference. Operationalization of stage-one was more fraught because it involved the liminal stage of semester one and the difficulties posed within this stage. It was not possible to gather post-test survey data as planned and this was re-planned to occur at the beginning of semester two. Thus, chronological sequencing was not as exact as required within the original data gathering design.

Stage-two of the process involved gathering data from geographically dispersed countries. The timing of semesters in each country differed from Ireland and this had to be factored into the process. The qualitative processes were dependent on the availability of academics for interview. The original plan was to visit and interview academics in person, but this rapidly became problematic due to timing issues. The plan was revised, and most academic interviews took place via Skype.

Skype interviews were recorded without incident and deemed to be appropriate within the process. Gathering quantitative data required support from academics in each country and surveys were conducted at times to suit. Language barriers were present in Estonia, Poland, Romania, and Russia. These barriers were overcome through translation of the surveys to the respective languages of the students. Translation of surveys was not accounted for in the original design and this stage slipped accordingly but was not onerous on the overall research.

A future two-stage convergent design would be cognizant of the difficulties experienced and more time would be allowed for each stage in the overall process.

7.2.5 Veracity of Semi-structured Interviews

The research study centred on giving voice to the students, and simply describing the voice was not a sufficient methodology. Interpretive phenomenological analysis to give voice in a contextual, veracious manner is paramount to the success of this research and to raising the perceptions of students. The onto-epistemology of critical realism within a socio-cognitive environment provided a sound theoretical framework for the research. Giving voice and allowing the truth to come to the fore, irrespective of grammar, is the researcher's mandate. Making sense of the interpretations is complicated by the presence of the researcher's preconceptions. It is not possible to access the inner worlds of students and academics by direct means, or even completely. Therefore, veracity is not a tautology of the data, it is a description of what the researcher subjectively considers to be close to the truth. To ensure the veracity of the interviews is as close as possible to the inner worlds of students and academics, the idiographic procedures were designed to be as fine-grained as possible within the time frame. The granularity of the process is subjective to the researcher and determined by the allocated time frame for interpretation. Thus, a detailed and extensive in-depth examination of the individual voice takes place within a uniquely contextualized environment as the individual's story is uncovered. Veracity cannot be reproduced at a later stage because experience is not a constant in life, and therefore may be seen as a limitation.

7.3 Recommendations for Practice

1. The study provides evidence that barriers experienced by students, whether perceived or actual, are difficult to quantify. This difficulty is reflected in academics' perceptions in the form of confusion or vagueness as to the actual barriers faced by students. Situational barriers may be attenuated through greater awareness by academics of the students' learning environment. Institutional barriers add to students' anxieties through poor instructional design, inappropriate or unsuitable learning spaces and ambiguous approaches to learning. The interpretations in Chapter 5 provide evidence that some physical barriers are shared, whilst other barriers vary depending on individual student experiences. It is recommended that holistic academic engagement at all institutional levels to address learning, from the individual to the collective, is designed into undergraduate engineering programmes.

2. Students carry pre-higher education experiences into their engineering programmes as evidenced in Chapter 2, Chapter 4, and Chapter 5. Academics consider pre-higher education issues to be a component outside their control. A mixed response to this issue is evident in the academic narratives, where some discourses demonstrate great awareness of students' prior experiences and other discourses dismiss the issue. Students from low socio-economic backgrounds with poor peer networks and little sense of career aspiration display stereotypical behaviours, such as lacking a sense of belonging. Failure to address negative behaviours leads to less than optimum learning experiences for students with potential to further compound negative traits. The introduction of high stakes eAssessment for students entering higher education compounds confusing and frustrating behaviours for many students. A collaborative support programme is recommended in the initial phases of first-year undergraduate study by academics with responsibility for first semester and student support teams. This approach has potential to inspire students to build a community of practice and subsequently develop a sense of belonging in engineering.

3. Self-efficacy is a significant influencing factor in the process of forming a sense of belonging. There are documented points of demarcation for academics regarding students' prior or pre-existing attributes and these are covered by the previous recommendation. The affordance of self-efficacy is not limited to the initial stages of eAssessment as evidenced in the students' narratives. The inclusion of second-year students allowed this to be explored as an organic concern in the learning process. Chapter 5 provides evidence that some academics display awareness of students' self-efficacy, whilst others do not. Inconsistent approaches to engagement are reflected in eAssessment methods and approaches. An eAssessment system requires feedback to be designed as a supportive metacognitive mechanism as the technology engages in a mediating manner. It is recommended that academics engage with eAssessment practices and methodologies specifically aimed at creating more dynamic feedback protocols which foster self-efficacy.

4. The motivational role associated with expectancy is a major factor in the eAssessment process as evidenced in the Chapter 2 literature review. Reward and justice for work done is expected and yet eAssessment tools are not sufficiently mature to ensure that all students receive appropriate rewards. This study shows that failure to reward in a timely fashion can contribute to negative student states with potential to confirm negative traits and behaviours. Expectancy and the nexus with feedback literacy may result in students feeling that the effort is not justified by the reward, resulting in underperformance and non-productive students' dispositions. The learning space should be where rewards are not simply utilitarian and are truly achievement related. Consistent eAssessment practices showing awareness of student psychographic processes to support autonomous growth is only achievable through the application of sound pedagogical design. Therefore, it is recommended that greater cognizance of expectancy as a factor in eAssessment be developed, by institutions and academics, to

promote feedback literacy in eAssessment and standard assessment environments.

5. The narratives regarding academic eAssessment concerns have focused mainly on the products of the eAssessment in terms of grades and performance. It is not obvious from the narratives that academics give priority to human processes in eAssessment. The process of eAssessment includes emotions for both students and academics, albeit via a technology mediated environment. Learning is a process, of which assessment forms a major component in higher education. Treatment of eAssessment as an object within learning negates the students' overall learning experience and does not provide justice for the effort. Tensions are visible in the students' discourse when eAssessment is considered as an object, resulting in conflict in the student-academic relationship. This study provides evidence that academics' narratives reflect the literature in Chapter 2. Few academics include knowledge of students' perceptions of students as prime factors in eAssessment design. It is recommended that academics take cognizance of the mediating affectances of technology for eAssessment, and not treat eAssessment practices simply as objects within the curriculum to be completed.

6. Relationships between students' and academics' perceptions are fundamental components of the meta-dialogue if a socio-cognitive and constructive learning environment is to be promoted. A meta-dialogue is made possible where a strong relationship connection exists between academics and students. It is understood within the student-academic nexus that improvement of learning is the responsibility of the student. However, the academic is not absolved from responsibility as a major actor in the learning process. Shared and individual interpretations of knowledge are affordances of a socio-cognitive learning environment. Sharing perceptions and concerns is atypical of the higher education environment for both students and academics. The lack of sharing is evidenced in Chapter 5 where some students struggled with the concept of sharing feelings. To facilitate the sharing and presentation of perceptions by both academics and students, it is recommended that

engineering programme designers include a means to support shared dialogue. Shared dialogue acting as an enabler of students' understanding of policies, processes, and practices situated within engineering mathematics allows academics to trace students' negative affectances.

7. The first six recommendations for practice are possible through appropriate use of the technology as a mediating technology. Sound pedagogy is only possible where 'teacher presence' is designed into the assessment paradigm. Teacher presence as a vital enabling factor ensures that learners are provided with a secure and safe learning environment. Whether the assessment environment is completely online or hybrid, the visible presence of the teacher ensures quality is maintained, learner-learner and learner-teacher communication pathways remain open, cultural dispositions are catered for, and learning goals are achieved.

7.4 Directions for Future Research

The findings and evidence from this study make a valuable and original contribution to the body of knowledge and understanding for academics teaching and designing engineering mathematics programmes in institutes of technology and similar institutions.

The evidence is generally in line with the findings of studies relating to research university students and demonstrates that not all higher education academics are fully cognizant of the issues faced by first-year students. A major issue evidenced within the study is that not all academics engaging with eAssessment are aware of the design and planning required to support a fully engaging eAssessment design.

The study has provided evidence elucidating the issues surrounding the transition from secondary level to higher education. Learners are decreed in the literature to be autonomous and individual in their learning, however findings in this study challenge the veracity of this statement. Pathways to higher education are moving away from the dominance of the second level to higher education route and are now increasingly accommodating second chance and mature learners. Institutional re-imagining of the learning space has not developed at the same pace as the opening of new pathways, and higher education institutions have maintained their traditional designs. Alternative student demographics and student profiles create tensions for higher education in their need for physical and temporal learning spaces. Further research into more supportive learning spaces for the changing student profile involving eAssessment should be conducted. Comparisons, between standard student entry and non-standard student entry engaged in eAssessment, are not visible within the literature to provide higher education institutions with data to support strategic and flexible re-imagining of the learning spaces.

The data gathered in this study is limited to seven countries in Europe and revealed interesting issues common to all participating institutions, students, and academics. The data also highlighted some stark differences in the use of technology enhanced learning technologies in the different countries. To provide a more comprehensive dataset it is recommended that this study be expanded to include a larger sample of institutions and participating countries.

7.5 Concluding Remarks

This study set out to provide a voice for students in a meaningful dialogue with academics. The study has given voice to the students and has allowed students to express feelings of pain, delight, difficulty, confusion, satisfaction, and achievement. Similarly, academics have provided a snapshot of their thoughts, perceptions, and concerns as well as their hopes for the students.

The profile of students and academics across the different geographic locales is not homogenous when the total students' sample is considered. Not all academic participants have engineering backgrounds, and not all participating academics have completed programmes of study involving the theory and practice of pedagogy. Cultural and social tensions are evident in certain countries where there is pressure to perform well at mathematics. Academics, acting as positive motivational agents, have the potential to support and help build a stronger sense of self-efficacy amongst students.

The theoretical underpinning of students' perceptions within a socio-cognitive epistemology from a critical realism perspective was examined in relation to the motivational factors affecting students. This research study makes a new contribution to the knowledge base primarily in Ireland and secondly with the wider global audience as academics engage with eAssessment practices in engineering mathematics.

The narratives have given an insight into a little studied area in the higher education eAssessment landscape by providing a lens on the perceptions of students and academics within engineering mathematics. It is intended that because of this study, meta-dialogue will be inculcated in institutional practices to enable meaningful communication between students, academics, and institutions.

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Appendix 1 – Supporting Documents

Documents

Ethics Licence

Participant Information

Consent Form

Input Questionnaire Ireland

Input Questionnaire Finland

Output Questionnaire Ireland

Questionnaire – Estonia, Finland, Ireland, Poland, Portugal, Romania, Russia

Interview Protocol

Student Interview Questions

Lecturer Interview Questions

Sampled higher education institutions

Ethics Licence

OAMK OULU UNIVERSITY OF APPLIED SCIENCES

Research plan

INFORMATION ON THE RESEARCH AND THE RESEARCHER

Researcher(s)

Ken Brown and Jarkko Hurme

Name of the research

Computer Based Assessment - determination of process rather than product.

Research background (presentation of the subject, reason for the topicality of the theme)

The research forms an extension to a component of study being conducted within Letterkenny Institute of Technology. The study is examining the learning processes that may be determined through online testing particularly within mathematics. Online assessment does not provide all the answers although it is viewed as being cost effective when assessing large groups. Some areas of dissatisfaction arise when examining the pedagogical reasoning behind the assessment strategies and the potentially negative effects on the cognitive and metacognitive processes of the students. This study forms part of the research that Ken Brown is actively pursuing for the qualification of PhD at University of Glasgow. Ethical approval for the study has been received from University of Glasgow and Letterkenny Institute of Technology.

Research objectives and problems

A major problem encountered through use of certain types of online assessment methods is that students feel they have not been justly rewarded for their efforts. The objectives of this research component are to establish a baseline of understanding of the issues from which to develop a programme aiming at addressing the issues of justification and reward.

Research subjects and methods for collecting data

The research subjects are 1st year engineering students. The data collection methods are based on a single questionnaire and optionally a video recorded group interview. The video recorded group interview is considered to be a source of very rich data to triangulate the findings from the questionnaire.

Research schedule (implementation and reporting)

The questionnaire data collection stage may be conducted before the Christmas holidays. It is anticipated that the completion of the questionnaire will take approximately 20 minutes to complete. If the video group interview recording is also utilised this may take place early in 2016 and it will also take approximately 20 minutes to complete.

The role of Oulu University of Applied Sciences in the research (responsibilities, duties, benefit)

The role of Oulu University of Applied Sciences is to distribute and collect the questionnaire. A copy of the questionnaire has been sent to Jarkko Hurme for approval. If the video interview is to take place it will be conducted by Ken Brown and sample questions will be forwarded to Oulu University of Applied Sciences in advance for approval. It is anticipated that the data will allow the schools/departments of engineering in Letterkenny Institute of Technology and Oulu University of Applied Sciences to engage in a comparative study of mathematics assessment for 1st year engineering students and disseminate this information within peer reviewed journals and/or conferences. It would also show the development of research linkages as a result of engagement within the Erasmus programme. Both Letterkenny Institute of Technology and Oulu University of Applied Sciences will be identified within the research to enhance their research image.

