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An Evaluation of Mathematical Teaching Pedagogies to Tertiary Engineering and Information Technology Students at the University of Canberra

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Abstract

Students' weak performance in mathematics subjects is a critical issue for many universities. While many studies have explored the causes of weak mathematics foundation of many students, there is a continued need to explore effective measures to improve students' learning outcomes.

This study examines the effectiveness of the pedagogical approaches used by educators in addressing the mathematics challenges faced by first-year engineering and information technology (EIT) students, with a particular emphasis placed on the University of Canberra (UC). It also aims to provide recommendations that could help educators motivate EIT students to improve their mathematics performance.

Three primary research questions guided this investigation: (1) What are the impacts of the UC mathematics teaching approach on the first-year EIT students' collaboration, understanding, and achievement in mathematics? (2) What factors motivate EIT students to engage or lose interest in mathematics? (3) Does implementing a multidisciplinary pedagogical approach enhance the effectiveness of student mathematics learning for UC's EIT students?

A mixed-methods approach of quantitative and qualitative techniques was employed. Where a quantitative study was carried out to elaborate on problem areas, and research questions were employed and investigated further in the collection and analysis of qualitative data.

The outcomes of the quantitative analysis showed that there was a significant and positive relationship between students' learning style and students' understanding, time management, effort and satisfaction. It also found more than one-third of the students had serious concentration issues, about 62% of the students had trouble keeping up with what they are learning, and a large portion of participants perceived experienced anxiety and a lack of motivation issues.

The qualitative analysis showed that each construct (dimension) of the teaching method (e.g., collaboration, understanding, engagement and motivation) is interconnected and interdependent - presumably, it cannot function in an isolated environment. Each dimension demands balanced attention during the learning session by the actors (EIT students, mathematics teachers, and education/curriculum experts). Learning and teaching sessions in the classroom can be identified as a system taking certain inputs processed by these interrelated dimensions of the teaching method to generate a set of outputs (student achievements) through

certain processes. Based on the findings of the qualitative data's emerging themes, questioning the impact of teaching methods on collaboration, understanding, and achievement cannot be seen as separate entities with one impacting the other; rather, they overlap. Therefore, a teaching method alone cannot be a single isolated unit of analysis. Still, the heavier burden is on the teachers' shoulders, but the institution's leadership and the highly qualified educators need to encourage innovative teamwork.

Within the setting of mathematical learning practice at UC, the fact that the actors (students, teachers, and experts) embrace the same awareness concerning what makes effective mathematical learning, along with their receptivity to ever-changing social and technological advancements, can be considered an advantageous condition to further experiment on effective educational approaches. For example, adopting action processes stipulated in teaching for robust understanding and lesson study (TRU-Lesson Study) framework.

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List of Papers and Presentation

Papers:

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List of Abbreviations

AI	Artificial Intelligence
ANS	Approximate Number System
AOI	Agency, Ownership, and Identity
AR	Augmented Reality
CAL	Computer-aided Learning
CAS	Computer Algebra Systems
CBL	Challenge Based Learning
CHAT	The Cultural-historical Activity Theory
E 1	Expert Number 1
EIT	Engineering and Information Technology
ERC	The Education Research Complete
ERIC	The Education Resources Information Centre
FAQ	Frequently Asked Questions
FfT	Framework for Teaching
FULT	The Foundations in University Learning and Teaching
GCULT	Graduate Certificate in University Learning and Teaching
HEIs	Higher Educational Institutions
HREC	The Human Research Ethics Committee of the University of Canberra
HTMT	Heterotrait-Monotrait Ratio
IBL	Inquiry-based Learning
ICT	Information and Communication Technology
IT	Information Technology
LB	Learning Behaviour
LMS	Learning Management Systems

LS	Lesson-Study
LTG	Learning and Teaching Geometry
LTTO	Learning to Teach Online
MAI	Meta-cognitive Awareness Inventory
MANOVA	Multivariate Analysis of Variance
MLD	Mathematical Learning Disabilities
MOOC	Massive Open Online Course
MQI	Mathematical Quality of Instruction
MT 1	Mathematics Teacher Number 1
NCTM	The National Council of Teachers of Mathematics
OECD	The Organisation for Economic Co-operation and Development
OTS	Object Tracking System
OUA	Open Universities Australia
PC	Personal Computer
PISA	The Programme for International Student Assessment
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
QDA	Qualitative Data Analysis
RBT	Revised Bloom's Taxonomy
SDL	Self-directed Learning
SEIL	Strategic Engagement for Increased Learning
SME	Subject Matter Experts
STEM	Science, Technology, Engineering and Mathematics
TAM	Technology Acceptance Model
TLC	Teacher Learning Community
TM	Teaching Methods

TPACK	Technological Pedagogical Content Knowledge
TRU	Teaching for Robust Understanding
UC	University of Canberra
UK	United Kingdom
USA	United States of America
VBL	Video-based Learning
VR	Virtual Reality
ZPD	Zone of Proximity Development

1 Introduction

1.1 Background

Mathematics education is crucial to the economic growth of any advanced country (Ma, 2010). Forward-thinking leaders are aware that to produce deep thinkers, they address the mathematics difficulties of students in universities (Markopoulos et al., 2015). In Australia, the federal government have invested millions of dollars in mathematics education with the goal of ensuring that students in primary and high school develop a high level of numeracy before they enrol in university programmes like engineering, computer science, and information technology (The Australian Institute for Teaching and School Leadership, 2019). However, research shows that a significant number of university students find it difficult to solve Mathematics problems. Students enter university programmes with suitable entry qualifications, but they lack a strong background in mathematics (Boyd et al., 2014; Hill et al., 2005). This problem, according to research, can be traced to students' socio-economic backgrounds and poor past experiences in learning mathematics (Lake et al., 2015). Hence, there is a need to explore the pedagogical methods employed by schools in Australia to teach students mathematics-related subjects as well as the impacts of these teaching methods on student mathematics performance.

1.1.1 What is Mathematics?

Mathematics is a broad subject with many abstract components. It covers many areas, including algebra, geometry, calculus, probability, statistics, and analysis (Wolfmeyer, 2017). Because of the broad nature of mathematics, scholars have struggled to agree on a consensus definition for this subject. Some scholars defined mathematics as the study of realities and systems and the relationship between magnitudes, quantities, and procedures (Schoenfeld, 2016a). Another group of scholars argued that mathematics was nothing but the "science of patterns" (Jansen et al., 2016; Schoenfeld, 2016a). Schoenfeld (2016a), for instance, characterised mathematics as a fundamentally social endeavour in which skilled mathematicians form a community that focuses on exploring the rules that govern nature or a system through reflection, observation, and experimentation. Regardless of their divergent views on mathematics, scholars agree that the instruments of mathematics are conceptualisation, representation of symbolic thoughts, and exploitation of these symbols.

Mathematical knowledge goes beyond manipulating numerical symbols. Just because an individual can solve algebra or arithmetic problems does not mean that the person can think mathematically. Being proficient in mathematics requires a tremendous amount of mathematical thinking, and this thinking involves having the ability to engage in computational reasoning, spatial reasoning and computational/analytic reasoning (Schoenfeld, 2016a). Ernest (2018) argued that mathematics required more than manipulating numbers and performing basic algebra. According to the scholar, there are three forms of essential mathematics: practical numeracy, practical job-related knowledge, and professional expertise. Practical numeracy is meant for productive functioning in the community, while practical job-related knowledge is required for all-purpose occupations at the end of schooling (Ernest, 2018). In sum, professional expertise in mathematics is needed to solve industrial problems and work-centred practical problems.

Furthermore, Ernest (2018) highlights two viewpoints on mathematics. One is the "absolutist" viewpoint in which mathematics is regarded "as an objective, absolute, certain and incorrigible body of knowledge, which rests on the firm foundations of deductive logic". The other one is the "fallibilist" mathematical philosophy in which mathematics is regarded as "human, corrigible, historical and changing … the outcome of social processes … open to revision" (Ernest, 2018). These two views influence how mathematics scholars define mathematics and teach the subject in the classroom.

However, having mathematical literacy is not tantamount to possessing mathematical competence. Niss and Jablonka (2014) differentiated between mathematical literacy and mathematical competence. The former is an instrument utilised for non-mathematical problems solving, while the latter means grasping mathematics broadly and being able to solve both mathematical and non-mathematical problems. Each branch of mathematics has different characteristics. Some scholars regard the characteristics as logical ideas, interrelated ideas, associations, forms, and communications. The Organisation for Economic Co-operation and Development (OECD) has added a suffix of 'literacy' to mathematics to denote an individual's competence to articulate, utilise and construe mathematics in a range of contexts. Mathematical literacy covers having the ability to apply mathematical concepts, identify facts, and explain and predict phenomena mathematically. Individuals with mathematical literacy are likely to employ logical and rational thinking in their decision-making.

Non-mathematical designate problems can be solved outside the field of mathematics, but mathematical procedures need to be adopted to solve the problems. Niss and Højgaard (2019) categorise proficiencies in mathematics into eight groups: (1) understanding mathematical modes of thought (mathematical thinking); (2) mathematical problems' presentation and solving; (3) analysing and creating models (mathematics modelling); (4) mathematical proof and proving; (5) symbolising mathematical objects; (6) operating mathematical signs and formalisms; (7) collaborative with others on mathematical problems; and (8) utilising instruments and technological aids. Each mathematical proficiency has three dimensions: (1) the coverage level, the extent to which one can grasp the distinctive facets of the proficiency; (2) the boundary of action, the range of contexts and circumstances in which one can demonstrate that proficiency; and (3) the level of technicality, the extent to which one knows how to apply the mathematical objects and instruments conceptually and technically.

1.1.2 Mathematics EIT Units at the University of Canberra

Mathematics-unit courses in Engineering and Information Technology at UC include Discrete Mathematics, Mathematical Methods, Engineering Mathematics, Contextual Physics with Mathematics, Engineering Mathematics G, Minor in Mathematics in Information Technology, Minor in Mathematics, Foundation Mathematics and Core Mathematics (University of Canberra, 2022a). Each unit specifically addresses the goal of mathematical education and the expected learning outcomes. For example, the objective of the Engineering Mathematics unit is to equip students with the mathematical knowledge and skills required to help them to solve problems in this field. The unit covers mathematical concepts such as integration and differentiation, matrices, complex numbers, functions, limits and continuity, and series and sequences. These mathematics subjects furnish students with firm mathematical knowledge and principles in software engineering. Apart from that, the unit-based courses encourage and reinforce vital all-purpose skills, including skills in self-reliance and group working, communication, inquiry and analysis, problem-solving, professionalism and societal accountability.

Some university mathematics-based units are crucial to the overall mathematics performance of students. For instance, core mathematical skills that students need to master include how to comprehend and operate the symbolic logic language and notation; to apply mathematical concepts to real-life problems; to solve elementary engineering questions manually and complex ones digitally; to perform mathematical analysis and modelling; to analyse real-world problems; to apply elementary mathematical techniques to multiple physical ideas; to use critical thinking, creativity, research and analysis talents for practical and theoretical problems solving, to articulate scientific enquiries, steer, record and assess trials to efficiently tackle them; and to understand and apply mathematical and statistical concepts in a diverse context. Students can develop these abilities by taking several mathematical courses. The knowledge gained from the subjects will enable UC learners to think critically and creatively and perform analysis and research skilfully to solve practical and theoretical problems; world citizens - build and use technology creatively in their education and professional lives.

UC provides study skills to help students develop the skills and confidence that will lead to their success. According to the UC website "The MASH (Mathematics, Stats and IT Help) Centre provides drop-in learning support for mathematics, statistics and IT for students across the University" (University of Canberra, 2022b). In these sessions, students can get help with a range of mathematics enquiries. It can be accessed both face-to-face and online. This learning support is an optional facility that students can benefit from besides the general learning conveyance through lectures, which is somewhat as conventional as chalk and talk method, but nowadays, it uses modern technology to present and deliver lectures.

The conventional or traditional method of teaching at UC is generally practised within Mathematics EIT units and encompasses the routines of reading texts and problems, formulate questions, attending lectures, student discussions, writing and reply brief or extensive questions and objective type questions, solving short or lengthy unstructured problems and cases, oral presentation of the topic and reply to short questions from the students.

1.2 Effective Mathematics Teaching

Vygotsky's social constructivism theory suggests that social communication, social interaction and understanding are fundamental components of successful mathematics learning. In other words, students' communication and interaction with their teachers are indispensable for successful mathematics learning. The processes of learning mathematics are active actions done by learners who carry out assignments and make sense of conceptual mathematical objects rather than obtaining evidence and learning concepts passively. Teachers will actively and creatively construct assignments that offer an invaluable experience to students. In the words of Mason and Johnston-Wilder (2006), students of mathematics will need “relevant experiences from which to extract, abstract and generalise principles, methods and ways of working with mathematics; stimuli appropriate to the concepts to be worked on; and a supportive and compatible social environment in which to work”.

Figure 1.1 shows the four dimensions of mathematics. The purpose of teaching students mathematics is to develop their numerical knowledge and skills, enable them to apply mathematical concepts to a wide range of problems and allow learners to share their mathematical and mathematical concepts. The goal of the teacher is to facilitate this learning. For instance, Pietsch (2009) suggested that “mathematics teachers need to be comfortable with a wide range of mathematical abstractions, techniques, concepts, ideas and generalisations”. Teachers also “need to feel comfortable working with individuals, with people who are fundamentally unpredictable, beyond complete understanding, each person representing a unique exemplar of multiple overlapping abstractions” (Pietsch, 2009). Teachers with weak mathematical knowledge are likely to provide learners with a poor foundation of mathematical concepts, thereby limiting students’ ability to solve complex mathematical problems in universities. Rather than providing shallow learning for mathematics development, educators should provide a fundamentally distinctive method that makes learning fun and entertaining for learners (Pietsch, 2009).

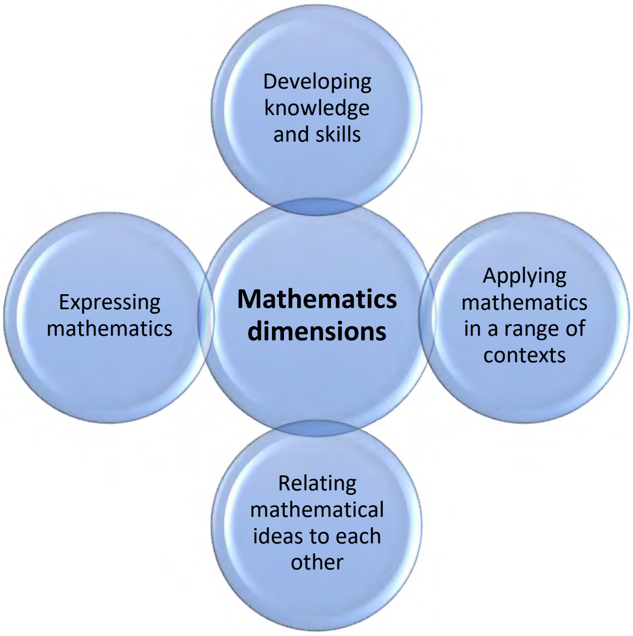


Figure 1.1 Mathematics dimensions

Many stakeholders in the mathematics department have recommended the shift from secluded facts and learning by rote to mathematical problem-solving and conceptual understanding (Chambers, 2008; Jaworski, 2002; National Council of Teachers of Mathematics (NCTM), 2020; Pietsch, 2009).

Researchers propose six codes and ten values to provide guidance to teachers on how to mathematics teaching in classrooms (Leinwand et al., 2014; National Council of Teachers of Mathematics (NCTM), 2000). The six codes are as follows:

1. Learning and Teaching. An outstanding mathematics instruction facilitates active learning. It helps learners to possess an awareness of mathematical concepts and logic.
2. Equity and Access. An outstanding mathematics instruction enables all learners, regardless of their socio-economic backgrounds, to have access to a high-quality mathematics curriculum and mathematics resources.

3. Curriculum. An outstanding mathematics instruction embraces a curriculum that advances significant concepts of mathematics with comprehensible learning developments, and it creates linkages between mathematics fields and between natural and artificial systems.

4. Technology and Tools. An outstanding mathematics instruction incorporates the usage of mathematical technology and tools as indispensable properties to assist learners to build awareness of conceptual mathematics.

5. Assessment. An outstanding mathematics instruction ensures that evaluation is an essential component of programmes, and it comprises a diversity of approaches and resources of data, and it notifies learners on programme pronouncements and programme enhancement.

6. Professionalism. An outstanding mathematics instruction allows teachers to challenge themselves mentally. Teachers are responsible for developing and customizing their pedagogical approach of imparting knowledge.

The teaching of the National Council of Teachers of Mathematics (NCTM) ensures that "students' understanding and ability to use mathematics to solve problems and their self-confidence in and disposition toward mathematics are all shaped by the teaching they encounter in school". To be effective, teachers "have to know and understand the mathematics comprehensively they are teaching and be able to employ that knowledge with flexibility in their teaching tasks … respond to students' questions, make curricular judgments, and look ahead to where concepts are leading and plan accordingly … need to know the areas with which students often have difficulty and ways to help bridge common misunderstandings". Given that "students learn by linking new ideas to prior knowledge, teachers must understand what their students already know".

Understanding mathematics conceptually is a central element of mathematics competency. It makes mathematics more sensible and becomes simpler to apply and remember (Schoenfeld, 1988; Schoenfeld, 2016a). Part of teachers' responsibilities is to create an atmosphere favourable to learning mathematics, one that "encourages students to think, question, discuss their ideas, strategies and solutions and solve problems". According to the NCTM, "learning mathematics without understanding is a big problem and a major challenge in mathematics education" (Leinwand et al., 2014; National Council of Teachers of Mathematics (NCTM), 2000, 2020). Successful teaching practices inspire and encourage learners to engage in reasoning and thinking mathematically and offer learners' the opportunities to test their ideas and challenge their reasoning.

The NCTM's ten standards designate the features of mathematics instruction that allow learners to comprehend and implement mathematics concepts. The standards are separated into two groups, Content and Process. The standards concerning the content comprise five elements: Algebra, Geometry, Number and Operations, Measurement, Data Analysis and Probability. Learners are expected to learn and master these elements at school. The standards concerning the process consist of five components: Representation, Reasoning and Proof, Problem Solving, Communication, and Connections. These components are intertwined, and they offer learners multiple perspectives of mathematics. By learning mathematical problem-solving, students will advance new mathematical understandings and attain new habits of thinking, new behaviour of determination and interest and self-confidence in unacquainted circumstances.

Furthermore, the NCTM indicates that communication is an indispensable fragment of mathematics. Without communication, teachers will find it extremely challenging to disseminate ideas to learners and clarify students' understanding. Students learn how to be certain and conclusive if mathematics knowledge is properly communicated to them. However, communication in mathematics education has been abandoned. The NCTM considers mathematics as a unified subject for a certain field of study, and it believes mathematical communication should be integral to students' experience of learning mathematics. By highlighting mathematical associations, students tend to communicate to solve problems of mathematics rather than considering them as separate ideas and aptitudes.

In addition to the importance of communication, the NTCM supports practices in which mathematical concepts are explained with symbols and applied to everyday problems. Symbolic languages, diagrams, and graphs are not self-explanatory, but they aid students' ability to identify associations and apply mathematics concepts to real-world problems. Students will significantly increase their capacity to think mathematically when they have access to mathematical illustrations. Besides, technological tools give students more opportunities to apply new models of depictions, and they permit students to investigate complicated models. The NCTM reports that students' application of symbols to model corporeal, social and mathematical experiences should be cultivated over time (Leinwand et al., 2014; National Council of Teachers of Mathematics (NCTM), 2000). According to the NCTM, what makes mathematics teaching practices successful is as follows:

1. *Set learning objectives*. Successful teaching creates well-defined objectives, places objectives along with learning development, and utilises the objectives to steer programmed choices.
2. *Employ tasks that encourage reasoning and problem-solving*. Successful teaching enjoins students to answer and debate tasks that foster mathematical reasoning and problem-solving, and it permits several entrance points and diverse approaches.

3. *Apply and relate mathematical illustrations*. Successful teaching results in students' creating relations among mathematical illustrations to extend their knowledge of conceptual mathematics and procedural techniques.
4. *Aid evocative mathematical discussion*. Successful teaching aids discussion among learners, and it helps them to shape their collective knowledge of mathematical concepts by elaborating and comparing students' reasoning and approaches.
5. *Ask focused questions*. Successful teaching uses focused questions to evaluate and develop students' arguments that are essential mathematical concepts and associations.
6. *Construct procedural skills*. Successful teaching enables learners to develop procedural skills in abstract knowledge, and it helps them to manipulate contextual and mathematical problems.
7. *Assist creative effort*. Successful teaching steadily offers learners the possibilities and assistance to involve in creative efforts as they succeed in implementing conceptual association.
8. *Prompt and exploit facts of learners' reasoning*. Successful teaching applies learners' reasoning to gauge advancement in mathematical knowledge and expand learning.

1.2.1 Obstacles to Effective Teaching

The standards mentioned above for successful teaching offer an outline to fortify mathematics teaching and learning. However, the following challenges limit the progress of effective teaching:

1. *Obstacles to Teaching and Learning*. Prevalent cultural views associated with mathematics learning hinder the successful learning and teaching of mathematics in classrooms. Educators and parents have a proclivity to request mathematical teaching styles similar to the ones they have used in the past, such as the habitual repetition of learning concepts, learning drills, remembering facts, and memorising formulas and procedures. This notion permeates the modern teaching style that emphasises evaluation, exposition, and practice. Proponents of this notion are not confident that changing from these conventional views and practices will improve student learning (Leinwand et al., 2014).
2. *Obstacles to Access and Equity. Researchers* have constantly uncovered that disadvantaged students or learners from poor families are more likely to have teachers with poor mathematics backgrounds or weak mathematics accreditation (Battey, 2013; Darling-Hammond, 2007; Flores, 2007; Stiff et al., 2011). In a study, Beswick (2017) explored the perception of mathematics teachers in Australian secondary schools regarding the traits of “poor” students and “good” students and examined how these traits manifested in teachers’ professional development. The researcher found that students with poor mathematics background had weak computational skills, and they lacked adequate knowledge of previously taught mathematical concepts. Findings also revealed that such students had low interest in attending classes, asking their teachers questions, and completing their assignments. Teachers, however, recommended one-to-one assistance, similar-capability group work and separate programmes for these students to improve their learning.
3. *Obstacles* to *Curriculum.* Standardised content for grade-level mathematics is commonly believed as a list of subjects. Content is nothing more than a bulk of

detached abilities, and it is often devoid of real-world settings or separated from associated themes. A conventional course arrangement for high school mathematics covers a year on geometry, a year on algebra, and another year on arithmetic. This curriculum comprises a list of themes and highlights the association among them during the three years. However, the same outcomes can be identified in another grade.

4. *Obstacles to Tools and Technology. Instructional* content occasionally integrates technology in a way that does not encourage logic, sense-making, or discussion. The incorporation of technology simplifies tasks that require time-consuming, complex computation. When students use MATLAB, R package or Excel to obtain solutions, they consider the presented outcomes as the right solution regardless of whether these solutions are plausible or not.
5. *Obstacles to Assessments*. *Assessments* place much emphasis on students' accomplishments, such as their grades. Many stakeholders in the education sector have linked students' performance to their exam scores. A major concern of this approach is the needless politicisation of students' evaluations. Besides, using students' exam scores to gauge students' performance often encourages learning by rote or passive learning (Herman and Linn, 2013). Teachers, therefore, need to prioritise the learning of mathematics concepts rather than emphasizing the acquisition of high-grade scores (Reeves, 2011).
6. *Obstacles to Professionalism*. *Professional* seclusion undermines efforts to improve teamwork among teachers, mathematicians, and other educators (Bill and Melinda Gates Foundation, 2014). This professionalism seclusion limits learning effectiveness for all students, and it impedes professional development for teachers. Nonetheless, some educators have adopted the customs of seclusion

(Hattie, 2012; Hattie and Timperley, 2007). The perils of seclusion are numerous. It sets a dangerous precedent for educators, allowing them to create inequalities among learners (Ferrini-Mundy et al., 1998). However, a study showed better progress in students' attainment when teachers adopted a collaborative habit compared to when they utilised seclusive practice (Moller et al., 2013).

Mathematics has been a difficult subject in the minds of many learners (Tall and Razali, 1993; Tseng et al., 2013). The prevalence of this concept in academic circles is to such an extent that there is a belief only very few individuals can obtain mastery of ranging disciplines. Hypothetically, this would mean that anyone with the capacity to teach mathematics would have to overcome psychological obstacles before they could effectively reach and educate the students. When the students acquire the homework, the mathematics problems are quiet familiar to hear because almost every student has experienced it. The students seemed to be struggling with their homework, especially mathematics problem-solving. According to Amalia, Surya and Syahputra (2017), mathematical skills are involved in mathematics problem solving and these basic skills aren't conceptualised to most of the students, especially those who belong to the non-mathematical background.

As expected, there are many different perspectives on what mathematics is. Most people consider mathematics to comprise arithmetic, algebra, geometry, trigonometry, statistics and probability, a subset of logical thinking and a mechanism for reasoning. In 1962, some 75 well-known U.S. mathematicians produced a paper wherein they stated "to know mathematics means to can do mathematics: to use mathematical language with some fluency, to do problems, to criticise arguments, to find proofs, and, what may be the most important activity, to recognise a mathematical concept in, or to extract it from, a given concrete situation" (Ahlfors et al., 1962).

So, this includes the ability to use cognitive abilities in learning, which is crucial for better understanding, but most of the students find it difficult to use, and that affects their learning ability. Surya (2017) reported that such types of students experienced difficulty in accurate perception and interpretation, using logical thinking and gaining concentration (Amalia et al., 2017; Syahputra and Surya, 2017).

The NCTM believes that communicating mathematics is neglected in mathematics education (National Council of Teachers of Mathematics (NCTM), 2000). It holds mathematics is an integrated field of study and that mathematical connections to contexts outside of mathematics should be part of students' mathematics learning experiences. By emphasizing mathematical connections, students build tendencies to use communication to solve mathematical problems instead of seeing mathematics as a set of isolated concepts and skills (Clements et al., 2017). By considering the burden or already developed schemas about mathematics, the students perceive anxiety, frightened, loss of interest and motivation, and consider it as a boring subject. This dramatically affects their learning behaviour and especially their tendency to solve mathematical problems (Ritonga et al., 2017). Barlow et al. (2017) explored that when a mathematical problem is presented in class, the students act as the problem performers rather than the problem solvers. Rather than understanding the problem, students prefer to use an operation in order to solve it. So, due to this, the conceptuality of the students regarding the problem-solving abilities of mathematics' is not developed. The study showed that undergraduate students face regarding passing mathematics courses (Benken et al. 2015; Searl 1985). Studies from countries around the world and in Australia show that a large percentage of students fail to pass mathematics courses in their last year of high school or first-year of college (Clements et al., 2017).

In order to have a better performance and understanding of mathematics, the NTCM highlighted learning problem-solving strategies in mathematics, which included: students should develop new mathematical understandings and should acquire new ways of thinking. When engaged in problem-solving, students should develop metacognition, and they should frequently monitor their progress and adjust their strategies accordingly. Reasoning and proof include: developing ideas; exploring phenomena; justifying results (arguments consisting of logically rigorous deductions or conclusions); and using mathematical conjectures (informed guessing). The NCTM maintains that students' use of representations to model physical, social and mathematical phenomena should grow through their school years (National Council of Teachers of Mathematics (NCTM), 2000).

Pedagogical Approaches can be categorised into the following:

- Collaborative Learning
- Inquiry-based Learning (IBL)
- Project and Problem-based Learning
- Games-based Learning
- Realistic/Context-aware Ubiquitous Learning
- Social Constructivist Learning
- Instructions Learning
- Experiential Learning
- Knowledge Building
- Situated Learning
- Student Self-evaluation

On the other hand, it is not the learning behaviour of the students that leads to poor performance in mathematics, but the teaching strategies and methods also play an important part. Different studies indicated the factors that affect students' anxiety levels because of the teaching strategies (Pardimin et al., 2019). Some of them include:

Effective Feedback: in which the teacher or the instructor of the mathematics subjects behaves strictly with the students, he/she never appreciates the students, due to which the student remains dumb and loses interest in that subject because of fear.

Too much repetition: in which the mathematics teacher doesn't explain the problem well on the board but repeats the same statement again and again that does not clarify by the students and the point remains ambiguous.

Providing enough Examples: mathematics can't be learned, but it is the subject that is to be conceptualised by practice. So, the instructor or the teacher did not give many examples of the problem so that the student understood the method and comprehended it. The teacher only solves a problem rather than explaining the procedure and the method of solving by putting examples.

Incorporate collaborative problem-solving tasks, open-ended tasks or computer-based work: this point is related to the assignment and papers that the teacher gives to the students. The teacher should design the paper in such a way that the student should collaborate on the previous knowledge in order to solve the problem. It should include open-ended questions that make the student think. The computer-based assignment should be avoided because it is not led to healthy learning (Azimigaroosi et al., 2015).

This area of learning can be enhanced by effective identification of the areas of weakness and addressing the specific needs in an effective and efficient manner. Instructors should move away from traditional methods and adopt modern technological methods for teaching mathematics. The teaching-learning approach may accomplish by the introduction of techniques that would reduce the erratic performance of the students in mathematics and by imparting basic mathematics skills and encouraging the students to take part in collective development (Mushlihuddin, 2018). Strategies, such as the use of appropriately designed and implemented diagnostic testing to actively inform knowledge gaps, have been found to improve teaching mathematics for EIT students. It is evident that there are certain techniques that may implement and improve mathematics learning. Some of the strategies involve allowing the student to interact with their own thought process rather than lecturing. Another is the implementation of technology as a means of ensuring there is complementary input. This enhances access to proper material or provisions of an interface within which they can interact with education software. All in all, some of these strategies show positive results where learners are able to improve their mathematics learning in tertiary institutions.

1.2.2 Mathematics Learning Difficulties

The section above outlines obstacles to effective mathematics learning with more emphasis on the macro-structure of the environments where students experience the learning processes. Equally important for this study is the consideration of an individual learner as a real actor who takes the learning processes pertaining to the difficulties in learning mathematics seriously. The persistent difficulties encountered by a student studying mathematics translates into the constructs of mathematics disability. Mathematics learning disability stems from the inability to embody evidence in one subject of mathematics (i.e., algebra, arithmetic, statistics, and probability). The identification of the cognitive phenotypes is obscured by the problem of differentiating bad accomplishments solely on the ground of insufficient teaching or deficiency in ideal macro-structures (Geary and Hoard, 2005).

The cognitive deficits of children with mathematical disabilities are grouped into three categories (Geary and Hoard (2005). They include the procedural, semantic-memory, and spatial categories. The procedural category indicates students’ ability to solve simple arithmetic problems within a specified time frame. The tactics may not only be an outcome of oral working-memory shortfalls, but it could be a shortfall in understanding abstract conception. The semantic memory category shows students' inability to access evidence due to a shortfall in long-term memory, while the spatial category indicates learners' shortfalls in the three-dimensional depiction of numeral places.

Karagiannakis et al. (2014) proposed more detailed subtypes of cognitive skill deficits. The subtypes consist of a core number, memory, reasoning, and visuospatial. The core number involves estimating numbers and quantities, having number line ability, managing symbols, and performing basic counting. Memory focuses on retrieving math facts, performing calculations, and remembering rules and formulae. Reasoning covers grasping math concepts, complex math procedures, logical problems and problem-solving. Lastly, visuospatial encompasses geometry, written calculations, tables, and graphs. Also, (Andersson and Östergren, 2012) categorised shortfalls in these cognitive skills deficit schemes into several groups: faulty ANS (approximate number system), faulty OTS (object tracking system), faulty numeracy inscribing, and shortfall retrieval. These categories provide insights into mathematics learning difficulties.

The fundamental source of MLD is linked to a shortfall in elementary cognitive functions as specified by the hypothesis of cognitive field shortfall. Students with MLD can achieve considerably worse performance on various cognitive tasks that require the use of long-term memory or working memory. The faulty ANS proposition suggests that students with MLD would find it difficult to tackle tasks that involve a non-symbolic number, such as tasks with scale differences and the number-line. The expectation of a faulty OTS is that students with MLD demonstrate impaired subitising skills. The retrieval of the shortfall proposition suggests that students with MLD would expose to difficulties in tackling tasks that involve symbolic numbers compared to non-symbolic number tasks such as subitising and scale discernment. The multiple shortfall proposition expects students with MLD to perform considerably worse on tasks connected to two of the core shortfall propositions, such as subitising (the faulty OTS proposition), comparing two numbers symbolically (the retrieval shortfall proposition) and comparing non-symbolic numbers (the faulty ANS proposition) (Andersson and Östergren, 2012).

Cognitive deficits could result in mathematic learning difficulties for children in preliminary school. However, Soares et al. (2018) extended this research inquiry to students in high school and found that high school students showed symptoms of mathematics difficulties, which they carried on to the next stage of their learning at the university. Such students may find it difficult to utilise mathematical concepts in day-to-day life, approximate numerical values when solving equations and inequalities, take measurements, and perform exponential and logarithmic functions.

1.2.3 Mathematics Anxiety

A moderate level of mathematics anxiety has a positive impact on students' mathematics accomplishments. Some research revealed that learners perform satisfactorily on mathematical tasks (Jamieson et al., 2016), although it is evident that anxiety affects students' performance, especially in the performance of tasks that require working memory (Dowker et al., 2016). Math anxiety is an adverse emotive reaction that interferes with leaders' mathematics performance (Hembree, 1990). The literature shows that a considerable number of students experience Mathematics anxiety. Chinn (2009) found that 2-6% of high school students in England experienced fear. Johnston-Wilder et al. (2014) discovered that about 30% of trainees in the UK were exposed to excessive mathematics anxiety, with an additional 18% influenced to a lesser degree. In Australia, about 33% of fifteen-year-old students experienced mathematics anxiety (The Australian Mathematical Sciences Institute, 2019), and a 2019

OECD reported that Australia was among OECD countries whose mean performance in mathematics did not change significantly between 2015 and 2018 (OECD, 2019).

Students with mathematics difficulties are known to develop a feeling of apprehension when confronted with questions that require the manipulation of numbers or when asked to solve mathematical problems. Teachers without a proper understanding of Mathematics anxiety often compound students' Mathematics anxiety problems. Weak mathematical attainment is highly associated with mathematical anxiety, particularly when students are required to finish the tasks quickly to obtain the correct answer (Rubinsten and Tannock, 2010). Some studies have explored the relationship between mathematics anxiety and measures of general anxiety. However, there is little evidence of whether mathematical anxiety is a distinctive problem or a general feature of anxiety. Wang et al. (2014) found evidence that general anxiety grounded on genetic variances promoted mathematics anxiety. Nevertheless, other studies reported that measurement items of mathematics anxiety were associated with higher inter-items, not with test anxiety or general anxiety (Ashcraft and Krause, 2007). Students' mathematics anxiety is believed to grow as early as first grade (Maloney and Beilock, 2012). Brain activity showed that mathematics anxiety was associated with aberrant activity in the right amygdala. Students with lowered reactions in cortical and subcortical zones were found to have poor mathematical thinking (Menon et al., 2000). This agitated amygdala function influences anomalous working communications when a person is solving mathematical problems (C. B. Young et al., 2012).

1.2.3.1 Mathematics Anxiety and PISA Findings in Australian Settings

The Australian Council for Educational Research studied learners' manners and enthusiasm for mathematics in its 2012 cycle, where mathematics constituted the major field. Compared to the outcomes of the 2003 cycle, the outcomes of the 2012 survey show a growth in mathematics anxiety, particularly among female students (Thomson et al., 2013a). The findings verify that Australian scores on motivation, self-efficacy, and attitude are similar to or somewhat greater than the average scores of OECD countries. Higher marks demonstrating higher levels of Mathematics anxiety were common among girls aged 15 years. The mathematics anxiety index permits comparative evaluations of various groups' mathematics performance. The motivation level to study mathematics was below the OECD average for Australian female students. The biggest gap in the mathematics anxiety index between gender was found among individuals in New Zealand and Australia. Male students were confident that they were more proficient in mathematics than female students. These results suggest mathematics anxiety poses a huge threat to students' mathematics performance in Australia.

In Australia, the biggest difference in the mathematics anxiety index was found among males and females. The difference is huge and comparable to that between aboriginal and non-aboriginal students. This poor mathematics performance index can be traced to the declining socio-economic status of students. Statistics suggested that 33% of students aged 15 were from disadvantaged families. In 2012, most students with mathematics anxiety were from single-sex schools, not from co-ed schools (Stoet et al., 2016). The PISA report also found greater mathematics anxiety among girls in years seven and eight (O'Keeffe et al., 2018).

In conclusion, several researchers found a negative relationship between mathematics anxiety and mathematics self-efficacy (Goetz et al., 2010; Hoffman, 2010: Jain and Dowson, 2009). Students are more likely to feel anxious if they think that they are not good at mathematics. Furthermore, the higher the age of students, the more they feel tense about mathematics. Research, however, shows that mathematics anxiety tends to fade as students grow older (Dowker, 2005); Mata et al., 2012).

1.3 Research Motivation and Rational

A considerable number of learners consider mathematics a difficult subject (Tall and Razali, 1993; Tseng et al., 2013). The notion that only a few individuals can master a range of disciplines is prevalent in the academic community. Hypothetically, this view suggests that anyone with the capacity to teach mathematics needs to overcome psychological obstacles before they can effectively teach students. A teacher needs to maintain an approach that reduces students' negative perceptions of mathematics. However, a difference in outcomes could exist if the students already have a strong background in mathematics. In such cases, teaching mathematics to EIT students may not pose a great challenge to teachers, given that much of their coursework involves the application of mathematical principles. Despite this general assumption, some students in the engineering department still find it difficult to grasp mathematical concepts (Nortvedt and Siqveland, 2019). Such students may still fall into the category of those not pursuing technical courses. Therefore, mathematics may or may not be difficult to teach, depending on the audience's background in mathematics.

Undergraduate students struggle to pass mathematics courses (Benken et al., 2015; Searl, 1985). A significant proportion of students do not pass mathematics courses in the first year of college, as it was evidenced by global studies and in Australia (Kafata and Mbetwa, 2016b; Nicholas et al., 2015; Oliveira and Freitas, 2016; Saxe and Braddy, 2015). Even though some nations have invested in encouraging students to acquire Science, Technology, Engineering and Mathematics (STEM) education, some students are yet to adept at solving mathematics problems (OECD, 2015; Yaşar et al., 2006b).

For decades EIT students have been confronted with finding mathematical solutions to real-world problems. Several learning methods have been leveraged to achieve this goal, yet more effort is needed to improve students' learning outcomes in mathematics.

Mathematics manipulation has been performed conventionally with traditional tools such as paper, pencils and whiteboards. Currently, PowerPoint and interactive lessons have been integrated into college learning to enhance students' learning experience. Despite the emergence of advanced education technologies, many undergraduate EIT students lack computational and mathematics problem-solving capabilities. EIT instructors are expected to create learning or teaching methods that enable students to understand mathematics concepts and apply them to solve real-life problems (Chubin et al., 2008; Pinder-Grover and Groscurth, 2010).

The EIT instructors aim to create a conducive environment that accommodates those students with poor qualifications in mathematics. This goal could be achieved by identifying areas of weakness and addressing students' mathematics needs effectively and efficiently. It can also be accomplished by introducing techniques that will reduce students' mathematics anxiety, imparting basic mathematics skills, encouraging the students to take part in collective development, promoting a culture of studying and utilisation of the available resources in improving their competence, and conducting personal investigations aimed at identification of problems. No single approach can fully address the mathematics needs of all students. Hence, it is pertinent that instructors develop tailored solutions to meet individual challenges.

Most EIT students must treat mathematics not as their primary program of study but as a secondary subject. Non-specialist mathematics classes can be organised for students with poor backgrounds in mathematics. To provide satisfactory teachings to such groups is difficult, however, as some learners think mathematics has no relevant connection to their primary subject. Most learners think mathematics is difficult and boring because they have no use for it in their future careers or because they do not have a strong background in the subject. (Searl, 1985). Such difficulties are linked to inadequate fused content. Moreover, it is difficult to verify the cause or the symptom of mathematical learning difficulties that bring about the low accomplishment of undergraduate students.

Jaworski (2008), for example, showed that class attendance was erratic, with no definite pattern to define the nature of the students. This trend was the same for first-year EIT students with low scores in Mathematics subjects, a trend that makes it difficult to establish a probable conclusion. Learners' behaviour towards the learning course, as well as the interaction of the students with the information sources, was fairly good. However, the unit did not have the desired outcomes as the performance was low.

Evidence from the literature review indicates that there is a need for effective methods for teaching EIT students mathematics. Instructors should abandon traditional methods and adopt modern methods for mathematical learning. Strategies should include the application of appropriately designed and implemented diagnostic testing to actively close knowledge gaps and improve EIT students' performance in mathematics.

It is evident that certain techniques can help improve mathematics learning. Some of the strategies involve allowing students to interact with their thought processes rather than lecturing them. Another strategy includes using technology tools to enhance learning. Some of these strategies have shown positive results: learners have been able to improve their mathematics learning in tertiary institutions. Educators should also acknowledge the need to incorporate more efficacious methodologies, curricula, strategies, and professional training to satisfy students' pedagogical needs in EIT fields.

The literature review of this study has demonstrated that the benefits of EIT students' engagement are moot. However, the degree of enhancements resulting from active-engagement approaches may fluctuate in different cases. Another finding is that content-driven subjects enhanced by modern technologies will make students concentrate and remember concepts taught in the classroom. Several studies suggest that mathematics educators should structure their mathematics courses to improve student mathematics performance.

After reviewing the literature on mathematics education, this paper finds that some research areas need to be fully developed or tested. These areas include:

- Investing more time in selecting, developing, and presenting high-quality content on mathematics learning materials;
- Fostering the use of adaptive blended learning in teaching courses;
- Designing an effective diagnostic tests and assessments system; and
- Integrating a multidisciplinary pedagogical approach, such as incorporating the cooperative learning approach with modern technology.

In addition, factors that can affect students' engagement in mathematics classes were not systematically explored in the reviewed papers. The factors include the following:

- Students' anxiety levels;
- Effective feedback;
- Too much repetition;
- Providing enough examples; and
- Integrate cooperative activities for spontaneous responses, software-related tasks, and problem-solving tasks.

1.4 Research Questions

The three main research questions of this study are as follows:

Q1. What are the impacts of the UC mathematics teaching approach on the first-year EIT students' collaboration, understanding, and achievement in mathematics courses?

Q2. What factors motivate EIT students to engage or lose interest in mathematics?

Q3. Does implementing a multidisciplinary pedagogical approach enhance the effectiveness of student mathematics learning for UC's EIT students?

1.5 Aims and Significance of the Study

This study aims to examine the effectiveness of the pedagogical approaches used by teachers in addressing the mathematics challenges faced by first-year EIT students at UC. It discusses and explores some of the research gaps found in the literature. The goals of this study include the examination of the impact of mathematics teaching approaches on first-year EIT students' collaboration, understanding, and achievement in mathematics courses at UC. It also provides suggestions that can make EIT students more motivated and successful in their mathematics-related courses. This study is worthwhile in that the findings can provide insights into the factors that cause university students to be uninterested in learning mathematics.

1.6 Organisation of the Thesis

The remainder of this thesis is organised as follows: Chapter 2 reviews and discusses previous literature related to the research topic. The identification of the knowledge gap in the research area is also carried out in this chapter. Chapter 3 elaborates on the comparative studies between online and face-to-face learning methods with reference to mathematics subjects in Australia. Chapter 4 discusses the justification and selection of research design and methodology, while Chapter 5 highlights the pilot study results conducted prior to the main research. Chapter 6 discusses the quantitative phase, including the survey data analysis and survey findings. Chapter 7 elaborates on the qualitative phase, including the interview data analysis and the emerging themes and findings of interview responses. Chapter 8 presents the discussion and highlights the findings of the quantitative and qualitative phases, while Chapter 9 presents the new contributions, recommendations, and suggestions.

2 Comprehensive Literature Review

Despite equal opportunity policies and significant investments in mathematics education, educators still face complex challenges in improving the mathematical skills of undergraduate EIT students. This chapter offers insights into how educators have addressed the challenges encountered by students with weak mathematics backgrounds. As well as focusing on some of the pedagogical techniques used to enhance the mathematics performance of these students, this chapter explores the development and application of creative methods that can improve mathematics learning outcomes. The literature review process was comprised of three main steps: the search for relevant papers, the screening of research data, and the analysis of the literature. Research information on university mathematics education and teaching was obtained electronically from the literature through three primary databases: Scopus, the Education Research Complete (ERC), and the Education Resources Information Centre (ERIC). Analysis of the literature reveals the significance of understanding the underlying causes of students' weak foundation in mathematics. The review indicates the need to further develop innovative pedagogical strategies that can improve EIT students' mathematics performance.

2.1 Introduction

Mathematics is generally perceived as a "problematic subject" worldwide (Fritz et al., 2019; Tall and Razali, 1993; Tseng et al., 2013). The pervasiveness of this perception in the academic space has reinforced the notion that only individuals with special numerical abilities can gain mastery of mathematics. Compared to other university students, EIT students are expected to have a strong background in mathematics, but a significant proportion of them have been found to have poor numerical skills and weak quantitative reasoning (e.g. (Nortvedt and Siqveland, 2019). To overcome this psychological barrier, mathematics educators must identify students' underlying problems of mathematics incompetency. They should also create enabling environment that can diminish these psychological roadblocks to learning mathematics. Even though mathematics learning is brain-racking and time-consuming for students, mathematics educators are responsible for tailoring their pedagogical methods to make mathematics learning easy and fun for students, especially those from low socio-economic backgrounds.

The difficulties in mathematics learning are believed to stem partly from neurocognitive aspects of the brain (dyscalculia). In a survey, most low-performers acknowledged that most mathematics difficulties could be traced to environmental factors such as students' quality of education and opportunities to learn mathematics. However, the basis for students' weak mathematics performance cannot be explained by a single causal model. Other interrelated factors that explain why many students are struggling to become adept at numerical skills include students' social background, public policies, the school environment, and the quality of pedagogy used by educators. By examining these factors, researchers can identify pedagogical models suitable for improving mathematics learning outcomes in universities (Marope et al., 2017).

A considerable number of undergraduates worldwide have been finding it difficult to pass mathematics-related courses. (Benken et al., 2015; Searl, 1985). Many studies indicated that a high proportion of students failed to complete mathematics courses in their last year in high school or first year in college (Kafata and Mbetwa, 2016b; Oliveira and Freitas, 2016;

Saxe et al., 2015). More worrying is the fact that integrated approaches to education in STEM, which aims to improve labour force development, have not succeeded in mitigating students' hardship in learning mathematics (OECD, 2015; Yaşar et al., 2006b). Even though mathematics educators experimented with different teaching strategies to help EIT students cope with the challenges of acquiring mathematical skills, students' poor socio-economic background has remained a dampening factor to mathematics interventions.

The advancement of information technology (IT) has led to the replacement of traditional teaching methods with modern pedagogical techniques. Pencils, papers, chalks, chalkboards, whiteboards and other traditional teaching materials are now replaced with electronic hardware and software applications that enhance learning, such as laptops, tablets, PCs, Microsoft Word, and PowerPoint. However, the shift in pedagogical practice has not made a significant difference in terms of students becoming more attuned to learning mathematics. Today's EIT mathematics educators and researchers are expected to cope with students' learning difficulties in mathematics, and part of their responsibilities is to continuously develop and perfect their pedagogical approaches and ensure students' behavioural change towards learning mathematics and using mathematical concepts to solve real-life problems (Chubin et al., 2008; Pinder-Grover and Groscurth, 2010).

One of the main goals of mathematics teaching in the first-year undergraduate programme is to provide a favourable learning environment to "mathematics-disadvantaged" students. This goal serves as a guide to educators, helping them to assess the distance between the actual development level as determined by independent problem-solving and the higher level of potential development as determined through problem-solving in collaboration with competent peers and teachers (Walshaw, 2016). Teachers are expected to assist students with mathematical learning difficulties through the introduction of techniques that would diminish students' poor performance in mathematics by strengthening their basic mathematics skills, offering learning support, encouraging such students to engage in collective development, and fostering a culture of learning mathematics at school and home. Admittedly, there is no one approach that can meet the mathematics needs of all students.

Furthermore, the perceived irrelevance of mathematics in relation to students' main subject discipline may explain why some students elect not to take the subject seriously. Many non-specialist mathematics classes consist of diverse students with different mathematical backgrounds and capabilities. This diversity may also pose a problem to teachers as no single pedagogical approach can meet all the mathematics needs of such learners. At times, students' motivational problems arise from this kind of situation. Some researchers pointed out that students' mathematical difficulty is mainly due to the lack of basic mathematical skills, not due to inherent intellectual difficulties (Reeve, 2019; Searl, 1985). Advanced mathematical concepts are usually based on basic mathematics concepts, and students who lack the former knowledge are likely to find it herculean to understand new mathematics concepts. Jaworski (2008), for instance, pointed out that students with a weak background in mathematics skipped classes or showed low interest in learning mathematics-related courses in the classroom. This tendency was common among first-year EIT students, including learners who believed that mathematics was irrelevant to career goals. The review indicates the need to further develop innovative pedagogical strategies that can improve EIT students' mathematics performance.

This chapter aims to critically review the variety of pedagogies and strategies adopted by educators teaching mathematics at the EIT undergraduate level and to identify the most effective approaches currently applied in the universities. The rest of the chapter is organised as follows: Section 2 provides a background to the methodology employed in this review. Section 3 discusses previous literature reviews related to the topic, while Section 4 analyses relevant research works published on the research inquiry. Finally, the conclusions and recommendations regarding the pedagogies best suited to teaching mathematics are provided in Section 5.

2.2 Methods

2.2.1 Study Design

The study design, which was a systematic literature review, consisted of three steps: the search for research papers, the screening of researcher papers based on inclusion and exclusion constraints, and the analysis of the literature.

2.2.2 Search Strategy and Databases Sources

All research information was obtained from three electronic databases: ERC, Scopus and ERIC. These databases were selected because they included a wide range of high-quality mathematics education journals. Scopus is a cloud database that provides comprehensive research materials relevant to numerous disciplines, including research information on mathematics learning and teaching (Leydesdorff et al., 2016). Compared to databases such as ProQuest and Google Scholar, Scopus comprises in-depth research information (Aguillo, 2012; Bosman et al., 2006). Also consulted and supplemented with Scopus searches were the ERC and ERIC cloud databases.

Table 2.1 Search strategy keywords for Scopus, ERC, and ERIC

Scopus	ERC	ERIC
TITLE (math* OR calculus OR algebra OR geometry OR arithmetic OR statistics)	(TI (math* OR calculus OR algebra OR geometry OR arithmetic OR statistics))	+title:(math OR mathematics OR math OR calculus OR algebra OR geometry OR arithmetic OR statistics)
AND	AND	AND
TITLE (teaching OR learning OR pedagog*)	(TI (teaching OR learning OR pedagog*))	+title:(teaching OR learning OR pedagogy OR pedagogical)
AND	AND	AND
TITLE-ABS-KEY (engineer* OR "it" OR "information technology")	(engineer* OR "IT" OR "information technology")	(engineer* OR IT OR "information technology")
AND	AND	AND
TITLE-ABS-KEY ("higher education" OR university OR college OR post-secondary OR post-compulsory)	("higher education" OR university OR college OR post-secondary OR post-compulsory)	("higher education" OR university OR college OR post-secondary OR post-compulsory)
AND NOT	AND NOT	AND NOT
TITLE-ABS-KEY (primary OR elementary OR secondary OR "early childhood" OR kindergarten OR preschool OR k-12))	(primary OR elementary OR secondary OR "early childhood" OR kindergarten OR preschool OR k-12)	(primary OR elementary OR secondary OR "early childhood" OR kindergarten OR preschool OR k-12)

2.2.3 Research string

Several research keywords were used in the review to improve the search for research materials needed. All information pertaining to tutoring and learning mathematics in universities or institutions of higher learning was obtained from the aforementioned databases. Logical connectives such as AND, AND NOT, OR were employed to streamline the search. After the search, some research materials were excluded from the list. The excluded research papers included publications on specific didactical practices, including documents that examined special groups of students, such as disabled or gifted students. Also excluded were materials that failed to deal with first-year students in universities and those that were not relevant to the research objectives. Regardless, only research papers published in English were considered in the review, and the overall enquiry was customised according to the search guidelines of each online database. The search filters used in the review included the language, search dates, and type of documents (e.g., journals, conference proceedings). Table 2.1 illustrates the search terms and phrases.

2.2.4 Inclusion and exclusion criteria

The inclusion criteria employed in performing the systematic review are as follows:

- Research papers published between 1970 and 2022.
- Peer-reviewed journals and conferences translated into the English language.
- Represent a formal study design that can be replicated in other universities.
- Validation of studies in real settings.

However, the excluded research materials are as follows:

- The exploration, application or implementation of pedagogies and teaching strategies in elementary school, middle school or high school.

- Thesis, opinion papers, technical reports, posters, book reviews, commentaries or editorial reviews.

2.2.5 Study selection process

Two tasks were performed in the selection process. The tasks are listed and explained below:

- Task 1. Title and abstract selection. Preliminary screening of titles, keywords, and abstracts. This screening was instrumental in choosing research projects that explore the use of diverse strategies for teaching mathematics at the EIT undergraduate level.
- Task 2. Exclusion of duplicate items. All research papers identified were recorded in a library database, i.e. Endnote[1] software. This software has a built-in feature to identify and remove research duplicates.

2.3 Related Literature Reviews

The systematic review was performed using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) model. All the themes related to pedagogical approaches in the identified research papers were compiled and thematically coded. The identified themes contained information related to mathematics education, and they aided the achievement of the research objectives. The following questions guided the research articles selected for the review: Is the article peer-reviewed? What were the limitations and recommendations? Was the evaluation of the research paper rigorous and compelling?

This review explores diverse research papers that identify strategies and pedagogies for mathematics teaching. They can be categorised as follows:

[1] https://endnote.com

- **Systematic reviews**. These are reviews of education methodologies associated with topics about college-level mathematics. In their systematic review of 82 studies, Rakes et al. (2010) characterised the methods of instructional enhancement in Algebra. They found five improvement strategy types. They include manipulatives, instructional strategies, nontechnological curriculums, technology curriculums, and the use of technology tools. These strategies yielded positive results, and the outcomes were statistically significant. The learning focus of the results standardised students' learning curve.
- **Reviews of didactic methods**. These are reviews about science pedagogies for higher education. Having explored the effects of teaching mathematics to Australian students, Sullivan (2011) found six imperative methods that could be applied to upgrade the effectiveness of teaching mathematics. They include the articulation of the goals, the development of scholarly connections, the coordination of students, the differentiation of existing challenges, the creation of lesson structures, and the promotion of seamless comprehension of principles and knowledge transfer. Md Shamsudin (2014) performed a systematic review of science education in Malaysia. The review showed the importance of encouraging creative teaching based on learning styles
- **Reviews of teaching methodologies.** These are reviews concerning the application of teaching methods at different educational levels. Yousef et al. (2014), for instance, critically analysed 76 studies of video-based learning (VBL). The researchers identified four learning dimensions: (i) effectiveness, (ii) teaching methods, (iii) design and (iv) reflection. The review results revealed the efficacy and usefulness of VBL as a potent medium for teaching. M. F. Young et al. (2012) performed a systematic review, examining more than 300 articles on gaming-based education at the K-12 level. Although they found that video games could positively impact language learning,

history, and physical education (specifically exergames), the effect was not the case in science and mathematics. Heo and Choi (2014) examined the flipped classroom practice in middle schools in Japan and found that students' self-directed learning has a positive association with academic achievement. Also, Rocha and Araújo (2016) researched 30 studies on mobile learning for teaching mathematics and science at different educational levels and found that interest in mathematics learning has intensified since 2009. These studies revealed a positive effect of the application of m-learning activities.

Nevertheless, the previous studies mentioned above were driven by the search for a specific methodology or instructional strategy (e.g., video-based learning and video games) in primary and secondary schools. For some teachers and students, teaching and learning mathematics in engineering and information technology (IT) has been a tricky endeavour. Extant studies have revealed that pedagogical methodologies impact students' level of understanding. Educators acknowledge the necessity to incorporate the most effective curricula, methodologies, strategies, and professional development to enhance students' learning in EIT fields. R. B. Young et al. (2012) noted that less than 20% of high school seniors understood essential mathematical concepts. The National Assessment of Educational Progress (2000), however, found only a slight improvement in mathematics. For instance, an estimated 26% of high school seniors demonstrated a sufficient understanding of mathematical concepts (Perry and Steck, 2015). Based on these findings, the literature will be reviewed to ascertain pedagogies for teaching EIT students mathematics effectively.

2.4 Literature Analysis

This study found in the literature six innovative methods for teaching mathematics to EIT students effectively. They include assessment-based methods, technology-based methods, interdisciplinary methods, instructional and content-driven methods, lesson study, and teaching for robust understanding.

2.4.1 Assessment-based methods

Yang et al. (2017) conducted an experimental study by examining the effectiveness of an interactive mathematics learning system. Their approach was grounded on a two-tier test diagnostic and directing strategy, which was employed in refining students' learning performance and confidence in learning calculus. In their study, learning performance was linked to selecting the correct answers and then justifying the selection of answers. Yang et al. regarded mathematical skills as a core competence for science and engineering students in the university. They further observed that many mathematics and engineering departments were displeased with the enthusiasm of first-year students towards improving their mathematics competency. To counter the decline of mathematics performance among first-year students, they suggested the incorporation of effective instructional tools and approaches into mathematics learning in universities. The incorporation included the practice of pedagogical approaches, new tools, and methods. Yang et al. (2017) further proposed a new mathematics learning system, which is based on an instant diagnostic and guiding strategy, to enhance students' calculus learning outcomes. Diagnostic testing refers to a technique used by educators to examine students' learning misconceptions or problems. The proposed approach not only improved the students' learning performance but also boosted their confidence in learning calculus (Yang et al. (2017).

The use of diagnostic tests is highly effective in assessing students' learning outcomes and providing learners with useful assistance. Originally proposed by Yang et al. (2015a), the two-tier testing method is one of the widely adopted diagnostic testing approaches. It includes a set of two-tier multiple-choice questions. The first tier, on the one hand, aims to test students' factual knowledge of the phenomenon under investigation. The second tier, on the other hand, aims to examine the reason underlying the choice made by learners in the first tier. The analysis of the work of (Yang et al., 2017; Yang et al., 2015a) showed that the diagnostic test approach is highly effective in the teaching and learning process. This approach not only improves students' learning performance but also boosts learners' confidence in solving calculus problems. Despite the importance of their work in offering a hands-on tool for solving mathematics problems, their approach has some limitations. One limitation is that their findings may not be applicable to the other groups of learners. Another limitation is that the subject sample was not representative of the actual population. These limitations should be considered when considering the implementation of the two-tier testing method.

Furthermore, Vandenbussche et al. (2018) examined the impact of the prerequisite skills on students' ability to learn calculus successfully. According to them, the lack of prerequisite knowledge was an obstacle for students with poor mathematics backgrounds. Vandenbussche et al. (2018) suggested that for students to succeed in mathematics-related courses, they needed to participate in a remediation program. Universities and colleges in the US have continued to develop and implement programs that aim to bridge the gap between students' present mathematical knowledge and the knowledge required for them to succeed in calculus. Therefore, prerequisite assessment is essential to increasing mathematical skills and knowledge among students taking engineering and IT courses.

Some researchers have performed various studies with the aim of assessing mathematics teaching methods, students' mathematics performance, and the central role of assessment-based learning methods on students' mathematics achievements. For instance, Zhan (2020) performed an exploratory study of classroom assessment strategies. Ukobizaba et al. (2021) conducted a systematic review with the aim of assessing strategies used to assess learners and the extent to which these strategies supported the reinforcement of learners' mathematical problem-solving. While Frank et al. (2018) investigated the impacts of formative feedback and scaffolding to develop outcomes for complex problem-solving, Radmehr et al. (2018) proposed an assessment-based model to explore a mathematical problem-solving system by utilising a revised bloom's taxonomy and facets of metacognition.

In addition, Zhan (2020) conducted a simulation study in which he investigated and evaluated the performance of four estimation strategies for classroom assessment. The strategies included the simultaneity strategy, the Markov strategy, the anchor-item strategy, and the separated estimation strategy. Findings revealed that the simulation could provide effective diagnostic feedback to practitioners. This result was congruent with the idea of ''assessment for learning'' and the need for a formative assessment. A longitudinal study evaluated students' knowledge and skills and identified their strengths and drawbacks over a period. The data gathered from the longitudinal learning diagnosis provided researchers insights into learning models that could be used to guide individual development over time, as well as evaluation of remedial teaching effectiveness. Timely diagnostic feedback is beneficial for teachers and students, allowing them to correct their learning and teaching mistakes found in the existing diagnosis.

In their systematic review, Ukobizaba et al. (2021) addressed two proposed questions: (i) what assessment strategies have been used to assess learners' mathematical problem-solving skills from 1997 to 2020? and (ii) to what extent have these assessment practices reinforced learners' mathematical problem-solving skills? The results showed that authentic assessments and performance assessments had been performed in most of the reviewed studies. All the reviewed assessment strategies have been instrumental in encouraging learning achievement, motivating students to solve complex problems, and boosting students' active learning in understanding mathematics concepts. Ukobizaba et al. (2021) suggested that the assessment of students in a way that improves their understanding of mathematical concepts would strengthen their ability to solve real-life problems.

Frank et al. (2018) discussed the role and influence of formative feedback and scaffolding in amplifying results for complex problem-solving in a compulsory first-year course in engineering design and practice at a medium-sized research-intensive Canadian university. They categorised formative feedback into tasks and process-level feedback on scaffolded tasks in-class, formative assignments, and post-assignment review. They also evaluate the enhancement of complex problem-solving and modelling responses from student surveys, an external longitudinal study, and a direct criterion-referenced assessment of course outcomes from 2013 to 2015. The findings indicated that students improved their mathematics performance in solving complex mathematics problems during the period. Also, the inclusion of new feedback and scaffolding enhanced students' accomplishments.

Radmehr and Drake (2018) proposed a novel assessment-based model for exploring mathematical problem-solving by utilising a revised bloom's taxonomy and facets of metacognition. They employed Revised Bloom's Taxonomy (RBT) in conjunction with Efklides's metacognition framework to design questions to address the different RBT cognitive processes and knowledge types. Exemplified by considering the case of integral calculus, the method could be used to review the teaching, learning, and/or assessment of mathematics at either senior secondary levels or undergraduate levels or both. Findings revealed that in terms of RBT, many students demonstrated more competency in tasks that required basic knowledge and cognitive processes than in tasks that required advanced knowledge. They also found that the inclusion of definite question types could enhance students' understanding of the topic.

Overall, several studies explored in this study confirmed that they were suitable for both the specific RBT units.

2.4.2 Technology based methods

Madeira et al. (2012) noted that blended learning or hybrid learning, which combined both traditional and computer-mediated activities, appeared to be an effective pedagogical approach of teaching mathematics to engineers and IT students. Web-based teaching systems have been instrumental in the application of blended learning. According to Madeira et al. (2012), hybrid learning is essential in enhancing engineering students' mathematics abilities. The Moodle-based tool is highly effective in integrating assessment tests. A similar study has shown that Moodle can improve engineering and IT students' mathematics performance. Moodle offers various functionalities that focus on participation, communication, and collaboration between teachers and students. Madeira et al. (2012) advised a pedagogical approach that integrated Moodle and the b-Learning4Math project. They believed that both approaches improve learning outcomes in mathematics courses. Currently, they are rated as one of the leading open-source course management systems.

Furthermore, Madeira et al. (2012) pointed out that e-learning technologies offered opportunities for new methods of monitoring teaching process outcomes. In their words, an online test module combined with the option to print in a pdf format was a powerful instrument for knowledge acquisition. As well as facilitating students' performance assessment, the tool enabled students to exercise their learned knowledge and stimulate their engagement in mathematics learning. Hence, blended learning implementation, which combines Moodle-based teaching tools, has substantial effects on student learning. Aktas and Omurtag (2013) studied effective strategies for teaching mathematics to engineering students. They observed that while different forms of online education keep gaining traction in higher institutions of learning, engineering courses seem to be lagging behind. In their view, this challenge could be traced to the difficulties experienced with mathematics-based lecturing courses (Aktas and Omurtag (2013). The study divided the subjects into two categories: one category experimented with the usual classroom lecture style, while the other category integrated a partial online style. The purpose of the categorisation was to compare the two methods' effectiveness in addressing mathematics teaching among engineering students. Compared to those in the traditional lecturing setting, students subjected to online teaching reported a slightly higher grades. The statistical tests, however, showed no statistical difference between the two approaches. The findings suggested that online courses could improve mathematics learning among students enrolled in engineering courses. In this case, partial online teaching could play a fundamental role in improving the teaching of mathematical-based engineering courses. Hadjerrouit (2015) was among the researchers that suggested appropriate methods of teaching mathematics to EIT students. They evaluated the appropriateness of SimReal+ in pedagogy education. The tool was initially developed to teach mathematics in higher institutions of learning. Today, mathematics-oriented schools use SimReal+ because of its effectiveness.

SimReal+ is an important pedagogical teaching tool for imparting mathematics knowledge to EIT students. According to Hadjerrouit (2015), SimReal+ is a useful learning tool for teaching and learning several topics related to mathematics, such as physics and engineering. This tool shows that visualisations are effective methods for learning mathematics, and it systematically presents various topics and concepts related to mathematics. Visualisation refers to the capacity to depict information using graphs, pictures, images, animation, and diagrams, with the main objective of improving the understanding of vast amounts of information. With SimReal+, vast amounts of data can be visualised and understood easily.

Unlike other researchers, An et al. (2011) considered music as an essential tool in enhancing engineering teachers' attitudes and confidence toward mathematics. In their exploratory research, they suggested that by incorporating music in a mathematics classroom, teachers' confidence and positive attitude toward mathematics would improve. Their results indicated that mixing music in a mathematical lesson had a positive influence on educators' beliefs and attitudes towards teaching and learning mathematics. Researchers have long argued that traditional approaches to teaching mathematics played a major role in students' poor performance in mathematics. They suggested the curriculum should integrate new pedagogical techniques, such as the incorporation of music in classrooms when teaching mathematics to EIT students. Silva et al. (2021) sought to understand how artefacts were orchestrated where math was done with music and identify how these artefacts became epistemic tools for students. Their findings suggested that mathematics performance could be enhanced with music.

Shih et al. (2012) performed quasi-experimental research to examine the effectiveness of an instructional model and learning system that integrates a computerised adaptive diagnostic testing system, ubiquitous learning, and the campus mathematics path learning in refining the teaching and learning mathematics. In their study, they developed a ubiquitous learning environment known as the adaptive U-learning mathematics path system. The findings justified the effectiveness of the system in enhancing students' achievement in mathematics and the rationale for incorporating the U-learning mathematics path.

Díaz et al. (2010) investigated the effectiveness and reliability of Computer Algebra Systems (CAS) in refining mathematics teaching and learning for engineering students. They pointed out that the use of traditional methods limited mathematics teaching and learning. Díaz et al. (2010) enhanced pedagogical approaches to teaching mathematics courses for EIT students by highlighting the need to properly use CAS, including Maxima, as it allowed students to build their own numerical knowledge and solve complex mathematical problems. CAS also equip learners with the skills needed to be productive in society.

Juan et al. (2011) stressed the role of technology in driving the quality of education. They mentioned several learning systems as essential in facilitating high-quality education, such as learning management systems (LMS), internet resources, individual and collaborative learning, and academic content in digital format. Also crucial in refining the quality of education is such software as groupware, subject-related software, and social network software. et al. (2011) made many suggestions in this study with the single aim of improving the quality of education. They suggested the need to increase mathematical proficiencies by integrating robust learning management systems. This strategy encompasses devoting extra time to selecting high-quality learning content, creating an assessment system that is based on regular assessment during the course, and nurturing the use of statistical and mathematical software in teaching mathematical courses (Juan et al., 2011).

Rubio et al. (2010) emphasised the role of the web-based appliance in descriptive geometry learning. According to them, computer-aided learning (CAL) is instrumental in developing teaching and learning approaches. They shared the view that technology could improve the dissemination and learning of STEM subjects. Apart from that, CAL has proven effective in assisting undergraduate students in studying descriptive geometric learning. Karr et al. (2003) expounded on the effectiveness of online learning in improving mathematics teaching. While mathematics is a central subject, a large number of students are yet to notice improvements in their mathematics performance of ineffective teaching/ learning strategies. The better performance of an online teaching model is a strong signal that online-based systems are essential in augmenting students’ achievements in technical subjects like engineering, IT, and mathematics.

Karr et al. (2003) compared both online and traditional pedagogical methods. Students who used online delivery modes performed better academically than those who employed traditional teaching methods. Karr et al. examined whether a difference existed between the online delivery approach and the mixed delivery approach. Comparatively, students that adopted hybrid learning performed better than those that used either traditional or online learning. Their findings indicated that despite the effectiveness of an online-based delivery system over the traditional delivery methods, blending both online and traditional delivery methods proved to result in higher academic performance.

Martin (2011) noted that the advent of information technology had unlocked tremendous opportunities for mathematics teachers. The researcher observed that the role of technology in improving the students' skills acquisition was apparent in schools. Today, most schools have blended IT into their curriculum. Thanks to advancement in IT, many colleges and universities can now expand their reach and presence around the globe. Compared to the traditional classroom, a computer-aided classroom motivates students to visualise learning concepts better. Hence, it is pertinent that schools provide computers and IT resources to students and teachers to improve teaching and learning. Incorporating technology-based strategies can also enhance the quality of education. The use of additional instructions has drawn research attention in the last ten years as it is believed to enhance learning and teaching and enhance the academic performance of children as well.

In their research, Tawil et al. (2013) confirmed the effectiveness of e-learning platforms. They employed methods a student-focused learning method in retrieving information and understanding concepts. According to their findings, engineering students learning mathematics favoured the traditional learning methods over e-learning ones. They also found that engineering students learning mathematics preferred individual learning styles to group learning styles. In their case study, Fredriksen (2015) observed the impact of streaming lectures while teaching engineering mathematics at Narvik University College. All lectures and overviews were conducted online in the study. The drawbacks and advantages were evaluated to ascertain the model's feasibility and effectiveness. After analysing the data collected, Fredriksen (2015) found that students acknowledged the new method and saw improvements in their learning performance. The students acknowledged that streaming lectures were an effective approach to teaching and learning mathematics.

Some studies have explored evolving practices in teaching and learning mathematics. Aldon et al. (2021) reported the teaching challenges faced by mathematics teachers in France, Israel, Italy, and Germany. More specifically, they discovered that educators teaching remotely found it difficult to support students' learning. Hodgen et al. (2020) investigated heads of departments in the UK and noticed a decline in student-teacher collaboration in teaching mathematics. Clark-Wilson et al. (2020) claimed that in many countries, mathematics teachers were ill-equipped for online teaching. Owen (Nesta) and Hannay (2020) inferred that the COVID-19 pandemic contributed to widespread inequalities between students in terms of their engagement and access to technology. Another major concern to educators is students' learning loss (Engzell et al., 2021). Current policy documents have emphasised the need for new teaching formations, practices, and advocacy in mathematics education (National Council of Teachers of Mathematics (NCTM), 2020).

The incorporation of IT tools into classrooms for improving learning often poses major challenges to teachers in part because of the limited policy and pedagogical support. To incorporate technological tools into their teaching praxis, the TPACK (technological pedagogical content knowledge) and TAM (technology acceptance model) models have been extensively utilised to elaborate educators' perceptions and make it comfortable for them to use the technology. Koehler et al. (2017) stated that the TPACK model outlined the networks interlaced between the information associated with technology, including the knowledge being lectured and taught. Part of the responsibility of teachers is to reinforce the connection between information and communication technology (ICT) and educational settings for students. Educators are presumed to be responsible for motivating students and helping them cope with tangible difficulties.

Information Communication Technologies (ICTs) refer to a form of integrated communications that allow users to retrieve, save, and transfer relevant information to them. These incorporated communications are regarded as facilitators of transformation (Ratheeswari, 2018). Most higher education institutions and universities have merged teaching with technology to improve students' learning experiences. New learning technologies are utilised with the aim of improving students' engagement and academic results. The development in IT has spawned current trends in higher education, such as the development of webinars, discussion forums, simulation, wiki space, virtual reality, Kahoot, as well as social media technologies.

The TPACK model is a heuristic framework for exploring the active elements for teaching effectively with the aid of technology (Glowatz and O'Brien, 2017). The initiation of the TPACK model was done with the purpose of incorporating technology into teaching. The framework entails a multifaceted interface among three major elements: content, pedagogy, and technology. A multifaceted interface among the three areas produced three additional components: (i) pedagogical content knowledge, (ii) technological content knowledge, and (iii) technological pedagogical knowledge. Technological content knowledge denotes lecturers' knowledge regarding the use of appropriate technology applications to convey a specific discipline's course content. Pedagogical content knowledge consists of suitable methods of teaching specific content. Apart from being knowledgeable about the subject matter, teachers apply diverse ways of conveying the information. Technological pedagogical knowledge refers to the use of technology resources to improve teaching and learning. Technology is applicable in different ways to suit the context and purpose.

2.4.3 Interdisciplinary methods

Abaté and Cantone (2005) explored the influences of current mathematics conveyance instructions and studied the underlying historical, social and psychological causes of such influences. As well as exploring the effectiveness of a case study in smoothing the teaching and learning of mathematics, they evaluated several circumstances that mathematics instructional conveyance methods must consider to become a workable discipline. The results of Abaté and Cantone (2005) disproved the permanent use of traditional methods to impart mathematics learning. According to them, such methods have not only proven unsatisfying but have also made students uninterested in learning. Abaté and Cantone (2005) suggested the use of an integrated learning method as it enables students to tackle learning obstacles in today's fast-changing environment. Integrating a multidisciplinary pedagogical approach is inevitable for today's mathematics teachers who are interested in maintaining thoroughness and improving their academic performance.

The acquisition of mathematical skills is crucial in today's technology-rich society. The reason is that such skills enable individuals to solve everyday problems. Although mathematics plays a crucial role in today's society, studies have revealed a decline in students' performance across the globe. Mathematics is difficult to learn and master for students with or without disabilities. However, different strategies and mechanisms can be applied to improve teaching and learning mathematics with the aim of enhancing the quality of mathematics teaching and students' achievement (Little, 2009).

In his research, Little (2009) noted the cruciality of using diverse research-based instruction strategies to encourage effective teaching and mathematics learning. A strategy for planning and teaching must convey diverse instruction, and it should be founded on the principle that teachers must determine what and whom they are teaching. Little (2009) claimed that differentiated instructions should be encouraged by actively engaging students by employing metacognitive strategies, levels of learning, and integrating the right technology in a classroom setting. These strategies are expected to improve the quality of mathematics teachings and boost students' mathematics performance.