Research funding, financiers and budget

The research is funded by Letterkenny Institute of Technology for the PhD study. The study will not be at a cost to Oulu University of Applied Sciences. It is hoped that this study will form the beginning of a stronger research linkage between both organisations.

DATE AND SIGNATURE

Place and date

Signature

OULU UNIVERSITY OF APPLIED SCIENCES :: P.O. BOX 222, FI-90101 OULU :: +358 20 6110 200 :: oamk.fi/english

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OAMK OULU UNIVERSITY OF APPLIED SCIENCES

Research licence application

APPLICANT

Name: Ken Brown

Identity number:

Street address: School of Engineering, Letterkenny Institute of Technology, Port Road, Letterkenny, Co. Donegal, Ireland

Postal code: F92 FC93

City: Letterkenny

Telephone:

E-mail address:

Research institute, educational institue or other community: Letterkenny Institute of Technology

Applicant's job or position: Lecturer

RESEARCH SUPERVISOR

Name: Professor Victor Lally

Degree and occupation: Professor, Education

Institute and address: University of Glasgow, School of Education

Telephone:

E-mail address:

CUSTOMER OF THE RESEARCH

Customer: Letterkenny Institute of Technology

Contact information: Ken Brown, Lecturer, School of Engineering, email:

DATE AND SIGNATURE

Place and date:

Signature:

Filled by the decision-maker

GRANTING A RESEARCH PLAN

Decision about (research licence)

☒ **The research licence is granted**

☐ **The research licence is declined.**

Grounds for the reseach licence / Grounds for refusing the research licence

Decision-maker

DATE AND SIGNATURE

Place and date:

Signature and clarification of signature:

☒ The research plan is attached.

University of Glasgow

College of Social Sciences

Letterkenny Institute of Technology

Participant Information Sheet

Study title: Computer Based Assessment – determination of process rather than product

Researcher: Ken Brown, School of Engineering

'You are being invited to take part in a research study. Before you decide it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask me if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

Thank you for reading this'.

What is the purpose of the study?

This study is intended to provide an insight into the effectiveness of online assessment of learning within Mathematics teaching in the School of Engineering. The study is an integral component of the research being conducted for PhD by Ken Brown. The overall study duration is expected to be between 4 and 5 years.

Why have I been chosen?

The study focuses on the experiences of first year engineering students. Mathematics is common to all first year engineering students and all students will be invited to participate.

Do I have to take part?

Participation in the research is entirely voluntary. Students will be encouraged to participate because the outcomes of the research may help future students. However, any student who decides not to participate will not be disadvantaged in any way. Your grades and assessments will not be affected whether you decide to participate or not. You may also withdraw from the research at any time.

What will happen to me if I take part?

If you decide to participate you will be asked to give your consent. The consent is necessary to allow the collection of data from questionnaires, interviews and focus groups. All consenting participants will participate in completing a short questionnaire taking approximately 15 minutes to complete. A small sample of participants will be selected to take part in focus group activity and interviews. The focus group activity may take approximately 30 minutes to complete. The interviews should not last more than 30 minutes.

Will my taking part in this study be kept confidential?

All questionnaires will be completed and collected without any means of identifying participants. Focus group and interview participants will be recorded on video. The video material will be stored in a secure location and all names will be replaced with pseudo names to ensure privacy and confidentiality. The videos and questionnaires will be destroyed upon completion of the research.

Please note that assurances on confidentiality will be strictly adhered to unless evidence of wrongdoing or potential harm is uncovered. In such cases the University may be obliged to contact relevant statutory bodies/agencies.

What will happen to the results of the research study?

It is intended that the results of the information gathered will be published for the benefit of the wider educational community. The results of the research study will be used to support the submission of a thesis for PhD. The results may also be used in publications of the research in research journals and conferences. Participants will not be identified in any published report.

Who is organising and funding the research? (If relevant)

The research is supported by the School of Engineering, Letterkenny Institute of Technology.

Who has reviewed the study?

The project has been reviewed by the College of Social Sciences Research Ethics Committee.

Contact for Further Information

Primary Contact: Ken Brown, School of Engineering – email:

Secondary Contact: Prof. Victor Lally, School of Education – email:

If you have any concerns regarding the conduct of this research project, you can contact the College of Social Sciences Ethics Officer Dr Muir Houston, email:

lyit | Institiúid Teicneolaíochta Leitir Ceanainn | Letterkenny Institute of Technology

University of Glasgow
College of Social Sciences

Consent Form

Title of Project: Computer Based Assessment – determination of process rather than product

Name of Researcher: Ken Brown

1. I confirm that I have read and understand the Plain Language Statement for the above study and have had the opportunity to ask questions.

2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason.

3. I consent to interview and/or focus group participation being video recorded.

4. Any research publication reference to my participation in completing any questionnaire, participation in any interview or focus group will be by means of a pseudonym.

5. I understand that my participation or non-participation in the research will have no effect on grades or assessment.

6. I agree / do not agree (delete as applicable) to take part in the above study.

______________________	__________	______________________
Name of Participant	Date	Signature

______________________	__________	______________________
Researcher	Date	Signature

For further information contact:

Primary Contact: Ken Brown, School of Engineering – email:

Secondary Contact: Prof. Victor Lally, School of Education – email:

Pre-Test Questionnaire Stage One - Ireland

1. Please circle your gender: Male / Female

2. A. If your entry is via CAO or A level please tick the box that describes your points

< 100	101 to 200	201 to 300	301 to 400	401 to 500	>500
☐	☐	☐	☐	☐	☐

B. If your entry is via Access please tick this box ☐

3. Do you have previous experience of Computer Based Tests (Please circle)? Yes / No

If you answered "Yes" to question 3, please go to question 4.

If you answered "No" to question 3, please go to question 5.

4. Please complete the following and then go to question 6:

The main things I find good or bad about Computer Based Tests are ……………………………………

……
……
……
……
…………

5. Please complete the following and then go to question 6:

I do not have experience of Computer Based Tests because

……
……
……
……
……………………………………………………………..

6. This question relates to your experience(s) of the support and training you have received in the use of Computer Based Tests as a first year student in the School of Engineering. Please complete the following by placing a tick in one space only, as follows:

1 = none; 2 = very little; 3 = moderate amount; 4 = a lot; 5 = quite a lot; 6 = a very great deal

In your opinion what level of support and training has the School of Engineering provided in the following areas?

		1	2	3	4	5	6
a	Computer systems and applications	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
b	Using Blackboard	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
c	Computer Based Quizzes within Blackboard	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
d	Answering mathematical Computer Based Quizzes	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

7. This question relates to your experience(s) using Computer Based Tests as a first year student in the School of Engineering. Please complete the following by placing a tick in one space only, as follows:

1 = none; 2 = very little; 3 = moderate amount; 4 = a lot; 5 = quite a lot; 6 = a very great deal

Tell me about the following?

		1	2	3	4	5	6
a	Your confidence	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
b	Your preparation	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
c	Have you completed many quizzes?	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
d	Things that hamper the quizzes	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

Thank you for your participation and cooperation in this research. Yours responses will be kept confidential. Please scan your answers and complete any questions that you may have left out. I will present an overview of the results of this study to inform you about some of the findings.

Pre-Test Questionnaire Stage Two - Finland

1. Please circle your gender: Male / Female

2. A. If your entry is via Matriculation please tick the box that describes your Mathematics grade.

A	B	C	M	E	L	
☐	☐	☐	☐	☐	☐	☐

B. If your entry is NOT via Matriculation please tick this box ☐

3. Do you have previous experience of Computer Based Tests (Please circle)? Yes / No

If you answered "Yes" to question 3, please go to question 4.

If you answered "No" to question 3, please go to question 5.

4. Please complete the following and then go to question 6:

The main things I find good or bad about Computer Based Tests are ………………………………

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………..

5. Please complete the following and then go to question 6:

I do not have experience of Computer Based Tests because
……
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…………………………………………………………..

6. This question relates to your experience(s) of the support and training you have received in the use of Computer Based Tests as a first year student in the Department of Engineering. Please complete the following by placing a tick in one space only, as follows:

1 = none; 2 = very little; 3 = moderate amount; 4 = a lot; 5 = quite a lot; 6 = a very great deal

In your opinion what level of support and training has the Department of Engineering provided in the following areas?

		1	2	3	4	5	6
a	Computer systems and applications	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
b	Using Promentor, Optima or Moodle	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
c	Computer Based Quizzes within Promentor, Optima or Moodle	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
d	Answering mathematical Computer Based Quizzes	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

7. This question relates to your experience(s) using Computer Based Tests as a first year student in the Department of Engineering. Please complete the following by placing a tick in one space only, as follows:

1 = none; 2 = very little; 3 = moderate amount; 4 = a lot; 5 = quite a lot; 6 = a very great deal

Tell me about the following?

		1	2	3	4	5	6
a	Your confidence	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
b	Your preparation	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
c	Have you completed many quizzes?	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
d	Things that hamper the quizzes	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

Thank you for your participation and cooperation in this research. Yours responses will be kept confidential. Please scan your answers and complete any questions that you may have left out. I will present an overview of the results of this study to inform you about some of the findings.

Post-Test Questionnaire Stage One - Ireland

1. Please circle your gender: Male / Female

2. A. If your entry is via CAO or A level please tick this box ☐

   B. If your entry is via non-CAO /Access/other route please tick this box ☐

3. The main thing I find good about Computer Based Tests is

………
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4. The main thing I find bad about Computer Based Tests is

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6. This question relates to your feelings of confidence that you now have in relation to being assessed using Computer Based Tests. Please complete the following by placing a tick in one space only, as follows:

In your opinion you feel that your level confidence is

1 = none; 2 = little; 3 = a moderate amount; 4 = a lot; 5 = quite a lot; 6 = a very great deal

	1	2	3	4	5	6
Your confidence	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

7. This question relates to your feelings of preparedness that you now have in relation to being assessed using Computer Based Tests. Please complete the following by placing a tick in one space only, as follows:

In your opinion you feel that your level of preparedness is

1 = none; 2 = little; 3 = a moderate amount; 4 = a lot; 5 = quite a lot; 6 = a very great deal

	1	2	3	4	5	6
Your preparedness	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

8. This question relates to your having completed a semester and having engaged in Computer Based Tests. Do you think that there are barriers or things that hamper your participation in Computer Based Tests?

In your opinion you feel that there amount of barriers would be described by

1 = none; 2 = little; 3 = a moderate amount; 4 = a lot; 5 = quite a lot; 6 = a very great deal

	1	2	3	4	5	6
Barriers	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

Thank you for your participation and cooperation in this research. Yours responses will be kept confidential. Please scan your answers and complete any questions that you may have left out. I will present an overview of the results of this study to inform you about some of the findings.

Pre-Test Questionnaire Stage Two – Estonia, Finland, Ireland, Poland, Portugal, Romania, Russia
Delivered by Google Forms

1. Please select your gender
Mark only one.
Male /Female

2. Before studying your current higher education programme, did you have any experience(s) of Computer Based Tests?
Mark only one.
Yes /No

3. This question is about feelings of confidence that you now have in relation to being assessed using Computer Based Testing. In your opinion, you feel that your confidence is:
Mark only one.
Very Low / Low / Moderate / Above moderate / High / Very High / Not Applicable

4. This question is about feelings of preparedness that you now have in relation to being assessed using Computer Based Tests. In your opinion, you feel that your level of preparedness is:
Mark only one.
very Low / Low / Moderate / Above Moderate / High / Very High / Not Applicable

5. This question relates to any barriers that you may encounter when accessing Computer Based Tests. The number of barriers or things that get in the way of your participation in Computer Based Tests is best described as:
Mark only one.
None / Low / Some / Moderate Amount / Many / Too many / Not Applicable

6. This question relates to the personal feelings you had about mathematics before your higher education programme. How would you have described your abilities in mathematics?
Mark only one.
Poor / Below average / Average / Above average / Good / Very good

7. This question relates to your personal feelings about mathematics now that you are in higher education. In your opinion, your feel that you are:
Mark only one.
Poor / Below average / Average / Above average / Good / Very Good

8. This question relates to your feelings of confidence in successfully completing the mathematics component of your higher education programme. In your opinion, the possibility of completing the mathematics component is:
Mark only one.
Very poor / Below average / Average / Above average / Good / Very good

9. This question relates to how well you think you can learn mathematics. Do you feel that learning mathematics is:
Mark only one.
Very difficult / Difficult / A bit of a struggle / Alright / Quite easy / Very easy

10. This question relates to how you think you will successfully complete your current study programme. Completing the whole programme will be:
Mark only one.
Very hard / Hard / A struggle / Okay / Quite easy / Very easy

11. This question relates to the amount of work you need to put into mathematics assignments. The amount of work that you need to put into mathematics assignments is:
Mark only one.
Very little / Little / Less than I should do / About right / A bit much / Too much

12. This question relates to the rewards you receive for mathematics assignments. The reward you receive for the amount of work you need to put into mathematics assignments is:
Mark only one.
Very little / Little / A bit less than it should be / About right / A bit much / Too much

13. This question relates to your perceptions about your mathematics instructor(s). The awareness of the mathematics instructor(s) of your mathematical abilities is:
Mark only one.
Very poor / Poor / Not good / Good / Very good / Excellent

14. This question relates to the amount of work you need to put into assignments in general within your programme of study. You feel that the amount of work you need to put into assignments within your programme of study is:
Mark only one.
Very little / Little / I should put in more work / About right / A bit much / Too much

15. This question relates to the rewards you receive for assignments in general. The reward you receive for the amount of work you put into assignments within your general programme of study is:
Mark only one.
Very little / Little / Not enough / About right / A bit much / Too much

16. This question relates to perceptions you have regarding your programme instructors in general. The awareness the programme instructors have about your abilities is:
Mark only one.
Very poor / Poor / Not good / Good / Very good / Excellent

Thank you for your participation and cooperation in this research. Yours responses will be kept confidential. Please scan your answers and complete any questions that you may have left out. I will present an overview of the results of this study to inform you about some of the findings.