Stanberry (2018) emphasised the positive effects of active learning in enhancing the teaching and learning of calculus. According to the researcher, active learning has the ability to improve students' comprehension abilities (Stanberry (2018). Stanberry (2018) applied a number of active learning methodologies to determine whether or not active learning is pertinent in improving learners' performance in STEM subjects. He stated that Strategic Engagement for Increased Learning (SEIL) had the potential to facilitate students' success in taking calculus and enriching mathematical needed for the STEM workforce in the US.

Conducted at the department of industrial engineering at Pancasila University, a study found a significant transformation of lecturer-focused learning to student-centred learning. The method focused on student self-directed learning (SDL) with an all-inclusive online scheme that facilitates students' academic enhancement (Darmawan and Hidayah, 2017; Eddy et al., 2015). Students significantly evaluated their accomplishments in the preceding semester. In their Meta-cognitive Awareness Inventory (MAI) study, Tarmizi and Bayat (2010) examined the effective learning mode of problem-based learning and focused on augmenting a strong evidence-based educational system. Students performed satisfactorily on three separate tests using this model of learning mathematics (Prodromou and Lavicza, 2017a). Additionally, there were positive attitude adjustments with strong intrinsic and extrinsic motivation from the students.

Today, there is a growing need for a STEM labour force. As students' appeal in STEM studies is decreasing, researchers across the globe have shown interest in resolving this challenge (Attard et al., 2020; Tubb et al., 2020; Zaza et al., 2020). Most learners perceive STEM subjects to be difficult even though, with practice, students can succeed in STEM courses (Kaleva et al., 2019). To address the declining rate of student registration in the STEM field, educators need to equip themselves with appropriate instructional methods that can simulate learning among students (Kelley et al., 2020; Rosli et al., 2019). In short, the promptness and capabilities of educators in prioritizing STEM subjects over the teaching process are critical to enhancing student engagement (Maass et al., 2019; Park et al., 2017).

It is pertinent that teaching methods not be identical. This is because custom teaching and learning with one-to-one communication are inappropriate for making the next 21st generation fronting the approaching worldwide revolutions (Koehler et al., 2017). Therefore, hands-on, diverse teaching strategies can encourage high-level thinking and 21st-century skills in mathematics teaching and learning (Gravemeijer et al., 2017b; Penprase, 2020). Educators participate in formal STEM learning by providing hands-on, project-based instructions (Morrison et al., 2020). The improvement of procedures that can successfully train new teachers, especially those in the STEM fields, has a positive impact on student accomplishment (El Nagdi et al., 2018; Wang et al., 2020).

The communities are responsible for providing integrated STEM education. This initiative starts with the overview of new instructional practices and materials, curriculum development, publications of supportive materials, and professional development. The initial supporters within the community use new teaching materials, while academics in the community start to observe their usefulness. These procedures have enabled each of the STEM education communities, the National Mathematics Standards (National Council of Teachers of

Mathematics (NCTM), 2020), to validate STEM education integration over the past two decades.

The extant literature focuses on the approach of integrating several disciplines into STEM. Some studies examined all four domains of STEM (Bell et al., 2017; Bergsten and Frejd, 2019; Mert Uyangör, 2019). Another study elaborated on the integration of three domains: science, technology, and mathematics (Luneeva and Zakirova, 2017). Other studies mentioned two domains (Albano and Dello Iacono, 2019; Brown, 2017; Drovosekov et al., 2019; Dvoryatkina et al., 2019; Jacobs et al., 2017; Mailizar et al., 2020; Nygren et al., 2019; Parker et al., 2017; Poon and Wong, 2016; Reinhold et al., 2020).

The studies related to best practices in STEM education cut across various countries worldwide. The purpose of using digital technology in teaching practice is to amplify Australian students' knowledge (Brown, 2017). Reinhold et al. (2020), for instance, examined interactive and adaptive materials using eBooks and iPads for learning Algebra (fractions) in German. In their study, Parker et al. (2017) found that teachers' cultural familiarity in the mathematics classroom allowed teachers to identify and support students' manners. Learning and teaching geometry (LTG) using video, however, aided US mathematics teachers to teach geometry concepts (Jacobs et al., 2017). Drovosekov et al. (2019) noted that science project-based learning and integrated mathematics aided Russian students' mathematics learning. This finding was reinforced by Luneeva and Zakirova (2017), who performed a drill set to Russian teachers in project-based activities. In their study, Bell et al., 2017 acknowledged that STEM teachers' participation in STEM subjects helped shape their classroom teaching practices. Modern lesson proposals have prepared Swedish preservice teachers to design innovative STEM activities in the classroom (Bergsten and Frejd, 2019).

2.4.4 Instructional and content-driven methods

Mathematicians frequently use mathematics-dedicated software applications to guide mathematics teaching and learning. Borovik (2011), however, highlights the significance of mathematics teachers utilising teaching methodologies that are subject-specific and content-driven. The same study, nonetheless, contradicted generic teaching approaches such as content-free and generalist. As noted by Borovik (2011), mathematics requires delicate handling not only because of its highly specific cognitive nature but also because the mathematics community has accrued considerable experience in using computers and IT in learning, teaching, researching, and communicating. Borovik (2011) claimed that IT needed to be content-driven and subject-specific to significantly improve mathematics teaching and learning.

Fengchun et al. (2009) argued that universities and colleges were designed to encourage quality education and nurture hands-on capability and innovative skills. However, major mathematics courses relevant to engineering colleges have problems in terms of teaching and learning mathematics effectively. They highlighted the need to teach mathematics and implement mathematical concepts that inspire hands-on engineering problem-solving to develop the professional practice of laboratory, mathematics, innovation research, and research. All of these components are fundamental to improving mathematics teaching.

Peng et al. (2010) emphasised the ideas that are essential in developing mathematical analysis for colleges and universities. Promoting a mathematical culture among mathematics major for EIT students are fundamental to boosting the quality of teaching mathematics. They stressed the value of integrating technology into mathematics teaching and learning to improve the learning process and guarantee higher accomplishment among mathematics majors taking courses in EIT.

In their review, Vázquez et al. (2018) pointed out that most students failed mathematics compared to other courses. They attributed students' poor numerical performance to the shortage of effective pedagogical strategies. To upgrade mathematics performance in EIT courses, mathematics instructors should apply modern instructional strategies. Vázquez et al. (2018) highlighted several strategies that could be explored by teachers to enhance mathematics teaching/ learning. The researchers categorised the strategies into different groups by incorporating instructional strategies embedded in information technologies. An example is project-based learning and instructional strategies for teaching mathematics at the undergraduate level. The underlined strategies include the application of a technology curriculum, instructional strategies, technology, and manipulative tools. Other strategies include making relations, nurturing engagement, segregating challenges, encouraging fluency, and organising lessons. This study attempts to enhance mathematics learning/teaching by using the above-highlighted strategies.

Prediger and Neugebauer (2020) suggested teaching practices in language-responsive mathematics classrooms by using the analytic framework L-TRU to evaluate language-responsive teaching practices quantitatively. They used the framework to shorten the gap with the presumption that students with inadequate access to academic language ability attain less conceptual understanding in mathematics than their peers with more language ability. The L-TRU framework is based on Schoenfeld's teaching for robust understanding (TRU) framework by adopting five dimensions to language-responsive classrooms. The dimensions include cognitive demand, mathematical richness, agency, equitable access, and use of student contributions. The dimensions are further divided into two dimensions: connecting registers and discursive demand.

Several qualitative studies have listed criteria for effective teaching practices that facilitate language learners' mathematics learning. Quantitative evidence for these characteristics is scarce, however (see Erath et al. (2021) for an overview). Hence, there is a need for an analytic framework with quantitative measures for capturing quality into three domains: namely, general instructional quality, mathematics-specific instructional quality, and focus on aspects relevant to promoting language development. Prediger and Neugebauer (2020) employed TRU's five dimensions for language learners. To create the language-responsive TRU Framework (L-TRU), they extended the dimensions with two language-related dimensions (Prediger and Neugebauer (2020). Utilising this framework, they explored the methodological question of how to capture the instructional quality of different teaching practices in language-responsive mathematics classrooms. Current analytic frameworks for quantitative approaches are still unrelated (Charalambous and Praetorius, 2018).

The general instructional quality is described by some frameworks in broad fashions. The frameworks include the three basic dimensions of classroom management, student support, and cognitive activation (Praetorius et al., 2018). Other frameworks, however, aimed to describe mathematics-related dimensions by developing and elaborating on the meaning of cognitive activation. Schlesinger et al. (2018), for instance, included subject-specific features such as mathematical correctness, mathematical richness, dealing with multiple representations, and appropriateness of the examples.

In contrast to the general instructional quality, mathematics-related quality evaluates high cognitive demand and emphasis conceptual understanding. In their review, Prediger and Neugebauer (2020) reviewed critical aspects in relation to language learners and the framework. They include mathematics-related instructional quality, generic instructional quality, and the TRU framework for integrating generic and mathematics-related instructional quality that enhance conceptual understanding.

Table 2.2 illustrates the main challenges encountered by students in studying mathematics and the methods employed in addressing them in reviewed papers. The arrangement of information in Table 2.2 is constructed based on the quality framework originally developed by Ronau et al. (2011). It focuses on the existence of appropriate elements and fails to analyse the adoption level of the elements and the rating of the suitability of design and measurement selections. The quality framework includes many features such as the research design; the validity of the statistical conclusion and reliability; the group designation and selection mechanisms; and the extortions to internal and external construct (Ronau et al., 2011). Based on literature analysis, this study ranks the reviewed papers using three criteria: theoretical connections, measurement trustworthiness, and design clarity and validity.

Table 2.2 Literature summary

Category	**Author(s)**	**Challenges in Teaching Mathematics**	**Methods Adopted**	**Rank ***** Highest * Lowest**
Assessment-based methods & prerequisite knowledge	Yang et al. (2017) and Yang et al. (2015a)	Insufficient diagnostic testing and understanding of learners' current mathematical level	- Application of diagnostic testing methodologies contains two-tiered testing. Analyses learners' factual knowledge and their reasoning for formulating a particular decision or answer.	****
		Insufficient confidence in students' mathematical capabilities	- Applying alternative pedagogical techniques to improve the learning experience. For instance, playing music was considered to help students focus during learning to promote self-confidence and make it easier to focus on the topic.	
		Qualitative drop in the mathematical skill of entry-level students	- Incorporating instructional tools and effective methods adapted to mathematical teaching, as well as pedagogical approaches and new methods and models. Utilise diagnostic testing.	

	Juan et al. (2011)	Inadequate rolling assessment of students' progress.	- Moodle implementation. - Utilise a blended learning platform. - Deliver feedback and instructions. - Assessments are performed during the course period.	****
	Vandenbussche et al. (2018)	Insufficient prerequisite knowledge on the part of the students	- Register students in a remedy program to improve understanding and achievement rates and perform a pre-assessment.	***
Technology based methods	Madeira et al. (2012)	Poor course management systems and monitoring of the teaching process results	- Blends traditional and computer-mediated activities. - Apply Moodle-based tools to encourage the integration of assessment tests. - Empowering students to exercise their acquired knowledge.	****
	Aktas and Omurtag (2013)	Insufficient effective strategies	- Implementing partial online teaching methods.	**
	Hadjerrouit (2015)	Finding the best approaches for teaching mathematics.	- They built SimReal+ instrument as an interactive learning tool, emphasised visualisations and explained diverse topics and concepts.	**
	An et al. (2011)	Enhancing preservice teachers' confidence and attitude	- Integrating music to influence preservice teachers' beliefs and attitudes towards teaching and learning mathematics.	**
	Shih et al. (2012)	Low effectiveness of an instructional model and learning system.	- Combining computerised adaptive diagnostic testing system, the ubiquitous learning system, and the campus mathematics path learning system to improve mathematics teaching/learning.	****
	Díaz et al. (2010)	Difficulty in understanding subject matter.	- Applying computer technology to computer algebra systems (CAS) enable students to form their own knowledge and solve complex mathematical problems.	***

	Juan et al. (2011)	Inadequate quality learning materials impeding the capacity of students to understand topics.	- More time needs to be spent to guarantee that educators choose quality learning materials and resources that will improve students' learning and enhance learners' mathematical skills.	***
	Rubio et al. (2010)	Difficulty in learning descriptive geometry.	- Applying computer-aided learning (CAL) to improve teaching and learning.	****
	Karr et al. (2003)	Single delivery approach (online vs traditional) hindering learners' potential.	- Blended conveyance methods should be encouraged, which use both traditional and digital teaching methods.	***
	Martin (2011)	Poor students' learning experience.	- Motivating students to learn in a computer-aided classroom can help improve students' quality of education.	***
	Tawil et al. (2013)	Inadequate students focus.	- The study showed that individual learning styles are better than group learning styles.	**
	Fredriksen (2015)	Determining the practicability and effectiveness of streamed lectures.	- In the study, a majority of students acknowledged the new method and reported great achievements.	**
Interdisciplinary methods	Abaté and Cantone (2005)	Investigating the effect of the current mathematics conveyance.	- The study suggested the application of a combined learning method because it prepares students to develop the mindset to overcome challenges in today's rapidly evolving environment.	**
	Little (2009)	Insufficient student engagement.	- Different strategies for different students should be encouraged, including metacognitive strategies and differing levels of learning based on unique learner prerequisites and aptitudes. The	****

			strategies can help increase students' performance and enhance the quality of the teaching.	
	Stanberry (2018)	Insufficient active learning.	- Strategic Engagement for Increased Learning (SEIL) was crucial to the success of students taking calculus. Improving mathematical skills for college students, and helping them to produce highly productive STEM graduates.	***
	Darmawan and Hidayah (2017) and Eddy et al. (2015)	Insufficient students focus.	- The study discovered that there was a significant change of lecturer-focused learning to student-centred learning.	**
	Prodromou and Lavicza (2017a)	Increasing students' performance and attitude.	- Apply problem-based learning and focus on improving a strong evidence-based educational system.	***
Instructional and content-driven methods	Borovik (2011)	Generic teaching practices inhibiting students from attaining their full potential.	- Specific mathematical software should be encouraged to allow students to experience simulated problem-solving and to foster content-driven and subject-specific technologies.	***
	Liu Fengchun et al. (2009)	Insufficient hands-on knowledge.	- Teaching should be tailored so that it is relevant to the industry and practical applications, so that students are not overwhelmed when they enter the industry. Part of this goal can be attained by highlighting the significance of scientific innovation and technology in mathematics subject areas.	***
	Peng et al. (2010)	Improving the quality of teaching mathematics.	- Cultivating a mathematical culture among mathematics major for EIT students. - Highlighting the importance of integrating technology in teaching mathematics to improve the process and confirm better performance among mathematics majors taking courses in EIT disciplines.	****
	Vázquez et al. (2018)	High rates of academic failure in the field of mathematics.	- Supplementary pedagogical strategies should be supplemented with learners' teaching experience alongside modern instructional strategies.	****

2.4.5 Teaching for Robust Understanding

Researchers, as described below, share the view that TRU provides a useful structure for examining learning and teaching inside a professional learning community (Schoenfeld, Baldinger, et al., 2018a). According to Jacob Disston as explained in the book titled “Learning With and From TRU: Teacher Educators and The Teaching for Robust Understanding Framework” by (Schoenfeld, Baldinger, et al., 2018a), the TRU framework delivers ways of creating a shared terminology and a set of lenses for recognizing what to notice and inspect during teaching and learning and what to plan for and reflect on the development of effective teaching practices. David Foster and Tracy Sola in (Schoenfeld, Baldinger, et al., 2018a) also explained that TRU mathematics had altered their thinking in some ways. Before the use of TRU, they designated the role of the student in the classroom ineffectively. All the depictions and distinct classifications, formerly described, are confined and condensed with the aim of advancing students with agency, authority and identity. Besides, TRU enabled language to become more succinct, and it focused on students’ role in learning mathematics.

Schoenfeld, Floden, et al. (2018) put forward several questions regarding the resemblances, affordability, and variances of three experimental frameworks broadly used in mathematics classrooms. They include the framework for teaching, teaching for robust understanding, and mathematical quality of instruction. The study designates how each framework evaluates selected instances of mathematics instruction. It also documents the ways in which the three frameworks can be compared and contrasted. These broadly used frameworks disagree on what counts as high-quality instruction: questions of whether a framework provides arranged classrooms or disorderliness that often goes along with inquiry, including which aspects of disciplinary thinking are consequential. The study acknowledges the importance of the three experimental frameworks: the mathematical quality of instruction (MQI), the framework for teaching (FfT), and teaching for robust understanding (TRU). The numbers involved are not important. Put simply, all three frameworks can be used reliably. Given the underlying values they represent, the frameworks have some validity.

2.4.6 Lesson Study

Lesson study is a collaborative human activity championed by a group of teachers who aim to improve student learning. it is a method of practice-based teacher professional development that has been globally implemented due to its advantages for enduring teacher professional learning. The Japanese translation of "Lesson study" is "jugyou kenkyuu." Jugyou connotes "live instruction" (e.g., a lesson or numerous lessons), while kenkyuu connotes "research" or "study" (Lewis, 2016). The Japanese lesson study has been adapted into diverse modes, mainly in China, the United Kingdom, Hong Kong, and Sweden (Huang and Shimizu, 2016). The important features of lesson study comprise being knowledgeable about the subject matter, the curriculum, and student learning; being ongoing, inquiry-based and incorporated into the day-to-day tasks of teachers; offering opportunities for teachers to actively engage in the profound analysis of teaching and learning; and encouraging consistency between teachers' professional development and other professional experiences (Wei, 2019). Irrespective of the place, be it Japan, China, the United Kingdom, or the United States, lesson study has been carried out for years and has improved teachers' professionality (Chen, 2017). As a usual method of employing teachers' school-based professional development, lesson study is rooted in teachers' day-to-day tasks in a unified way.

Lesson study has enabled professional development and facilitated students' learning outcomes. It is characterised by openness, participation, dialogue, and applicability. Lesson study gives new momentum to educational research. Wei (2019) pointed out the difficulty of discovering a suitable theoretical perspective that could take advantage of lesson study. Wei (2019) elaborated on the cultural-historical activity theory (CHAT) to contextualise lesson study. The researcher believed that doing so would provide numerous insights cultivated by both teachers and researchers.

Amador and Galindo (2021) performed a study in which they engaged preservice teachers in a reformed mathematics subject experience. The purpose of the study was to explore the indicators of effective teaching through purposeful reflection on practice and through lesson study. Findings suggested that revised teaching enhanced by revised pedagogical approaches had a positive effect on students' learning outcomes. Compared to students who participated in conventional teaching practice, students involved in teaching experiments and lesson study were found to have lesson plans that fostered collaboration and involved exploratory mathematics. Those in the revised group applied lessons during student teaching that was more student-centred and considerate of classroom culture than groups who participated in the conventional field experience. Based on these findings, it is pertinent that educators integrate either teaching experiments or lesson study into their teacher education programs. Our findings reinforce other recent findings on teaching experiments, such as the findings of (Özdemir, 2017; Torres et al., 2019).

The CHAT could encourage researchers and teachers to tackle the complexity of and dynamics within the holistic process of lesson study. This theory is invaluable in gaining insights into the development and progress of teachers' professional learning in lesson study endeavours. Wei (2019) argued that the main advantage of incorporating the CHAT into lesson study was that it could help both teachers and researchers make sense of complex contexts in a practicable and profound manner. In the lesson study process, the CHAT assists teachers and researchers in working with a manageable unit of analysis, understanding systemic inconsistencies, discovering teacher learning mechanisms, and transforming findings into next-stage changes and practices.

After appraising all of these papers, a number of research elements require further development and/or testing. They include the following:

- Devoting longer time in choosing, developing, and giving high-quality content-driven mathematical learning materials;
- Nurturing the application of adaptive blended learning in teaching courses;
- Devising effective diagnostic tests and thorough assessments systems;
- Incorporating a multidisciplinary pedagogical method, such as using a collaborative learning approach with a special kind of technology.

Additionally, many aspects not studied in-depth in the reviewed papers can influence students' mathematics engagement. They are as follows:

- Issues that influence students' anxiety levels
- Effective comment
- Numerous reiteration
- Offering enough examples
- Integrate collaborative problem-solving tasks, open-ended tasks or computer-based work.

Addressing these elements will compel EIT students to be more motivated to take their academic work seriously. They will also contribute to the delivery of high-quality education to EIT students and make mathematics teaching for EIT students more effective.

2.5 Summary

In summary, this study explored the pedagogy literature with the aim of identifying effective pedagogies for teaching mathematics to EIT students. The review suggests that to teach mathematics effectively, instructors should replace traditional pedagogical approaches with modern pedagogical approaches. Strategies such as the use of properly designed pedagogies and applied diagnostic testing methods have been found to enhance EIT students' mathematics performance. Analyses of the literature also indicate that some techniques can be applied to facilitate the effective learning of mathematics. Some of the strategies enable students to be aware of their thinking process. Other strategies include the application of IT to make learning fun and easy for students. Review findings indicate that educators teaching mathematics subjects to EIT students acknowledge the need to integrate IT tools into pedagogical strategies and methods.

Even though the literature provides mixed results, this review has discovered that EIT students' engagement is essential to their learning performance. The degree of students' academic improvements from active-engagement approaches, however, may vary in different cases. This review also found that content-driven subjects facilitated by modern technologies could improve student engagement. Overall, a plethora of research recommends that mathematics educators should structure their mathematics courses to boost learning outcomes.

3 A Comparative Study of Online Learning and Face-to-face Learning

This chapter aims to compare face-to-face learning with online learning and discuss their impacts on post-secondary and first-year tertiary mathematics education in Australia during the pandemic. A review of the relevant literature was performed to gain insights into the research objective. The extant literature suggests that online learning is an effective tool for imparting knowledge beyond the course materials and sharing information with a diverse group of students, including learners with unique learning styles. Findings, however, reveal a few drawbacks of online learning. These drawbacks will be discussed in detail in this chapter. Scholars, nonetheless, advise universities and all stakeholders in the tertiary education sector to carry out some transformations, such as promoting empathy in virtual classrooms, encouraging collaboration and conversation in online discussions, and providing networking opportunities to students taking online courses.

3.1 Introduction

The COVID-19 pandemic has altered the functions and planned outcomes of the education system. In Australia and New Zealand, governments restricted the academic activities of schools and universities in 2020 and 2021 to enforce social distancing (Albeshree, 2022). Students in these two nations have been requested or mandated to stay home from school (UNESCO, 2020). The two countries, however, have employed different strategies to limit the spread of the virus among students. The New Zealand government recalibrated their school programs, shifting the timeline of the school holidays and demanding roughly 800,000 students to switch to distance learning (Gerritsen, 2020). The New Zealand government proclaimed that the nationwide school shutdown would last indeterminately (Collin, 2020). In contrast, the

Australian government provided various guidelines and timelines for school closing. Some schools nonetheless disobeyed these government directives.

The Australian Capital Territory, Queensland, Victoria, and Tasmania have embraced distance learning in term two of 2020. New South Wales has scheduled a plan to reopen schools gradually. South Australia, Western Australia, and the Northern Territory have implored parents to allow their children to come to school for term two (Carey and Fowler, 2020). However, during 2020-2021 it was unclear when most Australian students would be coming back to school. To allow students to continue their education while remaining safe from the COVID-19 pandemic, a quick move to online modes of teaching and learning was mandatory.

The idea of teaching students online had been suggested even before the advent of the COVID-19 pandemic. Many educators believed that online classes through platforms such as Microsoft Teams, Zoom, CANVAS, and Google Classroom would allow them to improve their tutoring style and provide personalised learning to students. However, many teachers were not familiar with the latest technologies used for teaching online courses. Teachers, for instance, could not correctly assess their students' performance in online learning. Their ability to assess students' skillset was limited compared to using traditional teaching methods. In online learning, students have to learn subjects and take exams from home. Without proper supervision, students could game the system and participate in all forms of examination malpractices. This challenge has limited teachers' ability to assess the skill set of students online. On the other hand, in face-to-face (conventional) learning, students take exams under the supervision of teachers. They pass the exam without relying on any external assistance. In an online class, however, the system permits students' use of online search engines and social media platforms to solve exam questions. Besides, by learning from home, students will have few opportunities to interact with teachers and fellow students. This isolation forces students to put more effort into grasping the concept being taught in the classroom. Students studying mathematics require a critical understanding of methods, solutions, and algorithms (Park and Shea, 2020). In an online environment, this critical understanding is even harder to attain. Hence, new online learning strategies are needed to enhance the quality of student education.

This chapter aims to shed light on the existing literature on effective online student learning by comparing online learning with face-to-face learning and offering insights into the importance of online learning during the pandemic. This research is worthwhile in that it enables education policymakers to understand how online learning can be beneficial to students taking and tutoring mathematics classes and what strategies teachers can apply to deal with the growing challenges of online learning. The rest of the chapter is organised as follows: Section 2 provides a research background of online learning during the pandemic and discusses previous literature reviews related to the topic. Section 3 elaborates on various aspects of learning during the pandemic. An examination of the challenges of the online learning model is presented in Section 4, while the main differences between face-to-face learning and online learning are explored in Section 5. Section 6 emphasises the importance of online learning during the COVID-19 pandemic. Sections 7 and 8 present the benefits of online learning and conventional learning, respectively. Section 9 examines the challenges of online learning, while Section 10 indicates and explains the best form of learning. Section 11 explores how mathematics subjects are taught online in Australia. The conclusion of this chapter is drawn in the last section.

3.2 Background

The advancement of information communication tools and platforms has enabled universities to explore the breadth and depth of online learning (Coates et al., 2005; Shirley and Tanja, 2007). Research shows that online learning will be the future of education. In 2019, a group of researchers analysed 35 studies on online learning and found that self-regulated learning supports, such as the use of prompts or feedback, improved the learning experience of students taking online courses. Without an instructor's presence in online learning situations, learners must decide when to study and how to approach the study materials. The encouragement of self-regulated learning activities, for instance, may help students to become more proficient in self-regulating their learning and enhance their overall learning performance. Hence, learners' ability to self-regulate their learning is becoming a significant factor in their total learning process (Taylor, 2020).

While many educators have provided divergent views on the efficacy of online classes (Valverde-Berrocoso et al., 2020), the literature has focused mainly on students' experiences and sentiments (Park and Swanson, 2021). Another gap found in the literature is the lack of studies that examine students' encounters with personal and web-based learning programs (Bliuc et al., 2007). For the most part, research shows that students cannot respond adequately to mathematical problems as they do not have the required instruments to produce appropriate mathematics documentation and outlines. Even when they have such instruments, the expectation to learn and master how to use the devices can be overwhelming and mentally challenging for some students (Leventhall, 2004; Smith and Ferguson, 2004). The present online learning model is asynchronous, and it, therefore, makes learning mathematics online difficult for students (Giannakos et al., 2021).

3.3 Learning During the Pandemic

The COVID-19 pandemic has complicated the academic routines of higher educational institutions (HEIs), forcing them to shift their learning model from a traditional setting to a web-based setting (Bao, 2020; Crawford et al., 2020; Rapanta et al., 2020). Colleges are responsible for providing quality education to students in a safe environment (Reigeluth and

Garfinkle, 1994). However, governments' policy on containing the virus has made it difficult for HEI to perform their duties and become effective.

Due to the lack of knowledge and limited time to tackle the burdens of the pandemic, many HEIs have postponed their plans to deliver excellent teacher education. This postponement happened in many countries, including Australia. In contrast to the preceding change, the industry has not been able to manage time and formulate reactionary actions to mitigate the effects of the pandemic. Systems and structures, nonetheless, have been available to provide quality online learning to learners (Rumble, 2019). Research suggested that programs for teacher education were prepared in mind to cater for the needs of students who prefer to acquire knowledge online (Assunção Flores and Gago, 2020; Donitsa-Schmidt and Ramot, 2020; la Velle et al., 2020). However, academic staff are yet to master how to use modern information technology to enhance the learning experience of students moving from traditional learning to online learning(Hurlbut, 2018). Teachers and educators, therefore, need to be properly trained on how to use advanced technology tools to impart knowledge in the virtual world.

Governments and private organisations worldwide provided relief to students and educators to improve education outcomes (León and Bourk, 2018). They offered schools stable internet connections and reliable digital devices to cushion the effects of learning or teaching from home. The Ministry of Education and Sciences in Georgia, for instance, embarked on a path of comprehensive education reforms, ensuring that schools were not lacking in education resources and tools during the pandemic (Basilaia and Kvavadze, 2020). In Australia, university staff were warned that the students faced a decline in their learning as they switched to online classes during the pandemic (Nicola et al., 2020). During this difficult period, many government-funded schools received support from large organisations, such as Microsoft, Google, Zoom, and Slack. Microsoft provided students with its collaboration Teams free of charge for half a year. Similarly, Google offered its video conferencing tools to tutors and educators at affordable prices. Zoom, a teleconferencing software program, also played an essential role during the pandemic crisis (Molla, 2020). Overall, these stakeholders contributed significantly to the widespread acceptance of online learning during the pandemic (Leary et al., 2020; Reimers and Schleicher, 2020).

Nonetheless, the implementation of online learning has not been a smooth journey. It has been fraught with many challenges. Only a few schools and colleges, mostly private ones, have incorporated online learning into their curriculum. Simply put, college administrators need to invest in online learning infrastructure to exploit the full potential of online learning (Zaharah and Kirilova, 2020).

3.4 Online Learning Common Barriers and Benefits

3.4.1 Challenges of Online Learning

Barriers to implementing online have been explored in the literature. The challenges were grouped into four categories: students, teachers, foundation and innovation, and institutional administration (Quadri et al., 2017). The noteworthy obstacles were framework and excogitation, while the least critical ones were students. Findings revealed that constrained timeframes to make online learning were the most critical aspect hindering the implementation of online learning, whereas the lack of students' ICT skills was the least important aspect. Hadijah and Shalawati (2017) examined hindrances faced by instructors when applying online learning. A substantial challenge faced by instructors was the lack of time to prepare innovative tasks. Other noteworthy constraints included the lack of satisfactory progression about innovative ideas, restricted tangible resources, resource deficiency, and the absence of specialised support. While online learning enables work flexibility, most schools do not have an enabling environment for online learning, thus resulting in poor time management. Another barrier is a lack of motivation. Students may find it difficult to grasp concepts explained by their teachers online as they cannot ask their tutors to explain confounding questions in real time. The other obstacle is technical issues. Internet and technical issues could frustrate teachers and students and discourage them from adopting online learning (Baticulon et al., 2021).

A successful online learning system is contingent on various factors, such as the students' and educators' engagement with the online learning system. Chen et al. (2020) performed a survey in Australia and found substantial obstructions to students' learning in a virtual setting, especially students of Chinese origin. The challenges of online learning included the lack of networking, the declining involvement of teachers, and the limited communication among students and their peers in an online setting. Other studies performed in Australia discovered that the adoption of digital learning did not correlate with an improvement in teaching and learning (Henderson et al., 2017). These challenges suggest that online learning may not be a formidable alternative to conventional learning.

To ensure education programs and courses performed can meet students' learning needs, an adequate understanding of the issues affecting online learning is essential. The incorporation of online learning into course delivery organisations has some benefits, such as increasing teaching effectiveness, improving students' achievement, and meeting students' learning needs (Coates et al., 2005). To take advantage of these benefits, a proper strategy that considers online learning is needed.

Australia has 2316 post-secondary institutions (The Good University's Guide, 2021), most of which implement some forms of an online learning system to enrich the learning experience of students and provide instructors with much flexibility. The success of an online learning system in empowering the learners, however, is hampered by learners' privacy, online learners' attrition, lack of IT skills, and course instruction development. A summary of the four noticeable cases is provided in the following sections:

3.4.1.1 Learners' privacy

Learners' privacy is an obscure realm in the education environment (Polonetsky and Tene, 2014). Educators need to know about students' behaviours to provide meaningful responses to students, such as students' nationality, working record, and marital status. Learners can be asked this information on an online learning system as a prerequisite to complete course enrolment. Yang and Wang (2014) observed the problem of confidentiality in online learning. The researchers found that learners generally had positive attitudes toward providing private data to their academic institutions even though there were hesitant to provide some data, such as personal images and home addresses.

3.4.1.2 Online learners' attrition

Conflicting employment commitments have been a source of worry for some Australian universities. It is not uncommon for online students to drop out of school because of employment commitments. Moore (2017) examined students' decreasing number in the Open Universities Australia (OUA) and found that students' declining population could be traced to working-related needs. The study also indicated that occupation was the major contributory cause of low school commitments. Even though an online learning system offers a large dose of adaptability to students, the study underlines the need for universities involved in online learning to be aware of this problem.

3.4.1.3 Lack of IT skills

In Australia, IT knowledge is a vital skill that must acquire undertaken to successfully navigate from traditional classroom learning to online learning. The University of New South Wales proposed three programs to help students improve their IT skills (Mirriahi et al., 2015).

The first proposal was a FULT (university teaching foundation course) that aimed to assist students in understanding how to use learning resources online. The second proposal was the GCULT (reform for the university's post-graduate course), which aimed to foster blended learning. The last proposal was the MOOC (Learning to Teach Online --LTTO), which targeted members of external institutions. After evaluating the three programs, scholars concluded that technology acceptance among teaching personnel should be nurtured to help students embrace not only online learning but also blended learning (Al Meajel and Sharadgah, 2018; Scoppio and Luyt, 2017).

3.4.1.4 Course instruction development

It takes weeks of full-time work to develop an online course, especially when it is done with best practices and quality assurance over an official evaluation procedure, e.g., Online courses, Quality Matters, Inc. that put quality at a high stake enable students to keep on until they finish their study (Stavredes and Herder, 2013). To foster learner's accomplishment by embracing critical thinking, problem-based learning, and insightful effort, one may join quality online courses with reliable learning aims (LaPrade et al., 2014; Stavredes and Herder, 2013). The stigma of technology and virtual learning disputes continue, though online learning has revealed no substantial effect on grades in contrast with face-to-face learning. Moreover, an obligatory online mode has not been researched sufficiently (Fonolahi and Khan, 2014). Being aware of the constraints of technology and enduring to be practical when making virtual learning can help advance learners' achievement (Anderson, 2008).

3.4.1.4.1 Teacher

To acquaint themselves with the talents and means required to be effective, teachers must be online learners themselves. Some universities recommend that their online teachers join an online course that will demonstrate to them the way to create online instructions. This approach is beneficial, as teachers undergo the same encounters that their students naturally will confront: difficulties with insufficient PC skills, studying regarding the diversity of screen interfaces, and miscalculating the length of time required to finish the online comprehensions and completing homework. Teachers must not only advance novel instructive skills, but they must also increase new aptitudes. Didactic aptitudes are of paramount importance in online settings as are traditional learning in interacting with students and helping them acquire technical or IT skills.

3.4.1.4.2 Time and resource management

Student activities will probably be erratic because of the intrinsic environment of online courses and may outpour emails for the teachers to reply to solicit help from a technical aid to answer messages, generate a frequently asked questions (FAQ) page, where students locate the info commonly required during the course, make a procedure in which students enquire through the forum, before emailing the teachers. Faculty is greatly suggested to acquaint with their web developers and related units to create a solid connection with those backing units. Effective arrangement and time management are crucial to the efficacy of the course instruction.

3.4.2 Advantages of Online Learning

3.4.2.1 Educational Advantages

Online courses enable students to acquire skills beyond the main course contents, such as IT skills. Weiner (2003) found that web-based teaching and learning improved American students' performance in IT aptitudes. Another study showed that online courses encouraged young students to develop an interest in learning and the use of Internet-based applications (Bahasoan et al., 2020).

3.4.2.2 Anonymity

Another advantage of online learning is that it protects the identity of students. The impersonality of online learning promotes honesty and equality, thereby allowing students to provide feedback to their instructors without the fear of retribution. The absence of viewable signals also allows educators to treat all students equally and fairly (Annansingh, 2019).

3.4.2.3 Flexibility

The flexibility of online learning makes it appealing to students. According to a study, students feel more self-guided and independent using well-structured online learning, and they can spend more time watching and re-watching lecture videos to understand knowledge concepts (Firestone et al., 2019). When students become self-regulated learners, they can use many strategies to attain their learning goals. Learners who can successfully self-regulate their learning have the advantage of quickly grasping concepts and improving their academic performance.

Moreover, online learning provides students with the benefit of attending classes from anywhere. Unlike traditional learning, in online learning, students are not bound to a physical class session (Little and Street, 2020). Rather, they can easily access learning materials at their convenient time and desired locations via online platforms. This flexibility allows them to save s the time and cost associated with travelling to classes.

3.4.2.4 Asynchronous

Web-based learning is an asynchronous form of learning that enables to participate in courses at their convenient schedule (Stone and Perumean-Chaney, 2011). Put simply, in asynchronous online learning; students are not compelled to log in and participate in class sessions at a particular time. An advantage of web-based asynchronous learning is flexibility and cost-saving (Means et al., 2010). A study showed that students offering online courses performed better than those who preferred traditional learning (Means et al., 2010). The study suggests that asynchronous online learning can enable students to complete their assignments on time and improve their academic performance.

3.4.2.5 Self-Paced Learning

Online learning promotes self-paced learning, meaning students can study knowledge concepts at their own pace. When the students can complete class assignments at their time pace, they learn with confidence and focus on and tackle knowledge aspects that they find challenging. Self-paced learning also promotes learning efficiency and minimises wasted time. Overall, students who learn at their own pace have the opportunity to gain competency in areas that they find interesting(Bringula et al., 2021).