Interview Protocol/Guide

Students

There is potential for students to feel vulnerable because of the power relationship between them as my students, and me as their lecturer. To reduce the effects of the power relationship the students will be informed that all commented will be received without prejudice. The students are to be reminded of their consent to participate and that they may leave the process at any time.

If any student exhibits signs of distress or anxiety, acknowledge the issue. Allow the issue to be expressed but contain it within the context of the interview. If a student is unsure about the meaning of something use alternative language or ask the others to help explain.

Remind the students that an audio recording is being conducted. Employ a recording backup device to cater for any malfunctions.

Timing is critical because the interviews will take place during free timetable periods – typically lunch. This time is precious to the students – limit time to 30 minutes to allow them time for a short lunch. Do not interview more than one group per day. This will ensure a focus is maintained on the group being interviewed and to reduce strain on the researcher (me). The rule of thumb is 4 hours transcription per 30 minutes recorded time. Ensure sufficient time is allocated for transcription.

The interviews with students will be conducted face-to-face. The process may be intimidating for the students because of their lack of familiarity with the process. Questions will be semi-structured and based on the initial data analysis from the pre-test questionnaire. Thank the students for sharing their precious time and intimate details. Reassure them as to the confidentiality and anonymity of responses and participation.

The location for the interview is a room that students are familiar with. This is to provide a safe, known space. The room is to be quiet, airy, and private to minimise disruption. Seating is comfortable and situated around an oval table. The recording equipment will be situated in the centre of the table for all students to see. Explain to the students that audio recording is used to allow full attention to be made to the students' responses. All students will be located around the table and light refreshments will be made available.

The research is of personal interest – explain why this is, using a relaxed manner. Open the interview with a greeting and thank the students for participating. Close the interview by thanking them for their views and participation. The semi-structured questions are a guide and not to be followed slavishly - be spontaneous when considered appropriate. Don't push for answers – let the answers flow organically. Avoid coming across as an expert and lecturing the students – it is the students' voices that this research is attempting to hear. Silent periods may be used for reflection – these are important so don't rush them.

Academics Face-to-Face

A peer relationship exists amongst those work colleagues being interviewed (Braun & Clarke, 2013, describe this as an acquaintance interview. It is vital to the objectivity of the research that colleagues are not pressured into participating. Any information disclosed during the interview must remain confidential within the boundaries of the research. The delicacy of such interviews is such that it is important not to 'react to' or 'gloss over' issues. Avoid using jargon or complex language – avoid patronising language too.

In advance of the interview all participants must provide their consent and be supplied with a participant information document

Thank the academics for their participation and for sharing their views. Reassure the academics that any comments made will remain confidential and will only be used for the purposes of the research.

Arrange to meet the academic in a neutral space or perhaps their office for purposes of the interview at a convenient time and allocate no more than 60 minutes for the interview.

Interview questions are semi-structured and based on the data analysis from the pre-test questionnaire. Each academic will be asked similar questions and opportunities to explore issues will be sought where appropriate. Do not arrange more than one academic interview in any particular day.

Inform the academic that the interview will be recorded for audio and situate the equipment in a visible and suitable location in the room. Explain the reasons for the research and that it is of personal interest. This will ensure that academics participating are fully aware of the purposes and reassure them of the confidential nature of the process. Inform the academic that they may quit the process at any time as set out in the participant information sheet.

Emphasis that the purpose is to obtain the academics' views and that there are no right or wrong answers. Manage body language and do not allow personal thoughts to be mis-construed. Develop a rapport to elicit engaging responses.

Close the interview by thanking the academic for their time and participation.

Academics Virtual

It may not be possible to conduct all academic interviews face-to-face. A virtual interview is made possible using video tools with suitable Internet Bandwidth. Academics engaging with the research will be provided with participant information sheets in advance and consent forms. The consent forms may be signed electronically in advance or at the beginning of the interview.

The target group is academics resident in Finland, Estonia, Portugal, Romania and Russia. English language is not the first language in these countries and allowance must be made for interpretation. Academics will be selected if they meet the following criteria: fluent English, teach mathematics in 1st year of Higher Education.

Body language is difficult to determine using video conferencing so extra care must be given to issues such as distress or anxiety. The same semi-structured questioning will be employed as for face-to-face but it may be necessary to use extra probing or explanations without directing the process.

Inform the academics that the audio will be recorded purely for the purposes of the research and will remain confidential and anonymous – this may be of particular sensitivity for some academics. Allow time for translation and reflection of responses. Do not harry if academics are not responding quickly enough – the language may be complex.

Show appreciation during the session that their participation is highly valued. Acknowledge responses and views and always explore with the academics if long silences occur – they may be distressed, embarrassed, or distracted. It may be better to stop and return at a later date.

Open and close the interview by thanking the academic for their participation and time. Visually display appreciation for their expertise.

Interview Questions for Students

The participants are all full-time engineering students. The number in the group is expected to be 8 to 10.

Questions/Thematic Areas – Responses to be probed during interview

1. Age range: Max / Min

2. Male / Female ratio

3. Training/Preparation for online assessment

    Do you think that you were adequately trained or prepared in advance of the online assessment?

4. Confidence levels before and after online assessment

    Do you feel that you are now more confident using online assessment or less confident?

5. Barriers perceived or actual

    Is there anything you can think of that made or makes the online assessment more difficult for you?

Academic Interview Questions

Baseline Information

1. What University/department are you in?
2. What year(s) of study do you cover in teaching mathematics?
3. How many students in total and each group?
4. Do you use online methods for teaching and assessment?
5. When did you begin using online methods?

Online Teaching

6. Please describe the methods you use for teaching online
7. Please describe the pedagogical design process for teaching online

Online Assessment

8. Please describe the methods you use to assess online
9. What methods are used for formative and summative assessment? Do you differentiate between the two and if so, why?
10. When you are engaging with online assessment what preparation or training to you use with the students?
11. Are the assessments hosted on a VLE or other system? Why?
12. Do you engage with students online or do you just let them go online and wait for the results to come in?
13. What types of questions do you use with the online assessments? Why do you use those types?
14. In terms of learning, how does online assessment aid your determination of their learning?
15. Are the assessments conducted on campus or off campus? If off-campus what techniques are employed to ensure security?

Beliefs, Attitudes and Perceptions

16. What is your perception of the levels of confidence of the students actually engaging online?
17. How confident are the students with online assessments?
18. Are you concerned that the students may not have any prior experience of online engagement prior to third-level study?
19. Are you aware of any barriers to the students in actually doing the assessments and studying online?
20. Have any of the students expressed anxiety about doing an assessment at home or wherever?
21. Are you aware of any issues regarding off-campus access?
22. How long have you been conducting online tests?
23. Do you have any suggestions?

Sampled Institutions

Ireland

Letterkenny Institute of Technology (LYIT) is a state professional higher education institution located in County Donegal, Ireland. LYIT provides education in the fields of engineering, architecture, law, business studies, computing science, nursing, digital media, graphic design, general science, veterinary nursing, health and social studies, sports coaching, tourism, culinary arts, and hospitality. The degree programs are offered at ordinary pass (180 ECTS), honours (240 ECTS), masters and doctoral level. LYIT is one of thirteen institutes of technology in Ireland and currently has approximately four thousand students in part-time and full-time study using face-to-face and blended delivery mechanisms. The study sample is drawn from students within the School of Engineering and academic staff with responsibility for mathematics.

Finland

Oulu University of Applied Sciences (OAMK) is a state professional higher education institution offering professional higher education degrees in Oulu, Finland. OAMK currently educates approximately eight thousand five hundred students in the fields of technology, engineering, natural sciences, business, economics, management, social sciences, life sciences, environmental and marketing studies. The degree programs are offered at ordinary pass (180 ECTS), honours (240 ECTS) and master's level. The study sample is drawn from students within engineering studies and academic staff with responsibility for mathematics.

Estonia

TTK University of Applied Sciences (TTK UAS) is a state professional higher education institution offering competitive professional higher education in the fields of engineering, production, technology, architecture and construction in Tallinn, Estonia. TTK UAS is the largest university of applied sciences in Estonia, currently educating approximately two thousand two hundred students. TTK UAS offers four-year professional higher education study programs (240 ECTS), for daily learners, distance learners and in-service training courses in the Open University. The focus of the teaching, research, and development activities of TTK UAS staff is to meet the needs of the Estonian labour market and enterprises. TTK UAS has six institutes with sixteen study programs. The study sample is drawn from students studying engineering.

Poland

The University of Warmia and Mazury (UWM) in Osztyn, Poland, is a state professional higher education institution offering professional higher education in the fields of engineering, humanities, medicine, economics, social sciences, environmental sciences, law, health, fine arts, and theology. UWM offers four-year degree programs (240 ECTS) to twenty-seven thousand students and degrees at masters and doctoral levels. The study sample is drawn from students studying engineering.

Portugal

The Polytechnic Institute of Porto (IPP) is the largest polytechnic school in Portugal, in the upper segment of the Portuguese higher education national ranking. IPP involves eight schools, more than twenty research and development units, and is the best positioned in international scientific rankings in Portugal. Porto Accounting and Business School (ISCAP) has a four thousand-strong student population studying Bachelor and Master courses. The study sample is drawn from ISCAP because the mathematics curriculum is the same for all first-year undergraduate students.

Romania

The Technical University of Cluj-Napoca is a third-level educational institution comprising twelve faculties, in the two academic centres of Cluj-Napoca and Baia Mare as well as in locations, such as Alba-Iulia, Bistrita, SatuMare and Zalau. Bachelor level studies contain minimum 180 and maximum 240 ECTS points, according to the Bologna system. The TU Cluj-Napoca has more than twenty thousand enrolled students. The study sample is drawn from those students in engineering and academic staff with responsibility for mathematics.

Russia

Ural Federal University named after the first President of Russia B.N. Yeltsin (UrFU) is a leading third-level educational institution in Yekaterinburg, Russia and was formed in 1920. Bachelor, master's, and doctoral level studies are offered within eighteen faculties including natural sciences, social sciences, engineering, humanities, economics and management to approximately thirty-five thousand full-time students by a staff of more than four thousand two hundred faculty members. The study sample is drawn from those students in engineering and academic staff with responsibility for mathematics.

United Kingdom

Queens University Belfast (QUB) is a public research university in Belfast, Northern Ireland founded in 1845. QUB offers degree programmes at bachelors, master's, and doctoral levels within fifteen schools including law, engineering, mathematics, medicine, natural and built environment, and social sciences to approximately nineteen thousand undergraduate students and five thousand postgraduate students. The study sample is drawn from academic staff responsible for mathematics within the School of Mechanical and Aerospace Engineering.