3.4.2.6 Cost-Effectiveness

Online education is affordable compared to conventional education (Bahasoan et al., 2020). Students taking online courses pay fewer tuition fees than those opting for traditional classes. In online learning, students can text or message their instructor rather than leaving their homes or comfort zones to converse with their teacher, thereby saving costs on transportation (Garrison and Cleveland-Innes, 2005). However, if such online communications are not controlled and planned effectively, school administrators may incur institutional costs, such as teachers spending too much time on the Internet rather than teaching students.

3.5 Face-to-face Learning

3.5.1 Quality of Education

Online and face-to-face learning share many similar characteristics. In both forms of learning, students are mandated to attend classes, study course materials, complete their homework, and participate in group discussions. Teachers are also expected to design school curriculums, maximise instructional quality, grade assignments, provide feedback to students, and motivate them to learn. Apart from these similarities, online learning and face-to-face learning have many differences. Conventionally, traditional classroom settings encourage passive learning, while online settings promote active learning. The traditional methods of teaching in the classroom are a deep-rooted didactic mode. This teaching style has been employed for centuries, and it has numerous advantages over online learning (Xu and Jaggars, 2014).

One advantage of face-to-face learning is that it is engaging and interactive (Kemp and Grieve, 2014). Face-to-face learning offers real-time instructions and stimulates forward-looking questions. This learning method permits teachers to provide instant responses to students' questions. Besides, many students use this learning approach, and some students have a phobia of reading e-books or using technology devices to take notes in the classroom (Rovai and Jordan, 2004). Another benefit of face-to-face learning is that it is not dependent on Internet connections. Without the Internet, students can still have access to their books and course materials.

3.5.2 Learning atmosphere

Face-to-face learning offers more direction, motivation, and encouragement to students. In face-to-face learning, instructors can easily recalibrate their teaching structures and styles to enhance student learning (Kemp and Grieve, 2014). However, online teaching methods restrict teachers' ability to communicate with their students online. Some teachers nonetheless think that direct communication with students is important for constructing esprit de corps (Conole et al., 2008; Upton, 2006).

3.5.3 Communication

Limited communication is not uncommon among online learners. A study observed that online students have detached feelings toward their peers and lecturers due to limited interactions (Holley and Oliver, 2010; Otter et al., 2013; Zhang and Perris, 2004). However, learners showed more empathy for their colleagues when discussions were incorporated into online courses (Evans et al., 2004). The literature, therefore, suggests that face-to-face learning may support or hamper students' learning performance.

Students experienced more engagement during the learning processes done in a face-to-face social setting rather than in a virtual setting. The more students were engaged with the courses, the more they conversed with their colleagues. A better flow of discussion was also a benefit of the direct communication setting. Other advantages included the expansion of networking and improvement in person-to-person dialogue (Kemp and Grieve, 2014).

3.6 Online Learning vs. Face-to-face Learning

Online learning is different from face-to-face learning. Face-to-face learning, in contrast to online learning, is a synchronous form of knowledge acquisition in which students learn knowledge concepts in real time. A physical environment for knowledge exchange is required in face-to-face learning. However, in online learning, students need only Internet connections and a computer device to have access to learning content. Table 3.1 and the following sub-sections provide more information about the difference between the two forms of learning.

Table 3.1 Online vs. face-to-face learning

CRITERIA	ONLINE LEARNING	FACE-TO-FACE LEARNING
Personality Development	The educational features of online learning are much more beneficial to students.	Educational facilities in a conventional classroom depend on the college's wherewithal
Quality	The quality of education might be hindered, depending upon the technological components a student and a teacher have.	The quality of education is top-notch since there is direct communication between the teacher and the student.
Localisation	Online learning does not facilitate the component of localisation since it is being done through technology, and most of the components are not under the control of the teacher and the student.	There is a major benefit for Face-to-face learning concerning localisation and the control of the class's atmosphere and environment.
Communication	There is a major barrier to communication with the students, which might cause a hindrance to the understanding of students with the teacher and the respective subject, such as mathematics.	There is the profitability of direct communication between the student and the teacher, which may result in effective education, especially in the subject of mathematics.
Flexibility	There is much more flexibility in online learning, such as subjects, assignments, quizzes, and the direction of the educational curriculum. Online learning permits students to facilitate themselves without having to pursue classes and travel long distances.	The teacher in a typical classroom environment is restricted to the curriculum described for the class. Face-to-face learning requires students to make their way into the classroom every day; hence, it poses a much more struggling approach for the students as compared to online classes.
Integrity	The educational facilities provided in online learning are much more beneficial, and students facilitate themselves quite greatly.	Educational facilities in a conventional classroom depend on the college's environment and integrity.
Anonymity	Online learning permits the student to remain anonymous and provides them with ease of study, especially for those students who find it a bit difficult to keep up with the other classes fellows.	Face-to-face learning requires every student to keep up at the same pace, restricting the teacher from focusing on one student at a time since the time division is extremely restricted according to the course.
Management	Online learning requires the college staff and administration to exhibit proper management for the execution.	Face-to-face learning does not require such complexity in organisational management (Jefferson, 2019).

3.6.1 Personality Development

Students in an online learning setting cannot engage in physical interactions with their peers or teachers compared to a face-to-face learning setting. Online students are deprived of social information, and they are less likely to participate in social activities compared to students involved in classroom learning (Bowles, 2016; Diekelmann and Mendias, 2005). Learning conditions affect students' behaviour. Overbaugh and Lin (2006) compared web-based learning and lab-based setting and found that web-based learning was lengthier than lab-based learning. Regardless, several research attempts have been made to improve how fast students can acquire knowledge through online learning platforms. Restructuring courses is one way to achieve this objective. Research findings also indicate that extra instructions are needed for both lab-based and Web-based courses to ensure that students are well-equipped to participate in collaborative activities.

1) Online Learning

   The educational features of online learning are much more beneficial to students.

2) Face-to-face Learning

   Educational facilities in a conventional classroom depend on the college's wherewithal.

3.6.2 Flexibility

The flexibility of online learning provides students with full control of their knowledge acquisition. In online learning, students can decide whether to attend lectures during the day or night. Web-based learning also gives students the flexibility to learn at their own pace, thanks to the advancement of information technologies that have removed the barrier of location and time differences. As online learning has shifted the entire focus of education to students, academic institutions should design online curriculums to accommodate students' schedules, learning styles and technology preferences (Robinson and Hullinger, 2008).

1) Online Learning

There is much more flexibility in online learning, such as subjects, assignments, quizzes, and the direction of the educational curriculum. Online learning permits students to acquire knowledge without leaving their comfort zones.

2) Face-to-face Learning

In a typical class environment, a teacher's teaching effort is circumscribed to the class curriculum. Besides, in face-to-face learning, students are forced to attend classes every day. This requirement is stressful and time-consuming for most students.

3.6.3 Assessment

Students have different views regarding the use of feedback mechanisms in online learning and face-to-face learning. In a face-to-face setting, students obtain instantaneous feedback from their teachers. They ask questions from their instructors and receive real-time responses to their inquiries. In an online setting, students rely on emails and class-discussion portals to communicate with their teachers and peers (McCarthy, 2017). Nonetheless, online learning allows learners to engage in self-reflection, personalise their questions, and engage in constructive discussion with tutors and other learners (Seifert and Feliks, 2019).

1) Online Learning

Online learning allows students to remain anonymous and learn at their own pace.

2) Face-to-face Learning

Face-to-face learning compels students to acquire knowledge at their own pace, and teachers cannot provide personalised teaching to each student.

3.6.4 Quality

The examination of similarities and differences between blended learning with traditional classes shows that blended learning approaches are more favourable and beneficial to students than conventional learning. Although online learning seems to be as efficacious as traditional learning, it is more student-friendly and teacher-friendly than conventional learning. Online students achieve greater academic performance than students studying in a traditional setting. Both blended and online learning enhance learners' knowledge. However, blended learning is superior to traditional learning as students embracing the former can partake in online classes and still have access to class materials anywhere an Internet connection is accessible (Means et al., 2010).

1) Online Learning

   The quality of education might be hindered, depending upon the technology that students and teachers can access.

2) Face-to-face Learning

   The quality of education is top-notch, as both students and teachers can communicate with one another in real time.

3.6.5 Localisation

In face-to-face learning, students have to visit the educational venue. In online learning, students can have access to class content on the web regardless of their geographical location and time zone. Online learning also comes with much flexibility for students. Students can attend lectures from home, office, or any place they like as they are not obliged to attend the venue physically. As long as students have a computer device and a reliable Internet connection, they have much control over their learning process on the web. Compared to online learning models, traditional learning models are beneficial to teachers in localising educational content and monitoring the performance of students.

1) Online Learning

   Online learning is not constrained by space.

2) Face-to-face Learning

There is a major benefit of Face-to-face learning that teachers and students may control the class's atmosphere and environment.

3.6.6 Management

Effective online teaching and learning demands strategic plans and forming a sense of presence and connection between teachers and learners. Producing a sense of presence encompasses awareness and understanding of being in a virtual classroom for the online learner. Designing, delivering, and evaluating online teaching, compared to traditional instruction, necessitate distinguishing types of management, which rest on the components of the design process, e.g. content type, course format, strategies, teacher role, technology, and support; the influencing factors workload, e.g., number of courses taught, learner enrolment, position held, and teacher responsibilities.

1) Online Learning

Online learning requires the college staff members to exhibit proper management for the execution.

2) Face-to-face Learning

Traditional learning does not require much complexity in organisation management.

Control the class's atmosphere and environment.

3.6.7 Anonymity

Online learning allows students to keep on anonymous and offer them with ease of study, particularly for those students who are problematic to keep up with the other class fellows. While face-to-face learning needs every student to retain at the same speed, constraining the teacher to focus on one student at a time since the time division is very limited according to the course time.

3.6.8 Integrity

The educational conveniences arranged in online learning are much more helpful, and students ease themselves quite significantly. Educational facilities in a conventional classroom depend on the college's environment and integrity.

3.7 Preference

Considering the COVID-19 pandemic and the demands of today's students, online learning can be employed to deliver quality education. An advantage of online learning over traditional learning is that the former can be utilised simultaneously by a large population of students scattered across the globe. Besides, online learning ensures that learners can acquire learning information and course materials from any location with an Internet connection. Face-to-face learning, on the other hand, restricts students' learning in the classroom. With suitably designed online learning courses, students can replay recorded videos of their lectures and gain more insights into the knowledge concepts. Academic staff can also tailor their courses to meet each student's learning needs (Son, 2019). These benefits have attracted many institutions to incorporate virtual learning into their curriculum.

However, considering the influence of the pandemic, academic institutions should consider the costs and risks of implementing online learning. Most students are still learning online to neutralize the negative effects of the pandemic on their academic performance. Hence, schools need to consider the emotional needs of students when shifting from traditional learning to online learning. Concerted efforts will also be needed to ensure that students develop the IT skills to learn in virtual settings. Schools alone cannot train teachers and ensure that provisions are made for students to aid their learning process. By partnering with private organisations and government agencies, universities have a better chance to deliver excellent online learning to students.

3.8 Dealing with Teaching and Learning Mathematics Online.

Because of the economic restrictions caused by the COVID-19 pandemic, some schools in Australia changed their teaching models from face-to-face learning to from-home virtual learning. Government authorities mandated school authorities to make quick changes to their academic routines to ensure students' safety. Studies showed that teachers were overwhelmed with stress when implementing the abrupt changes and that they were worried that students' academic needs would be compromised (Flack et al., 2020; Hamilton et al., 2020).

Furthermore, educators were worried that learning mathematics from home might weaken students' academic performance. Worried about students' learning experience, some mathematics teachers refused to teach their courses online (Clark et al., 2014). This attitude is not unprecedented, however. Scholars observed that teachers who taught professional development courses or employed inquiry-based methods were hesitant about adopting online learning approaches (Russo et al., 2021). According to Sullivan et al. (2020), tutors who took courses needed greater clarifications regarding how to leverage video technology in online courses. However, teaching mathematical concepts to students necessitates the need for rigorous dialogues (Russo and Hopkins, 2017; Stein et al., 2008). Without synchronic face-to-face learning, it would be difficult for instructors to teach students mathematical concepts.

Findings of an online survey conducted in Australia and New Zealand showed the effect of obligatory online learning during the pandemic on educators, students, and the quality of educational results (Flack et al., 2020). According to the survey results, educators were overburdened with adopting new technologies to impart knowledge, changing their teaching styles, and building relationships with students online. Policymakers need to consider these challenges and find formidable solutions to the problems. A guideline provided to the Australian Government by Dr Alan Finkel (The Australian Chief Scientist) highlighted three aspects mediating the success of virtual teaching (Drane et al., 2020). They included the accessibility of smartphones, tablets, and other Internet tools, the provision of a conducive learning environment at home for students, and the willingness of teachers and students to embrace online learning. Similar recommendations were provided by Drane Vernon, and O'Shea, (Drane et al., 2020).

Furthermore, there should be much emphasis on the quality of teaching rather than the quantity of homework assigned to students. Eri et al. (2021) advised universities to carry out six changes. First, they should restructure how they teach mathematics courses to students with different learning abilities. Second, they should establish innovative personnel training programs so that students can understand how to use their digital devices to enhance their learning. Third, academic administrators should provide dedicated training that will help teachers to engage students in an online environment. Fourth, universities should develop assistance arrangements for learners with the guidance of student representatives and fresh alumni to stimulate and assist online learners emotionally. Fifth, they should review assessment approaches that can fulfil the didactic objectives of the students. In conclusion, instructors need to be more sympathetic to the demands of their learners.

3.9 Summary

This study compares online learning to face-to-face learning and discusses the effects of these learning methods on post-secondary and first-year tertiary mathematics education in Australia during the pandemic. The results of the present study showed that both face-to-face learning and online learning have a few similar features but many different characteristics. The scheduling of online learning, for instance, is distinct from that of face-to-face learning. To participate in virtual classrooms, online learners must have access to Internet connections. Learners adopting face-to-face learning, on the other hand, need to visit classes physically to attend lectures and have access to course materials. Face-to-face learning is not as flexible and convenient for students with full-time jobs and distance learners. Hence, this study does not recommend this conventional learning method to such learners. As the name suggests, online learning relies on the Internet to download course videos, upload assignments, or have chat sessions with students and lecturers. Face-to-face learning communication may be either done verbally or nonverbally, depending on teachers' preference. Both face-to-face learning and online learning are similar in that teachers coordinate the teaching process. Furthermore, the evaluation techniques are similar for both online and face-to-face learning environments. Tests and assignments are used to gather information to evaluate students' performance.

However, this current study identifies a few challenges to online learning, such as student privacy, online learners' decreasing population, and inadequate online-learning infrastructure. These challenges need to be addressed, particularly within the Australian context. Some scholars recommended that universities should introduce some transformations, such as restructuring course delivery strategies, establishing novel professional development programs, developing school-level support structures for students, reviewing assessment strategies, engaging instructors to be more sympathetic to students' needs, and providing more collaboration and dialogue tools in online classes.

4 Research Design, Methodology and Justification

4.1 Introduction

"The purpose of research was to enhance knowledge, to in some way enable us to know more" (King et al., 2018). The main aims of this study revolved around establishing new information, understanding, and answers to the three primary research questions:

Q1. What is the impact of the UC mathematics teaching approach on the first-year EIT students' collaboration, understanding, and achievement in mathematics courses?

Q2. What factors motivate EIT students to engage, or not engage, with mathematics?

Q3. Does the implementation of a multidisciplinary pedagogical approach enhance the effectiveness of student Mathematics learning for UC EIT students?

The research design process represents the activities researchers have to apply to secure the answers to the research questions. Research simply refers to the systematic processes made up of related activities, including the identification of the problem, development of a hypothesis, gathering data or information, analysing of such information, and developing conclusions based on such analysis and information gathered (Kothari, 2004). The conclusions can be used to develop solutions to problems or to develop theories upon which future actions can be anchored upon.

Research design is also defined as an organised process that emanates from efficient decision-making to secure logical results. Research also relates to actions with a corresponding goal or aim. It is an "organised, systematic, critical, scientific, data-based, objective, scientific inquiry or investigation into a specific problem, undertaken with the purpose of finding answers or solutions to it (Sekaran and Bougie, 2016). In effect, researchers' functions include undertaking enquiries on the research question. This study utilised the mixed method approach in order to establish factors impacting the process of teaching mathematics to EIT students.

As the specific design for this study is being developed, this section will add to the first chapter and discuss further the theoretical background for the such chosen design.

Numerous studies point towards affect as a primary and important factor affecting the learning process; however, it is a very complicated process that is hard to measure. According to Chamberlin (2010), affect in the context of mathematics simply relates to the point where mathematics, psychology, and education converge. Some studies also indicate how emotions build on mathematics problem-solving in the classroom (Op't Eynde et al., 2006; Op't Eynde and Hannula, 2006).

Ernest (2011) also considers different qualities associated with mathematics, including confidence and anxiety or beliefs about mathematics (how it is taught and learned) and other elements like feelings about mathematics, referring to the affective domain. Ernest further highlights that not doing well in mathematics can often build on the previous fear or dislike one has had for the subject, and such previous fear or dislike can impact the individual's self-confidence. This then leads to a self-fulfilling cycle of failure in relation to mathematics and sometimes in one's self-confidence. By contrast, gaining success in mathematical activities can make one happy and confident. This can further build on one's motivation and persistence. Ernest notes that one of the foundations by which mathematical learning is anchored is in developing relevant out-of-school activities which motivate students. These activities are also very much goal-oriented and purposeful (Ernest, 2011).

Ernest (2011) set out to understand mathematical myths. He believes that these myths can lead to erroneous beliefs about how math is carried out. Another myth is the gender stereotypes about mathematics that males and females have differences in terms of their math abilities. Still, another myth is that math is a rigid and logical subject. There are those who also claim that there is only one way to get a correct answer in math and that having a good memory is essential in studying and using mathematics**.** Ernest believes that experiences in the classroom are very much important in directing a child's perspective of mathematics. He further highlights that in one study related to mathematics teaching, students described math subjects to be hard-easy or useful-not useful, and in another research, they believed that math is primarily about making computations. He noted how the experiences of the learners became the basis for the appreciation of mathematics, and how such appreciation has often been lacking because the experiences of the students have mostly been negative ones. Ernst believes that students have a dualistic perspective of mathematics, with teachers assigning students different unrelated tasks, which include the use of memorised formulas or solutions and with teachers highlighting that each problem has a specific and objective answer. Teachers also seem to disapprove failures in securing the specific correct answer. Such methods in teaching math have made the subject seem unreasonable, inhuman, and cold. Ernest (Ernest, 2011) has emphasised the need for more studies to be undertaken to understand the human aspect of mathematics. He points out how children, on their own, usually develop stereotypes about math in relation to their experiences in the classroom while learning the subject matter. He also believes that the teachers' perception on the quality of mathematics also impacts how they teach the subject, and he indicates how teachers in math must also consider the question: "what is mathematics" (Ernest, 2011).

The beliefs and perceptions of teachers are very much crucial as these perceptions dictate the qualities of the classroom setting, which also guide the beliefs of students on the nature of mathematics.

4.2 Research Design

Choosing the appropriate methodology in research is very much important in resolving the issue being studied or investigated. In effect, this section will present the issues noted in choosing an appropriate design, selecting a proper approach to the study, and developing the data collection analysis.

4.2.1 Frameworks

Debates have long persisted among researchers on the general importance of qualitative as well as quantitative studies. Quantitative studies seek to generate answers to hypotheses and establish objective information unaffected by the researcher's biases and fact-finding processes. Qualitative data seeks to develop a clear understanding of phenomena. It is also considered more subjective as compared to quantitative data (Collis and Hussey, 2013; King et al., 2018).

Philosophical frameworks form the basis by which studies have to be carried out; however, ultimately, it is the reason and argument provided by the study which would give credibility to new information. The quality of findings produced is very much based on rigid and methodological tools within the specific research paradigm. The quality of research is generally evaluated on its validity and reliability. The results from quantitative studies are very much reliable, but these have lower validity; results from qualitative studies have high validity but low reliability (Collis and Hussey, 2013). Reliability is the extent by which findings would be affected incidental circumstances. Reliability tests if similar results would be secured by future researchers using similar processes, where results and interpretations match, the study is considered reliable. Validity is the degree by which the study represents the issue being evaluated. It is an assessment of how well a test or instrument measures what it is supposed to measure (Price, 2017). Validity was first considered to minimise a Type I error in quantitative studies, i.e., the researcher rejects the null hypothesis when in fact it is true and Type II errors, i.e. the researcher fails to reject the null hypothesis when in fact it is false (Salkind, 2010). For qualitative studies, the researcher's impact on the study's setting, including his values, all account for the validity of the study (Silverman, 2015).

Although positivism has mostly been seen as a common research paradigm, there have been numerous issues with the use of measurable strategies instead of evaluating the specific experience of individuals. The subjective strategy in managing the direct experiences of individuals in a fixed setting is now the preference for most individuals (Cohen et al., 2008). The two types of research are very much important, and by combining data gathered from both, a clearer picture of the phenomena or research problem can be generated (Ernest, 2011).

4.2.2 Selected Research Framework

The method of research used must fit the research questions and hypothesis as well as the nature and framework of the information being sought. Figure 4.1 points out the hypothesis of this research which is stated as follows:

Understanding the impact of the UC mathematics teaching approach on the first-year EIT students' collaboration, understanding, and achievement in mathematics subjects, the factors that motivate EIT students to engage or not to engage with mathematics, and the implementation of a multidisciplinary pedagogical approach will enhance the effectiveness of Mathematics learning for UC EIT students.

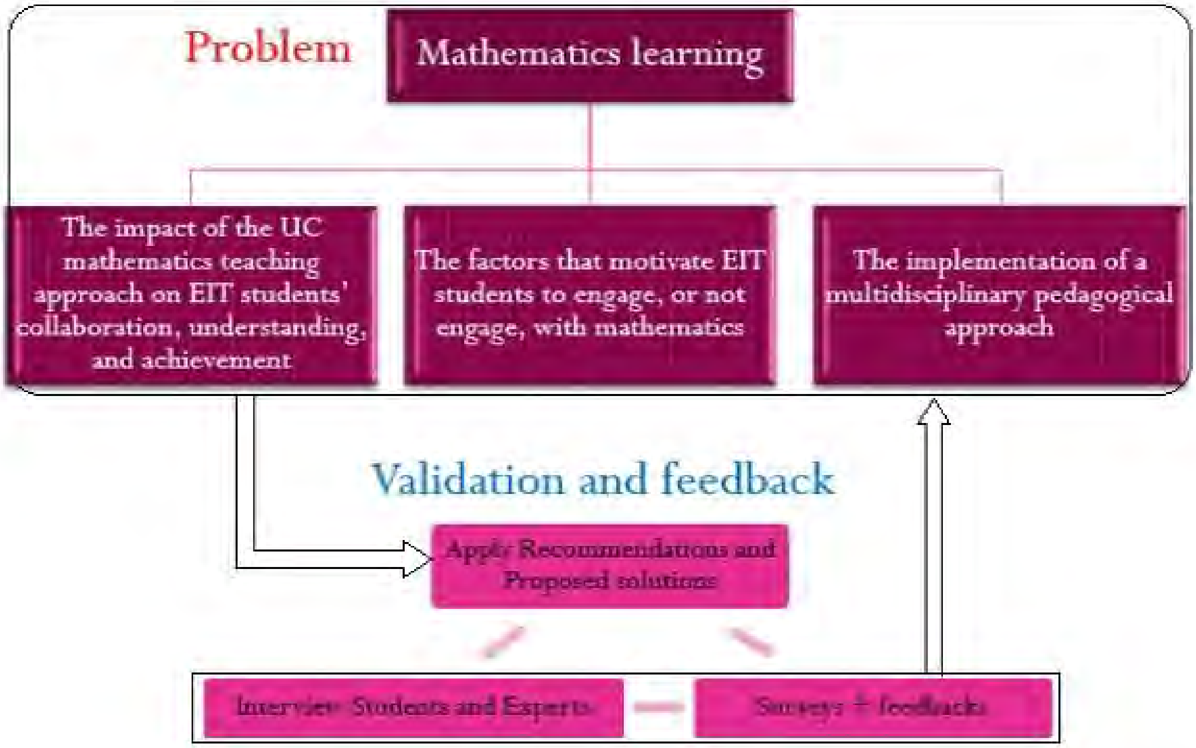


Figure 4.1 Research hypothesis

Mixing quantitative and qualitative methods in research is set to secure a powerful blend of data (Creswell and Creswell, 2017). Mixed methods research combines aspects of quantitative and qualitative research to establish a better and more corroborative understanding of a problem (Johnson et al., 2007). It is applied when the researchers integrate useful elements of both types of research into the mix.

Through sequential mixed-method, results from one method can be verified and specified by the other. A study, for instance, may start off applying the quantitative method, and this method can be followed through by the qualitative method, which usually includes a specific evaluation of some cases. Applying mixed-method research will help reduce the impact of a method’s weakness in the course of the study. Although both methods provide specific data in relation to the research questions, the results in one method are usually comparable to the results in the other. Having a qualitative element to the study secures the validity of the research and addresses the unique situation in each scenario, thereby ensuring the replicability of results (Cohen et al., 2008). Applying different methods of research is also known as “triangulation”, which refers to the application of numerous processes in research to understand the same problem. In triangulation, the conclusion and the results from the process of research can be improved.

The quantitative assessment of EIT students’ mathematics learning is to establish new data; however, such an assessment would not effectively explain the results. Qualitative research is more appropriate for answering “why” as it includes subjective perspectives from the researcher. Applying the mixed-methods approach can greatly help provide objective as well as subjective information. Due to the coverage and diversity of the EIT mathematics learning perspectives, it is important to secure objective data about EIT. Subjective data would provide personal information based on the experiences of EIT students. Such information is very much crucial for this study as the research sees such students as individuals who make up a relatively silent group of individuals, mostly due to the lack of research on the application of math by engineers (Alpers, 2010, 2013; Cardella, 2007). Providing a voice to EIT students in the context of research questions can ensure the proper context of this study in terms of establishing new information. In relation to the two methods of study, a deeper conceptualisation of the research topic can be made possible. Using one method cannot secure similar goals. Another advantage of applying the mixed methods approach is to improve the credibility of the results, as the results can easily be corroborated by the other research method (Johnson et al., 2007).

In explanatory mixed-method, data is first gathered using the quantitative approach, and then the qualitative method is applied to provide an explanation for the quantitative results (Creswell and Creswell, 2017). This study used the sequential design, which basically gathers and analyses data using quantitative methods and then collects and analyses qualitative information while adding to the results secured in the quantitative method. This is demonstrated in Figure 4.2.

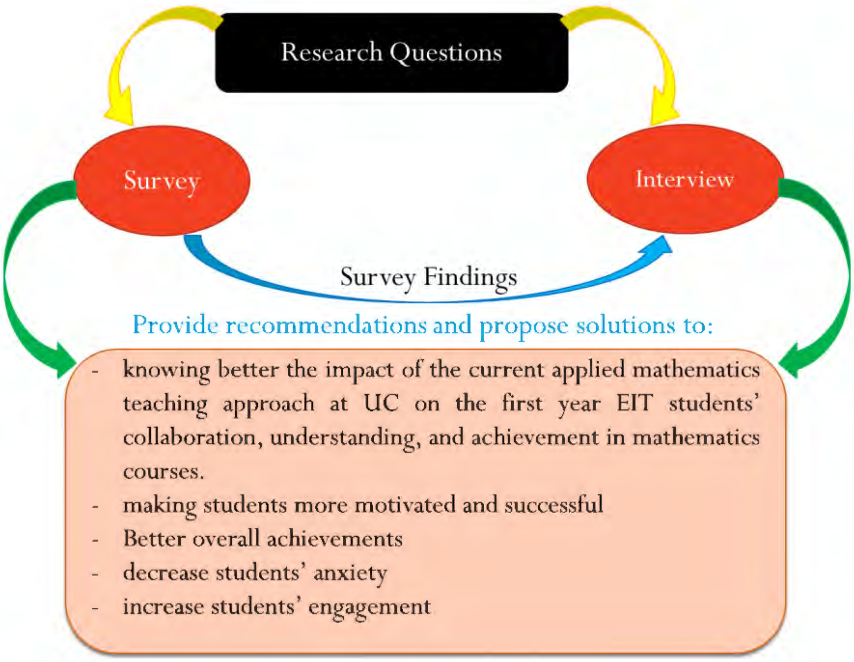


Figure 4.2 Sequential explanatory strategy mixed methods design

In the sequential approach, there is a need to have secondary qualitative information and evaluation in order to develop a more in-depth conceptualisation of the quantitative results. The use of both approaches in this study is based on several factors, including the need to have both objective and subjective qualities of research questions; also, the importance of asking EIT students by applying both methods of research; to ensure that the data gathered has depth and breadth, and to ensure the reliability and validity of the study. This sequential strategy is a comprehensive approach to evaluating the quality and responsiveness of mathematics teaching among students based on their views and feelings on teaching methods and related approaches.

At the core of this mixed methodology approach, there is the awareness that both quantitative and qualitative research methods have specific limitations with respect to research questions and the mathematical education research domain. By mixing both quantitative and qualitative research designs, these limitations are minimised. Applying the mixed-methods approach can help provide objective as well as subjective information. Because of the coverage, diversity, and complexity of the EIT mathematics learning perspectives, it is important to secure objective data about EIT. Subjective data would provide personal information based on the experiences of EIT students. This information is vital for this study as the researcher sees such students as individuals who make up a relatively silent group of individuals, mostly due to the lack of research on the application of mathematics by educators. The researcher means by the mixed-method is the integration of quantitative and qualitative methods (Tashakkori and Teddlie, 2009).

Under the hood, the researcher is aware of the challenging task of making clear that the mixing of methods in this research design of those the quantitative and qualitative findings must be integrated in a coherent way and that it will never be satisfactory simply to piece together different types of data and analysis methods. Essentially, the researcher must be assured that the different data and methods utilised are connected to an overarching research framework and make sure that the mixing of methods does not break the research questions into unrelated parts.

The Evaluation of Mathematical Teaching Pedagogies explores the constructs (dimensions) of teaching method, collaboration, understanding, achievement, motivation, learning effectiveness, and multidisciplinary approach. Within the first sequence of the quantitative phase, these constructs were operationalised by instruments of close-ended survey questionnaires that assessed the participant perception resulting in quantifiable, comparable, and correlatable constructs. Some of the first phase quantitative findings became the base of this second phase qualitative open-ended interview questions that assess the interpretable teaching and learning experience shared among students and teachers of mathematics. Within the second sequence of the qualitative phase, based on the participants’ answers to the open-ended interview questions, the analysis was carried out to find outstanding categories, axial points, and themes emerging from the participants' answers.

4.2.3 Data Collection Methods

The primary methods in positivism include surveys, longitudinal studies, experimental studies, as well as cross-sectional methods. Interpretivism includes the use of ethnography, action research, case studies, and hermeneutics, among others (Collis and Hussey, 2013). In this study, the survey questionnaire and semi-structured interviews are the chosen data collection methods.

The survey questionnaire was selected as a data collection method as it is the most effective method for gathering data from an extensive population. In such a survey, the questionnaires are the same for all respondents. These questionnaires can also be easily distributed online and automatically distributed to a significant population. The quantitative part of this study was mostly about understanding the current EIT pedagogies in mathematics, including the efficacy of success students are able to experience based on their current performance in mathematics.

In applying the qualitative method, the interviews would be considered effective in terms of gathering data about the actions of participants, including their feelings about the subject matter. Interviews ensure that respondents would be able to express their opinions on the issues. This would help give the researcher more flexibility in understanding the research questions. Qualitative data gathering applies open-ended questions, thereby supporting different responses while also ensuring that the interviewer can interject appropriate follow-up questions where necessary. The respondents can also reply in their language and based on the way they feel like answering in each question. Audio recordings ensure that the researcher can give his/her full attention to the interview without having to write down or transcribe the answers. Open discovery is the primary advantage of interviews; however, where the interview is structured, there may be restrictions in the discovery of new information. Unstructured interviews are often time-consuming and may divert from the primary research questions. For purposes of this study, the semi-structured interview is appropriate as it ensures that the interview with numerous respondents can still be systematic. An interview protocol has been applied to provide structure to the interviews. This protocol included the different questions as well as possible areas of inquiry that the interviewer would likely cover during the interview. For this study, such a protocol will help structure the time of the interview, ensuring that the interviewer will cover the necessary questions within the limited time. Such protocol can be adjusted during the interview where necessary.

The grounded theory methodology and the method which will be applied in this study are mostly differentiated from each other in terms of their data analysis. For grounded theory, the data is collected numerous times and assessed until data saturation is reached. For this research, as the respondents come from diverse disciplines and to give due course to the quantitative method, the aim is not to gain data saturation but to provide meaning to results and ensure that new information would materialise.

4.2.4 Population

As this study seeks to understand what role mathematics teaching methods play among EIT students and to establish if there is a link between student learning and their performance, the focus of this study is on EIT students in their first-year at the University of Canberra, Australia. These students may be enrolled in UC subjects such as Discrete Mathematics, Engineering Mathematics, Engineering Mathematics Fundamentals, Foundation Mathematics 1, Foundation Mathematics 2, and IT Mathematics.

For quantitative studies, the sampling method often applied is probability sampling. This method randomly chooses a sample and a representative number of respondents from the bigger population (Collis and Hussey, 2013). Random sampling is advantageous in terms of allowing the generalisation of results to a larger population. The researcher will set out to secure the highest sample of the population, which can be included in the first part of the quantitative stage.

Contrary to random sampling is purposeful sampling, which is usually the method applied in qualitative studies. This type of sampling usually considers data-rich cases which can be specifically evaluated (Patton, 2002). Different types of purposeful sampling are available, and for this study, the maximum variation sampling will be applied. It is a sampling method that seeks to consider and define specific themes or primary outcomes which cover a wide range of respondents. For qualitative studies, the sample sizes can be as small as possible as interpretivists believe that the aim is to secure numerous perspectives on the complexities involved in the social context; in effect, the researchers carry out their studies using a “sample of one” (Collis and Hussey, 2013).

Specific details for the participants can be noted in maximum variation sampling; however, among smaller samples, heterogeneity may not be efficient as each case may differ from the other. Still, Patton (Patton, 2002) believes that such an issue of heterogeneity can be turned into an advantage as patterns that come about due to the greater variation in participants can help feature the primary experiences and core effects of the program (Patton, 2002). For the qualitative level, maximum variation sampling is applied to chosen respondents from different fields of engineering and informational technology.

4.2.5 Pilot Study and Initial Quantitative Stage

The pilot study helps test the questionnaire and helps define the initial model better. The study proper has been carried out to evaluate the research model, apply the pilot-tested questionnaire, and test the hypothesis, which refers to the corroboration of the model variables. The pilot study can assist in determining if the effects the researcher is looking for can be detected with the current study's design. Also, the pilot study can assist in determining the sample size and margin of error for the main study.

It is very important to pilot the questionnaire and conduct item analysis. ‘Field testing’ is an essential part of questionnaire construction. It allows the researcher to collect feedback about how the instrument works and whether it performs well in what it is intended to measure. Based on this information, the researcher can make the final version of the questionnaire (Opie, 2019).

Teijlingen and Hundley (2001) listed some advantages of conducting a pilot study:

- It might provide an advance warning about the areas in which the research project could fail.

- It gives indications about the complexity of the unsuitability of the proposed instrument and method.

- It helps in anticipating the limitations and logistical problems which might occur during the actual data collection stage.

- It might provide an advance warning of whether the research protocols are realistic and workable.

Accordingly, performing a pilot study helps in terms of refining the research instrument and increasing the accuracy of the method and the anticipated results.

A validation process is also an essential step in developing a survey questionnaire. The recommended way to assess validity is to solicit experts in the field to assess if the scale items have a face and content validity (Straub et al., 2005). Face validity indicates that the selected scale items look like they measure the variable which they are intended to measure. Content validity assessed whether the measure covers a sufficient and representative set of items that tap the concept. The higher the representation of the scale items for the measured concept, the greater the content validity. For this study, the piloting has been conducted on two different groups; students and experts. Further details are explained in Chapter five.

The sample size of pilot studies does not generally have a common range. According to Hill (1998) and Isaac and Michael (1995) a sample size between twelve and thirty is recommended. For this study, the researcher sent the questionnaire to fifteen students and five experienced Mathematics and education teachers at UC to obtain their understanding of each item in the questionnaire.

Figure 4.3 illustrates the design for this study. It shows the main three stages of this research, including corresponding managerial decisions and processes.

The first results of the quantitative research guide the secondary processes in the qualitative phase, and in turn, data gathered there would add to or support the initial quantitative stage. Although much value is attributed to quantitative data in terms of reliability, as noted from its larger population coverage, the qualitative stage can further explain and provide details for the quantitative data results.

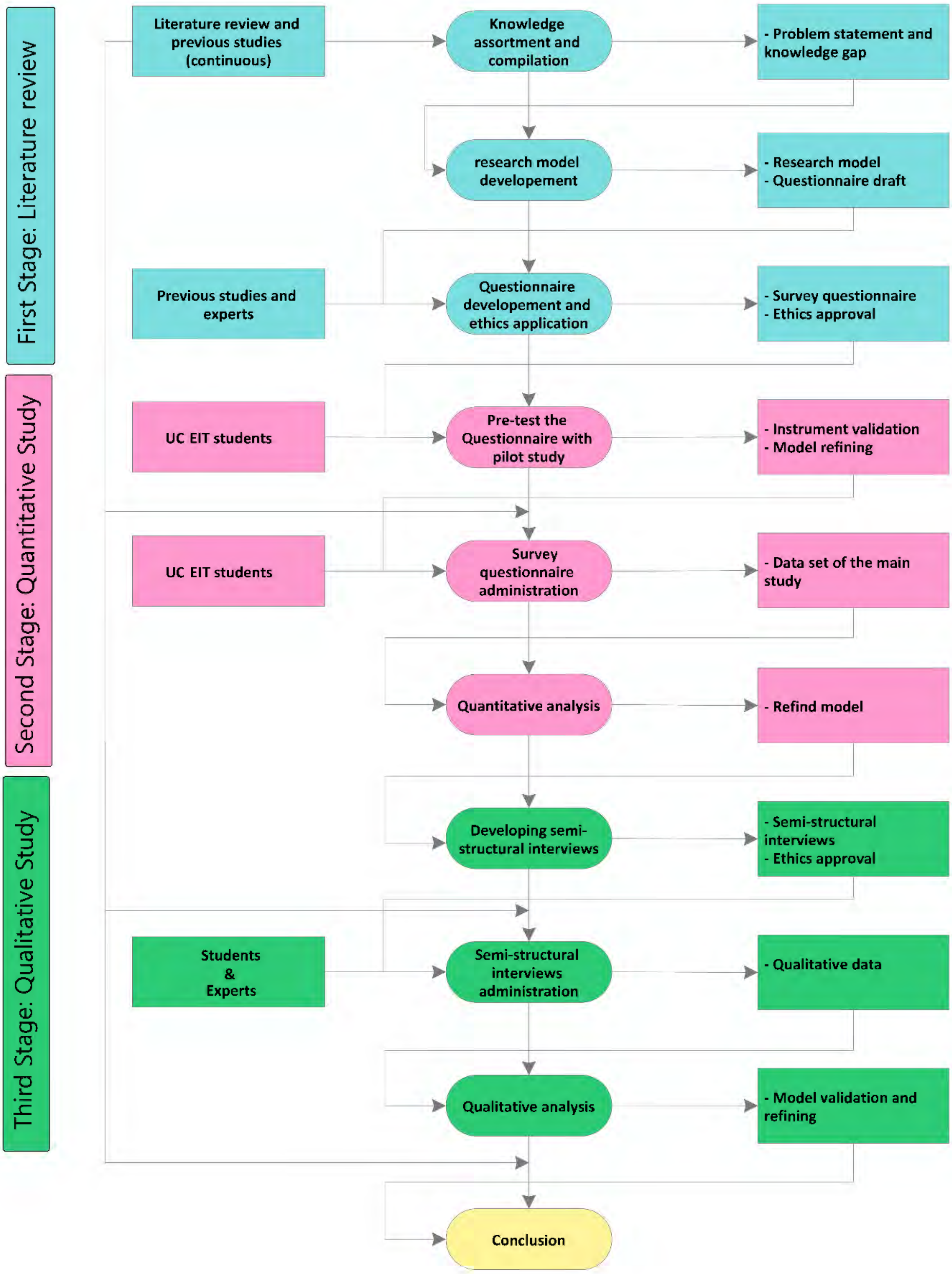


Figure 4.3 Study research design

4.2.6 Secondary Qualitative Stage

For the second stage in the sequential strategy mixed methods model, the data collection process has been carried out using semi-structured interviews. This stage of the study is meant to gather data on the actions and decisions of participants, their thoughts, feelings, and collaboration on the applications of mathematics teaching.

4.2.7 Quality Considerations

The credibility of the results significantly reflects the quality of the study. For this study, the use of numerous approaches is a way of overcoming quality and credibility issues often associated with single-method approaches. Also, an advantage of mixing methods in research is to allow for more comprehensive and rich results from the participants and research population (Cohen et al., 2008). Applying different strategies in research helps provide a means of triangulation, evaluating results using different observations and outcomes (Cohen et al., 2008).

In order to provide a basis for evaluation research, the tools of reliability, validity as well as generalisability has been used. Reliability focuses on how consistent the data-gathering process would be as well as the extent to which the results can be duplicated by future researchers. Validity relates to the degree the study results relate to the phenomenon being evaluated. Generalisability refers to the extent to which the findings can be applied to a larger population (Collis and Hussey, 2013). Details for such evaluation tools are indicated below.

4.2.7.1 Reliability

In general, the data collection processes for quantitative research relates to the application of exact measurements of specific variables. As such, the data gathering process for quantitative data is duplicable and repeatable and, therefore, highly reliable. The same cannot be said for qualitative data collection, as the subjectivity of the researcher can impact the results or data gathered. In effect, qualitative data has limits of reproducibility and low reliability. Reliability cannot, therefore, be used in establishing the quality of qualitative research. To improve such quality, there must be an extensive process undertaken to interpret data collected using qualitative methods. In securing such a goal, researchers have to indicate the different steps they undertook to gather data and to analyse the same in order to convince the reader of the soundness by which the data gathering and analysis have been undertaken (King and Horrocks, 2010).

4.2.7.2 Validity

Validity is high in qualitative research as this type of data gathering allows for access to respondents as well as the chance to study their participants in-depth. For quantitative studies, the process of gathering data may not show much of the phenomena being studied. As such, validity may be low. Researchers, therefore, have to make sure that the measures used actually apply well to what they are measuring (Collis and Hussey, 2013). The validity of results in mixed method studies is enhanced by the application of in-depth interviews with respondents, especially where the interviews are able to provide data on the personal experiences of the respondents on the phenomenon being studied. In quantitative studies, validity can be improved when attention is paid towards the survey design, including measurable aspects in the questionnaire.

4.2.7.3 Generalisability

Generalisability simply refers to how applicable the results are to the rest of the population. For small sample sizes, generalisability can be limited, and for larger samples, the results may be more generalisable.

In using random sampling for large populations, disparities in the profile of the samples and the population are usually small and may appear by chance, not due to any biases attributed to the researcher (Fraenkle and Wallen, 2009).

Generalisability may relate to quantitative studies only, but Collis and Hussey (2013) note that generalisability can still be seen in single qualitative studies where the analysis was able to observe the interactions of the phenomenon being observed.

For this study, generalisability is based on the research participants, their selection, and their number during the quantitative stage, alongside a comparison of the findings in both quantitative and qualitative stages.

4.2.8 Ethical Considerations

In the process of research, it is important to follow ethical processes, mostly securing the informed consent of respondents. Respondents have to volunteer as participants in the study, they must be fully informed, and they must also clearly understand the research being conducted (Cohen et al., 2008). Moreover, the participants have to be respected, treated and addressed with courtesy, and they must feel comfortable at all times. They must not also be made to answer unrelated and sensitive questions (Collis and Hussey, 2013). For student respondents, teacher consent has to also be secured, and the students also have to be fully informed of the study and their possible participation as respondents. They have to be informed of their right to refuse to be part of the study.

Although it is often pointed out that being vague about the purpose of the research is important in order to gain relevant findings, ethical guidelines indicate that respondents need to be fully informed about the purpose of the research and their participation in it, how the research will be used, and the possible implications of their participation in the study (Creswell and Creswell, 2017). It is also important to ensure respondent anonymity. In ensuring such anonymity, the respondent may feel more inclined to be open in his answers and to actively take part as a participant in the study (Creswell and Creswell, 2017).

Punch (2013) highlights that it is crucial to consider the questions which can eventually benefit the respondents as well as other individuals aside from the researcher. Cohen et al. (2008) emphasise that presenting a selfish purpose to the research is considered not ethical. They consider what the research will actually serve in terms of the respondents, the community in general, as well as the researcher himself (Cohen et al., 2008).

Information gathered has to be presented honestly, and findings should not be distorted in favour of a specific interest group. In presenting the findings, materials from other studies have to be cited using in-text citations with the corresponding bibliographical entries indicated in the paper (Creswell and Creswell, 2017). In the process of education studies, there are lesser incidents of ethical dilemmas as compared to other studies in psychology or medicine. Still, the welfare of the students in this study has to be given strong attention even if the results of the research may be compromised (Cohen et al., 2008).

No ethical concerns were anticipated for this study. And this study has been carried out based on the ethical standards of the University of Canberra, and the following points have been considered:

- Initial work on EIT students has been approved by lecturers in mathematics classes.
- The students taking part in this study have been notified about the aims and purpose of this study, and they were informed that their participation is purely voluntary and they can withdraw at any time.
- The respondents have been asked to give their consent to an audio recording of the interview.
- Their anonymity at all times has been ensured.

- The transcript and the audio recordings have been secured in a safe place accessible only to the researcher.
- The recordings and transcript will be destroyed at the completion of this study if required by UC regulations.
- Data from other sources and studies have been properly acknowledged via in-text citations and bibliographic entries.

4.3 Survey Design and Implementation

The systematic approach of collecting information using questionnaires that draw quantitative conclusions about the respondent's opinions, behaviours, attitudes, and beliefs is known as survey research. The questionnaire's design is essential in ensuring that reliable information is collected and that the results remain generalisable and interpretable. A mix of methods was used to conduct the study, in which quantitative and qualitative research designs were used. This section focuses on the quantitative part of the study. A survey questionnaire was used as a preferred method of quantitative data collection because the population was large. In such a survey, all respondents fill out the same questionnaire. The quantitative aspect of this study was primarily concerned with gaining a better grasp of existing EIT pedagogies in mathematics, as well as the efficiency of achievement students can reach based on the present math performance.

This survey is important to improving the understanding of the influence of current mathematics teaching methodologies at UC on collaboration, knowledge, and performance of first-year EIT students in mathematics courses. It would also be useful to learn more about new EIT students' mathematical anxieties. The findings of this survey will give some insight into present pedagogies and strategies and students' learning behaviours, resulting in a piece of greater knowledge about how to keep EIT students less worried, more motivated, and more effective at learning mathematics.

4.3.1 Survey Population

As this study seeks to understand what role mathematics teaching and learning play among EIT students and to establish if there is a link between student learning and their performance, the focus of this study is on EIT students in their first-year at UC, Australia. The survey was conducted throughout the year 2020. The participating students were enrolled in the following courses: Discrete Mathematics, Engineering Mathematics, Engineering Mathematics Fundamentals, Foundation Mathematics 1, Foundation Mathematics 2, and IT Mathematics.

In this survey, the questionnaire is the same for all respondents. This questionnaire was distributed by email to the whole population. For this study, we were able to have 107 EIT students from the UC partake in this study. One hundred one final responses were appropriate for analysis. Three responses were eliminated because they were redundant, and another three were eliminated because they were not answered.

4.3.2 Survey Design

A survey questionnaire is generally the preferred method of quantitative data collection when the population is large. Survey design considerations include the time required to complete the survey; the clarity of the survey questions and their relevance to the research questions; the administration of the survey; and the method of analysis. The study was conducted in order to find the relationship between the impact of learning behaviours and teaching methods of mathematics. The reviewed literature of the current study was used to be the initial source of the measures and the questions for each variable (Albeshree et al., 2020).

The questionnaire was created after a thorough examination of the literature, an assessment of this study objectives, and collaboration with academic staff from the Faculty of Education. Adjustments made to the questionnaire included rephrasing the wording of some questions to fit the research context and adding new questions based on the opinion of experts. For this purpose, the pilot study was initially conducted to assess the reliability and validity of the questionnaire used and to analyse the results based on the responses and the subject matter experts (SME) or simply experts. Performing a pilot study helps in refining the research instrument and increasing the accuracy of the method and the anticipated results. For this purpose, the piloting study was conducted in two phases, including students and experts.

In the first phase, the researcher administered the questionnaire randomly to fifteen EIT students. They were asked if the questions were worded in an understandable and clear way. Based on their feedback, some of the questions were re-worded and refined. In the second phase, the updated questionnaire was sent to five experienced Mathematics and education teachers to obtain their understanding of each question in the questionnaire for further clarity. They were asked if the questions were worded in a correct, understandable, and clear way. They were also asked to examine if the questions would measure their construct and assess the ambiguity, simplicity, and redundancy of each question. Based on their feedback, some of the questions were rephrased and refined. Finally, the questionnaire was modified to meet the experts' recommendations and classified into different factors/measures according to the nature of each question.

The final questionnaire included the demographic variables and several measures covering different aspects of learning behaviour and teaching and learning methods, including questions related to students' learning styles, collaboration, general understanding, time management, learning effort, emotions, motivation, satisfaction, and anxiety. The questionnaire also gives feedback on the teaching approach, assessment, and technology's role in learning. Appendix IV shows a sample of the before-mentioned measures and the related items.

The pilot study results were analysed in SPSS software. Correlation analysis indicated a highly significant relationship between learning behaviour and teaching method, and regression analysis indicated teaching behaviour as a significant predictor of learning behaviour.

In survey design, it is standard practice to include a range of response options to survey questions where the participants can just tick the box beside their preferred answer, and this is one way of reducing the time required to complete the questionnaire. Such questions allow variables to be quantified and measured efficiently. Apart from the demographics' questions, the questionnaire contains closed-ended 5-point Likert scales questions only, ranging from "strongly disagree" to "strongly agree" or from "very frequently" to "very rare". These were chosen as an efficient way of collecting quantitative data about the research questions presented in this study. Using a Likert scale can show a convenient response set, and it is very familiar to the students since it is used frequently when conducting various research surveys.

Adding to the measurement scale section, the survey is composed of a set of elements. The first section of the survey is a participant sheet that contains information about the purpose of the study, an introduction to the questionnaire and a guarantee of participants' confidentiality and privacy. Moreover, contacts and names of the researcher, the supervisors, and the university were provided to give the survey a formal and legal shape. Also, it is mentioned in the first section that a copy of the results will be available on request as a motivation to complete the questionnaire. Then, each followed section contains instructions and guidelines for the participants to help them in filling the questionnaire.

4.3.3 Survey Data Analysis

IBM® SPSS® Statistics software (version 26) has been used to analyse the quantitative data collected in this study. IBM® SPSS® Statistics software has a number of statistical packages that are widely used in industry and academia.

To analyse the quantitative data, this research started with descriptive statistics. This descriptive analysis was employed to obtain an overview of the quantitative data. The percentage and frequency of participants' responses have also been calculated. Other statistical calculations, reliability tests, and finding the data pattern have also been employed to provide in-depth analysis, as demonstrated in Chapter 6. Since there are no open-response questions in the questionnaire, this study had not compiled a 'codebook' that usually comprised coding lists for variables.

4.4 Interview Design and Implementation

Following the collection and analysis of survey data in this two-phase sequential explanatory mixed methods research study, semi-structured interviews have been employed to further investigate answers to the research questions. Its purpose is to explicate and expand on the survey findings. There were two phases of interviews. The first has been conducted among EIT students, while the second one has been conducted among education and mathematics experts. They both share the same design, interview protocol, coding, and data analysis as described below and in Chapter 7. However, the experts' interview questions have been slightly modified to gather more details and give them a chance to provide suggestions and recommendations in light of the survey findings.

4.4.1 Selection of Interview Participants

The interviews target participants groups include Engineering and IT students, mathematics teachers, and education experts. It uses a purposeful sampling technique that is commonly adapted for a qualitative study (Creswell and Creswell, 2018). The selection of interview participants allows the diverse disciplines type to be identified from the pool of EIT students, and it allows the selection of experts who have related backgrounds in mathematics education.

After the initial contact, the researcher sent the main questions to the participants, and the interview took place in specified time frame agreed upon by the participants. A final sample of fifteen participants completed the interview.

4.4.2 Interview Design

The interview design is based on the research questions and the survey findings conducted in the first sequence of the quantitative phase. A list of questions and predetermined inquiry areas that the researcher wants to explore during each interview helps make interviewing multiple participants more systematic. The main objectives of the interviews will be to capture EIT students' personal experiences in relation to the research questions and to give a more in-depth exploration of the survey findings. The interview design is organised according to the three main research questions; see section 4.4.3 below.

Before the interview was conducted, the participant information form was distributed containing the following information:

- Purpose of Study
- Use of Result
- Participant Involvement

- Confidentiality
- Anonymity
- Data Storage
- Ethics Committee Clearance
- Queries and Concerns

4.4.3 Research questions and the relevant interview questions

The Q1 of research questions pertains to the constructs of teaching method, collaboration, understanding, and achievement. The Q2 concerns with students' motivation and factors that influence them, and Q3 is related to the multidisciplinary approach's influence on the effectiveness of mathematical learning and teaching. Table 4.1 shows the relevant direct interview questions related to these three research questions. Some questions were based on the analysis of the results of the quantitative stage of the research, see Chapter 6. The rest of the interview questions were directly and indirectly, related to the research questions to enrich and mature our understanding (see Appendix II for full interview questions).

Table 4.1 Relevant interview questions related to research questions

Research questions	Relevant interview question
Q1	- What are the activities you feel the mathematics teacher could additionally use to help students better understand mathematics? - What are the ways you feel students can add to face-to-face learning environments to be more involved in discussions for collaborative and active learning of mathematics? Does this apply to the online learning environments as well? Or are there other ways?

	- Is it necessary to describe clear objectives of each lesson to the students? Why? - To what degree do you think student/student collaborations can facilitate lessons discussion and increase students understanding? - In your view, why do you think more than one-third of the students have serious concentration issues? What should they do to get less distracted? - About 62% of the students have trouble keeping up with what they are learning, and about 69% of the participants think they usually move to a new topic before they really understand the one at hand. Why do you think this is happening? What can be done to resolve this issue?

Q2	- About half of the students aim just to pass the course while doing as little work as possible.
	  - What reasons could be behind their lack of motivation?
	  - How can they get more motivated while learning mathematics?
	  - What factors motivate EIT students to engage, or not engage, with mathematics?
	- More than 44% of the participants get tense when they prepare for a mathematics test, about 30% consider working on mathematics assessments is stressful for them, and about 22% worry that they might not know enough mathematics to do well in future mathematics-related courses. Apparently, some students have a high level of anxiety and a lack of confidence in their learning.
	  - Why do you think is that?
	  - How can this be lessened?

Q3	- Do you think the implementation of a multidisciplinary pedagogical approach can enhance the effectiveness of student mathematics learning? e.g., blended approaches (online and face-to-face) for example.

4.4.4 Interview Protocol

Participation in the interview is completely voluntary, and all of the responses are kept confidential. All reports and publications of the research will contain no information that can identify any individual, and all data will be kept in the strictest confidence. The interview takes 30-60 minutes to complete. The interviews were conducted via Zoom or MS Teams. The semi-structured interview form, which contains 17 open-ended questions, is given to all participants. The interview questions are simple and easy to understand; they link to the umbrella of the study goals, and they open up the conversation to get more details.

The questionnaire will include the primary questions that focus on the primary objectives of the study. These questions will be asked directly before doing anything else to encourage a response. Then, the researcher will ask planned follow-up questions or probes. These are the questions that make an interview question more specific and help direct the participant to the central issues of the study. By means of conversation, the researcher will ask spontaneous follow-up questions. These are the questions that will be asked after listening to the first responses to a question to help encourage the participant to say more. Something like:

- Please say more about that.
- Can you give me more details?
- What is it about?
- Tell me more about…
- What is your experience with?
- Describe.
- Imagine.
- What caused you to?
- What features of (the topic/specific aspect) do you particularly like/dislike?
- How, when, where, and how often do you?

4.4.5 Conducting the Interviews

The purpose of the interviews is to capture the participants' personal stories, to elicit their direct experiences of mathematics learning and their feelings about mathematics in the context of the research questions and to explain the survey findings.

The interviews were conducted at UC, where the researcher is a postgraduate student, all participants are EIT students, Mathematics teachers and educator experts are academic staff at UC. To help put the participants at ease, to build rapport with the interviewees and in accordance with ethical guidelines, each interview was opened with a brief description of the study where the researcher discussed the purpose of the research, the format of the interviews, analysis of the data and the proposed publication of any findings. The interviewees were assured of anonymity and provided confirmation of their consent to the audio recording of their interviews. Prior to embarking on the main interview questions, participants were asked about their educational background. The interviews followed the general structure of the interview protocol, and interviewees were allowed to present additional concepts if relevant to the research questions. While the main focus was on the interviewees' own experiences, the interviewees were also questioned in relation to the survey findings. Probing questions were used extensively to extract deeper information from the interviewees. In order to reduce research bias, the researcher avoided leading questions and refrained from commenting on the interviewees' responses. The researcher regularly sought clarification and confirmation that the interviewee's views were interpreted correctly. Overall, the interviews were conducted in a friendly and casual manner.

4.5 Summary

For this study’s research methodology, the sequential strategy mixed method design was applied. The collection and analysis of data were carried out first using quantitative data collection, followed by qualitative data collection, which will support any further quantitative data collection processes. The data collection methods included the use of a semi-structured interview and a survey questionnaire. The questionnaires were developed based on a careful review of the literate, considerations of the study aims and consultation with academic staff (including from the Faculty of Education).

5 Pilot Study

This study was conducted in order to know the relationship and impact of learning behaviours and teaching methods of mathematics. For this purpose, a pilot study was conducted in order to know the reliability of the questionnaire used and to analyse the results on the basis of the responses of the respondents and the experts. The quantitative research design in the pilot study used data collected from 15 participants from the EIT students at UC. In addition, the questionnaire was given to five experts in mathematics and education for further clarity. As per the comments and to improve the reliability of the questionnaire and authenticity of the data, the questionnaire was rephrased and modified into different factors of learning behaviour and teaching methods. The results were analysed in SPSS software. Our correlation analysis indicated a highly significant relationship between learning behaviour and teaching method. Our regression analysis indicated teaching behaviour as a significant predictor of learning behaviour.

5.1 Pilot Study Design and Sampling

For this pilot study, a quantitative method design was used in which questionnaires were administered on the students. Probability sampling was used in which the targeted population was EIT students at the University of Canberra.

5.1.1 Participants and Setting

The participants were EIT students enrolled in their first-year at the UC in Australia. These students may be enrolled in the following courses: Discrete Mathematics, Engineering Mathematics, Engineering Mathematics Fundamentals, Foundation Mathematics 1, Foundation Mathematics 2, and IT Mathematics.

5.1.2 Procedure

The piloting study was conducted in order to know the validity and reliability of the questionnaire along with the ambiguity in the items. For this purpose, the piloting study was conducted in two phases, including students and experts. In the first phase, the researcher administered the questionnaire to fifteen students of EIT. They were asked if the items were worded in a correct, understandable, and clear way. Based on their feedback, some of the items will be re-worded and refined. In the second phase, the same questionnaire was sent to the five experienced Mathematics and education teachers at the UC to obtain their understanding of each item in the questionnaire. They were asked if the items were worded in a correct, understandable, and clear way. Based on their feedback, some of the items were rephrased, such as "*I look for more material, if I'm not clear about some of the content*", and also refined to increase their clarity and to make sure the participants' answers will be easy to analyse next time.

In the second step, the same questionnaire was sent to the experts to examine if the items would measure their construct and items' ambiguity, simplicity, and redundancy. Finally, both questionnaires were modified into different factors according to the nature of the items, which will help in better clarity of which learning difficulty the students experienced in mathematics and which teaching method isn't considered suitable for them. The factors of the learning behaviour questionnaire included learning styles, learning environment, difficulties, etc., and the factors of teaching methods included understanding, class collaboration, teacher role etc.

5.1.3 Outcome Measures

The measures include demographic variables, a questionnaire related to the learning behaviour of the students and a questionnaire on teaching methods.

5.2 Statistical Analysis

The results of the study were extracted by descriptive and inferential analysis.

5.2.1 Descriptive Statistics

Descriptive statistics described the frequency and percentage of the demographic variables. The frequency and percentage of the variables are:

Table 5.1 Frequency and percentage of the demographic variables (N=15)

Variable	*f*	%
Gender		
Male	15	100%
Age		
2000	1	8%
2001	9	60%
2002	5	33%
Is English our native language?		
Yes	11	73%
No	4	26%
Was your Mathematics course at high school?		
Advance Course	5	66%
Basic Course	10	33%
Did you attend a mathematics pre-course?		
Yes	2	13%
No	13	87%
How do you pay for your studies?		

Parents	6	40%
Job	1	6%
Scholarship	1	6%
Other	7	46%
How much time a week (in hours) do you dedicate to:		
• Doing a part-time job?		
0-4	8	55%
5-10	6	35%
10-15	1	7%
• Study, without classes?		
1-5	3	20%
6-10	7	46%
11-15	3	20%
16-20or more	2	13%
• Do other non-university Activities?		
1-5	3	20%
6-10	8	53%
11-15	2	13%
16-20 or more	2	13%
How important were the following reasons for choosing your study subject for you?		
• Personal preferences and talents		
Significant	12	80%

Important	3	20%
• Good earning potential		
Significant	8	53%
Important	5	33%
Not important	2	13%
• Advice from parents or friends		
Significant	5	33%
Important	7	47%
Not important	2	13%
Not significant	1	7%
• Advice from academic and professional consultants		
Significant	5	33%
Important	3	20%
Not important	3	20%
Not significant	4	27%

The results indicated that male participants participated in the study, from which 60% were born in the year 2002, and 33% were born in the year 2003. About 73% of students reported that English is their native language, and 26% reported that English isn't their native language. 66% of students reported mathematics as their advanced course in high school, while 33% reported mathematics as their basic course. About 87% reported that they didn't study mathematics as a pre-course, and only 13% studied it as a pre-course. The results also showed that 40% of students reported that their parents pay their fees, 46% of students have other resources to pay for fees, and 6% paid their fees by doing a job or through a scholarship. 55%

of students reported that they spent 4 hours doing a part-time job, 35% spent 5-10 hours doing a part-time job, and only 15% spent 10-15 hours doing a part-time job in a week. About 46% of students reported that they studied 6-10 hours without classes, and 20% studied 1-5 hours or 11-15 hours in a week. 13% studied 16-20 or more hours in a week without classes. Related to no-university activities, 53% of students spent 6-10 hours, 20% spent 1-5 hours, and 13% spent 11-15 or 15-20 or more hours in non-university activities in a week. 80% of students showed significance in choosing a subject according to personal preferences and talents, 53% showed significance in selecting a subject with good earning potential, 47% described it as important to choose because of the advice of parents and friends, and 33% showed significant in selecting subject according to the advice of an academic and professional consultant.

5.2.2 Inferential statistics

Inferential statistics is carried out on IBM SPSS Software, in which the correlation and regression analysis was conducted in order to know the relationship and impact of the variables, respectively.

5.2.2.1 Correlational Analysis

Correlation analysis describes the relationship between the variable, which is either positive or negative. Karl and Pearson (1985) developed this test to study correlation. If the value of Pearson correlation came as +1, then the two variables are said to be positively related to each other. Contrary to that, if the value came as -1, then the two variables are said to be negatively related to one another. In this chapter, Pearson correlation analysis was used to know the relationship between the variables.

Hypothesis 1: There is a significant positive relationship between Learning Style and Teaching Behaviour

Table 5.2 Correlation analysis between variables

Correlations

		LB	TM
LB	Pearson Correlation	1	-.468
	Sig. (2-tailed)		.092
	N	14	14
T	Pearson Correlation	-.468	1
M	Sig. (2-tailed)	**.092**	
	N	14	14

Note: LB=Learning Behaviour, TM= Teaching Methods

The results indicated that the learning behaviour is positively correlated with teaching methods as the p <.001. Hence the hypothesis is approved, so there is a significant positive relationship between learning behaviour and teaching methods.

5.2.2.2 Linear Regression Analysis

Linear regression analysis was conducted in order to know the impact of teaching methods on learning behaviour. For this purpose, learning behaviour was taken as a dependent variable, and the teaching method was taken as an independent variable.

Hypothesis 2: It is hypothesised that teaching methods are significant predictors of learning behaviour.

Table 5.3 Linear regression analysis between variables (N=15)

Variable	B	SE B	β
Teaching methods	-.55	.16	-.46**
R^2		.21	
F		3.35**	
ΔR^2		.15	

*Note: **= p<.001*

Table 5.3 shows the linear regression analysis of predictors of learning behaviour. The result showed that teaching methods are significant predictors of learning behaviours. The .21% variance was explained by the model comprising teaching methods (R^2 = .15). The overall model was also significant F (1, 12) = 3.35%, p < .001.

5.2.2.3 Independent T test

t- Test was conducted to compare the native English language speakers with learning behaviours along and teaching methods.

Hypothesis 3: It is hypothesised that those students who have effective learning behaviour are native English speakers.

Table 5.4 Means, standard deviations, t and p values of native English language on learning behaviour and teaching methods (N=15)

	Is English your native language?						Confidence interval	
	Yes		No					
	M	SD	M	SD	t	p	LL	UL
LB	78	13.09	71	10.42	1.09	.30 (ns)	-8.42	23.02
TM	57	9.70	67	10.61	-1.5	.17 (ns)	-25.32	5.92

Note: LB= Learning Behaviour, TM= Teaching Methods, CI=95%

The results indicated a non-significant difference between the native English language and learning behaviours and teaching methods. It means that the participants who had native English language have the same learning behaviour and teaching methods as compared to those who weren't native English speakers. The values .30 (p>.001) and .17 (p>.001) at a 95% confidence interval showed a non-significant difference in learning behaviour and teaching methods with the native language, respectively.

Attend Mathematics Pre-course and Learning Behaviours

t- Test was conducted in order to compare the students who attended mathematics pre-course or not with learning behaviours.

Hypothesis 4: It is hypothesised that those students who attend mathematics pre-course have effective learning behaviours related to mathematics.

The results indicated a non-significant difference between attending mathematics pre-university and learning behaviours. It means that the participants who studied mathematics in the pre-course have the same learning behaviour as compared to those who haven't studied mathematics in the pre-course. The significant value .16 (p>.001) at 95% confidence interval showed a non-significant difference in learning behaviour with studying mathematics in pre-course.

Table 5.5 Means, standard deviations, t and p values of attending mathematics pre-course on learning behaviour (N=15)

	Did you attend a mathematics pre-course?						Confidence interval	
	Yes		No					
	M	SD	M	SD	t	P	LL	UL
LB	3	2.12	12	13.32	1.49	.16 (ns)	-2.85	15.19

Note: LB= Learning Behaviour, ns = non-significant, CI=95%

Nature of study Mathematics at High School and Learning Behaviour

t- Test was conducted in order to compare advanced and basic mathematics courses at high school with learning behaviours.

Hypothesis 5: It is hypothesised that those students who studied the advanced course of mathematics in high school have effective learning behaviour towards mathematics.

Table 5.6 Means, standard deviations, t and p values of mathematic course at high school on learning behaviour (N=15)

	Mathematics course at high school?							
	Basic course		Advance course				Confidence interval	
	M	SD	M	SD	t	P	LL	UL
LB	74	14.01	82	3.31	-1.86	.09**	-19.21	1.61

*Note: LB= Learning Behaviour, ** = significant at alpha=0.001, CI=95%*

The results indicated a significant difference between the nature of the mathematics courses at high school and learning behaviours. It means that the participants who study advanced mathematics in high school have different learning behaviour as compared to those who studied basic mathematics in high school. The significant value .09 (p<.001) showed a significant difference in learning behaviour with the nature of studying mathematics in high school.

5.3 Discussion

The results indicated a significant positive relationship between learning behaviours and teaching methods. It is estimated through the research that there are numerous teaching strategies. Content-based learning and collaborative training are considered as most important. Challenge-based learning (CBL) is known as one of the philosophical forms of problem-based learning and is considered as a strategy that is helpful in the training of mathematical students. The purpose of collaborative training is to promote learning's effect on performance, during which collaborative work between the teacher as facilitator and participants as students is accomplished. Thus it creates a purposeful environment in which both the teacher and the student engage with each other (Hasanpour-Dehkordi and Solati, 2016). Another strategy of learning behaviour is collaboration work in which the involvement of teamwork increases the involvement of the classroom activities and especially the communication skills of the students. These learning types are linked with the teaching methods. On the other hand, related to mathematics, Stanberry (2018) accentuated the importance of active learning in enhancing the teaching and learning of calculus, which is one of the branches of mathematics. Stanberry (2018) contended that active learning has the ability to enhance the comprehension or understanding of students. To ascertain whether active learning is indeed important in improving performance in STEM subjects, Stanberry (2018) utilised a number of active learning methodologies. For instance, he asserted that Strategic Engagement for Increased Learning (SEIL) had the potential to escalate the success of students taking calculus, enhance mathematical skills for college students, and help to produce highly productive STEM graduate required for the STEM workforce in the USA.

The studies also indicate teaching methods as significant predictors of learning behaviour. This complies that effective teaching strategies enhance the ability of the students to learn effectively and to adopt useful learning behaviours as the researcher identified that encouragement of the students by the teacher-led to effective problem solving as compared to the discouragement that led to the fear and the anxiety in the students (Uzair-ul-Hassan et al., 2016).

So, for more effective teaching methods, the teachers should understand and master different types of learning behaviours (learning styles) to better control the learning steps and urge college students to participate better in all aspects of learning. This will foster effective learning behaviours of the students by reducing procrastination and anxiety and by developing motivation (Yang and Juan, 2018). In another study undertaken at the department of industrial engineering at Pancasila University, it was found that there was a significant transformation from lecturer-focused learning to student-centred learning. The approach was purely directed to student self-directed learning (SDL) with an all-inclusive scheme to direct the online activities to student academic improvement (Darmawan and Hidayah, 2017; Eddy et al., 2015).

Vázquez et al. (2018) highlighted various strategies that teachers can use to improve teaching/ learning mathematics. They classified the strategies into different categories, including instructional strategies rooted in information technologies, such as project-based learning and instructional strategies for teaching mathematics at the undergraduate level. Among the highlighted strategies include implementing a technology curriculum, instructional strategies, technology, and manipulative tools. They also emphasised making connections, differentiating challenges, fostering engagement, promoting fluency, and structuring lessons. Based on this study, an effort to boost learning and teaching mathematics should be geared towards incorporating the above-highlighted strategies.

5.4 Summary

The pilot study was conducted in order to test the questionnaire and helps define the initial model better. The study was based on learning behaviours and teaching methods and was to explore the challenges and difficulties that EIT students at the University of Canberra faced in mathematics class. The purpose of the study is also to framework the pedagogic approaches of enhancing teaching strategies in exploring the motivation of mathematics in EIT first-year students. The quantitative study used 15 respondents who responded to the questionnaire. The results were analysed in SPSS software. The correlation analysis indicated a significant relationship between teaching methods and learning behaviours. The regression analysis may suggest teaching methods as a significant predictor of learning behaviours.

6 Survey Analysis and Findings

Mathematics has significant impacts in the fields of EIT, yet there are significant barriers to its effective student education with regards to teaching and learning methodologies at the tertiary level. The main objective of this study was to investigate the barriers impacting effective learning that EIT students encountered, such as mathematical anxiety and worry, low levels of motivation, and inadequate educational behaviour. This study combined quantitative and qualitative approaches to investigate such difficulties. A total of 101 participants were involved in this study, with the findings suggesting that there is still a need to continue developing and delivering creative pedagogical approaches to improve the effectiveness of mathematics teaching for EIT students. The outcomes of this study would support EIT learners and lecturers in identifying potential problems which may be obstructing the effective learning and teaching of mathematics, as well as practical measures to help build a strong learning collaboration structure in rapidly changing environments.

6.1 Introduction

In the new international economy, circumstances ask for a workforce that is equipped with up-to-date knowledge and the skills that would enable them to compete. There is a need for them to be problem solvers, innovators, and logical thinkers and enhance their cognitive abilities. A crucial factor in solidifying these skills is strengthening EIT competencies (Toulmin and Groome, 2007), with mathematics being a significant impact in the fields of Engineering and Information Technology (Goold, 2012).

There is a plethora of literature that demonstrates a strong association between cognitive abilities and achievement in mathematics-related fields (Giofrè et al., 2017; Soares et al., 2015), with the reason being that unravelling mathematical tasks necessitates the ability to link second-order relationships in a logical and orderly manner and the ability to manipulate visual representations (Hunt, 2011). Additionally, a recent study by Adkins and Noyes (2018) found that advanced mathematics skills can predict success in other academic domains – highlighting the importance of mathematics.

Unfortunately, various studies from countries across the globe have demonstrated that a large proportion of pupils fail their mathematics courses in their last year of high school or first-year of college (Kafata and Mbetwa, 2016a; Oliveira and Freitas, 2016; Saxe and Braddy, 2015). Even though several countries have been working on promoting STEM disciplines, it has evidently not helped overcome the struggles faced by EIT students (OECD, 2015; Yaşar et al., 2006a) – mostly because the EIT instructors struggle as educators to develop innovative and relevant teaching and learning approaches that meet the needs of millennial learners (Albeshree et al., 2020; Chubin et al., 2008; Pinder-Grover and Groscurth, 2010). Hence, there is a need for more advanced, up-to-date, and innovative learning and environments (Albeshree et al., 2020).

The rapid advancement in digital technology, e-learning systems, and new learning environments is yet another challenge that is making educators around the globe conceptualise the prospects of teaching and learning (Alterator and Deed, 2013). Since different people have different learning modalities (Oxford, 1993, 1995) and a positive correlation between learning styles and academic performance has been found, the physical settings of numerous educational institutes appear to be now more focused on transforming the classroom experience, with three modes of learning having been identified in the scientific literature (Fisher, 2006). The first mode is more of a traditional classroom-focused or didactic pedagogy approach. The second mode is more of a student-centred approach focusing on transactional approaches to teaching. The third mode is more interactive, with the concept of the third space being employed where conceptual learning is combined with experiential learning in outdoor learning areas, hallway nooks and lounge styled rooms (Brooks, 2011; Fisher, 2006). However, there is still a need to shape and update teaching methodologies that facilitate student effective learning for those with different learning styles to keep up with a more advanced classroom environment so the academic performance of the students can be enhanced (Balakrishnan and Gan, 2016; Nja et al., 2019).