Appendix 2 - Quantitative Analysis

Table A2-1 Prior Experience of eAssessment – Ireland

Table A2-1 Prior Experience of eAssessment

T-Test

Group Statistics

	Year	N	Mean	Std. Deviation	Std. Error Mean
Has_Experience_eAssessment	2015_16	66	1.3333	.47502	.05847
	2016_17	50	1.5000	.50508	.07143

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means							
						Significance				95% Confidence Interval of the Difference	
		F	Sig.	t	df	One-Sided p	Two-Sided p	Mean Difference	Std. Error Difference	Lower	Upper
Has_Experience_eAssessment	Equal variances assumed	6.142	.015	-1.821	114	.036	.071	-.16667	.09152	-.34798	.01464
	Equal variances not assumed			-1.806	102.108	.037	.074	-.16667	.09231	-.34976	.01642

Independent Samples Effect Sizes

		Standardizer[a]	Point Estimate	95% Confidence Interval Lower	95% Confidence Interval Upper
Has_Experience_eAssessment	Cohen's d	.48816	-.341	-.711	.029
	Hedges' correction	.49141	-.339	-.706	.029
	Glass's delta	.50508	-.330	-.702	.045

Table A2-2 Pre-Test Questionnaire Responses - Ireland

Table A2-2 Pre-test Questionnaire Responses – Ireland Stage One

Test	None	Very Little	Moderate	Quite a lot	A great Deal	Mean	Std Dev
Training in General Computer Systems	33	9	24	40	5	2.77	1.333
Training in use of virtual learning environment	49	14	15	16	17	2.44	1.536
Training for eAssessment	6	33	37	28	7	2.97	1.013
Confidence in doing eAssessment	5	25	42	32	7	3.10	0.972
Preparation for mathematics eAssessment	6	28	48	22	7	2.96	0.962
Perception of barriers to eAssessment	7	38	38	25	3	2.81	0.949
Quantity of eAssessment conducted prior to first mathematics eAssessment	4	50	32	18	7	2.77	0.981

Table A2-3 Mapping from Likert 6 point to Likert 5-point scale

Table A2-3 6-point Likert scale mapping to 5-point Likert scale – Ireland Stage One

6-point Likert scale code	5-point Likert scale code
1	1
2	2
3	3
4	3
5	4
6	5

Table A2-4 Post-Test Questionnaire Responses - Ireland

Table A2-4 Post-test Questionnaire Responses – Ireland Stage One

Test	None	Very Little	Moderate	Quite a lot	A great Deal	Mean	Std Dev
Post-test Confidence	0	3	59	31	11	3.48	0.724
Post-test preparation	0	4	62	28	10	3.42	0.720
Post-test barriers	19	33	46	5	1	2.38	0.874

Table A2-5 Post eAssessment ANOVA for Confidence, Preparation, and Barriers - Ireland

ANOVA

		Sum of Squares	df	Mean Square	F
Post_eAssessment_Confidence_Perception	Between Groups	8.303	1	8.303	11.280
	Within Groups	161.936	220	.736	
	Total	170.239	221		
Post_eAssessment_Preparation_Perception	Between Groups	12.416	1	12.416	16.750
	Within Groups	163.080	220	.741	
	Total	175.495	221		
Post_eAssessment_Barriers_Perception	Between Groups	9.540	1	9.540	11.615
	Within Groups	179.055	218	.821	
	Total	188.595	219		

ANOVA

		Sig.
Post_eAssessment_Confidence_Perception	Between Groups	<.001
	Within Groups	
	Total	
Post_eAssessment_Preparation_Perception	Between Groups	<.001
	Within Groups	
	Total	
Post_eAssessment_Barriers_Perception	Between Groups	<.001
	Within Groups	
	Total	

ANOVA Effect Sizes[a]

		Point Estimate	95% Confidence Interval	
			Lower	Upper
Post_eAssessment_Confidence_Perception	Eta-squared	.049	.008	.114
	Epsilon-squared	.044	.004	.110
	Omega-squared Fixed-effect	.044	.004	.109
	Omega-squared Random-effect	.044	.004	.109
Post_eAssessment_Preparation_Perception	Eta-squared	.071	.019	.143
	Epsilon-squared	.067	.015	.139
	Omega-squared Fixed-effect	.066	.015	.139
	Omega-squared Random-	.066	.015	.139

Table A2-6A Gender Comparison between - Ireland and Finland

Country * Gender Crosstabulation

			Gender		
			Male	Female	Total
Country	Ireland	Count	114	5	119
		Expected Count	113.8	5.2	119.0
		% within Country	95.8%	4.2%	100.0%
	Finland	Count	106	5	111
		Expected Count	106.2	4.8	111.0
		% within Country	95.5%	4.5%	100.0%
Total		Count	220	10	230
		Expected Count	220.0	10.0	230.0
		% within Country	95.7%	4.3%	100.0%

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.013[a]	1	.910		
Continuity Correction[b]	.000	1	1.000		
Likelihood Ratio	.013	1	.910		
Fisher's Exact Test				1.000	.582
Linear-by-Linear Association	.013	1	.911		
N of Valid Cases	230				

a. 1 cells (25.0%) have expected count less than 5. The minimum expected count is 4.83.

b. Computed only for a 2x2 table

Table A2-6B Academic Entry Comparison - Ireland and Finland

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.[a,b]
1	The distribution of Entry_Points is the same across categories of Country.	Independent-Samples Mann-Whitney U Test	.254

Hypothesis Test Summary

	Decision
1	Retain the null hypothesis.

a. The significance level is .050.

b. Asymptotic significance is displayed.

Independent-Samples Mann-Whitney U Test Summary

Total N	142
Mann-Whitney U	1771.000
Wilcoxon W	2551.000
Test Statistic	1771.000
Standard Error	208.034
Standardized Test Statistic	-1.142
Asymptotic Sig.(2-sided test)	.254

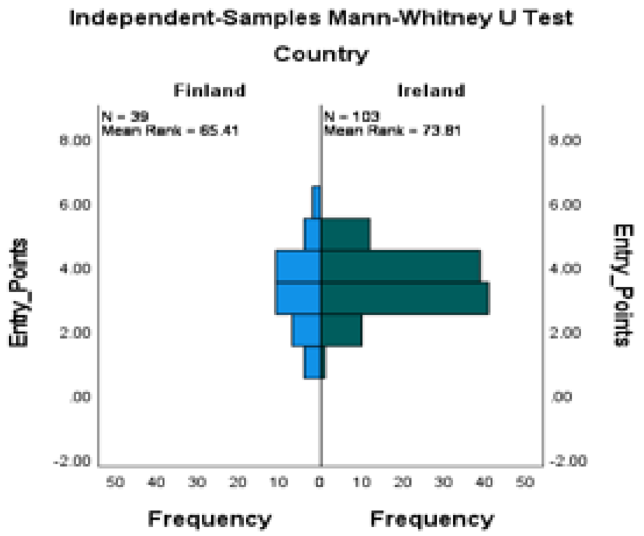

Table A2-6C Comparison Prior eAssessment Experience - Ireland and Finland

Means

Notes

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	Cases Used	Cases used for each table have no missing values in any independent variable, and not all dependent variables have missing values.
Syntax		MEANS TABLES=Has_Experience_eAssessment BY Country /CELLS=MEAN.
Resources	Processor Time	00:00:00.00
	Elapsed Time	00:00:00.00

Case Processing Summary

	Cases					
	Included		Excluded		Total	
	N	Percent	N	Percent	N	Percent
Has_Experience_eAssessment * Country	230	100.0%	0	0.0%	230	100.0%

Report

Mean

Country	Has_Experience_eAssessment
Ireland	1.4034
Finland	1.1892
Total	1.3000

Table A2-6D Comparison Confidence - Ireland and Finland

Means

Notes

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Missing Value Handling	Definition of Missing	For each dependent variable in a table, user-defined missing values for the dependent and all grouping variables are treated as missing.
	Cases Used	Cases used for each table have no missing values in any independent variable, and not all dependent variables have missing values.
Syntax		MEANS TABLES=Confidence_eAssessments BY Country /CELLS=MEAN.
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	Elapsed Time	00:00:00.01

Case Processing Summary

	Cases					
	Included		Excluded		Total	
	N	Percent	N	Percent	N	Percent
Confidence_eAssessments * Country	228	99.1%	2	0.9%	230	100.0%

Report

Mean

Country	Confidence_eAssessments
Ireland	3.0932
Finland	4.0818
Total	3.5702

Table A2-6E Comparison Preparation for eAssessment - Ireland and Finland

Means

Notes

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Missing Value Handling	Definition of Missing	For each dependent variable in a table, user-defined missing values for the dependent and all grouping variables are treated as missing.
	Cases Used	Cases used for each table have no missing values in any independent variable, and not all dependent variables have missing values.
Syntax		MEANS TABLES=Preparation_For_eAssessments BY Country /CELLS=MEAN.
Resources	Processor Time	00:00:00.00
	Elapsed Time	00:00:00.00

Case Processing Summary

	Cases					
	Included		Excluded		Total	
	N	Percent	N	Percent	N	Percent
Preparation_For_eAssessments * Country	228	99.1%	2	0.9%	230	100.0%

Report

Mean

Country	Preparation_For_eAssessments
Ireland	2.9492
Finland	3.2636
Total	3.1009

Table A2-6F Comparison Barriers to eAssessment - Ireland and Finland

Means

Notes

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	N of Rows in Working Data File	230
Missing Value Handling	Definition of Missing	For each dependent variable in a table, user-defined missing values for the dependent and all grouping variables are treated as missing.
	Cases Used	Cases used for each table have no missing values in any independent variable, and not all dependent variables have missing values.
Syntax		MEANS TABLES=Completed_eAssessments BY Country /CELLS=MEDIAN.
Resources	Processor Time	00:00:00.00
	Elapsed Time	00:00:00.00

Case Processing Summary

	Cases					
	Included		Excluded		Total	
	N	Percent	N	Percent	N	Percent
Completed_eAssessments * Country	228	99.1%	2	0.9%	230	100.0%

Report

Median

Country	Completed_eAssessments
Ireland	3.0000
Finland	3.0000
Total	3.0000

Table A2-6G Comparison Amount eAssessment - Ireland and Finland

Means

Notes

Output Created		08-DEC-2021 11:03:07
Comments		
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	Active Dataset	DataSet1
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	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	230
Missing Value Handling	Definition of Missing	For each dependent variable in a table, user-defined missing values for the dependent and all grouping variables are treated as missing.
	Cases Used	Cases used for each table have no missing values in any independent variable, and not all dependent variables have missing values.
Syntax		MEANS TABLES=Completed_eAssessments BY Country /CELLS=MEDIAN.
Resources	Processor Time	00:00:00.00
	Elapsed Time	00:00:00.00

Case Processing Summary

	Cases					
	Included		Excluded		Total	
	N	Percent	N	Percent	N	Percent
Completed_eAssessments * Country	228	99.1%	2	0.9%	230	100.0%

Report

Median

Country	Completed_eAssessments
Ireland	3.0000
Finland	3.0000
Total	3.0000

Table A2-6H Comparison Training & Support for eAssessment - Ireland and Finland

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.[a,b]
1	The distribution of Aggregate Training and Support is the same across categories of Country of Study.	Independent-Samples Mann-Whitney U Test	.009

Hypothesis Test Summary

	Decision
1	Reject the null hypothesis.

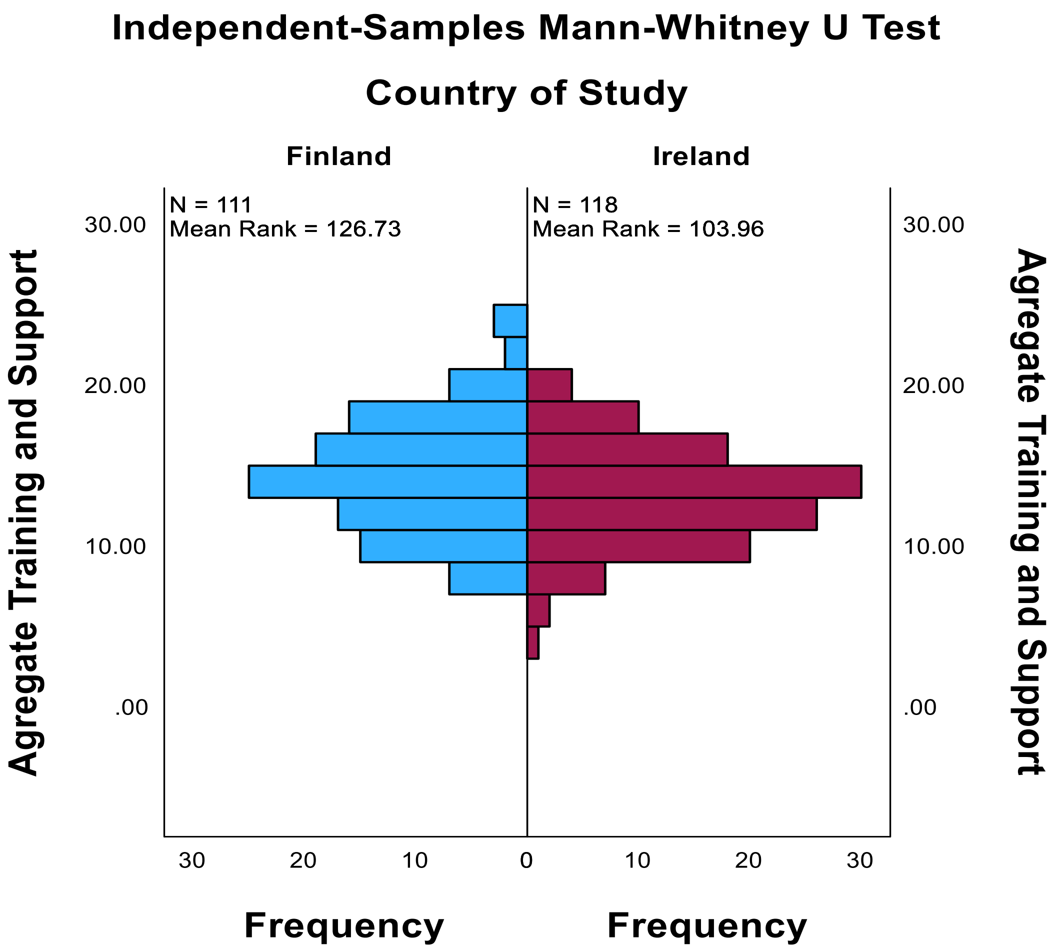
a. The significance level is .050.

b. Asymptotic significance is displayed.