It has also been established that motivation and self-efficacy act as predictors of academic achievement when it comes to mathematics (Stevens et al., 2004), and motivation can be enhanced using high tech student-centred learning (Star et al., 2014). Research led by Imms and Byers (2017b) found that a more student-centric pedagogy, where the students were encouraged to exercise choice in problem-solving, take more ownership, and ultimately to be more engaged within a more dynamic and adaptive space, combined with the affordances of technology, had a positive impact and facilitated enhanced and rich learning experience for students.

There are different measures that cover various aspects of teaching methods and learning behaviour. Students' learning styles determine how they adapt to the environment in the classroom (Altintas and Ilgün, 2017). For example, using the Grasha-Riechmann Learning-style Framework, Azarkhordad and Mehdinezhad (2016) discovered that cooperative teaching strategies can help students attain educational goals or engage in more mental activity. Collaboration entails mathematics teachers working together on a single goal, engaging in critical discourse and study, and providing mutual support; discussing topics that confront teachers professionally, while focusing on their school and the community (Jaworski et al., 2017). Effective education environments create learning experiences and assignments which are founded on good and important mathematics and make certain all students are assigned activities that will help them enhance their comprehension of the current subject of study.

Furthermore, time is an important variable because it cannot be reclaimed if it is spent incorrectly. The research area’s mathematics achievement is significantly influenced by lack of topic knowledge, pedagogical competency, and students’ views of time management. Time management can be defined as self-management with such a clear focus on the time when determining what’s what, how much time to assign to tasks, how to accomplish activities more efficiently, and then when the time seems ideal for specific activities. Poor concentration, poor time management, or unseriousness throughout terms of consistent practice of mathematical ideas, among many other things, were cited as indicators of students’ diminishing poor mathematics achievement (Eyong et al., 2020).

Accurate and effective assessment is also crucial. According to the findings of (Yang et al., 2017; Yang et al., 2015b), diagnostic testing must be introduced into teaching and learning activities since this not only improves students’ learning and performance but also their assurance in solving calculus issues. Assessments were used for a variety of purposes, including assigning grades to students, national accountability, monitoring capabilities, allocation of resources within such a district, student placement as well as monitoring, deciding interventions, working to improve learning and teaching, and providing necessary feedback to the students and their families (Suurtamm et al., 2016).

Learning mathematics enables students to think analytically and to reason more effectively. It assists individuals in developing their lifelong learning skills to address difficulties in their daily lives. Students memorise the formulas and rules used in a mathematics class. There is no science, contemporary technology, and national growth without mathematics (Usman and Musa, 2019). As a result, Za'ba et al. (2020) argue that technology integration in teaching/learning occurs when teachers are trained to use technological devices to assist them in getting information, researching and integrating it, and effectively communicating it to students.

A recent study looked at students' real-time emotional responses in mathematics in relation to teaching approaches that have been thought to differ in terms of how much they positively influenced students' control-related judgments (Bieg et al., 2017). Incorporating technology into mathematics instruction, motivational attitudes, and the role of teachers is critical (Backfisch et al., 2020). Furthermore, it is critical that teachers obtain and employ various technological equipment at their universities (McCulloch et al., 2018). Learning styles analysis can be advantageous to students and can help them focus on learning, improving academic performance and satisfaction. When assessment tasks are aligned with instructional activities, anxiety may be minimised, and tests may be a better predictor of student progress.

Another important aspect that acts as an obstacle for mathematics teaching for educators is mathematics anxiety (Gresham, 2007; McLeod, 1988; Sloan et al., 2002; Vinson, 2001). There is a need to find a way around it. Mathematics anxiety, or even the tension and sadness generated when predicting and finishing mathematical assignments, is common among Australian students (Thomson et al., 2013b). According to research, mathematics anxiety can disrupt working memory, resulting in more errors as well as a reduced ability to participate successfully in mathematics (Ashcraft and Kirk, 2001; Eden et al., 2013; Ma, 1999). Students who are persistently anxious about mathematics seem to be more likely to skip mathematics courses, programs, and jobs. As a result, mathematics anxiety would be a short-term learning problem because it reduces performance, as well as a long-term learning problem as it pushes students away from mathematics opportunities and career paths (Buckley et al., 2016).

It has been found that students, especially in the last year of high school or first-year of college, face significant challenges and a large proportion of students fail to pass mathematics units (Kafata and Mbetwa, 2016b; Nicholas et al., 2015; Oliveira and Freitas, 2016; Saxe and Braddy, 2015). We wanted to explore the contributing factors of this.

The main aim of this study was to propose suggestions and recommendations to enhance the effectiveness of teaching approaches for mathematics and to provide insights into issues like mathematics anxiety and fear experienced by EIT students. This study also aims to enhance understanding of the efficiency of the current applied mathematics teaching approaches at UC on the first-year EIT students' teamwork and engagement, comprehension and perception, and success in mathematics courses and provide recommendations to improve the motivational level of EIT students at UC.

6.2 Survey Analysis

The credibility of quantitative findings is highly dependent on the design of the research instrument and its content validity. While the research instrument must comprehensively cover the domain or items it purports to cover. Cohen et al. (2002) say it is not possible to address each item in its entirety without risking the respondents' motivation to complete, for example, a long questionnaire. This analysis was done as the survey design was given extra care to ensure good presentation, clarity of instructions and survey questions and automated data collection to maximise the response rate of survey questionnaire.

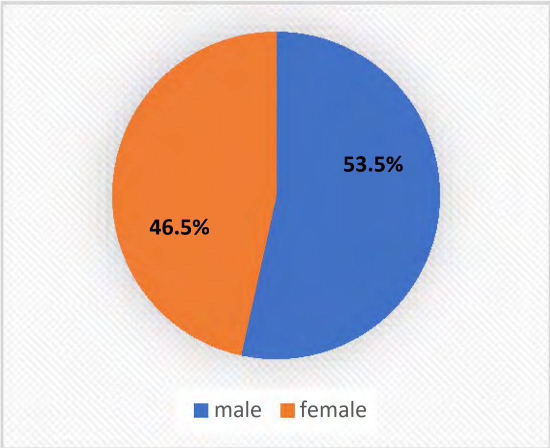
Collected data was analysed using SPSS 26.0 software. Descriptive statistics were used to analyse the demographic variables. Correlation analysis was used to assess the relationship between different variables of study. Multivariate analysis of variance (MANOVA) analysis along with its assumptions of independence, random subjects, normality, and homogeneity of covariance matrices were also conducted to determine the impact of the UC mathematics teaching and learning approaches on the first-year EIT students' collaboration, understanding, and achievement in mathematics courses (Field, 2018). MANOVA is used to analyse how one or more factor variables affects multiple response variables. Lastly, linear regression analysis was used to determine how one variable affects another variable.

6.2.1 Descriptive Analysis

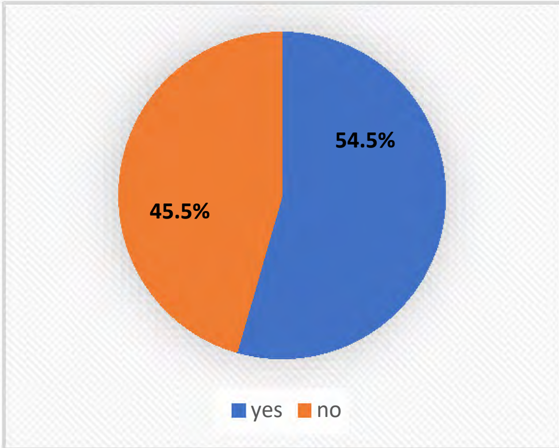
In the first step we used descriptive statistics to analyse the demographic variables. Figures 6.1-6.4 shows the demographic variables of the (N=101) students. The results in Figure 6.1 showed that the survey participants were roughly evenly split by gender. Close to half of participants said English is their native language.

In this survey, 42.6% participants were international students. Only 41.6% participants said that they studied an advanced mathematics course in High School while 58.4% reported they studied a basic mathematics course. Almost three quarter of participants stated they did not attend any mathematics pre-course.

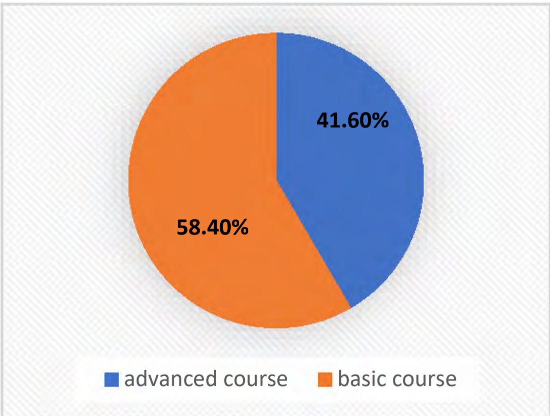
The descriptive analysis also showed that 25.7% of participants pay for their studies solely through their parents, the same percentage of participants pay for their studies through their scholarship and 16.8% of participants pay for their studies through taking loan. The rest depend on more than one source to pay for their studies as shown in Figure 6.2. Figure 6.3 depicts that 44.4% of participants did not do any employed work and only 3.0% of participants dedicate more than 20 hours per week for employed work. Figure 6.4 shows that more than half of participants dedicate 1-5 hours to co-curricular activities. Appendix V shows the detailed values of the descriptive data and further descriptive analysis.



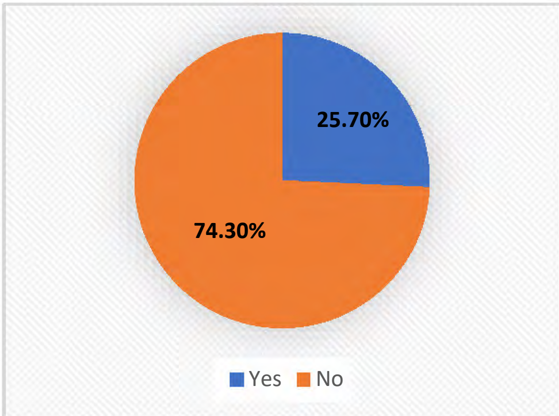
a. What is your gender?



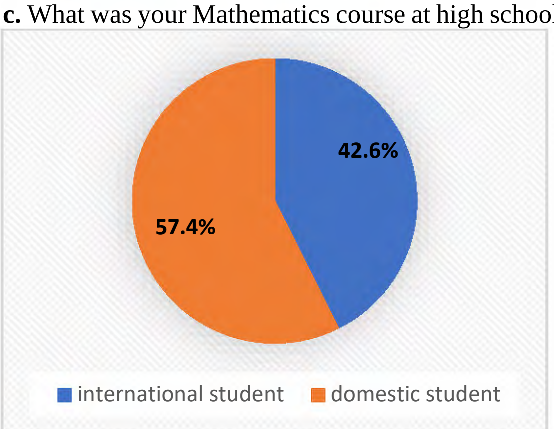
b. Is English your native language?



c. What was your Mathematics course at high school?



d. Did you attend a mathematics pre course?



e. Are you international or domestic student?

Figure 6.1 Basic demographic details

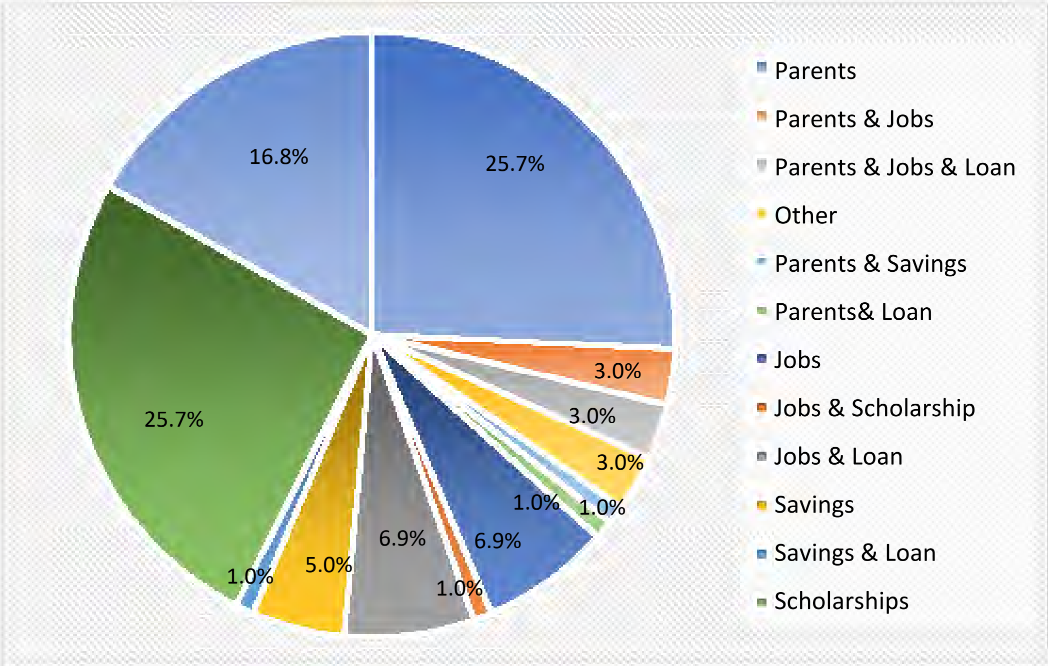


Figure 6.2 How do you pay for your studies?

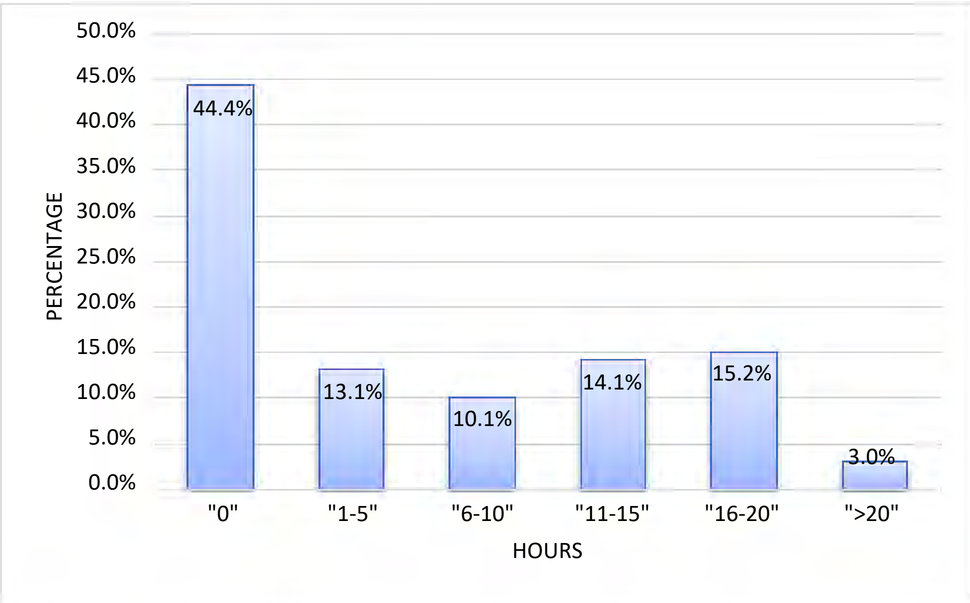


Figure 6.3 How many hours per week do you dedicate to employed work?

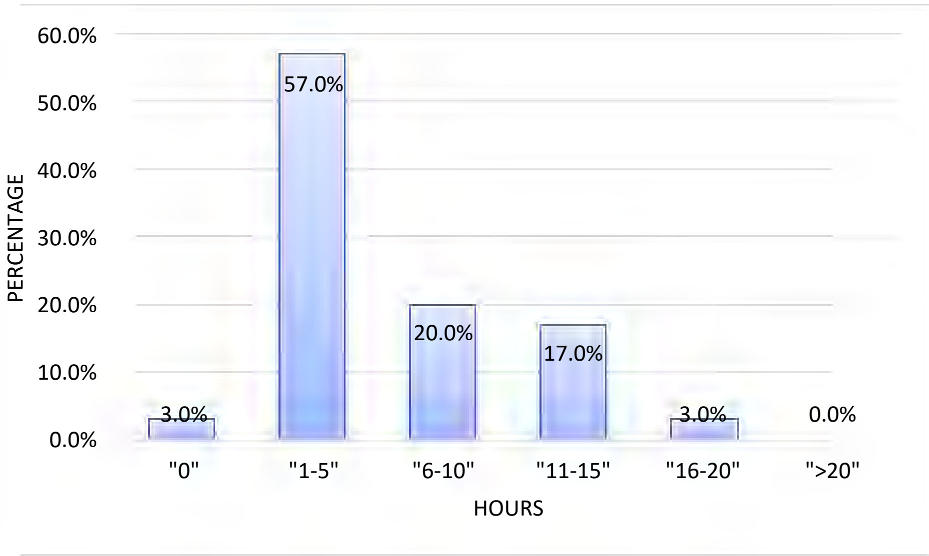


Figure 6.4 How many hours per week do you dedicate to co-curricular activity?

6.2.2 Reliability and Validity Scale of the Variables Analysis

Collaboration.

Reliability scale of the variable using Cronbach-Alpha, Dijkstra–Henseler's ρ_A, and Composite Reliability (CR) are respectively 0.62, 0.85. and 0.78. Latent convergent validity is assessed using Average Variance Extracted (AVE) shows value of 0.55. Latent divergent validity using Fornell-Larcker Criterion and Heterotrait-Monotrait Ratio (HTMT) respectively informs the value of the square root of the average variance extracted (√AVE) of 0.74, which is larger than the correlation between the Collaboration variable and any other latent variables and the value of Collaboration's HTMT that are less than 1.00 (in respective adjacent row and column). Both Fornell-Larcker Criterion and (HTMT) values indicate the establishment of divergent validity of Collaboration (see appendices Table V.9, V.10, and V.11).

Understanding.

Reliability scale of the variable using Cronbach-Alpha, Dijkstra–Henseler's ρ_A, and Composite Reliability (CR) are respectively 0.16, 0.56, 0.16. Latent convergent validity is assessed using Average Variance Extracted (AVE) shows value of 0.22. Latent divergent validity using Fornell-Larcker Criterion and Heterotrait-Monotrait Ratio (HTMT) respectively informs the value of the square root of the average variance extracted ($\sqrt{AVE}$) of 0.47, and the value of Understanding's HTMT that less than 1.00 (in respective adjacent row and column) (see appendices Table V.9, V.10, and V.11). The reliability scale of understanding has only Dijkstra-Henseler' ρ_A that is more than accepted cut off, while two other values of CR and Alpha were below cut off value (Hair et al., 2019).

Teaching method.

Reliability scale of the variable using Cronbach-Alpha, Dijkstra–Henseler's ρ_A, and Composite Reliability (CR) are respectively 0.85, 0.87, and 0.88. Latent convergent validity is assessed using Average Variance Extracted (AVE) shows value of 0.44. Latent divergent validity using Fornell-Larcker Criterion and Heterotrait-Monotrait Ratio (HTMT) respectively informs the value of the square root of the average variance extracted ($\sqrt{AVE}$) of 0.66, which is greater than the correlation between the Teaching variable and any other latent variables and the value of Teaching's HTMT that are less than 1.00 (in respective adjacent row and column). Both Fornell-Larcker Criterion and (HTMT) values indicate the establishment of divergent validity of this latent variable of Teaching method (see appendices Table V.9, V.10, and V.11).

Motivation.

Reliability scale of the variable using Cronbach-Alpha, Dijkstra–Henseler's ρ_A, and Composite Reliability (CR) are respectively 0.39, 0.48, and 0.35. These reliability scales were not satisfactory. Latent convergent validity is assessed using Average Variance Extracted (AVE) shows value of 0.36. Latent divergent validity using Fornell-Larcker Criterion (Table 14-1) and Heterotrait-Monotrait Ratio (HTMT) (Table 15-1) respectively informs the value of the square root of the average variance extracted ($\sqrt{AVE}$) of 0.60, which is greater than the correlation between the Motivation and any other values and the value of Motivation HTMT that are less than 1.00 (in respective adjacent row and column). Consequently, the values of

Fornell-Larcker Criterion and (HTMT) indicate the establishment of divergent validity of this latent variable of Motivation (see appendices Table V.9, V.10, and V.11).

6.2.3 Correlation Analysis

Correlation analysis is usually undertaken to assess the relationship between different variables of study. The basic purpose of this analysis was to determine whether all the constructs of the current study are significantly positively or negatively correlated. Table **6.1** describes the mean and standard deviation for correlation analysis between the variables of study. The 12 measures of students' learning styles, collaboration, general understanding, time management, learning effort, emotions, motivation, satisfaction, and anxiety, in addition to the teaching approach, assessment, and technology role in learning are all involved. Here up to 101 students participated in the survey.

The results of Table **6.2** show the correlation between the different variables of study. The results showed that there is significant and positive relationship between learning style and understanding, time management, student effort and satisfaction. Learning style showed negative relationship with emotional role and anxiety, meaning an increase in anxiety and emotional role affects the learning styles of EIT students negatively. The results also showed that there is negative and significant correlation between understanding and emotional role of the students. Student role and technology showed positive and significant relationship with understanding of EIT students. Further correlation analysis showed that time management, motivation and satisfaction of the participants is significantly but negatively associated with the anxiety of the students. This means that decreasing the anxiety of EIT students leads to increased satisfaction and motivation.

Table 6.1 Mean and standard deviation of the measures

Descriptive Statistics			
	Mean	**Std. Deviation**	**N**
Learning Styles	22.30	5.957	100
Collaboration	17.83	4.042	101
Understanding Related	21.84	2.643	100
Time Management	10.40	1.917	100
Teaching	36.28	6.589	99
Assessment Related	19.67	2.916	101
Student Effort	7.56	2.313	101
Technology Role	5.19	1.501	101
Emotional Role	11.74	2.533	100
Motivation	9.78	2.536	101
Satisfaction	11.78	2.057	101
Anxiety	23.74	5.849	98

Table 6.2 Correlation coefficients between study variables (N=101)

	Learning Styles	Collaboration	Understanding Related	Time Management	Teaching	Assessment Related	Student Effort	Technology Role	Emotional Role	Motivation	Satisfaction	Anxiety
Learning Styles		.168	**.408****	**.419****	**-.416****	**-.356****	**.663****	.070	**-.412****	.017	**.199***	**-.490****
Collaboration		-	-.136	.137	.015	-.173	.026	**-.280****	.029	-.166	.051	-.029
Understanding		-	-	**.234***	-.196	.134	**.299****	**.350****	**-.370****	.070	.164	**-.357****
Time Management		-	-	-	-.170	-.045	**.329****	.166	**-.287****	-.023	.154	**-.311****
Teaching		-	-	-	-	**.281****	**-.319****	**-.228***	.240*	-.065	-.013	**.474****
Assessment Related		-	-	-	-	-	**-.310****	.117	.169	.186	.080	.067
Student Effort		-	-	-	-	-	-	**.211***	**-.270****	**.256****	-.039	**-.439****
Technology Role		-	-	-	-	-	-	-	-.103	.187	.081	**-.254***
Emotional Role		-	-	-	-	-	-	-	-	-.042	-.189	**.440****
Motivation		-	-	-	-	-	-	-	-	-	-.088	**-.212***
Satisfaction		-	-	-	-	-	-	-	-	-	-	**-.236***
Anxiety		-	-	-	-	-	-	-	-	-	-	-

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

*. Correlation is significant at the 0.05 level (2-tailed).

6.2.4 MANOVA Analysis

Another hypothesis of the study was to determine the impact of the UC mathematics teaching approach on the first-year EIT students' collaboration, understanding, and achievement in mathematics courses. In order to test this hypothesis, MANOVA analysis was considered along with its assumptions of independence, random subjects, normality, and homogeneity of covariance matrices. This hypothesis included one fixed (independent) factor i.e., teaching approach while the three dependent factors are students' collaboration, understanding, and achievement. The results of this hypothesis are given in Table **6.3**.

In Table **6.3**, the results of MANOVA analysis are described. The results showed that teaching approach is positively and significantly associated with the collaboration, understanding, and achievement of the students in mathematics course. The results also revealed that F (75, 210) = 1.48, significant at $p < .015$ and Wilks' Lambda = .28. The MANOVA assumptions of independence, random subjects, normality, and homogeneity of covariance matrices were all satisfied. The dependent variables were continuous, and we had categorical independent variables. The observations were independent of one another, no pattern for the selection of the sample existed, and the sample was completely random. Multivariate normality was confirmed in the data. Also, the population variance and covariances amongst the dependent variables are even across all levels of the factor.

Table 6.3 Multiple analysis of variance among the study variables (N=101)

Multivariate Tests[a]

Effect		**Value**	**F**	**Hypothesis df**	**Error df**	**Sig.**	**Partial Eta Squared**
Intercept	Pillai's Trace	.991	2433.713[b]	3.000	70.000	.000	.991
	Wilks' Lambda	.009	2433.713[b]	3.000	70.000	.000	.991
	Hotelling's Trace	104.302	2433.713[b]	3.000	70.000	.000	.991
	Roy's Largest Root	104.302	2433.713[b]	3.000	70.000	.000	.991
Teaching	Pillai's Trace	1.029	1.504	75.000	216.000	.012	.343
	Wilks' Lambda	.280	1.488	75.000	210.124	**.015***	.346
	Hotelling's Trace	1.606	1.470	75.000	206.000	.018	.349
	Roy's Largest Root	.699	2.012[c]	25.000	72.000	.011	.411

a. Design: Intercept + Teaching

b. Exact statistic

c. The statistic is an upper bound on F that yields a lower bound on the significance level.

In Table **6.4**, the results of test of between-subject effects are described. In order to determine whether independent variables are significant in predicting the dependent variable, we need to look at the results of the F-test of between-subject effects. The results showed that collaboration is $F(25, 72) = 1.64$, significant at $p < .054$ with the teaching approach of mathematics; meaning collaboration is dependent on teaching approach. Whereas, understanding of mathematics is $F(25, 72) = 1.96$, significant at $p < .014$ with the teaching approach of mathematics and similarly, understanding of satisfaction of mathematics students is $F(25, 72) = 1.09$, non-significant at $p < .376$ with the teaching approach. In other words, the variation in teaching approach impacts the variation in collaboration, understanding, and satisfaction, i.e., teaching approach is statistically significant at influencing collaboration, understanding, and satisfaction.

Table 6.4 Tests of between subjects effects of MANOVA analysis

Tests of Between-Subjects Effects							
Source	**Dependent Variable**	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**	**Partial Eta Squared**
Corrected Model	Collaboration	567.759[a]	25	22.710	1.640	.054	.363
	Understanding Related	277.965[b]	25	11.119	1.969	.014	.406
	Satisfaction	111.189[c]	25	4.448	1.090	.376	.275
Intercept	Collaboration	16151.571	1	16151.571	1166.488	.000	.942
	Understanding Related	26310.933	1	26310.933	4659.488	.000	.985
	Satisfaction	7760.511	1	7760.511	1901.363	.000	.964
Teaching	Collaboration	567.759	25	22.710	1.640	**.054***	.363
	Understanding Related	277.965	25	11.119	1.969	**.014***	.406
	Satisfaction	111.189	25	4.448	1.090	**.376**	.275
Error	Collaboration	996.935	72	13.846			
	Understanding Related	406.566	72	5.647			
	Satisfaction	293.872	72	4.082			
Total	Collaboration	32672.000	98				
	Understanding Related	47590.000	98				
	Satisfaction	13994.000	98				
Corrected Total	Collaboration	1564.694	97				
	Understanding Related	684.531	97				
	Satisfaction	405.061	97				
a. R Squared = .363 (Adjusted R Squared = .142)							
b. R Squared = .406 (Adjusted R Squared = .200)							
c. R Squared = .275 (Adjusted R Squared = .023)							

6.2.5 Linear Regression Analysis

The multiple linear regression and its suitability for the purpose of this study analysis has been used to determine how one variable predicts another variable. It also explains which factor(s) significantly predicts the variables, and which factor(s) can be ignored. The basic purpose of using this analysis was to determine factors that predict and has relationship with motivation of EIT students to engage, or not engage, with mathematics. A more advanced multivariate structural equation modeling (SEM) can also be implemented to explore the relationships and paths direction amongst variables. However, for this study analysis, the linear regression is sufficed. According to the results of the linear regression analysis in Table **6.5** and Table **6.6**, it is revealed that assessments of the students and efforts of the students are significantly predict and positively associated with the motivation of mathematics students. The students' effort is highly significant at $p < .004$ with their motivation and assessment is significant at $p < .01$ with the motivation of the students.

Table 6.5 Linear regression analysis of the study variables

Model Summary				
Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**
1	.496[a]	.246	.145	2.354

a. Predictors: (Constant), Anxiety, Collaboration, Assessment Related, Satisfaction, Time Management, Technology Role, Understanding Related, Emotional Role, Teaching, Student Effort, Learning Styles

Table 6.6 Standardised and unstandardised co-efficient of linear regression analysis

Coefficients[a]						
Model		**Unstandardised Coefficients**		**Standardised Coefficients**	**t**	**Sig.**
		B	**Std. Error**	**Beta**		
1	**(Constant)**	9.959	4.510		2.208	.030
	Learning Styles	-.087	.070	-.210	-1.246	.216
	Collaboration	-.064	.066	-.103	-.980	.330
	Understanding Related	-.076	.116	-.079	-.651	.517
	Time Management	-.086	.145	-.065	-.592	.555
	Teaching	-.030	.048	-.074	-.622	.536
	Assessment Related	.259	.100	.303	2.594	**.011***
	Student Effort	.480	.161	.432	2.990	**.004****
	Technology Role	.096	.195	.056	.492	.624
	Emotional Role	-.024	.122	-.023	-.201	.841
	Satisfaction	-.047	.129	-.038	-.365	.716
	Anxiety	-.072	.057	-.165	-1.256	.213

a. Dependent Variable: Motivation

The other study factors showed no significant relationship with the motivation of the participants. Therefore, in this statistical test, only student effort and assessment significantly have relationship with and predict the motivation. The rest of the independent variables show no statistically significant relationships.

6.3 Discussion

As mentioned earlier, mathematics is one of the most scientific subjects in academies and since education plays a vital role in shaping how one thinks about themselves (Idris et al., 2012) that just highlights its importance.

In addition, a recent study by Adkins and Noyes found that advanced mathematics skills can predict success in other academic domains (Adkins and Noyes, 2018). The adaptations and variations in other subjects impact on the teaching and learning process in mathematics

(Abramovich et al., 2019). More and more universities are now internationalizing mathematics' curriculum which is an effective strategy that is not only helping students to acquire competence and attitude necessary to keep up with a rapidly changing and a globalised world but also playing a vital role in enquiring them with skills like problem solving abilities (Appelbaum et al., 2009), the ability to link second-order relationships in a logical and orderly manner and the ability to manipulate visual representations and other advanced skills (Hunt, 2011).

Researchers state that such skills help students in achieving higher education as well as enable students to behave responsibly in performing real life tasks (Gravemeijer et al., 2017a). Specialised mathematical software should be promoted to allow students to gain experience using an industry software and to further promote content-driven and subject-specific technologies to further enhance learning and understanding (Borovik (2011). Use of differing pedagogical techniques enhances the learning experience. Notably, playing music was seen to help students focus during learning in order to promote self-confidence and make it easier for said students to focus on the topic (Yang et al. (2017). Enrolling students in a remediation program to enhance understanding and success rates, and conducting pre-requisite assessment also helps improve the learning experience (Vandenbussche et al. (2018).

UC mathematics teaching approach and impact on collaboration, understanding, and achievement in mathematics units

There are number of elements involved in educational system such as students, teaching staff, administrations, curriculum, various technology, as well as financial resources. In all of these mentioned elements, teaching is the most significant element in educational sector and the quality of education is mostly dependent on the teaching competency of the teachers (Akcani and Doğanii, 2020). In Table **6.3**, the results $F(75, 210) = 1.48$, significant at $p < .015$

and Wilks' Lambda = .28 showed that learning behaviour is influenced by teaching and learning methods, which supports the research question of the study, meaning teaching approach strongly influences students' learning behaviour. If teaching and learning methods are negative, then learning of students will be strongly affected. This is the reason; teachers perform multiple roles in the institutes. They are responsible for developing learning plans, students' guidance, monitoring classroom activities, maintaining classroom discipline, and maintaining the motivating skills of students to learn further. Thus, educators are not only expected to adopt the latest teaching skills but also to incorporate teaching techniques more effectively, that boost the learning interests of the students (Karaduman and Emrahoglu, 2011).

Teaching Approach and Achievement in Mathematics Courses

In the same way, this concept has gained greater attention in the field of education. Different professionals from other fields or even school counsellors have expressed that the preference of student to learn new concepts is the key factor in increasing academic performance of students. Moreover, if teachers tend to teach students on the basis of their unique learning styles or modalities, students may get more motivated, gain a deeper understanding the concept, critically evaluate their understanding and can be more explorative as well as willing to apply their knowledge and skills into practice (Bhat, 2014). In order to identify different learning styles of students, different researchers have made contributions and suggested that identification of learning styles plays a significant role in learning of mathematics students. It is also believed that once learning styles are determined, it can benefit not only students but also teachers equally (Awla, 2014). As per outcomes, the negative correlation at 0.001 significance level shows that if learning behaviour is not appropriate then this affects achievement of students and cause anxiety, which further de-motivates students and deeply affects their explorative mind and skills.

Teaching Approach and Collaboration

Research has revealed that collaborative learning style leads to more variety and creativity and can improve project quality and performance through teamwork (Kyprianidou et al., 2012). Group tasks are important for updating already learnt procedures and skills. In addition to this, it is difficult for students to apply such knowledge flexibly, if they do not get better understanding of how these concepts are related. Therefore, such collaborative working experience results in minimum level of anxiety in mathematics subject (Esa and Mohamed, 2017). The negative correlation at 0.001 significance level shows that learning behaviour and teaching and learning methods were negatively correlated with anxiety, so the phenomena of mathematics anxiety present negative effect on students' ability to resolve numerical problems and their arithmetic performance, because this anxiety is affecting their performance by hindering their reasoning and judgment (Yanuarto, 2016). Therefore, it was suggested that teachers should consider anxiety among students related to their performance in mathematics and involve suitable teaching approaches, which decrease the anxiety among such students. Hence, one of the hypotheses of this study was supported by the findings of the existing literature.

Whereas, one of the study results also showed that students who get upset or anxious when they do not understand the concept about correction are negatively correlated with their motivation to study (Mat and Yunus, 2014). Furthermore, it is recommended that educational instructors should provide proper guidelines related to the classroom environment, and provide an effective learning environment to enhance performance and learning attitude of students (Ahmetovic et al., 2020).

Factors motivating EIT students to engage, or not engage, with mathematics

According to Marzano et al. (2001), the motivation and class performance of mathematics students is dependent on multiple factors, for example, teaching approaches, the content of curriculum, and personal characteristics of such students (Marzano et al., 2001). Similar findings are confirmed by Santos-Trigo (2007), as he has also highlighted the effect of teacher-student interaction, classroom environment, curriculum content, etc. on students' motivation.

Students' imagination, learning styles, and achievement are all the factors influenced by motivation (Dilek et al., 2020). Students could progress in mathematics more than before through controlling, recognising, and understanding with mathematics anxiety (Boaler, 2008). Motivation is a crucial emotional aspect in education, and that should not be neglected, particularly in courses which are difficult for students to understand, like mathematics (Purnami et al., 2018). Motivation would be a condition for learning, as per Schukajlow et al. (2017b). In most cases, students learn the topics in which they are intensely interested in such a short period of time. Students who are just not sufficiently motivated are not prepared to learn, however if they have been sufficiently driven, they would succeed in the sense that they will be highly motivated to study for their assignments and assessments. To put it another way, there would be a positive link among achievement and motivation (Acharya, 2017; Spector and Park, 2017).

As a result, researchers argued that investigating successful instructional approaches towards teaching mathematics, like novel devices, pedagogical approaches, or frameworks and procedures, was critical (Lopez-Morteo and Lopez, 2007; Pettersson and Scheja, 2008). Several efforts have been made in the last decade to create efficient strategies to aid students in improving their mathematical knowledge (Roth et al., 2008), in specific use of online training, that also is becoming an especially prominent assessment approach for higher education while teaching mathematics (Ellis et al., 2009; Roth et al., 2008). Integration of pedagogical approaches, new methods, and concepts, as well as instructional resources and best approach adapted to mathematics teaching. This could also be achieved through diagnostic testing.

Szabo et al. (2020) mainly concentrated on mathematics education by stating that students develop new things to practise beyond their encouragement and therefore are equally impressed by their teacher's hope. The college-based mathematical skills would further support such students in developing more knowledge to compete with mathematical challenges and opportunities in the future, that will further assist the students' efforts and motivation for learning mathematics.

Teaching of mathematics is based on variety of techniques and approaches. The method of investigation, simulation approaches, collaborative learning are involved in active learning methods, which present more effective results as compared to traditional teaching approaches which consist of "chalk and talk"(Barber et al., 2010). Similarly, in order to develop and maintain the interests and motivation of students to learn mathematics and aid them in understanding of mathematical or statistical subject, researchers suggest that the teaching methodologies be updated. According to the US Department of Education (2002), "mathematical ideas and mathematical concepts build on one another to create a coherent structure". Similarly, the mathematics teaching approaches and learning of mathematics leads toward development of in-depth conceptual understandings and among the mathematics student, which further help in developing sense of mathematics (Reid and Reid, 2017). The positive correlation between basic teaching methods and anxiety (significant at the 0.01 level) showed that basic teaching methods among EIT students causes more stress and worries.