Independent-Samples Mann-Whitney U Test
Aggregate Training and Support across Country of Study

Independent-Samples Mann-Whitney U Test Summary

Total N	229
Mann-Whitney U	7851.500
Wilcoxon W	14067.500
Test Statistic	7851.500
Standard Error	499.097
Standardized Test Statistic	2.610
Asymptotic Sig.(2-sided test)	.009



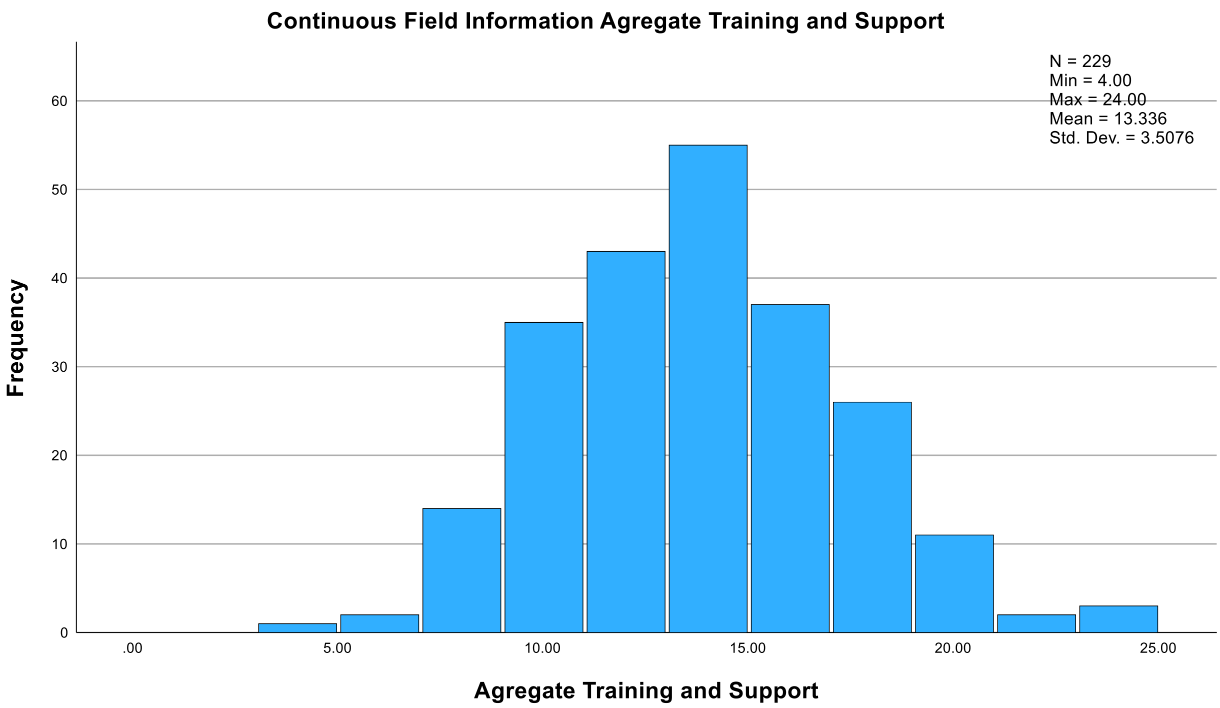
Means Case Processing Summary

	Cases					
	Included		Excluded		Total	
	N	Percent	N	Percent	N	Percent
Aggregate Training and Support * Country of Study	229	100.0%	0	0.0%	229	100.0%

Report

Aggregate Training and Support

Country of Study	Mean	N	Std. Deviation
Ireland	12.6610	118	3.17905
Finland	14.0541	111	3.70709
Total	13.3362	229	3.50758


Continuous Field Information Agregate Training and Support
N = 229
Min = 4.00
Max = 24.00
Mean = 13.336
Std. Dev. = 3.5076
Frequency
0
10
20
30
40
50
60
.00
5.00
10.00
15.00
20.00
25.00
Agregate Training and Support

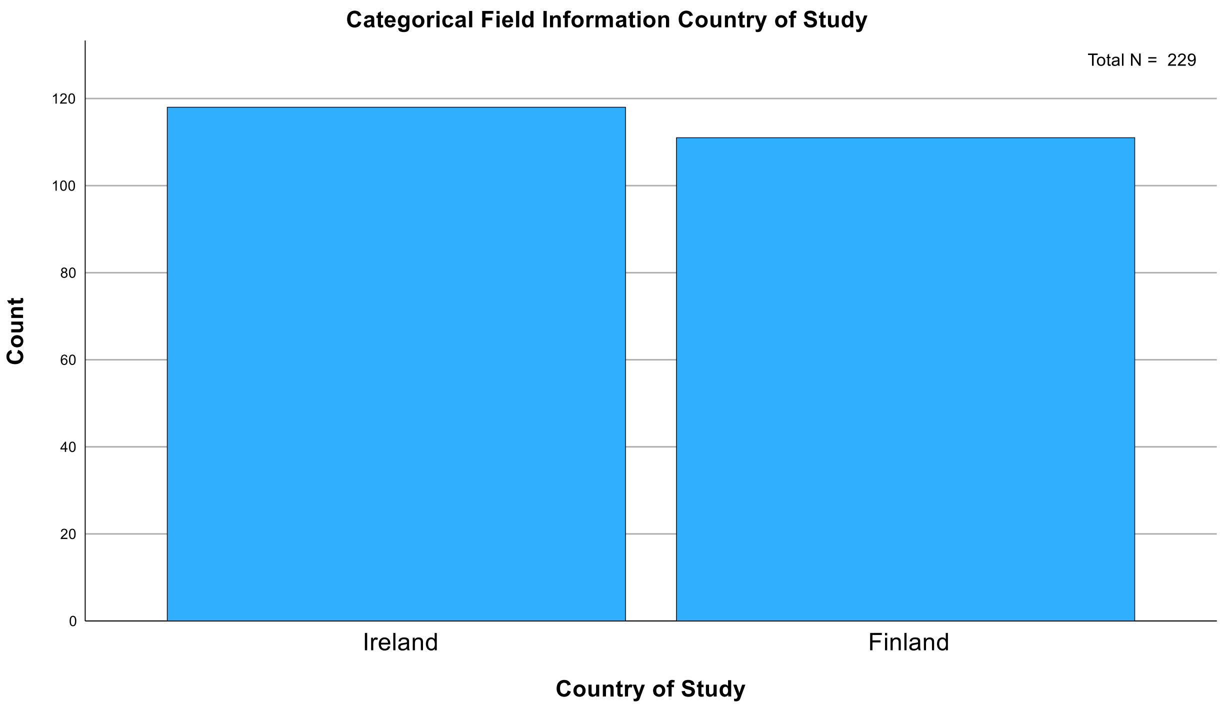

Categorical Field Information Country of Study
Total N = 229
Count
0
20
40
60
80
100
120
Ireland
Finland
Country of Study

Table A2-7 Comparison of Country Participation – Stage Two

Country	Male	Female		Country	Male	Female
Estonia	56	16		Estonia	78%	22%
Finland	82	15		Finland	85%	15%
Ireland	45	5		Ireland	90%	10%
Poland	34	34		Poland	50%	50%
Portugal	50	53		Portugal	49%	51%
Romania	36	17		Romania	68%	32%
Russia	25	31		Russia	45%	55%

Table A2-8 Comparison of Prior eAssessment Experience – Stage Two

Table A2-8, Ordinal Logistic Regression Test: Prior eAssessment vs Country

Test of Parallel Lines[a]

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Null Hypothesis	31.451			
General	31.451	.000	0	.

Tests of Model Effects

Source	Type III Wald Chi-Square	df	Sig.
Country	45.736	6	<.001

Parameter Estimates

Parameter		B	Std. Error	95% Wald Confidence Interval Lower	Upper
Threshold	[Prior_eAssessment_Experience=1]	-1.386	.3536	-2.079	-.693
[Country=1]		-2.721	.4574	-3.618	-1.825
[Country=2]		-1.914	.4113	-2.720	-1.108
[Country=3]		-1.866	.4327	-2.714	-1.018
[Country=4]		-1.719	.4061	-2.515	-.923
[Country=5]		-1.594	.4413	-2.459	-.729
[Country=6]		-2.795	.4880	-3.751	-1.839
[Country=7]		0[a]	.	.	.

Parameter Estimates

Parameter		Hypothesis Test Wald Chi-Square	df	Sig.	Exp(B)
Threshold	[Prior_eAssessment_Experience=1]	15.374	1	<.001	.250
[Country=1]		35.397	1	<.001	.066
[Country=2]		21.647	1	<.001	.148
[Country=3]		18.590	1	<.001	.155
[Country=4]		17.926	1	<.001	.179
[Country=5]		13.048	1	<.001	.203
[Country=6]		32.807	1	<.001	.061
[Country=7]		.	.	.	1

Parameter Estimates

Parameter		95% Wald Confidence Interval for Exp(B) Lower	Upper
Threshold	[Prior_eAssessment_Experience=1]	.125	.500
[Country=1]		.027	.161
[Country=2]		.066	.330
[Country=3]		.066	.361
[Country=4]		.081	.397
[Country=5]		.086	.482
[Country=6]		.023	.159
[Country=7]		.	.

Table A2-9 Comparison of Confidence – Stage Two

Table A2-9: Ordinal Logistic Regression Test: Confidence vs Country

Parameter Estimates

Parameter		Hypothesis Test			
		Wald Chi-Square	df	Sig.	Exp(B)
Threshold	[Confidence_Level_eAssessment=1]	123.987	1	.000	.009
	[Confidence_Level_eAssessment=2]	106.018	1	.000	.045
	[Confidence_Level_eAssessment=3]	25.524	1	<.001	.262
	[Confidence_Level_eAssessment=4]	.861	1	.354	.787
	[Confidence_Level_eAssessment=5]	31.083	1	<.001	4.603
[Country=1]		2.365	1	.124	.600
[Country=2]		.822	1	.365	.752
[Country=3]		2.922	1	.087	.563
[Country=4]		7.378	1	.007	.429
[Country=5]		7.361	1	.007	.388
[Country=6]		11.857	1	<.001	.296
[Country=7]		.	.	.	1
(Scale)					

Parameter Estimates

Parameter		95% Wald Confidence Interval for Exp(B)	
		Lower	Upper
Threshold	[Confidence_Level_eAssessment=1]	.004	.021
	[Confidence_Level_eAssessment=2]	.025	.082
	[Confidence_Level_eAssessment=3]	.156	.440
	[Confidence_Level_eAssessment=4]	.474	1.306
	[Confidence_Level_eAssessment=5]	2.691	7.874
[Country=1]		.313	1.150
[Country=2]		.407	1.392
[Country=3]		.292	1.088
[Country=4]		.233	.790
[Country=5]		.196	.769
[Country=6]		.148	.592
[Country=7]		.	.
(Scale)			

Table A2-10 Comparison of Mathematics Preparation – Stage Two

Table A2-10 Ordinal Logistic Regression Test of Mathematics Preparedness vs Country

Parameter Estimates

Parameter		Hypothesis Test			
		Wald Chi-Square	df	Sig.	Exp(B)
Threshold	[Preparedness_level_eAssessment=1]	122.310	1	.000	.011
	[Preparedness_level_eAssessment=2]	115.835	1	.000	.034
	[Preparedness_level_eAssessment=3]	14.089	1	<.001	.376
	[Preparedness_level_eAssessment=4]	.084	1	.772	1.077
	[Preparedness_level_eAssessment=5]	40.149	1	<.001	5.699
	[Preparedness_level_eAssessment=6]	49.085	1	<.001	186.839
[Country=1]		.123	1	.726	1.123
[Country=2]		.363	1	.547	.828
[Country=3]		4.368	1	.037	.495
[Country=4]		3.167	1	.075	.576
[Country=5]		6.488	1	.011	.452
[Country=6]		5.536	1	.019	.437
[Country=7]		.	.	.	1
(Scale)					

Parameter Estimates

Parameter		95% Wald Confidence Interval for Exp(B)	
		Lower	Upper
Threshold	[Preparedness_level_eAssessment=1]	.005	.025
	[Preparedness_level_eAssessment=2]	.018	.063
	[Preparedness_level_eAssessment=3]	.226	.627
	[Preparedness_level_eAssessment=4]	.651	1.782
	[Preparedness_level_eAssessment=5]	3.327	9.763
	[Preparedness_level_eAssessment=6]	43.254	807.077
[Country=1]		.588	2.146
[Country=2]		.449	1.528
[Country=3]		.256	.957
[Country=4]		.313	1.058
[Country=5]		.246	.833
[Country=6]		.219	.871
[Country=7]		.	.
(Scale)			

Table A2-11 Comparison of Barriers to eAssessment – Stage Two

Table A2-11: Ordinal Logistic Regression Test: Perceived Barriers eAssessment vs Country

Parameter Estimates

Parameter		Hypothesis Test			
		Wald Chi-Square	df	Sig.	Exp(B)
Threshold	[Perception_Barriers_eAssessment=1]	37.551	1	<.001	.186
	[Perception_Barriers_eAssessment=2]	.002	1	.961	1.013
	[Perception_Barriers_eAssessment=3]	28.563	1	<.001	4.165
	[Perception_Barriers_eAssessment=4]	95.342	1	.000	19.347
	[Perception_Barriers_eAssessment=5]	114.803	1	.000	69.271
[Country=1]		.322	1	.570	.828
[Country=2]		5.396	1	.020	.479
[Country=3]		8.948	1	.003	2.746
[Country=4]		4.803	1	.028	1.979
[Country=5]		3.893	1	.048	1.988
[Country=6]		4.504	1	.034	2.107
[Country=7]		.	.	.	1
(Scale)					