Collaborative teaching, also known as cooperative teaching as well as team teaching, is a type of innovative teaching in which two or more educators work together to guide, educate, and supervise a group of students (Jayashree, 2017). So, the involvement of innovative teaching approaches could assist students to become responsible investigator and to develop a link between their understanding and real-life issues. Furthermore, innovative teaching strategies can help the mathematics students to apply their knowledge and mathematical reasoning to problems in order to have the capacity to participate in today's and tomorrow's economy (Killpatrick and Swafford, 2002).

Bhat (2014) suggested that everyone has a unique learning style and if the teachers tend to students based on that, it can improve motivation, better understanding and in the long run better performance. However, this will likely also increase teaching costs significantly and hence may not always be a realistic approach to apply.

A study by Abramovich and colleagues explain that teachers can play an important role in developing effective teaching or learning activities, which aid in enhancing the interests of students and in the long run enhance performance (Abramovich et al., 2019). The results revealed a negative correlation between learning styles and anxiety with the significance of 0.001, that means increase in anxiety decreases the efficiency of EIT students learning styles. The use of suitable context, which is based in positive teaching approach, can serve as a highlighting factor in the mathematics classroom activities. Contextual teaching strategies are consisted of relating the concepts, experiencing the mathematical problems, applying the rules, cooperating with other, and transferring. Moreover, the high motivation of teachers to work with these approaches will lead toward more productive situation, thus improving the understanding of math's students to a higher cognitive level (Rifandi, 2013). Hence, we need to ensure that teachers are correctly supported to ensure quality delivery.

In educational settings, teachers try to change the effectiveness of teaching approaches, through variety of instructional practices. For this purpose, teachers not only try to pay attention to the teaching context but the needs of students as well. Research findings have confirmed that the quality of the implementation of a teaching practice also greatly influences its impact on student learning and enhance neuro-cognitive capacity. The importance of involving manipulative materials to teach as well as to investigate a concept, not only depend on whether manipulative are used, but also on how they are used with the students (Growvs and Cebulla, 2000).

6.4 Summary of Survey Findings

This section summarises some of the key findings that point out the importance of understanding the aspects of the implemented teaching and learning methods within the mathematics classes.

The following is a list of the key findings of this study:

1. Results showed that there is significant and positive relationship between learning style and understanding, time management, student effort and satisfaction.

   Learning styles play a significant role impacting student attainment in reaching study goals. If students know their own learning style, they will likely be able to consolidate it into their learning process. Consequently, the learning process will be pleasant, quicker, and more effective. Furthermore, educators' teaching styles should be balanced to match a variety of student learning styles.

2. Learning style showed a negative relationship with emotional role and anxiety.

   This may indicate the incongruence between learning style and the education system which leads to learning failure, demotivation, and frustration. Educators' concern about the effects of learning styles on mathematics anxiety is vital. The education system should recognise mathematics anxiety and use appropriate teaching and learning strategies enabling the students to overcome their mathematics anxiety.

3. There is negative and significant correlation between understanding and the emotional role of the students.

   Emotional roles are important precursors, mediators, and consequences of learning and achievement, i.e., understanding. The negative correlation between these two variables indicates that the worse the emotional state, the lower the level of understanding that is achieved. In a temporal emotional state or in persistent emotional trait, if students feel bored while solving a mathematical problem, their potential ability to solve problem is hindered.

4. Student effort and technological role showed positive and significant relationship with understanding of EIT students.

   This finding amplifies the awareness that the integration of lively technologies into mathematics education will bring transformative changes to mathematics teaching. However, it seems this is still a difficult process for education systems. Even though there is a rising consideration to the role of digital technologies in teaching mathematics, the knowledge of the design and influence of professional development programmes embedding digital technologies and how teachers' practices are influenced by the use of such professional development should not depend on the individual teachers' choice of style. It should be considered as part of institutional-level policies.

5. Time management, motivation and satisfaction of the participants was significantly but negatively associated with anxiety.

   Anxiety minimisation and time management in combination with relaxing activities may be an effective strategy for reducing students' academic stress. In a very competitive environment, students may confront several academic difficulties including exam stress, apathy in attending classes and incapability to comprehend the subject. Students should have access to appropriate counseling while picking their courses to ensure their choice is not beyond their capacities and capabilities.

6. Teaching approach is positively and significantly associated with the collaboration, understanding, and achievement of the students in mathematics course.

   This finding suggests that it is essential to foster innovative teaching and for teachers to undertake professional development so they can seek to adopt different innovative teaching strategies to cater to the varied needs of students. Traditional teaching strategies may be detrimental to the needs of students' creative learning. In a classroom where the lecturer is the focus instead of the learner, in which instruction and assessment is constructed without considering students' need, the learning process can only attain results at a superficial level.

7. Mathematics teachers should support and encourage students for their successful efforts. Positively encouraging feedback from instructors and ongoing motivational activities by teachers could lead to more effective pedagogical skills and increased learning effectiveness by lowering stress and anxieties. This also helps in the creation of confidence and self-assurance among students.

8. The assessments of the students and efforts of the students are significantly and positively associated with the motivation of mathematics students.

   The findings indicate that there is opportunity for teachers to fine-tune assessments that obviously impact student motivation, which in return influence student effort to improve their level of understanding. The goal of assessments is to provide students and teachers with feedback about the students' current state (actual developmental level of zone of proximity development-ZPD), while there are still prospects for student improvement (potential developmental level of zone of proximity development-ZPD). Through specific assessment, such as formative assessment, the students have a better idea of how they can improve. Moreover, when assessment feedback is provided in a timely manner, the outcome of the assessment is generally more meaningful.

9. To improve students' motivation and learning behaviour, educators not only need to offer suitable recommendations and progressive guidelines in relation with the classroom setting, but also an effective learning atmosphere. Effective and beneficial learning and teaching strategies embrace progression over various learning stages that would support the creation of learning competence in terms of neuro-cognitive processes, thereby reducing stressful thoughts associated with native language, personal history, economic status, and a variety of other factors.

The findings of this study have helped in identify various issues which may obstruct the process of learning mathematics effectively. This study focused on challenges affecting effective learning, such as mathematics anxiety and panic, low levels of motivation, and improper learning habits that EIT students encountered.

The main findings were: the employed teaching approach is positively and significantly related with the collaboration, understanding, and achievement of the students, suggesting that it is indispensable to adopt innovative teaching and professional development of the teacher must continuously undertake; there is a significant and positive association between learning style and understanding, time management, student effort and satisfaction; and the learning style showed a negative relationship with emotional role and anxiety, which shows the incongruence between learning style and the education system that may bring about failure, demotivation, and frustration in learning.

Moreover, there is negative and significant correlation between understanding and the emotional role of the students. In regard with student role and technology, a positive and significant relationship is exhibited, which indicates the benefits of integrating technologies into mathematics teaching.

Pertaining to time management, motivation and satisfaction of the participants, the study found it is significant but negatively associated with anxiety, suggesting that anxiety elimination and correct time management in combination with relaxing activities may be an effective strategy for reducing students' academic stress.

Based on the findings of this study, it is concluded that teaching styles were significantly and positively associated with EIT students' knowledge, performance, and collaborative efforts. As a result, it is suggested that mathematics teachers applaud and encourage students for their successful efforts, as this may reduce the severity of unfavourable judgement and improve neuro-cognitive processes in such students. Moreover, educators would have to provide adequate recommendations and progressive guidelines connected to the classroom setting, as well as an effective learning atmosphere, in order to improve students' motivation and learning attitudes. Finally, effective and beneficial learning and teaching strategies which include progression through various learning stages would then help in the creation of learning capability in terms of neuro-cognitive processes, thereby reducing stressful thoughts associated with native language, personal history, economic status, and a variety of other factors.

7 Interview Analysis and Findings

7.1 Introduction

This study of an Evaluation of Mathematical Teaching Pedagogies to Tertiary EIT students at UC was designed into two sequential research design of quantitative and qualitative design (Quantitative → Qualitative). It encompasses the collection of both quantitative—first phase (closed-ended) and qualitative—second phase (open-ended) data in response to research questions. This chapter presents the second phase of the research which is the qualitative design.

To accomplish the study aims and addressing the research questions within this second phase, a qualitative technique of thematic analysis was conducted. Briefly, it encompasses the steps of (1) familiarising with data during transcription of the recorded participants' interview, several iterations of reading the transcribed data, noting down initial ideas; (2) producing preliminary codes guided by the research question, i.e., coding interesting features of the data in a systematic manner throughout the whole data set, ordering data relevant to each code; (3) seeking for emerging themes, i.e., collating codes into possible themes, assembling all data relevant to each possible theme; (4) revising themes, i.e., inspecting whether the themes work in relation to the coded extracts and the entire data set generating a thematic 'map' of the analysis; (5) defining and naming themes, i.e., ongoing analysis to refine the specifics of each theme, and the overall story the analysis tells, generating clear definitions and names for each theme; and (6) creating the report of analysis through selection of vivid, compelling excerpt of examples, final analysis of selected excerpt, connecting back of the analysis to the research question and literature (Braun and Clarke, 2006). The created report resulting from these thematic analysis processes constitutes the Part (2) interview findings of this presentation.

The subsequent section 7.2 discusses the methods used to analyse the data and the role of the researcher in qualitative research in relation to reflexivity, subjectivity, and interpretative. It encompasses the presentation of coding the data (section 7.2.1), identification of emerging themes (section 7.2.2), which is enumerated in section 7.3 of those themes that arise as highlighted themes. Emerging themes are denoted by subheading entries followed by description and rationale how the touching of tangible data into the conjuring abstract categories; in the interview analysis subsection the researcher elaborates a way of looking on the data presenting some lens in guiding the researcher exploring the tangible data and interpreting them at the same time; within Chapter 8 the main findings are discussed further with regard to addressing the research questions.

7.2 Interviews Data Analysis

Qualitative data analysis is an inductive process in that the researcher translates the exhaustive data into a comprehensible thematic category, i.e., the finding of similarity. At the same time, it can also be an abductive process by which the researcher develops the new categories and seeks the most possible explanation of the phenomenon under study. The main purpose of data analysis is to generate new knowledge or theory that is intellectually rigorous.

Participant’s responses were imported into the QSR NVivo 2021 software program for analysis. This software program allows researcher to label segments of text with one or more codes and to subsequently rearrange data into wider themes. It also enables the researcher to easily search full-text throughout the imported documents in second, compared to processing text manually. Qualitative data analysis (QDA) software is better than working with manual processes and more suitable for this project in terms of the four clusters of components *providing data*, i.e., providing the data to QSR NVivo 2021 and everything to do with organizing, managing, and using data files; *conceptualizing data*, i.e., using code nodes to signify the concepts in a study, and connecting them to references, or by grouping them to characterise more broader concepts. Other components may be attached for these conceptualizing purposes, and code nodes may be connected for purposes other than conceptualizing data; *writing* i.e., writing can be taken in memos, in annotations (comments linked to references), in descriptions that are attached to components, and by directly editing sources inside QSR NVivo 2021, and *visualising* components can be displayed and worked with visually in an NVivo display called a map. In addition, the relations between components can be visually displayed in various types of charts (Woolf and Silver, 2017).

The data were analysed through a cyclical process in which the codes assigned initially according to research framework that are in agreement with the data's central themes (Saldana, 2015). The coding processes began by independently coding the same random selection of responses in three classification cases, students, teachers, and education expert (n= 15) using an established coding list as a start guide. The initial coding list is utilised to guide the coding processes. To some extent, rather than a 'data-driven' coding processes, it depends on the research's framework and it is more a 'theory-driven' approach. In the former, the themes will depend on the data, but in the latter, it approaches the data with underlying research questions in mind that the researcher tries to code around. The researcher is aiming to code the content of the entire data set to identify particular features of the data set (Braun and Clarke, 2006).

When it comes to data analyses, the researcher aware of the subjectivity that might shape the analysis processes. Hence, there will be no single correct way of analysing qualitative data (King et al., 2018). The researcher either intentionally or unconsciously must have brought into the interpretation of the data not without just a blank state of mind. The education experience that the researcher has been undergoing, the specific field the researcher presently studying, and the literature review specifically prepared for this study are brought together as instrument to understand the image made up from the data.

The nature of the analysis is to search for patterns in data and for ideas that help explain why those patterns are in the first place (Saldana, 2015). The three-stage process of thematic analysis was conducted that included descriptive coding, interpretative coding, and overarching themes. The descriptive phase identifies and labels portions of the interview data addressing the research questions. The interpretative phase groups descriptive codes that share some shared meanings to create interpretative codes. The third stage identifies overarching themes that characterise key concepts. King et al. (2018) stated that as the researcher's thinking about the coding process develops there was a need to redefine codes and to go back over coded transcripts and reapply the new codes. Saldana (2015) also posited that coding was a cyclical process and that "subsequent cycles further manage, filter, highlight, and focus the salient features of the qualitative data record for generating categories, themes, and concepts, grasping meaning, and/ or building theory". The model of qualitative analysis creates clusters of coded data that are grouped into categories. When "major categories are compared with each other and consolidated in various ways, you begin to transcend the reality of your data and progress toward the thematic, conceptual and theoretical" (King et al., 2018).

7.2.1 Coding the Data

The researcher identifies ten initial codes based on provision of the research conceptual framework and hypothesis as follows:

1. Student/teacher efforts.
2. Teaching pedagogical.
3. Collaboration.
4. Students' understanding.
5. Teaching methods.

6. Assessment.

7. Technology role.

8. Emotional role.

9. Motivations.

10. Anxiety.

The researcher makes a number of changes to the coding list during data analysis, making subsequent new codes that the researcher believes to be represented in the data. The researcher finds 95 items of code. Table 7.1 below informs some examples of the raw codes from the data.

Table 7.1 New codes created during coding process

Names	Description
Coping with distracting condition	Activities or actions to cope distracting situation
Different backgrounds	Student different background in terms of nationality, first language, and math competency
Distracting condition	Circumstances that create interference during the learning processes
External - School tradition	School culture that affects the learning processes
Bad learning behaviour	Activities or actions of student that hinder them from effective learning
Negative perception of Mathematics	A belief that math is not important

7.2.2 Identification of Themes

On the second cycle of coding, the researcher decides to remove or combine certain subcodes, reducing the number of codes by grouping together sections of interview transcripts corresponding to the total descriptive codes that share some common meaning or pattern, to establish a more parsimonious coding. Once the researcher completes final coding, they are assembled with similar codes into wider categories to examine higher patterns and themes. Six key themes emerged and were used to structure our interpretations. These are

1. Effectiveness of student Mathematics learning
2. Emotional role - Interest and Affect
3. Motivations
4. Teaching methods approach
5. Mathematical concept understanding
6. Challenges in teaching mathematics

The complete created subcodes are listed in the following paragraph.

1. Effectiveness of student Mathematics learning
    a. Circumstances
        i. Coping with distracting condition
        ii. Different backgrounds
        iii. Distracting condition
        iv. External - School tradition
    b. Institutional policy
    c. Multidisciplinary pedagogical approach
    d. Negative factors to effectiveness
        i. Bad learning behaviour
        ii. Negative perception of math

iii. Persistent problem

e. Positive factors to effectiveness

i. Good Learning Behaviour

ii. Learning Achievement

1. Collaboration Skills

2. Critical Thinking

iii. Learning Effectiveness

iv. Learning Engagement

v. Self-Efficacy

vi. Student-teacher communication

vii. Trying different approach

f. Student efforts

2. Emotional role - Interest and Affect

a. Coping

3. Motivations

a. Expert believes teacher must cope with motivation

b. External - Institutional system

c. Negative factors to motivation

i. Anxiety

1. Cause of student anxiety

2. Coping with anxiety

3. Teaching anxiety

ii. Discordant expectation

iii. Lack of motivation

iv. Lack of student engagement

v. Social aversion to math
vi. Unsuitable choice of Task

d. Positive factors to motivation
    i. Achievement
    ii. Engaging Student
    iii. Making some effort to solve problems
    iv. Social involvement
    v. Suitable choice of task
    vi. Teachers giving feedback
    vii. Teachers’ belief things to strengthen motivation
    viii. Teachers’ facilitation
e. Theories of motivation

4. Teaching methods approach
    a. Assessment related
        i. Assessing student knowledge gap
        ii. Grading, Rubric and teacher feedback
        iii. Students do not know what topics
    b. Boring Classroom
    c. Class Collaboration
        i. Benefits for teacher collaboration
        ii. Constrain to collaboration
        iii. Students' collaboration
            1. Teachers' belief
        iv. Teachers' collaboration
    d. Communications

e. Connecting math with real life

f. Constraints

g. Content selections

h. Curriculum

    i. Learning difficulties due to curriculum

i. Face-to-face method

j. Learning activities

k. Lesson Study

l. Online

m. Shifting student potential

n. Stimulating Creativity

o. Teacher need development

p. Teachers Effort

    i. Assisting as per student feedback

    ii. Lack of teacher attention

    iii. Teacher development

    iv. Teacher dispositions

    v. Teacher Efficacy

q. Teaching pedagogical

    i. Blended learning

    ii. Content driven instruction

    iii. Coping Class Problems

    iv. Multidisciplinary approach

    v. Student belief

    vi. Teacher instructional practice

vii. Traditional

r. Technology role

i. Having no experiences

ii. Teachers' belief it aids student understanding

iii. Teachers' belief it is detriment

5. Understanding

a. Learning objectives

b. Math subjects understanding

c. Mathematical concepts

d. Mathematical model

e. Preconceived ideas

f. Previous Math knowledge

i. Lack of basic math skills

g. Procedural understanding

6. Challenges in Teaching

a. Bad Course management

b. The practicability and effectiveness of streamed lectures.

c. Difficulty in learning descriptive geometry.

d. Difficulty understanding subject matter

e. Enhancing teacher's confidence and attitude

f. Exploring the forces that affect the present mathematics delivery.

g. Finding the best approaches of teaching mathematics.

h. Generic teaching practices preventing students from reaching their full potential

i. Improving students' performance and attitude.

j. Improving the quality of teaching mathematics

k. Lack of active learning.
l. Lack of confidence in students' own mathematical abilities
m. Lack of diagnostic testing and understanding of learners' current mathematical level
n. Lack of effective strategies
o. Lack of practical knowledge
p. Lack of prerequisite knowledge on the part of the students
q. Lack of student engagement.
r. Lack of students focus.
s. Low effectiveness of an instructional model and learning system.
t. Poor quality learning materials hindering the ability of students to understand topics
u. Poor students' learning experience
v. Qualitative decline in mathematical ability of entry level students
w. Single delivery approach (online vs traditional) hindering learners' potential

7.3 Emerging Themes

7.3.1 Teaching method approach

Teaching method approach is interpreted as all activities involving teachers, students, and other stakeholders in a specific classroom situation or any other learning processes such as online, institutional policies, and curriculum that is intended to achieve a set of learning objectives.

The theme of teaching method emerges from the data comprise of 314 aggregate number of coding references from 41 salient sub-categories such as collaboration, assessment, technological role, pedagogy and curriculum. Teaching pedagogy is dominated by the discussion of blended learning, while collaboration is occupied by the talking of students' collaboration and teacher's collaboration. Assessment of previous students' knowledge becomes the frequent talked issues in assessment related sub-category.

The following verbatim excerpts taken from the interview findings, ranging from a short sentence to a wider paragraph. The researcher tries to give a short note to each selected excerpt clarifying interpretative context of coding processes. A rather comprehensive commentaries will be presented in the discussion section.

7.3.2 Multidisciplinary approach

"Using multidisciplinary pedagogical approaches is improving the effectiveness of your mathematics learning." (Student 3)

"Merge between methods of education by creating a new way to deliver mathematics." (Student 3)

"I think that so far, there are no clear new ways or methods to be employed and followed by mathematics specialists and teachers*." (Student 4)*

These three statements expose explicitly term of teaching or learning approaches. Even though multidisciplinary pedagogical approach presumably lies within a greater concept than mere teaching method, in this context the researcher tends to put it in teaching method category.

7.3.3 Collaboration

"So, we will, we'll go back a little bit to the point where I said that the, the, the classes must be very interactive. So, they must be very interactive group discussions, giving the students have a lot of assessments, weekly assessments, that will help students a lot. I'm talking about this, because experienced these things in two ways. So, I did some units, that they give us a weekly assessment, and another unit, they can give us this weekly assessment. I think so. So much interactive, so much enthusiasm." (Student 2)

Group discussion is an activity of students that can be instructed or encouraged by teacher in a classroom session. Such activities construe a specific learning process, which is in this research context belongs to a teaching method category.

“The traditional method for mathematics teachers is only one, they write the laws and apply them to one example, which is mainly found in the book, but they write it on the board, and the answer takes half the board so that the result appears in the end that was written in the book from the beginning.” *(Student 4)*

This data explicitly mentions the method that is of traditional teaching approach in which teacher gives one prescription to solve mathematical problem. Contrary to this practice of giving only one solution, overing student to seek alternatives solution is considered good teacher practice.

7.3.4 Creativity

“I have experienced so far that my teacher already showed his creativity in his assignments. He has already given us different real-life problems to solve. Also, he also discussed about this problem before he popped before he posts is FMS approved.” *(Student 1)*

“I'm willing to give them videos, but I prefer basically as the main tool here, showing them physical and real-life problems. So, they could solve automatically using the software.” (MT 2)

Clearly these excerpts show a sign of student and teacher appreciation toward a creativity in connecting mathematical concept to a real-life situation. This student also considers this a positive teaching method.

“So, some of the tests or some of the exam, normally, they ask you, for example, to study materials from week one to week six. So, the students will, students will look at their objectives

and materials from week one to week six. That's one thing Another thing is maybe the unfortunately, in some units, they give us a very, very complex task." (Student 2)

It tells the story how sometime student finds difficulties in completing assessment successfully faced by student not because of not following teacher's instruction, but because of a discordance expectation of information assessment from teacher. Actually, this statement informs the students' feedback that can be one of important factor a teacher must attend.

7.3.5 Effectiveness of mathematics learning

Effectiveness of mathematics learning is identified by any achievement of mathematics study and positive supporting factors to successful achievement as perceived from the data. The theme of effectiveness of mathematics learning appears from the data comprise of 65 aggregate number of coding references from 48 outstanding sub-categories such as motivation, understanding, and activities that lead to positive impact of successful learning.

Although effective mean in a positive sentiment, the data provide biner situation of both positive and negative circumstances. Both are presented one after another.

Some verbatim excerpts from the interview findings summarised below, varying from a short statement to a broader one. A short annotation is given in each selected excerpt illuminating interpretative setting of coding processes.

7.3.5.1 Positive array

"It is best to teach students to rely on their understanding and try to research, analyse and find outcomes." (Student 4)

"Practicing what students learned can keep them up with all lessons that they learned." (Student 3)

"They start with us with a unit called general mathematics after that engineering mathematics. So that was of all the basics. So, I think I strained My, my, my mathematical basics, even though I didn't have a lot of very strong mathematics, foundations before joining UC. But I think it they taught us all the basics; I think they did a very good job. And after doing these units after finishing the first-year of my engineering course, I felt so much confidence." (Student 2)

From the above three excerpts, the previous two inform the positive belief to excel in mathematic learning. The third excerpt shows the learning activities experience to have basic mathematic course provided by university that helps extend student confidence to be able to solve further mathematical complexity. In this case, the data provides clues to the presumed situation arising from learning activities that lend to effectiveness of learning.

"So very differently. I felt, I felt confident with that. Even though when I joined UC, I didn't have much experience in mathematics. I would say my foundational my general knowledge and mathematics were very, very basic. And as you see, they need sort of the basics plus the advanced thing. Oh, yeah. So, this is probably what I this was really what comes to my mind now." (Student 2)

The data reveals the increase of students' self-efficacy in learning mathematics that he or she believes in their own competency higher than before after taking mathematical basic course.

"You have to take different app with a different solution method or different examples, you have to try different as much as examples as you can do to handle this much of complexity…I have gone through every PT I have almost gone to every video of all my topics to the YouTube I tried to find the solutions that other people came up with. And I ended up

learning more about concepts rather what have what our lectures have already taught." (Student 1)

Implicitly stated, this excerpt talks about the student effort to cope day-to-day mathematical problem posed to him in such a way that he tries the best to find any option available. This is a positive learning habit that can lead to effective learning.

"Well, what first thing in the class, I can interact with the teacher, I can add questions. And that's all it is. When other students are surrounding you, when you are in the class, like even yourself, you'll be more interactive. So, I think it's very important to always ask your tutor your mixture of questions if you don't understand. The third thing is, especially with mathematics, I think those discussions is something very, very important. Because even though if you don't know something, you'll learn from someone else. And if you know something, you will help others. So, it's and it's very interactive. Communication is a good example to find out the knowledge gaps by asking and answering. I expect if there was more communication and flexibility between me and the teacher." (Student 2)

There are several keywords concerning effective learning the above data conjures up, i.e., interaction, sharing, making question, communication, and knowledge gap. These students' awareness is the expected ingredient to achieve even more effective learning.

"She did this in maths methods she doesn't come to the lecture but then she watches it and she gets the slides because I put the slides up that I've written on and then she prints them all out and then she listens to the lecture and she writes extra things that I put on even though she's got what I've written so she doesn't have to write much but if she writes down some of the things that I say and then she works through it all and even though it seems like she's done next to no math she's going quite well because she's actually studying." (MT 1)

Being attentive and note taking is a good habit for effective learning. The context the above data exposes how this student action bring about the quite good achievement.

"So, I think interactive with the lecture is something important, and creativity, in like how creativity plays a role in this thing is that I have to repair your area before the class, I'll have to engage with the lecturer during the class, I'll have to maybe come up with, with, with like, like, if he gives or if she gives us a task will make the uncertainty in my own way. I think I think it's really strength myself, more than everything else, but also, I think it will help the lecturer or a chore, it will help the class to be engaged." (Student 2)

"Mathematics learning is always nonlinear. There cannot be one specific way of doing a math problem. So here is role of creativity. Be it problem solving or defining a problem, creativity plays a role. This is what distinguishes us from machines and robots. Mathematics is a creative subject. By asking students create their own problems and stuffs like that can add to their creativity" (MT 5)

Again, the data exposes keywords of interactivity, creativity, and engagement. These elements of student actions lend themselves to effective learning.

7.3.5.2 Negative array

"And so, they come in with quite a negative attitude towards mathematics." (E 3)

"I don't know much maths. It's alright. You'll be fine. All math is hard. I wasn't good at maths in school, you know, you'll be alright. Don't worry. That's what they told. And that. So, the idea is that no maths is math is just not important. I mean, I worried because my grandson who's just turned four loves maths. Well, he loves numbers. And I'm really worried when it gets to school, he's going to find lots of students, you know, lots of friends, and what do you want to know that for? And it will be such a negative form, and it will be hard for him to deal with. And we haven't poked with that yet." (MT 1)

Pervasive bad impression of mathematic is imbued in the society that affects detrimentally individual student learning process. The data indicates that student perception about mathematics is socially constructed. This social construction in a way influence student self-efficacy to such a low-level condition.

"I think social media is one of them. They're really good distracted, using social media all the time. And they think they use like 20% or 30% of the day. Spending time this 20% time of the day in the social media and different news, different topics, like different kind of concepts, stories or something like this." (Student 1)

Distraction will inevitably hamper the effective learning process. The habit of continuously attached to gadget and social media, even during the classroom session, will eventually diminish student engagement to learning and create the psychological state of lacking motivation to learn.

"Alright, so, I think um, the concentration issues are mainly in my opinion is related to the use of technology everywhere. Yeah. So, people are relying on technology, they have their phone handy. They have the internet available everywhere every time. Yeah. So yeah, I think this is this is a major problem then down the incorrect use of technology. And this can be fixed by limiting these distractions. So, for example, in the class, students are not allowed to touch their phones …are not allowed to use their phones." (MT 3)

"I think this is due to concentration issues. When you concentrate and learn something there are more chances to remember them for a longer period. So, for this question the same for concentration applies well here too." (MT 5)

Similar to the previous excerpt, this data concerns with the distraction issue. It shows student giving an alternative solution so that the learning process can be an effective one without any hurdle to the student concentration.

"They're waiting for the final exam to go through all of the contents, which is kind of not possible for everyone to totally understand what is being taught." (E 4)

"Another is they're very poor study habits. They, some of them do not have good study habits. So, they think that they can just listen to the lecture and watch it like it's a movie, and then they will know everything. And they don't work through what they have to do." (MT 1)

These last two excerpts, again, define the habitual learning that will be incompatible for effective learning.

7.3.6 Motivation

Motivation denotes processes that instigate and sustain goal-directed activities. Motivational processes are personal, internal influences that lead to outcomes such as choice, effort, persistence, achievement, and environmental influence. Motivation is crucial factor to attain set of learning objectives.

The theme of motivation emerges from the data comprise of 124 aggregate number of coding references from 9 salient sub-categories such as anxiety, discordance expectation, social aversion, and engagement.

There are positive and negative sentiment, the data offer bipolar situation about motivational state and action. Both elements are presented one after another in verbatim excerpts. Similarly, short annotation is provided in each selected excerpt revealing explanatory background of coding processes.

7.3.6.1 Positive array

"If I could encourage them to be creative. And they'd have to be a lot more motivated."

"I think teachers should be more Yes. This is the stage at this stage they need to clarify the things that's being taught in the class how they're going to impact the futures carrier of the

students I think that will definitely improve the motivation I think that might be the most significant things flow the teachers need to explain to students why they are learning this and how learning of these mathematics impacted students' future career." (MT 1)

These excerpts talk about the role of the teacher to motivate the learners to the higher level of motivation by explaining, giving information the relevancy of mastering mathematic with students' future career.

"Yeah, obviously they need to understand what is the purpose of the content … why they need to learn that particular concept that if they if I just jump to the actual material the questions and everything are, they then they don't know what it is for? They definitely don't engage … they think that is not worth doing… it is useless…That's actually crucial." *(MT 2)*

The data conjure the crucial moment about the strong relationship between student understanding of the content's purpose i.e., learning objective and students' engagement.

"So, the teacher should give me a list of tasks. And I think I mentioned this before, where students need to submit weekly, weekly assessments like small tasks. So, this way, as a student I will know my limitations. I will know what can I do and once I couldn't, and this way I can identify my gap I can identify my weakness then I find strength." (Student 2)

Identifying knowledge gap becomes the key point that the researcher can extract from the above data.

"But I think more generally, trying to make mathematics thought of as a, as a learning area, like any other learning area, that it's complex, it can be very motivating. Some people like it, some people don't. But it is possible to learn mathematics. It's not magic, in a sense." (E 2)

The experience that can be very motivating is thinking of complexity of mathematics as learning area. Although the data gives abstract stance, which is difficult to discern definitely, this statement implying something that could be identified as an important motivating factor to learn mathematics.

"Okay, so maybe if the two hours, why don't we just give them three hours and that can take the time? That'd be less stressed. Yeah. Yeah. So, what we should probably be doing is designing a test that we think takes two hours, but give them three hours. And then if they're not rushing as much, but they might be less stressed, right?" (E 1)

This data concern with the source of student anxiety. It explains that solving mathematical problem as a function of time and a Constanta. The function is not in a linear fashion. Each individual learner has his unique Constanta, which can be different widely from one individual to another and presumably varying with circumstances. One can solve a problem in just one hour, yet other can only finish it in a week. So much discrepancy. Hence, it is a real challenge for teacher to set timing test that make student less pressured.

"We should be providing students with strategies for reducing anxiety and teaching them how to take the test. I think that's an important aspect of any assessment, where we're saying, what we're trying to test is your ability to show us your mathematics knowledge, we're not testing your ability to do the test, you know, manage your time, write your answer down correctly, that's not really what we're on about. We're on about your maths, your math skills." (E 2)

This excerpt, again, talks about a way to reduce student anxiety, that is informing student the objective of assessment.

7.3.6.2 Negative array

"I don't know what you do to improve their motivation yeah I think it's it is the sise of attitudes the attitude is that maths is hard maths is not important ... that attitude is very pervasive through the whole of Australian society and so the students have got the idea that

you don't really need to learn it you can just google it it'll all be fine and it's just a waste of their time why would they need to know this and plus their parents will tell him I don't need to know." (MT 1)

The interesting part of this statement is that pervasive bad attitude toward math in the wide Australian society. Mathematics is socially perceived hard. This social cognitive will in turn affect individual student anxiety to learn mathematics.

"Oh, they said. So, I don't know, this is this has to be addressed in school. This is just the same attitude that we don't really need to know this. We can google it anyway. It's not important. Why am I going to use this in my job, they don't even know what job they're going to get. But they assure they're not going to have to use any of this information. They just don't want to do it. They have no motivation." (MT 1)

Lack of motivation is being addressed on this data.

"But part I mean, but a lot of it is the parents, if the parents were more supportive of education, and made them understand that education was important for them, then things could change. But so, you've got to change the whole of Australian society because there's too many parents that don't see education as being important." (MT 1)

Again, social cognitive prescribing that it is not important to learn mathematics as portrayed by many Australian parents challenge the educators.

"And in the same way, working on maths assessments may be just as stressful as working on other things. That will be my suspicion. But I but I do know, of course, that mathematics, that there's a whole body of knowledge about test anxiety in mathematics or in maths, anxiety, and that partly, that is a cultural sort of thing that we have said, we've allowed people, this is a criticism I think of all of us, as educators, from the very early stages, we've allowed students to sort of say, Oh, I'm not very good at maths, and that that's in a sense,

culturally acceptable. Whereas if you said, Oh, I'm not very good at reading. That's not culturally acceptable." (E 2)

Similar to previous except, this one shows how culture (as allowing children to think that they are not good in math) become a blocking factor to motivation.

"No, this is one of the things that they are afraid of. They're afraid of the subjects of the concept. And because of this, because of this fear, they think if I can just pass this course that will be enough for me, because I don't want to interact with you. I don't want I don't want to get I want to I don't want to ended up in this subject over and over again. This just give me the past marks and I'll be fine. I'll not complain about anything. This sport this I think this is the reason this is the reason that they fail to have motive have motivated by themselves. So, it's my How can they get more motivated by learning mathematics." (Student 1)

"Students have a high level of anxiety and lack of confidence in their learning. By this anxiety is either a high level of anxiety, really, I think this anxiety problem really start from the beginning of our students." (Student 1)

Anxiety of the mathematical subject makes student think that it is enough for them just to pass the grading, indicating at the same time lacking motivation to attain higher mathematical skills.

7.3.7 Understanding

Mathematical understanding is represented by the ability to solve mathematical problems, to convey its related elements (procedures, model or mathematical concept), and to communicate these abilities with others.

The theme of motivation emerges from the data comprise of 50 aggregate number of coding references from 8 salient sub-categories such as basic mathematical skills, learning objective, previous math knowledge, procedural, and conceptual.

"There has to be clear objectives and objectives that went when the students are all the depth the objectives of what's going to be taught should be presented to them very early in the lesson so that the students themselves can monitor their own learning." (E 1)

This excerpt suggests the necessity of teacher giving information on learning objectives. The information needs to be presented in the beginning of learning session.

"So, they tend to believe that, you know, mathematics is about learning about a type of problem and then learning a process to solve that problem. And then repeating that process to get a solution, right. They focus on algorithms they focus on, on getting the right answer, rather than the journey or the process they might follow to get to the right answer." (E 3)

The above data reveal how student processes a mathematical problem using procedural understanding, which is not an ideal skill to be attained.

"Yeah, so, um, again, I'll talk about things that I do, that I don't think are done as broadly as they could be. So, I put a heavy focus on conceptual understanding within my units. Yeah. So, I try not to focus on the, you know, what's the right answer? Or how do we solve these types of problems directly, I tend to talk about the understanding and the why things work." (E 3)

Apart from procedural understanding, this excerpt talks and stresses the importance of mastering conceptual understanding to solve mathematical problems.

"The main one is the students don't have enough background from let's say school years 11-12 mathematics .... They come to university not knowing even the basics of mathematics." (MT 2)

Lack of basic mathematic becomes the most hurdle for student to understand more difficult contents.

"Knowing that most students of the subject are international students, above trying to understand and communicate in a language that is not your mother tongue, her frustrating look and treatment during her explanation was another reason for the difficulty of understanding mathematics." (Student 4)

The circumstances where students come from different background of language, while the learning is delivered in English, creates communication difficulties.

7.3.8 Challenge in teaching mathematics

7.3.8.1 Improving the quality of teaching mathematics.

> "*Engage in hands-on engineering activities. Like doing a model of a building with such and such specifications and with the available raw materials. something like this. This will in the first place makes them think broader than the mathematics per se. secondly, they will eventually learn to apply the concepts. using a constructivist approach to learning and developing relevant contexts and encouraging cooperative learning are a few ideas that will help students understand math better." (E 5)*
>
> *"To exactly know the current trends, I think we should ask with the experts in the field. University can organise a programme with the experts where they can teach how to use those technologies effectively. Because when we don't know how to use those technologies it will be very time consuming and would go beyond our head. That would become even more complicated…. So, I think a training should be needed." (MT 4)*
>
> The data eminently show that there is a need to improve the teacher's quality.

7.3.8.2 Improving students' performance and attitude.

"At school, the development of the students' creative potential should start from the teachers' mathematical education. Only expert and creative teachers can provide the appropriate environment for developing students' creativity. To develop their original thinking, students should have the opportunity to work with ill-posed and open-ended problems, to go wrong and make mistakes, and to find different solutions to the same problems. Through these experiences, associated with positive emotions, students should develop an intrinsic motivation for creativity in mathematics." (E 5)

This must be an absolute necessity to improve students' performance and attitude toward learnings as there will be always room for improvement at every attained level.