Parameter Estimates

Parameter		95% Wald Confidence Interval for Exp(B)	
		Lower	Upper
Threshold	[Perception_Barriers_eAssessment=1]	.109	.319
	[Perception_Barriers_eAssessment=2]	.611	1.679
	[Perception_Barriers_eAssessment=3]	2.468	7.029
	[Perception_Barriers_eAssessment=4]	10.675	35.065
	[Perception_Barriers_eAssessment=5]	31.906	150.394
[Country=1]		.432	1.588
[Country=2]		.258	.891
[Country=3]		1.417	5.323
[Country=4]		1.075	3.644
[Country=5]		1.005	3.934
[Country=6]		1.059	4.195
[Country=7]		.	.
(Scale)			

Table A2-12 Comparison of Self-Reported Mathematics Ability Prior to higher education – Stage Two

Table A2-12 Ordinal Logistic Regression Test of prior mathematics ability vs Country

Parameter Estimates

Parameter		Hypothesis Test			
		Wald Chi-Square	df	Sig.	Exp(B)
Threshold	[Self_Reported_Mathematics_Ability=1]	86.447	1	.000	.048
	[Self_Reported_Mathematics_Ability=2]	41.144	1	<.001	.174
	[Self_Reported_Mathematics_Ability=3]	.053	1	.818	.943
	[Self_Reported_Mathematics_Ability=4]	8.372	1	.004	2.113
	[Self_Reported_Mathematics_Ability=5]	77.656	1	.000	12.946
[Country=1]		.434	1	.510	.805
[Country=2]		.238	1	.625	.859
[Country=3]		4.226	1	.040	1.990
[Country=4]		.009	1	.926	.972
[Country=5]		.022	1	.883	1.052
[Country=6]		15.147	1	<.001	3.992
[Country=7]		.	.	.	1
(Scale)					

Parameter Estimates

Parameter		95% Wald Confidence Interval for Exp(B)	
		Lower	Upper
Threshold	[Self_Reported_Mathematics_Ability=1]	.025	.091
	[Self_Reported_Mathematics_Ability=2]	.102	.297
	[Self_Reported_Mathematics_Ability=3]	.571	1.558
	[Self_Reported_Mathematics_Ability=4]	1.273	3.509
	[Self_Reported_Mathematics_Ability=5]	7.325	22.882
[Country=1]		.422	1.536
[Country=2]		.466	1.582
[Country=3]		1.033	3.835
[Country=4]		.531	1.778
[Country=5]		.535	2.069
[Country=6]		1.988	8.016
[Country=7]		.	.
(Scale)			

Table A2-13 Comparison of Self-Reported Current Mathematics Ability in higher education – Stage Two

Table A2-13 Ordinal Logistic Regression Test of current mathematics ability vs Country

Parameter Estimates

Parameter		Hypothesis Test			
		Wald Chi-Square	df	Sig.	Exp(B)
Threshold	[Current_Maths_Abilities=1]	92.158	1	.000	.016
	[Current_Maths_Abilities=2]	66.283	1	<.001	.096
	[Current_Maths_Abilities=3]	1.499	1	.221	.729
	[Current_Maths_Abilities=4]	6.569	1	.010	1.942
	[Current_Maths_Abilities=5]	77.286	1	.000	13.955
[Country=1]		.252	1	.615	1.181
[Country=2]		.030	1	.863	1.056
[Country=3]		.619	1	.431	.768
[Country=4]		.015	1	.902	.962
[Country=5]		.223	1	.637	1.178
[Country=6]		.030	1	.863	.941
[Country=7]		.	.	.	1
(Scale)					

Parameter Estimates

Parameter		95% Wald Confidence Interval for Exp(B)	
		Lower	Upper
Threshold	[Current_Maths_Abilities=1]	.007	.037
	[Current_Maths_Abilities=2]	.054	.168
	[Current_Maths_Abilities=3]	.440	1.209
	[Current_Maths_Abilities=4]	1.169	3.227
	[Current_Maths_Abilities=5]	7.754	25.115
[Country=1]		.617	2.259
[Country=2]		.572	1.949
[Country=3]		.398	1.482
[Country=4]		.524	1.767
[Country=5]		.597	2.325
[Country=6]		.474	1.869
[Country=7]		.	.
(Scale)			

Table A2-14 Comparison of Mathematics Confidence – Stage Two

Table A2-14 Ordinal Logistic Regression Test of Mathematics Confidence vs Country

Parameter Estimates

Parameter		Hypothesis Test			
		Wald Chi-Square	df	Sig.	Exp(B)
Threshold	[Confidence_Completing_Maths=1]	125.072	1	.000	.004
	[Confidence_Completing_Maths=2]	124.244	1	.000	.033
	[Confidence_Completing_Maths=3]	37.344	1	<.001	.191
	[Confidence_Completing_Maths=4]	5.646	1	.017	.536
	[Confidence_Completing_Maths=5]	17.748	1	<.001	3.102
[Country=1]		5.019	1	.025	.473
[Country=2]		6.481	1	.011	.447
[Country=3]		30.323	1	<.001	.149
[Country=4]		6.578	1	.010	.447
[Country=5]		10.656	1	.001	.318
[Country=6]		5.694	1	.017	.431
[Country=7]		.	.	.	1
(Scale)					

Parameter Estimates

Parameter		95% Wald Confidence Interval for Exp(B)	
		Lower	Upper
Threshold	[Confidence_Completing_Maths=1]	.002	.011
	[Confidence_Completing_Maths=2]	.018	.060
	[Confidence_Completing_Maths=3]	.113	.325
	[Confidence_Completing_Maths=4]	.320	.896
	[Confidence_Completing_Maths=5]	1.832	5.252
[Country=1]		.246	.911
[Country=2]		.240	.831
[Country=3]		.076	.294
[Country=4]		.242	.827
[Country=5]		.160	.632
[Country=6]		.216	.860
[Country=7]		.	.
(Scale)			

Table A2-15 Comparison of Amount of work per country – Stage Two

Table A2-15 Ordinal Logistic Regression of Amount of work required for mathematics per count

Parameter Estimates

Parameter		Hypothesis Test Wald Chi-Square	df	Sig.	Exp(B)
Threshold	[Work_Amount_Maths=1]	57.053	1	<.001	.015
	[Work_Amount_Maths=2]	38.039	1	<.001	.171
	[Work_Amount_Maths=3]	.802	1	.371	.791
	[Work_Amount_Maths=4]	43.312	1	<.001	6.130
	[Work_Amount_Maths=5]	136.060	1	.000	51.575
[Country=1]		.635	1	.426	1.309
[Country=2]		9.180	1	.002	2.659
[Country=3]		1.670	1	.196	1.557
[Country=4]		21.267	1	<.001	4.440
[Country=5]		1.068	1	.301	1.442
[Country=6]		13.801	1	<.001	3.848
[Country=7]		.	.	.	1
(Scale)					

Parameter Estimates

Parameter		95% Wald Confidence Interval for Exp(B) Lower	Upper
Threshold	[Work_Amount_Maths=1]	.005	.045
	[Work_Amount_Maths=2]	.098	.300
	[Work_Amount_Maths=3]	.474	1.321
	[Work_Amount_Maths=4]	3.572	10.519
	[Work_Amount_Maths=5]	26.589	100.042
[Country=1]		.675	2.536
[Country=2]		1.413	5.007
[Country=3]		.796	3.045
[Country=4]		2.356	8.365
[Country=5]		.720	2.889
[Country=6]		1.890	7.836
[Country=7]		.	.
(Scale)			

Table A2-16 Comparison of self-reported ability to learn mathematics per country – Stage Two

Table A2-16 Ordinal Logistic Regression Self-reported abilities to learn mathematics per country

Parameter Estimates

Parameter		Hypothesis Test				95% Wald Confidence Interval for Exp(B)
		Wald Chi-Square	df	Sig.	Exp(B)	Lower
Threshold	[Learning_Maths=1]	88.439	1	.000	.026	.012
	[Learning_Maths=2]	40.282	1	<.001	.174	.101
	[Learning_Maths=3]	.157	1	.692	.903	.545
	[Learning_Maths=4]	27.840	1	<.001	4.089	2.423
	[Learning_Maths=5]	98.576	1	.000	20.837	11.442
[Country=1]		14.094	1	<.001	3.531	1.828
[Country=2]		.408	1	.523	1.222	.661
[Country=3]		.010	1	.920	.967	.501
[Country=4]		.037	1	.848	1.061	.577
[Country=5]		14.889	1	<.001	3.899	1.953
[Country=6]		3.403	1	.065	.522	.262
[Country=7]		.	.	.	1	.
(Scale)						

Parameter Estimates

Parameter		95% Wald Confidence Interval for Exp(B)
		Upper
Threshold	[Learning_Maths=1]	.055
	[Learning_Maths=2]	.299
	[Learning_Maths=3]	1.497
	[Learning_Maths=4]	6.899
	[Learning_Maths=5]	37.947
[Country=1]		6.823
[Country=2]		2.260
[Country=3]		1.867
[Country=4]		1.950
[Country=5]		7.782
[Country=6]		1.041
[Country=7]		.
(Scale)		

Table A2- 17 Comparison of Rewards for learning mathematics per country – Stage Two

Table A2-17 Ordinal Logistic Regression Rewards received for learning mathematics per countr

Parameter Estimates

Parameter		Hypothesis Test Wald Chi-Square	df	Sig.	Exp(B)
Threshold	[Rewards_For_Maths=1]	121.740	1	.000	.015
	[Rewards_For_Maths=2]	88.679	1	.000	.057
	[Rewards_For_Maths=3]	25.868	1	<.001	.243
	[Rewards_For_Maths=4]	11.574	1	<.001	2.527
	[Rewards_For_Maths=5]	73.166	1	.000	24.224
[Country=1]		3.857	1	.050	.504
[Country=2]		7.116	1	.008	.414
[Country=3]		9.997	1	.002	.328
[Country=4]		5.248	1	.022	.473
[Country=5]		.508	1	.476	1.296
[Country=6]		.003	1	.953	.979
[Country=7]		.	.	.	1
(Scale)					

Parameter Estimates

Parameter		95% Wald Confidence Interval for Exp(B) Lower	Upper
Threshold	[Rewards_For_Maths=1]	.007	.032
	[Rewards_For_Maths=2]	.031	.103
	[Rewards_For_Maths=3]	.141	.419
	[Rewards_For_Maths=4]	1.481	4.312
	[Rewards_For_Maths=5]	11.670	50.285
[Country=1]		.255	.999
[Country=2]		.217	.792
[Country=3]		.164	.654
[Country=4]		.249	.898
[Country=5]		.635	2.646
[Country=6]		.476	2.011
[Country=7]		.	.
(Scale)			

Table A2- 18 Comparison of perceived awareness of mathematics instructors per country – Stage Two

Table A2-18 Awareness of maths programme instructors

Parameter Estimates

Parameter		Hypothesis Test Wald Chi-Square	df	Sig.	Exp(B)
Threshold	[Awareness_of_Maths_Instructors=1]	98.155	1	.000	.023
	[Awareness_of_Maths_Instructors=2]	68.178	1	<.001	.083
	[Awareness_of_Maths_Instructors=3]	18.740	1	<.001	.305
	[Awareness_of_Maths_Instructors=4]	17.260	1	<.001	3.115
	[Awareness_of_Maths_Instructors=5]	68.055	1	<.001	12.288
[Country=1]		.955	1	.328	.713
[Country=2]		1.970	1	.160	.631
[Country=3]		.950	1	.330	1.407
[Country=4]		4.120	1	.042	1.932
[Country=5]		1.873	1	.171	.609
[Country=6]		.852	1	.356	.713
[Country=7]		.	.	.	1
(Scale)					

Parameter Estimates

Parameter		95% Wald Confidence Interval for Exp(B) Lower	Upper
Threshold	[Awareness_of_Maths_Instructors=1]	.011	.049
	[Awareness_of_Maths_Instructors=2]	.046	.150
	[Awareness_of_Maths_Instructors=3]	.178	.522
	[Awareness_of_Maths_Instructors=4]	1.823	5.325
	[Awareness_of_Maths_Instructors=5]	6.771	22.302
[Country=1]		.362	1.405
[Country=2]		.332	1.200
[Country=3]		.708	2.795
[Country=4]		1.023	3.650
[Country=5]		.299	1.239
[Country=6]		.348	1.461
[Country=7]		.	.
(Scale)			

Table A2- 19 Comparison of students' self-reported confidence in completing first year of engineering per country – Stage Two

Table A2-19 Students' confidence to complete their first year of engineering

Parameter Estimates

Parameter		Wald Chi-Square	df	Sig.	Exp(B)
		Hypothesis Test			
Threshold	[Confidence_Completing_Programme=1]	68.983	1	<.001	.028
	[Confidence_Completing_Programme=2]	32.613	1	<.001	.200
	[Confidence_Completing_Programme=3]	1.639	1	.200	1.403
	[Confidence_Completing_Programme=4]	80.024	1	.000	13.327
	[Confidence_Completing_Programme=5]	131.855	1	.000	90.044
[Country=1]		5.262	1	.022	2.192
[Country=2]		5.823	1	.016	2.183
[Country=3]		8.116	1	.004	2.694
[Country=4]		10.426	1	.001	2.830
[Country=5]		9.484	1	.002	3.043
[Country=6]		.883	1	.347	.714
[Country=7]		.	.	.	1
(Scale)					

Parameter Estimates

Parameter		95% Wald Confidence Interval for Exp(B) Lower	Upper
Threshold	[Confidence_Completing_Programme=1]	.012	.066
	[Confidence_Completing_Programme=2]	.115	.348
	[Confidence_Completing_Programme=3]	.836	2.355
	[Confidence_Completing_Programme=4]	7.556	23.505
	[Confidence_Completing_Programme=5]	41.769	194.112
[Country=1]		1.121	4.288
[Country=2]		1.158	4.117
[Country=3]		1.362	5.327
[Country=4]		1.505	5.322
[Country=5]		1.499	6.178
[Country=6]		.353	1.442
[Country=7]		.	.
(Scale)			

Table A2- 20 Comparison of perceptions of amount of work required in first year engineering per country – Stage Two

Table A2-20 Students' perceptions of the amount of work in first year engineering

Parameter Estimates

Parameter		Hypothesis Test			
		Wald Chi-Square	df	Sig.	Exp(B)
Threshold	[Work_Amount_Programme=1]	77.976	1	.000	.011
	[Work_Amount_Programme=2]	76.927	1	.000	.062
	[Work_Amount_Programme=3]	7.237	1	.007	.488
	[Work_Amount_Programme=4]	25.375	1	<.001	3.954
	[Work_Amount_Programme=5]	95.254	1	.000	24.715
[Country=1]		.367	1	.545	1.230
[Country=2]		.103	1	.749	1.109
[Country=3]		1.257	1	.262	.679
[Country=4]		1.781	1	.182	1.534
[Country=5]		7.206	1	.007	2.628
[Country=6]		1.675	1	.196	.627
[Country=7]		.	.	.	1
(Scale)					

Parameter Estimates

Parameter		95% Wald Confidence Interval for Exp(B)	
		Lower	Upper
Threshold	[Work_Amount_Programme=1]	.004	.029
	[Work_Amount_Programme=2]	.033	.116
	[Work_Amount_Programme=3]	.290	.823
	[Work_Amount_Programme=4]	2.316	6.750
	[Work_Amount_Programme=5]	12.979	47.065
[Country=1]		.630	2.403
[Country=2]		.589	2.089
[Country=3]		.345	1.336
[Country=4]		.818	2.874
[Country=5]		1.298	5.320
[Country=6]		.309	1.271
[Country=7]		.	.
(Scale)			

Table A2- 21 Comparison of students' perceptions of work done for first year engineering per country – Stage Two

Table A2-21 Rewards for work done in first year engineering

Parameter Estimates

Parameter		Wald Chi-Square	df	Sig.	Exp(B)
		Hypothesis Test			
Threshold	[Rewards_For_Programme=1]	77.677	1	.000	.010
	[Rewards_For_Programme=2]	70.377	1	.000	.062
	[Rewards_For_Programme=3]	18.495	1	<.001	.284
	[Rewards_For_Programme=4]	37.017	1	<.001	6.303
	[Rewards_For_Programme=5]	92.225	1	.000	67.131
[Country=1]		.088	1	.767	1.117
[Country=2]		.354	1	.552	.811
[Country=3]		2.623	1	.105	.547
[Country=4]		.008	1	.928	1.032
[Country=5]		.140	1	.709	1.158
[Country=6]		10.577	1	.001	3.604
[Country=7]		.	.	.	1
(Scale)					

Parameter Estimates

Parameter		95% Wald Confidence Interval for Exp(B) Lower	Upper
Threshold	[Rewards_For_Programme=1]	.003	.027
	[Rewards_For_Programme=2]	.032	.118
	[Rewards_For_Programme=3]	.160	.504
	[Rewards_For_Programme=4]	3.483	11.405
	[Rewards_For_Programme=5]	28.449	158.410
[Country=1]		.537	2.326
[Country=2]		.407	1.617
[Country=3]		.263	1.135
[Country=4]		.520	2.049
[Country=5]		.537	2.499
[Country=6]		1.664	7.803
[Country=7]		.	.
(Scale)			

Table A2- 22 Comparison of students' perceptions of programme instructors per country – Stage Two

Table A2-22 Perceptions of programme instructors' awareness of students' abilities

Parameter Estimates

Parameter		Hypothesis Test			
		Wald Chi-Square	df	Sig.	Exp(B)
Threshold	[Awareness_of_Programme_Instructors=1]	90.357	1	.000	.012
	[Awareness_of_Programme_Instructors=2]	76.888	1	.000	.055
	[Awareness_of_Programme_Instructors=3]	27.456	1	<.001	.214
	[Awareness_of_Programme_Instructors=4]	23.916	1	<.001	4.187
	[Awareness_of_Programme_Instructors=5]	81.734	1	.000	31.356
[Country=1]		.427	1	.514	.785
[Country=2]		2.504	1	.114	.575
[Country=3]		.147	1	.701	.866
[Country=4]		.133	1	.715	1.135
[Country=5]		1.893	1	.169	.588
[Country=6]		.953	1	.329	1.463
[Country=7]		.	.	.	1
(Scale)					

Parameter Estimates

Parameter		95% Wald Confidence Interval for Exp(B)	
		Lower	Upper
Threshold	[Awareness_of_Programme_Instructors=1]	.005	.029
	[Awareness_of_Programme_Instructors=2]	.029	.106
	[Awareness_of_Programme_Instructors=3]	.120	.381
	[Awareness_of_Programme_Instructors=4]	2.359	7.433
	[Awareness_of_Programme_Instructors=5]	14.857	66.178
[Country=1]		.380	1.622
[Country=2]		.290	1.141
[Country=3]		.416	1.804
[Country=4]		.576	2.238
[Country=5]		.275	1.253
[Country=6]		.681	3.141
[Country=7]		.	.
(Scale)			

Table A2- 23 Comparison of students' mathematics expectancy per country – Stage Two

Table A2-23 Kruskal-Wallis test for mathematics expectancy

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.[a,b]
1	The distribution of Maths_Expectancy is the same across categories of Country.	Independent-Samples Kruskal-Wallis Test	<.001

Independent-Samples Kruskal-Wallis Test Summary

Total N	504
Test Statistic	31.069[a]
Degree Of Freedom	6
Asymptotic Sig.(2-sided test)	<.001

Pairwise Comparisons of Country

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
Russia-Portugal	11.431	27.218	.420	.675	1.000
Russia-Ireland	37.741	25.964	1.454	.146	1.000
Russia-Romania	61.828	27.443	2.253	.024	.509
Russia-Finland	81.310	26.276	3.095	.002	.041
Russia-Estonia	88.135	24.555	3.589	<.001	.007
Russia-Poland	99.334	24.310	4.086	<.001	.001
Portugal-Ireland	26.310	24.885	1.057	.290	1.000
Portugal-Romania	-50.397	26.424	-1.907	.056	1.000
Portugal-Finland	69.879	25.210	2.772	.006	.117
Portugal-Estonia	76.704	23.411	3.276	.001	.022
Portugal-Poland	87.904	23.154	3.796	<.001	.003
Ireland-Romania	-24.087	25.130	-.959	.338	1.000
Ireland-Finland	-43.569	23.850	-1.827	.068	1.000
Ireland-Estonia	-50.394	21.940	-2.297	.022	.454
Ireland-Poland	-61.594	21.666	-2.843	.004	.094
Romania-Finland	19.482	25.451	.765	.444	1.000
Romania-Estonia	26.307	23.671	1.111	.266	1.000
Romania-Poland	37.506	23.417	1.602	.109	1.000
Finland-Estonia	6.825	22.308	.306	.760	1.000
Finland-Poland	-18.024	22.038	-.818	.413	1.000
Estonia-Poland	-11.200	19.955	-.561	.575	1.000

Ranks

	Country	N	Mean Rank
Maths_Expectancy	Ireland	72	228.43
	Estonia	97	278.82
	Finland	68	272.00
	Poland	103	290.02
	Portugal	58	202.12
	Romania	56	252.52
	Russia	50	190.69
	Total	504	

Table A2- 24 Comparison of students' perceptions of programme expectancy per country – Stage Two

Table A2-24 Programme expectancy per country

Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk	
	Country	Statistic	df	Sig.	Statistic	df
Programme_Expectancy	Ireland	.290	72	<.001	.864	72
	Estonia	.281	97	<.001	.875	97
	Finland	.248	68	<.001	.908	68
	Poland	.304	103	<.001	.774	103
	Portugal	.248	58	<.001	.891	58
	Romania	.272	56	<.001	.901	56
	Russia	.225	50	<.001	.880	50

Pairwise Comparisons of Country

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
Romania-Russia	-80.953	26.899	-3.010	.003	.055
Romania-Finland	84.517	24.947	3.388	<.001	.015
Romania-Ireland	87.057	24.632	3.534	<.001	.009
Romania-Estonia	99.066	23.202	4.270	<.001	.000
Romania-Poland	105.653	22.953	4.603	<.001	.000
Romania-Portugal	138.551	25.900	5.349	<.001	.000
Russia-Finland	3.564	25.755	.138	.890	1.000
Russia-Ireland	6.103	25.450	.240	.810	1.000
Russia-Estonia	18.113	24.068	.753	.452	1.000
Russia-Poland	24.700	23.829	1.037	.300	1.000
Russia-Portugal	57.598	26.679	2.159	.031	.648
Finland-Ireland	2.539	23.378	.109	.914	1.000
Finland-Estonia	14.549	21.886	.665	.506	1.000
Finland-Poland	-21.135	21.602	-.978	.328	1.000
Finland-Portugal	-54.033	24.710	-2.187	.029	.604
Ireland-Estonia	-12.009	21.506	-.558	.577	1.000
Ireland-Poland	-18.596	21.237	-.876	.381	1.000
Ireland-Portugal	-51.494	24.392	-2.111	.035	.730
Estonia-Poland	-6.587	19.560	-.337	.736	1.000
Estonia-Portugal	-39.485	22.947	-1.721	.085	1.000
Poland-Portugal	-32.898	22.696	-1.450	.147	1.000

Ranks

	Country	N	Mean Rank
Programme_Expectancy	Ireland	72	251.08
	Estonia	97	263.09
	Finland	68	248.54
	Poland	103	269.68
	Portugal	58	302.58
	Romania	56	164.03
	Russia	50	244.98
	Total	504	

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.[a,b]	Decision
1	The distribution of Programme_Expectancy is the same across categories of Country.	Independent-Samples Kruskal-Wallis Test	.000	Reject the null hypothesis.

a. The significance level is .050.

b. Asymptotic significance is displayed.

Table A2- 25 Comparison of students' self-reported self-efficacy per country – Stage Two

Table A2-25 Self-reported mathematics self-efficacy per country

Descriptives

Maths_Self_Efficacy

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
Ireland	72	19.9167	4.41747	.52060	18.8786	20.9547
Estonia	97	19.1443	3.34785	.33992	18.4696	19.8191
Finland	68	19.1029	3.30599	.40091	18.3027	19.9032
Poland	103	19.6699	4.58341	.45162	18.7741	20.5657
Portugal	58	19.7931	3.75457	.49300	18.8059	20.7803
Romania	56	19.7143	4.04391	.54039	18.6313	20.7973
Russia	50	19.7800	4.34384	.61431	18.5455	21.0145
Total	504	19.5575	3.99113	.17778	19.2083	19.9068

Descriptives

Maths_Self_Efficacy

	Minimum	Maximum
Ireland	7.00	30.00
Estonia	10.00	27.00
Finland	13.00	28.00
Poland	7.00	30.00
Portugal	12.00	27.00
Romania	10.00	27.00
Russia	9.00	30.00
Total	7.00	30.00

Tests of Homogeneity of Variances

		Levene Statistic	df1	df2	Sig.
Maths_Self_Efficacy	Based on Mean	3.488	6	497	.002
	Based on Median	3.210	6	497	.004
	Based on Median and with adjusted df	3.210	6	463.809	.004
	Based on trimmed mean	3.482	6	497	.002

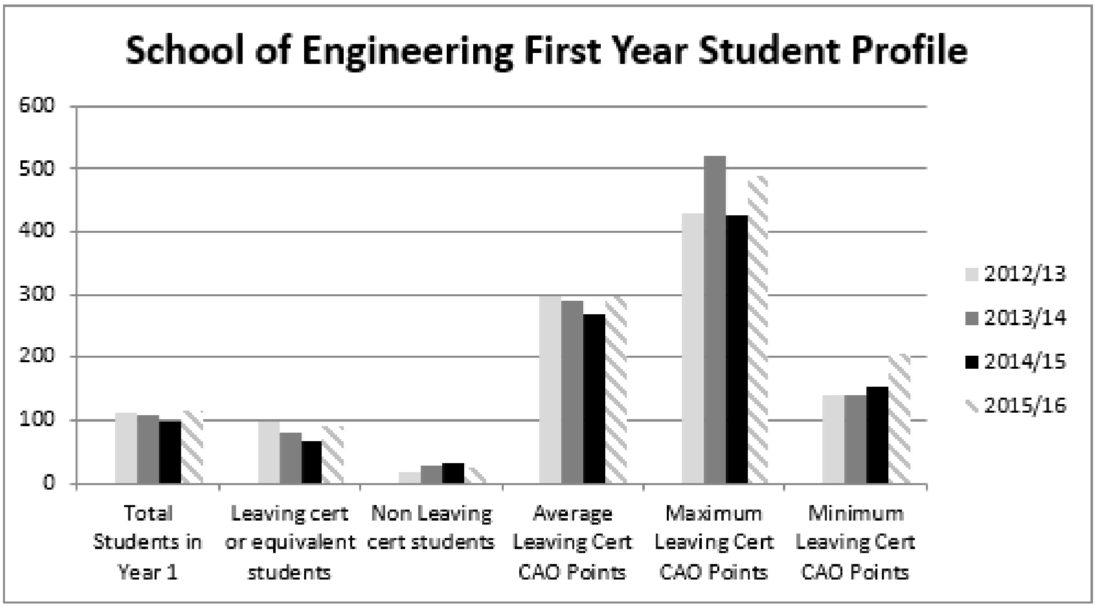
Table A2- 26 Comparison of entry qualifications for Irish students between 2012 and 2015

Table A2-26 Entry Qualifications 3 years prior to study

School of Engineering CAO 2012 to 2015

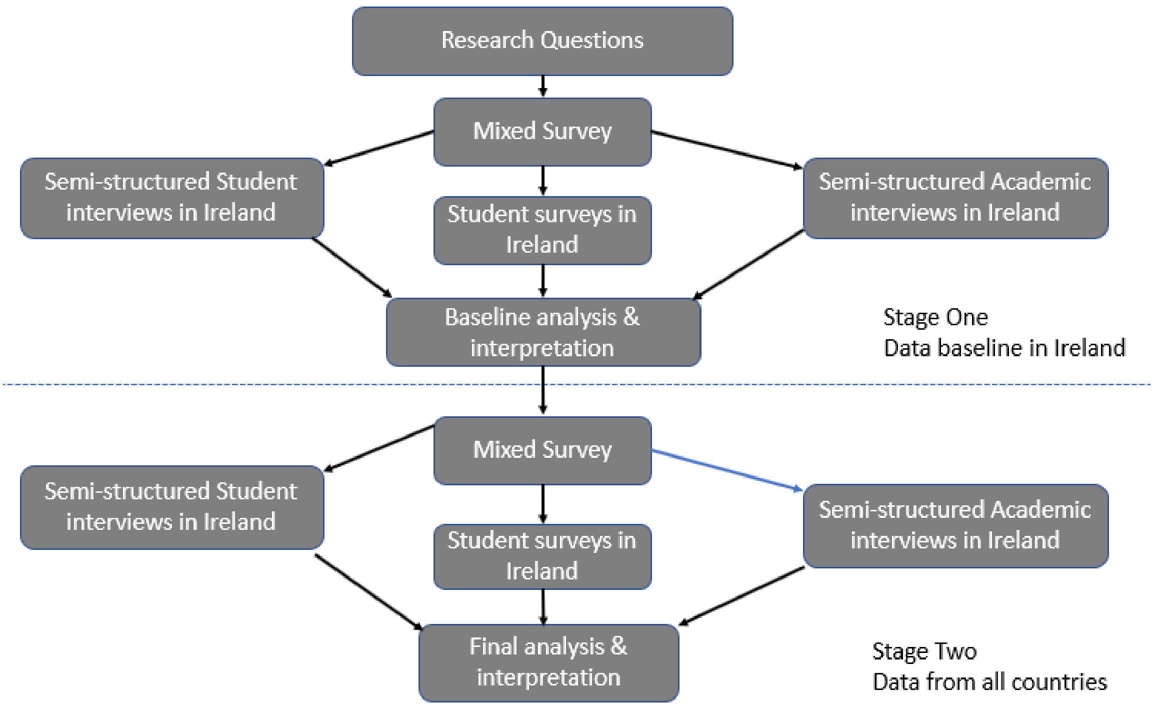
Source: HEA Census per academic year

Year	Total Students in Year 1	Leaving cert or equivalent students	Non-Leaving cert students	Average Leaving Cert CAO Points	Maximum Leaving Cert CAO Points	Minimum Leaving Cert CAO Points
2012/13	113	97	16	297	430	140
2013/14	108	81	27	289	520	140
2014/15	98	66	32	270	425	155
2015/16	115	90	25	297	490	205

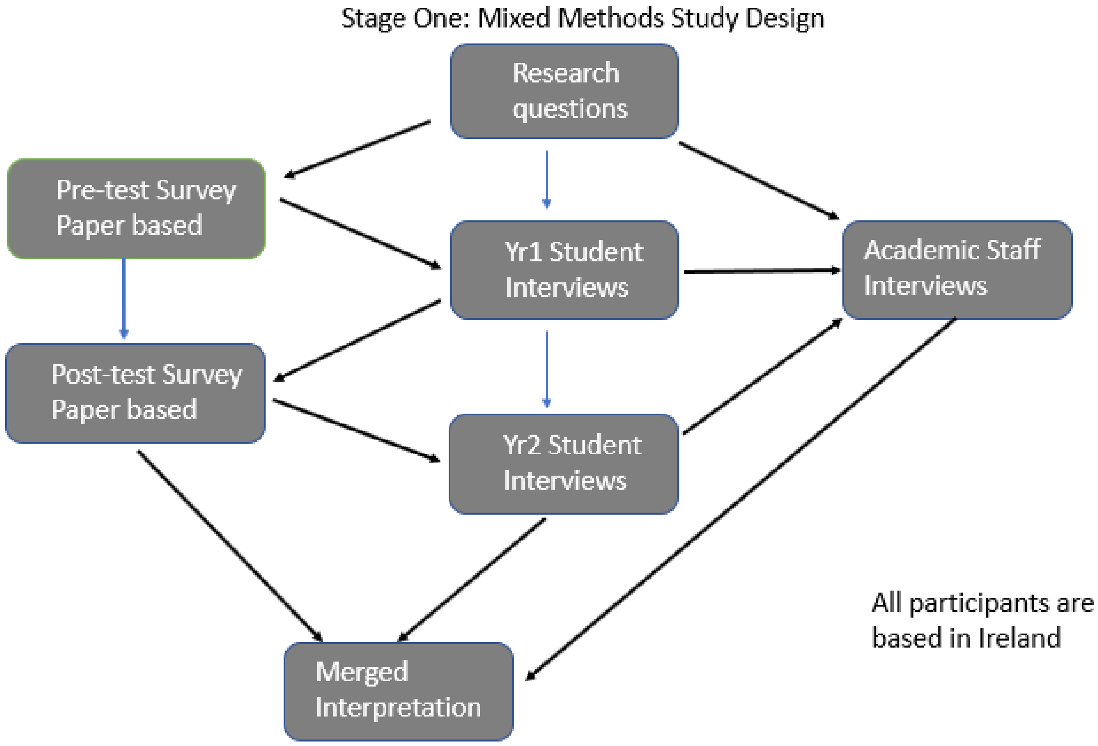


Appendix 3 – Design Methodology

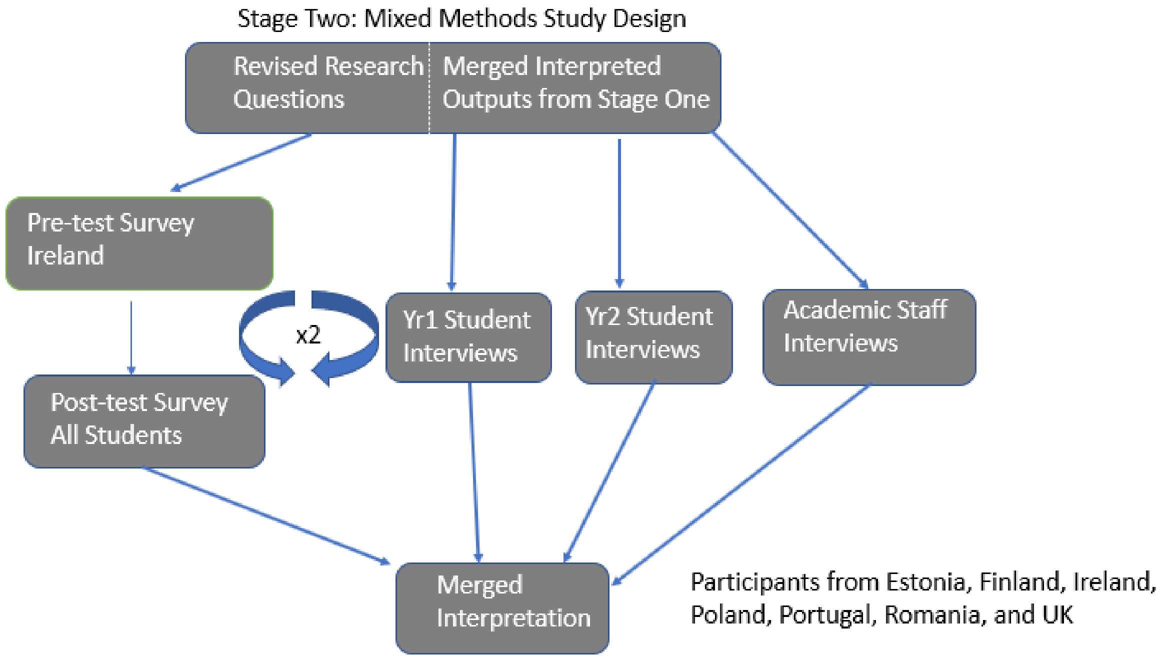
Overall Mixed Methods Design



Stage One Mixed Methods Design: Ireland



Stage Two Mixed Methods Design: Estonia, Finland, Ireland, Poland, Portugal, Romania, Russia, UK



Appendix 4 – Qualitative Analysis

1. Sample Partial Student Transcript Ireland

Do you think you were adequately prepared or trained in advance for the use of the online assessment?

S9 – Yes! Because there was nothing In the test that wasn't covered in the tutorial classes over the previous weeks.

S3 – It took a while to get the hang of using Blackboard and also access to the test. It took a few tries and I got lost. Getting the hang of it now though!

KB - *Did the practice tests help you?*

S3 – Yeah! They helped me figure out where I was going and what I was doing.

KB – *Do you feel that after having done an online assessment that you are now more or less confident using them?*

S5 – More confident. You know what to expect, where to answer the question, how to answer it. Just make sure that you continue until you get to the end. That's about it!

S9 – More confident as well. Very good way – I didn't think it would be as good. I have used pen and paper all the time. I thought doing an online test would be easy, but it was a lot harder than you think. One of the things I found good on it was if you were doing a pen and paper test you just put down your answer. With the online test there would be some answers that were pretty close, and you need to go over it again to make sure. You tend to be more certain before you click the button. Because if you are doing an exam paper you assume that if your method is right, there is no ambiguity. Here there is a right or a wrong answer.

S6 – It was getting used to the layout. The way the questions are asked and how they are answered.

2. Sample Partial Student Transcript Finland

KB - Can you describe the types of assessment and preparation you experience in mathematics?

S1 – It ranges a lot. It usually starts from easy, just basic when take engineering it is easy to understand. But then you go ahead and read up about it in mathematics. Sometimes that takes a lot of, a lot more, concentration because it is harder. But I would say it is not too hard. Not too much online but the questions are found online but we don't do it online. We hand write them.

S2 – Yeah! We have Moodle online and we handwrite them later. We should do a lot of work at home, I feel, for the assessment.

3:30 to 4:30 Explanation and translation by Finnish lecturer to help student find words to describe assessments.

S2 – We don't get grades from the questions online. It is just to see how we do. I feel that the types of mathematics we do here, it takes a lot of work, at least for me. We only have a few hours at school and then a lot of work at home.

3. Sample Partial Academic Transcript

KB – *When you are running the quizzes do you provide them with any preparation or training?*

DM – Yes! There are practice quizzes they can work through. The big thing I am trying to get over is their fear of maths, and I find that especially the mature learners. When they use the practice quizzes it really calms them down. So, if they can do the same and every time, they run the practice quiz they get a different version. I have seen some attempting up to 50 times and they come into class to do a new quiz with a new set of questions. They are calm coming in.

KB – *Have you spoken to them about fears?*

DM – I done it based on their feedback, so I created it based on their feedback. Every time I do maths I ask them – the big thing is breaking down the barriers. Often some of the mature learners have more maths than they realize, but they have a huge fear aspect to it. So, the whole way through I am asking for feedback on their speed and level of difficulty. They do it anonymously and we do this the whole way through. At the end of every time, I teach mathematics I ask them – even the school leavers coming in with good maths and who possibly didn't need to learn as much as the mature learners – was it beneficial? Was there anything that should have been left out? Was there anything that should have been included? I have them in second year and I ask at the end of second year

“Is there anything in first year that we should have done?”

“Is there anything now you are thinking that actually I need that at all?”

“Is there anything I should remove from the programme?”

It is based on that that I develop the mathematics.