7.3.8.3 Finding the best approaches of teaching mathematics.

"They are really helpful. Nowadays lot of schooling systems adopt artificial intelligence into students learning and find it easier to make students understand a concept better. They can be used to give a life like experience. So definitely they can improve the way we teach the students the concepts… like how we are forced to do everything online, there will be a time when students needn't come to college every day. They can just wear a google glass or some kind of stuff like that and learn everything at the comfort of being home." (MT 4)

Finding the best suited approach of teaching is always an ongoing process. The world is continuously changing. There is no single best suited approach might be stay effectively applicable. The yesterday's approach may be obsolete today.

7.3.8.4 Lack of diagnostic testing and understanding of learners' current mathematical level.

"Grading… yes… Grading cannot be done based on a single test or semester. Actually, this timed testing can make them more anxious rather than helping them. May be, if we adopt some kind of grading system that assess the students' assignments, their attentiveness, quality of their work and also the final test like the semester that we have… a combination of all these assessments will reflect the students' capability much better than a single test." (MT 5)

In search of excellent, a combination of various type assessments that will reflect the students' overall capability will be much better than a single test.

7.4 Summary of Interview Finding

The following summary of interview findings are extracted and selected from the data. It covers all the 17 interview questions. Some questions are merged together. Respectively, Q5 and Q6, and Q14 and Q15 are merged into teacher development and learning constrains.

1. Learning hurdles.

   The biggest hurdles for EIT student to learn mathematics at UC is the language barrier as most student come from social background where their first language is not English.

2. Learning activities supporting understanding.

The class should be as entertaining as possible utilising different teaching style. Teachers should motivate students harder.

3. How to increase student engagement.

    For example, by making problems into smaller question that can be answered to a bigger question, lead to increase the engagement and improve discussion.

4. Explaining learning objective.

    Predefined learning objective is effective to assist learning process.

5. Teacher development.

    Teacher should catch up with current knowledge by reading mathematic education journals. Teacher should keep up to date with the current literature, I think being part of a professional associations and know that there's a mathematics Teachers Association and having meetings with other teachers is a really important aspect of professional learning.

6. Grading system.

    Grading system needs to be improved. It must move to something different. Developing a grading system involves a team work of experts in various fields. The existing approach has some pitfalls it not clear if there is anything better than this. Perhaps, a new grading system must be developed and compare it with the existing one to know which is better.

7. Connecting math to a real life.

    The examples how to use math must be provided. Role play game can be developed that need mathematical application in engineering problem.

8. Encouraging student creativity.

It is important definitely to encourage student creativity. The more they are creative, the more they will be attached to the thing that they are learning.

9. Technological assistance.

   Student think it would be really interesting to have this kind of interactive ideas or features in the classroom. This will be definitely very helpful. And I think students will start learning faster than what they are used to.

10. Multidisciplinary approach.

   A multidisciplinary approach is a range of different disciplines being connected together to enhance a students' learning. A good example of that is STEM. It is about someone who are, say, professional mathematicians, but someone who are also mathematics educators, practicing engineers, these different people, these different disciplines, I think that is, is really important.

11. Knowledge gap.

   The teacher has to develop good assessment tools to assess the students' current knowledge.

12. Collaboration.

   Collaboration is always helping to achieve the best result of the learning.

13. Learning constrains.

   If the students have interest to learn then they will eventually concentrate in the class. To some extent the teacher can make the class engaging and interesting so that students concentrate in some way or the other. They should also come with a mindset to learn and implement something new. This makes them to concentrate well.

14. Lack of motivation for achievement.

Students should take a personal interest in their preferred future. They should learn the significance of each subject in relation to the others in their academic curriculum, so as to develop a strong grasp of fundamentals. When they are goal-oriented and future-focused in their mental and physical disposition, the end result will not be in just passing the exam but to acquire knowledge. And obviously they will be motivated.

15. Coping with anxiety.

    Fear of failure is the major reason. Unlike another subject's mathematics cannot be read and remembered. You have to know the concept right. So, there may be an increased anxiety for math test. Lack of enough preparation and poor previous performances could also be other contributors. Effective learning and time management strategies can help through this.

7.4.1 A way of looking at the data findings

What the researcher brings into this study is not just a blank state of mind. The life experience of education that the researcher has been undergoing, the specialised field the researcher currently studying, and the literature review specifically prepared for this study are brought together as utensil to see the firm image conjured up from the data. The researcher confesses not to create space between the self and the objects being investigated in this study. Being an instrument of this study itself, the researcher tries to present the analysis as simple as possible within the researcher understanding, some of which through borrowing other lenses of theoretical frameworks that the researcher beliefs can convey the understanding.

Guided by and in the attempt to address the research problems and research questions, the analysis focuses on the emerging themes from the data that aligned to these constructs: Mathematics teaching approach, collaboration, understanding, achievement, motivating factors, engagement, multidisciplinary approach, and effectiveness of learning. Beyond these constructs, there are systems surrounding them as superstructures such as organisational entity, socio-culture, and politics where the learning processes are taking place. At the core centre of the processes there are individual (people) playing the production of mathematical knowledge: Students, teachers, and experts.

The constructs, the superstructures, and the people are intertwining in a networked process constructing micro-systems of classrooms, both face-to-face classroom or online classroom, students' collaboration, teacher-expert collaboration, curriculum, time-table management, and other organised processes.

Altogether, these constructed micro-system make up as system of learning that geared to produce some outputs i.e., the development of students' mathematical skills and the developments of teacher professionalism in teaching skills.

Instead of looking constructs in its own bipolar relationship with another construct as in previous part of this study of quantitative section, the looking now is on a system environment where these constructs are interrelated simultaneously. By adopting this analysis approach of system framework, it is hoped that the research problems and research questions can be addressed in a plausible and simple manner. Most importantly, it is able to explain the phenomenon under the interest of this study.

This way of looking adopts a general system theory hallmarked by Ludwig von (Bertalanffy, 1972) and Joseph Litterer (1969). The researcher is comfortable with this theory in looking at the interaction of elements of interest of the study as the general system theory proposes the following assumptions that applicable to this research (Skyttner, 1996). These underlying assumptions are:

- **Interrelationship and interdependence of objects and their attributes.**

  In this study, constructs, people, micro-structure, and superstructure are interrelated and interdependent.

- **Holistic**

  The objects and processes under study are defined as a system: A Mathematics learning and teaching.

- **Goal seeking**

  It has sets of objectives: Students' mathematical skills and teacher's professional skills.

- **Transformation process**

  In attaining the goals, a system takes inputs to be processed. In this research setting, they can be contents, teaching method, pedagogical approach, and students.

- **Inputs and outputs**

  Depending on whether inputs are supplied at once or supplied to the system in incremental way. The former constitutes a closed system and the latter constitute an open system. The learning system can be considered as an open system, in which inputs are dynamically infused or changed.

- **Entropy**

  The occurrence of randomness processes in every system. The learning system, whatsoever it's strictly planned and set, due to the dynamic of social environment, technological advancement, and the dynamic of human attitudes (students, teachers) is prone to events that randomly happen.

- **Regulation**

In a learning system, objects such as constructs, teachers, students, expert, organisational structure etc. is operational in an intended regulation (curriculum to follow, teaching approach to be conducted, length of time to be consumed) to achieve its goals.

- **Hierarchy**

    The complex system that construed by smaller subsystems, sometimes nesting within other system. Actually, mathematical learning system is just a subsystem of the institutional system at UC, which is also just another subsystem of Australian education system.

- **Differentiation**

    A unit in a system perform its own functionality contributing its output to the whole system through another unit in the system. Essentially, understanding is a function of engagement as a unit trough student action of engagement to the learning processes (see Figure 7.1).

- **Equifinality and multifocality**

    There are two possibilities in attaining objectives in an open system, i.e., divergence and convergence. If the same objectives are attained, then it is divergence, while it is convergence if it obtains different and mutually exclusive objectives.

Figure 7.1 depicts this interrelated element of a mathematic learning system at UC based on the data findings guided by research questions.

Within the lens of general system theory, due to its hierarchical property, further analysis of the interview findings can be done through a more specific theoretical framework to learning behaviour such as Vygotsky’s activity theory (Walshaw, 2016). Vygotsky has provided many researchers a theoretical apparatus for interpreting the social backgrounds of thinking and learning in mathematics education research. Within this Vygotsky's framework the researcher tries to elaborate the specific relationship of teaching method approach, collaboration, achievement, factors motivating student to engage, the roles of teacher, educator expert and student.

Moreover, the researcher also explores the development of shared understanding as a cooperative activity between the joint achievement of teacher and students: as a consequence of what is made possible and what is occupied within the classroom setting. An analysis that identifies the activities significant to the potential development of mathematical thinking and learning within one classroom was also elaborated.

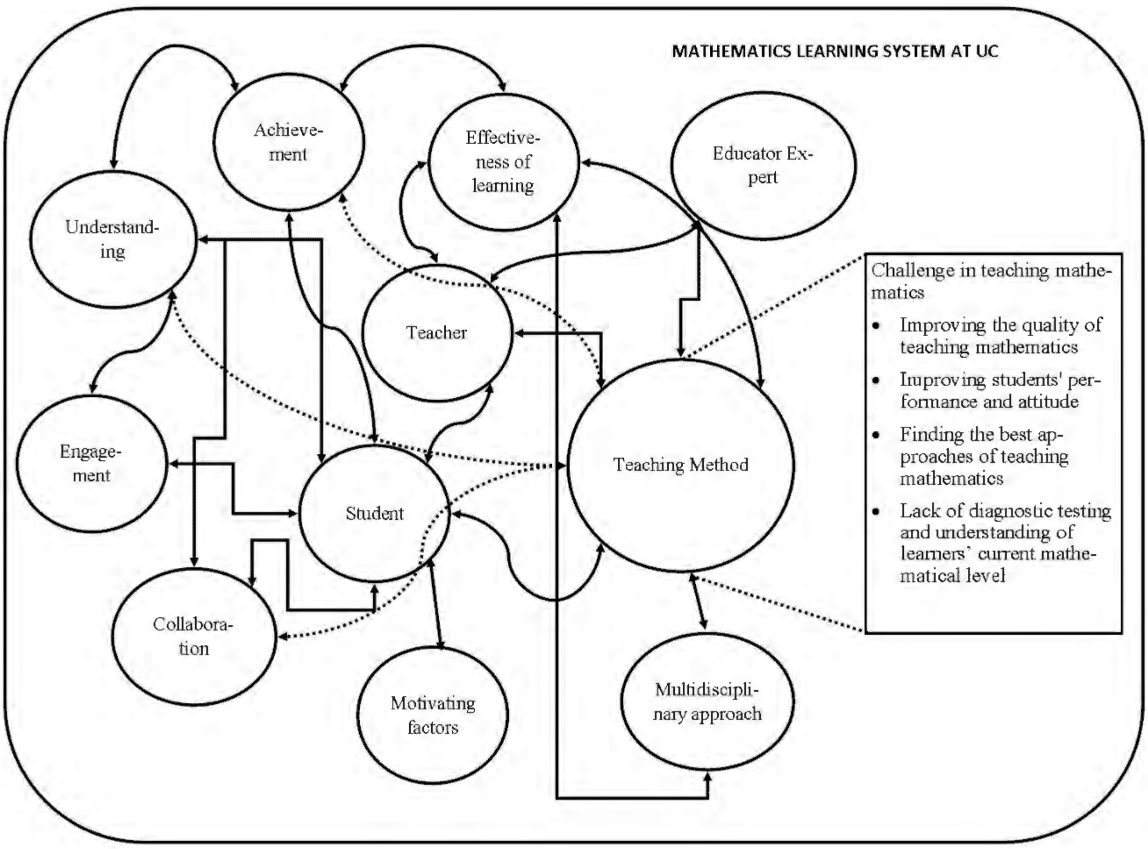


Figure 7.1: Relationship framework based on data findings

Within the discussion section below this analytical of general system theory lens will be used to address the research questions further.

7.4.2 The Vygotsky's Key term

According to Vygotsky, the individual has the status of agency, yet that agency springs from history, culture and society. This hypothesis offers us a frame to understand how people might engage in the creation or transformation of circumstances and to understanding how certain material and social settings might contribute to or hamper chances for people to reach full developmental ability. The following excerpt are the Vygotsky key terms adopted from (Walshaw, 2016):

7.4.2.1 Internalisation

> One internalises external processes by gaining control over them through his or her engagement in a various practice enabling him or her to use cultural tools. If an engineer achieves the skills of implementing a mathematical concept to an engineering project, then this engineer has 'picked up' the cultural tool i.e., Mathematics.

7.4.2.2 Mediation

> Higher mental function that student develops, which move concrete thinking to abstract one happen trough mediated, social and collaborative activities. Mechanical drawing used by an engineer is a cultural tools and signs that form a qualitative thinking change from concrete to abstract one.

7.4.2.3 Language and Thought

> Thought characterises the development of mental concepts and cognitive awareness and is apparent in problem solving activities.

> Language characterises both inner speech and oral language and is apparent in communicative utterance. A critical point in development is grasped when such the two trails converge.

7.4.3 Zone of Proximal Development

The Zone of Proximal Development (ZPD) relates a students' learning process and her cognitive development. It focuses on social transformation and is defined as 'distance between the everyday actions of individuals and the historically new form of the societal activity that can be collectively generated. (Engeström and Pyörälä, 2021). Vygotsky defines ZPD as the distance between a child's actual development level as determined by independent problem solving and their higher level of 'potential development as determined through problem solving under adult guidance or in collaboration with more capable peers' (Vygotsky, 1986). Hence, students' accomplishment in learning is a function of teacher development. A zone of proximal development (ZPD) is applicable for both student and teacher.

7.4.4 Scaffolding

It is the process whereby adult aid enables a student to solve a problem, carry out a task or attain a goal beyond her unaided efforts at that point in time. It entails a sensitivity to the level the incremental transformation in information needed to support the learner up to the highest level they can accomplish with support, that is, to meet the cognitive potential of the student. In other word, to grasp the distance between problem solving abilities shown by a learner working alone and that learner's problem-solving skills when aided by or collaborating with more-experienced people.

7.4.5 The Teaching for Robust Understanding – Lesson Study

Borrowing The Teaching for Robust Understanding (TRU) – Lesson Study framework as a practical teaching and learning activities (Schoenfeld, Baldinger, et al., 2018b), further analysis will explore the data findings, looking for the possibilities of current system learning advancement; lending analogues ZPD for a system, that is gearing the system to a more efficient and effective state of producing desired output of skilful students to solve mathematical problem. Transform it from current level to a higher potential.

The Teaching for Robust Understanding (TRU) framework marks five important dimensions of classroom practice. It claims that for students to arise from mathematics classroom as knowledgeable and flexible thinkers and problem solvers, the classroom has to provide substantial opportunities along the five dimension of learning content, cognitive demand, equity, AOI (agency, ownership, and identity), and formative assessment (Schoenfeld, 2016b).

The content (The Mathematics): Classroom activities create opportunity for student to become knowledgeable, flexible and resourceful mathematical thinkers.

The cognitive demand: Student has opportunity to grapple with and make sense of important mathematical ideas and their use.

The Equity: Classroom activities invite and support the active engagement of all the student in the classroom.

The A-O-I (Agency, Ownership, and Identity): Student has opportunity to contribute to conversation, to build on other’s ideas and has his on-other’s idea; in ways that contribute to his development of agency (willing to engage), his ownership over the content, and the development of positive identities as thinkers and learners.

Lesson-Study is a collaborative teacher learning program that engages teachers in inquiry and reflection around important problem of practice through inquiry cycle of studying, planning, enacting, and reflecting (Huang et al., 2019).

In one LS cycle, a teacher learning community (TLC) walk together along the four-phase process of study, plan, research, and reflect. In the *study* of materials for teaching phase, TLC chooses on a research theme and theory of action and picks mathematical topic to focus on. During this phase, the background research is conducted to assess current student understanding of the topic and at relevant instructional materials. Bringing these information forward, TLC make a lesson *plan*, identifying specific issues that teacher want to focus on at the lesson session. Some teachers conduct the *research* lesson, while the remaining teachers and invited educators observe, gather evidence of student thinking (they may be some education expert, such as experts in this research setting). The fifth cycle is the participant activities *to reflect* on how the lesson carried out and discuss their observation with an outside expert.

Therefore, TRU provides a theoretical and structural frame for professional learning content and Lesson Study provide overarching activity structure (Schoenfeld, Floden, et al., 2018).

7.4.6 The participants' shared awareness

The emerging themes from the data are snapshot of participants' awareness (students, teachers, and educator experts) concerning the respective themes. It does not necessarily the themes are being practiced or not practiced in the current situation, but most likely the participants have experienced the themes they talked about and having an awareness, knowledge, and opinion about it.

Let us take a look at one theme of collaboration that participants have talked about:

Student	"So, collaboration can help lessons discussions. What did we think? I think? I think it's really important. Like, it's really important for classmate's club collaboration." (Student 1)

Teacher	"Okay, so yeah, again, some students, they do not feel very confident to ask the question in front of the whole class. And even if they do not understand they prefer to keep it to themselves. But when the collaboration is empowered and encouraged by the teacher, this will help the students to talk to each other. So, imagine that someone asking you, for example, let's say you're allowed to have 50 students in class, and a group of three or four students like working together. So, the students are I think they are more confident to talk about what they concern about or what they do not understand in a smaller scale, rather than suppressing their misunderstanding or not totally understanding some concepts in front of the whole class." (MT 3)
Educator expert	"Yes, there's quite a bit of literature on this, this area in the education dimension. And we know, clearly that what we call peer mediated learning, where students are engaged, is a very powerful way of learning." (E 2)

The student, the teacher, and the expert are at the same wavelength, having a shared awareness, acknowledging the importance of collaboration in learning processes. In other words, in relation to other themes, e.g., effectiveness of learning, they perceived collaboration as important element to effective learning.

Nevertheless, this study does not gauge the existence of collaboration in the past and current practice of classroom environment at UC and consequently nor its frequent occurrence, consistently conducted, and how it has been conducted and encouraged.

Analogously, these snapshots of participants' awareness apply to other emerging themes focused in this research as a mere perceived construct of the participant (interpreted by the researcher) rather than real 'event' practicing in the classroom.

The researcher believes that it is important to point out this state of a snapshots of participants' awareness as a part of analysis lens and guide the researcher in addressing research questions. This awareness is students' awareness of the importance of learning in collaboration and the teachers' awareness of the important of personal development and research on practiced teaching and learning processes.

8 Interview Analysis to Build on the Survey Findings

8.1 Introduction

This chapter discusses the findings obtained from qualitative and quantitative data and elaborates on the answers to the three research questions. This chapter commenced by discussing the survey results and examining the impacts of teachers' pedagogical methods on students' mathematics performance (see Section 8.2). After that, we provide more detailed analysis of the quantitative and qualitative phases. The important parameters of their statistical values are discussed in Section 8.3, such as effect sizes and some excerpts from the interviews. In addition, we explore predominant themes of perceived learning activities experienced by students and teachers in day-to-day classrooms.

8.2 Using the Interview Analysis to Build on the Survey Findings

A quantitative study was carried out in this research to elaborate on problem areas and research questions explored with the collection and analysis of qualitative data. A qualitative approach was employed to obtain insights into the research questions. Results from the qualitative data can help improve the understanding of the relationship between teachers' pedagogical methods and student mathematics performance. Additionally, interview analysis can help overcome the lack of validity associated with quantitative measurements. Some of the interview questions (i.e., Q14 – Q17, see Appendix II) of this research provide evidence for the need to improve mathematics learning in universities. The four questions cover learning distraction, content understanding, motivation, and anxiety.

The qualitative research approach is different from the quantitative research approach. Interviews are usually performed in the quantitative research approach, while surveys are conducted, and variables are measured. In this research, the results of the quantitative research showed that teachers' tutoring methods significantly impacted on students' collaboration, understanding, and achievement. The findings were further explored using qualitative research to obtain more insights. In short, the qualitative analysis builds on the survey findings to complement each other.

The first research question comprises three dependent variables of collaboration. They include understanding, achievement and one independent variable of the teaching methods. In the quantitative part, the relationship between the teaching method and the three dependent variables is quantified and statistically tested in isolation. Figure 7.1 illustrates the comparison of the relationship between the variables in isolation with the qualitative proposed relationship framework of learning processes. As shown in the figure, it is clear that the qualitative part enlarges the angle's point of view in understanding the relationships between the variables. Even though the MANOVA analysis outcome states that there is a significant impact on collaboration affected by the teaching method, it is plausible to be sceptical due to many unanswered questions. For instance, is the teaching method the only factor that affects collaboration or are there any confounding factors simultaneously affecting collaboration that the quantitative steps do not measure?

The analogical flow of logic is applicable to the second research question. This question includes one dependent variable of motivation and other independent variables of learning styles, collaboration, understanding, time management, teaching method, assessment-related, student effort, technology role, emotional role, satisfaction, and anxiety. While the multiple regression analysis implies that multiple relationships exist between a dependent variable and some independent variables, the relationship between the dependent and the independent variable is technically (Field, 2018). Hence, the relationship between the modelled variables in the multiple regression analysis is isolated. The quantitative part outcomes pertaining to this multiple regression analysis in addressing the second research question show that only two independent variables of assessment related and student effort only are statistically significant.

In other words, motivation is significantly affected by students' effort and is assessment-related. While other independent variables of interest (learning styles, collaboration, understanding, time management, teaching method, technology role, emotional role, satisfaction, and anxiety) cannot significantly influence motivation. Again, it is plausible to be sceptical due to many unanswered questions. For instance, do these independent variables of interest influence motivation or does the technological role affect students' motivation?

The qualitative part addresses more the third research question. The discussion of the survey results and interview findings is presented in section 8.3 will address the above missing parts of the explanation.

8.3 Discussion of Survey and Interview Findings

This section discusses the statistical outcomes reported in the quantitative part concerning the dependent variables (collaboration, understanding, and achievement) and the independent variable (teaching method). This discussion focuses on the first research question, what are the impacts of the UC mathematics teaching approach on the first-year EIT students' collaboration, understanding, and achievement in mathematics courses? The multiple analysis of variance analysis (MANOVA) is presented below:

1. Using Pillai's trace, teaching method has a significant effect on collaborations, understanding, and achievement, $V = 1.03, F(75, 216), p < .05, \eta^2 = .34$
2. Using Wilk's Lambda, teaching method has a significant effect on collaborations, understanding, and achievement, $\Lambda = .28, F(75, 210), p < .05, \eta^2 = .35$

3. Using Hotelling's trace, teaching method has a significant effect on collaborations, understanding, and achievement, $T = 1.61, F(75, 206), p < .05, \eta^2 = .35$
4. Using Roy's Largest Root, teaching method has a significant effect on collaborations, understanding, and achievement, $\Theta = .70, F(25, 72), p < .05, \eta^2 = .41$

All the four multivariate analyses indicate that teaching method has a significant effect on all three dependent variables (collaborations, understanding, and achievement) with the large effect sise, eta $\eta^2 > .14$ (Cohen, 1992).

Students' perception of collaboration can only be analysed by relying on the following open-ended interview data:

Student	*"So, collaboration can help lessons discussions. What did we think? I think? I think it's really important. Like, it's really important for classmate's club collaboration." (Student 1)*
	"I learn most by discussing with my classmates. There are a few mates who are really like… they grasp whatever taught in the class. So, I prefer asking them the doubts or ask them to explain certain things." (Student 5)
Teacher	*"Okay, so yeah, again, some students, they do not feel very confident to ask the question in front of the whole class. And even if they do not understand they prefer to keep it to themselves. But when the*

	collaboration is empowered and encouraged by the teacher, this will help the students to talk to each other." (MT 3)
	"So, student collaborations are very important. Teaming them in a group of three or four or having a discussion session for ten minutes at the end of each class can be very effective in encouraging student collaboration." (MT 5)
Educator expert	*"Yes, there's quite a bit of literature on this, this area in the education dimension. And we know, clearly that what we call peer mediated learning, where students are engaged, is a very powerful way of learning." (E 2)*
	"Learning from their age group is an integral part of human development. Social learning theory explains how people can learn in different social contexts and how creating a more active learning community can positively impact a learner's ability and help meet individual learner goals. It is highly essential to establish a good student collaboration." (E 5)

All the participants (students, teachers, and experts) shared similar views. They acknowledged the importance of collaboration in teaching and acquiring knowledge. A teaching method that encourages collaboration is an ideal pedagogical practice. This qualitative information enriches the understanding of the statistical relationship between teaching methods and collaboration.

The following excerpts provide insights into the relationship between teaching methods and students' mathematical understanding.

Student	*"Math is difficult because each problem has to be done uniquely and the concepts are difficult to understand. Algorithms and theorems are confusing and are very difficult to remember… these are my difficulties. I don't think this is the problem with the university or it doesn't have anything to do with the university. It's about the subject. And it should be the same everywhere." (Student 5)*
Teacher	*"Yes. Obviously yes. Students cannot be sitting blank till the end of the class and wonder what the teacher is teaching. So, stating the objective of the session clearly is necessary. Telling them the objectives like what all they will learn from the lesson makes them more interested and will kindle their curiosity. This can even help in better learning." (MT 4)*
Educator expert	*"Yes, it is. A predefined objective is always effective because students get to know what the class is all about. They can decide where they have to pay their attention more and were less." (E 5)*

The second research question is concerned about the factors that motivate EIT students to engage or lose interest in mathematics. The multiple linear regression analysis models the dependent variable as motivation and the independent variable as collaboration, understanding, time management, teaching method, assessment related, student effort, technology role, emotional role, satisfaction, and anxiety.

The multiple linear regression statistical test results reveal that student efforts and assessment related are statistically significant ($standardized\ \beta = .43, p < .05$ and $standardized\ \beta = .30, p < .05$ and $R^2 = .25$).

This isolated relationships from the quantitative data offer limited answers to the research questions, whereas the analysis of the interview data complements the results of the qualitative research. The interview excerpts are as follows:

Student	*"Okay, if you can give me a different kind of solutions to this problem, or if you can find a real-life problem related to this problem. I'll give you like two points of one-on-one points I interactive price for you. This kind of interview programs can really motivate students by learning." (Student 1)*
Teacher	*"The biggest hurdle in learning math is a myth that only a few can excel in mathematics and that math is for genius fellows, not everyone can do it. A stigma that mathematics is one of the toughest subjects with no practical value is there…. Of course, learning math and developing numerical understanding is far different from other subjects. But this stigma and myth makes students less interested in*

	math. Every student carries the capability and interest to learn meaningful mathematics." (MT 5)
Educator expert	*"But I think more generally, trying to make mathematics thought of as a, as a learning area, like any other learning area, that it's complex, it can be very motivating. Some people like it, some people don't. But it is possible to learn mathematics. It's not magic, in a sense." (E 2)*

The study aims to examine the impact of the UC mathematics teaching approach on first-year EIT students' collaboration, understanding, and achievement in mathematics courses, what factors motivate EIT students to engage or lose interest in mathematics, and whether the implementation of a multidisciplinary pedagogical approach enhances the effectiveness of student Mathematics learning for UC EIT students. This discussion section presents the researcher's perspective on the issues based on data findings related to the three research questions.

8.3.1 The Relationships

This study explores the impact of teaching methods on students' collaboration, understanding, and achievement. More specifically, it investigates the relationship between teaching methods and collaboration, between teaching methods and understanding, and between teaching methods and achievement. The results of the quantitative phase suggested that the teaching methods used at UC in mathematical classrooms significantly impacted students' collaboration, understanding and achievement. In short, the qualitative phase provides more insights into the experiences of students and teachers about learning mathematics in the classroom.

Based on the findings of this study, these three constructs cannot be seen as a separate entity as they overlap one another. For example, collaboration emerges within the theme of teaching method, while creating robust understanding is part of teaching methods. Therefore, a teaching method alone is not a single unit of analysis isolated from collaboration, understanding, and achievement. The three variables are complementary. The relationship between the two constructs may be a two-way direction. However, the relationship among the three constructs may be multi-direction.

Through the lens of system theory, investigating these relationships is simple and clear. Each construct constitutes a single unit of function, and it contributes to the whole system. Figure 7.1 in the previous chapter depicts the relationship between the constructs. The figure shows that there is a significant relationship between teaching methods and other variables such as collaboration, understanding and achievement. Yet, this relationship does not answer the research questions. For example, considering only collaboration, the effect of this variable can be examined. The following excerpt is a students' collaboration perception:

"I think in the face-to-face learning environments, like teachers and students are interacting face to face right. So, I think a group discussion will be much more appreciated in this case, we wish to do the undergraduate program if we cannot solve a problem by our own. So, our lecturer or the process or institute that it takes by to six people, and the makeup group, So, the, so the group now starts to discuss the problem themselves and share the idea that how they can solve this are pathetic techniques to use, or even if an event if someone does not understand the problem at all. Okay, so he can also take some of the idea from his brain, right,

understand that problem by themselves. Sometimes you can see that students, some, some students are very afraid, or be shy to ask a question." (Student 1)

The function of collaboration is to enhance students' understanding (Amador and Galindo, 2021; Granata and Dochy, 2016; Ní Fhloinn and Carr, 2017). The higher a learner's understanding level, the higher the person's achievement and the more effective the teaching method. The zone of proximal development for a certain student may occur at this collaboration moment. The understanding level, however, can be shifted to a new higher level by peer or teacher scaffolding (Hirsh and Segolsson, 2019; Imms and Byers, 2017a; Soares, 2015)

Furthermore, the teaching for robust understanding (TRU) attribute may likely happen so that the content (the mathematics) by which activities to create opportunity for students to become knowledgeable, flexible and resourceful mathematical thinkers enabled; the cognitive demand, in which student has the opportunity to grapple with and make sense of important mathematical ideas and their use activated; the equity, in which classroom activities invite and support the active engagement of all the students in the classroom; and the A-O-I (Agency, Ownership, and Identity), in which students have the opportunity to contribute to conversations and build on their ideas and other's ideas in ways that contribute to their development (willing to engage), their ownership over the content, and the development of positive identities as thinkers and learners (Huang et al., 2019).

8.3.2 The Motivating Factors to Engagement

The regression analysis in the quantitative phase of this study suggested that motivation was significantly affected by assessment-related and student efforts. The assessment-related approaches are teachers' actions (partial processes of what teachers are doing in the classroom), while student efforts are responses to the teachers' actions. These constructs generate the environment for student mathematics engagement.

Mathematics engagement encompasses affective structures and immediate persuasion to drive continuous and productive learning behaviours. A productive learning behaviour is a social construct developed within the interaction of students' individual learning states and mathematical disposition. The interaction generates a stable structure of engagement within specific eliciting circumstances. The blend of intrinsic, extrinsic, social and individual factors is intertwined when a student engages in a mathematical activity (Goldin et al., 2011; Hannula et al., 2016).

As shown in Figure 7.1, the data show that students' mathematical engagement is driven by their self-interest.

"But I think engagement is driven by interest. And something doesn't have to be real life to be interesting. And that's true in all sorts of subject areas. You know, people don't people don't ask the question about when they're going to use art in real life. Because art is its own thing. It has value in and of itself, and so does mathematics. So, I tend to dodge the real-life question, as you can probably sense because I think it's a bit of a red herring. I think it's an It's a trap to try to justify mathematics as a real life, because it's not. And that's okay. It's okay that it's not it certainly can be applied. But once you're applying it, you're not doing mathematics anymore." (E 3)

8.3.2.1 Interest

Interest is a key motivating factor to student engagement, as shown in this excerpt. Studies show that interest is one of the most substantial predictors of mathematical achievement and persistence over the years. Similar to most motivation factors, Interest has both a short-term and a long-term manifestation (Hannula et al., 2016). This inward examination of the individual self brings other traits shown below.

8.3.2.2 Perceived instrumentality

The student senses that engagement will produce some valuable knowledge, skill, or social standing. This benefit may be instrumental to fulfilling some non-mathematical interest (Husman et al., 2004).

8.3.2.3 Personal goals

Motivation on the individual level is goal-oriented. As such, the kinds of goals and the process of achieving them drive much of academic effort. It must be pointed out that goals under this context are the learner's goals, not necessarily the teacher's or school's goals. Both task-level goals (short-term) and goal orientations (long-term) significantly influence students' motivation by affecting the desired outcomes of their imagined engagement (Sheeran et al., 2005). There are three dimensions that constitute personal goals: (a) goal proximity, (b) goal specificity, and (c) goal focus (Middleton et.al, in Hannula et al., 2016).

8.3.2.4 Goal proximity

The closer a goal is to the direct task at hand (proximity), the more students tend to adopt strategies for self-regulation, such as time management and regulation of effort (Rea, 2012).

8.3.2.5 Goal specificity

For both proximal and distant goals, the development of a comprehensible strategy needs to be specific. Wide-ranging goals such as "make life great again" do not provide direct information on or explain how to behave, what strategies to set, and whom to align with when engaged in mathematics. Goals such as "learning geometry", if they are expressed into a larger plan (becoming an engineer), gives evidence of the exogenous utility of one's engagement.

Therefore, the longer-term plan directs the students' behaviour directly. The literature shows that teachers can inspire students to create such plans and articulate their goals, thus leading to productive engagement patterns (Middleton et.al. in Hannula et al., 2016).

8.3.2.6 Self-efficacy

Self-efficacy is a core aspect of mathematical identity, and it is interrelated with the social norms and rules regulating what construes mathematical success in the classroom (Zientek et al., 2017). Students who successfully achieve higher mathematics self-efficacy, who find learning mathematics important to their learning goals, are likely to demonstrate help-seeking behaviours. They also have greater mathematics achievements than mathematics efforts have lesser efficacy (Skaalvik et al., 2015).

8.3.2.7 Affect

Engagement in mathematical struggle involves students' affective and emotional content. Schukajlow et al. (2017a) posited that students' expectations on struggle would shape their beliefs about the perceived value of being successful: Engagement ⋙ Reflection ⋙ Anticipation. If a student requests to engage in a mathematical task, he or she will build up an anticipatory emotion (e.g., anxiety and hope) that drive the cognitive appraisal of his engagement. After that, the person will reflect on the achievement or failure outcome by showing dullness, pride, irritation, or indifference.

8.3.2.8 Social factor

The above motivating factor to mathematical engagement is within an individual self. Based on the Vygotsky lens of analysis adopted in this study, a person needs to be socially governed. One can internalise or externalise processes by gaining control over them by engaging in various practices that enable them to use cultural tools (Walshaw, 2016).

A socio-mathematical motivation that drives students' reason for engagement is related to affective and cognitive judgement of the mathematics content and the judgement of a students' role in the social setting (classroom) (Patrick et al., 2007). It is the interaction among social and individual goals and behaviours and the requirements for engagement in mathematics tasks and pursuits that drive the depth and focus of engagement in students.

8.3.3 The Multidisciplinary approach

Braskén et al. (2020) pointed out that the concepts of multidisciplinary and interdisciplinarity (sometimes cross-disciplinarity) are closely related to the idea of curriculum integration. They inform the definition of multidisciplinary approach as, "multidisciplinary refers to a juxtaposition of various disciplines, sometimes with no apparent connection (e.g., music, mathematics and history) … Interdisciplinary is an adjective describing the interaction among different disciplines." The discussion of the multidisciplinary teaching approach is examined in the qualitative phase of this study. This is because multidisciplinary elaboration is excluded in the quantitative phase. Figure 1 captures a students' multidisciplinary views:

"I really like getting different areas, Different Brains here. They're not necessarily from our school…. So, it's very nice, showing them all the other thoughts ... bringing students different problems, they can solve with the same mathematics, the same tools, but problems in business in finance, science, even people from arts can give us some ideas of how can we

implement their own background. But again, one of the problems is we need to talk to them, we need to have a whole consensus of what they really want us to show here. Students demand that underpins those topics from those theories. Regarding the blending strategies, I think they actually do require a lot of effort from our side. We do need to getting more sense of how those ideas and methods would work here. But the main issue is we don't really have the agreement or the time to do it. So, every one of us is just concentrated sort of on our own units. Yeah, we try to do the best in our own unit is quite demanding. We are somehow plenty of things, not just for the things that we're doing at the moment. so, incorporate, as I mentioned, it needs to be done ... one is having an idea that needs to be learned and the second is how would you do it."

Hence, the actors involved in the teaching and learning at UC have a multidisciplinary mindset. This mindset means incorporating a mathematical learning system into a wider system comprising other interconnected disciplines. Simply put, a multidisciplinary approach in mathematics learning is about integrating mathematical education within other subjects in the curriculum (Von Wangenheim et al., 2017). The multidisciplinary teaching approach not only encourages a better understanding of mathematics but also develops students' logical reasoning and critical thinking (Jehlička and Rejsek, 2018). However, other study shows that despite some improvements experienced by teachers regarding collaboration with colleagues, the outcomes expose challenges associated with defining learning goals, as well as to the ambiguity of goals about the role of dissimilar subjects in the module. The study shows the importance of offering research-based support and time for shared sensemaking for stakeholders to avoid the problems identified when implementing multidisciplinary teaching (Braskén et al., 2020).

The data in this study above shows the lack of available teaching materials and teachers' guides. Apart from that, the absence of teacher development on multidisciplinary teaching makes the teachers' work to become ineffective and inefficient. The biggest issue that teachers face when delivering a multidisciplinary context, besides the lack of time, is the lack of curricular resources and instruments for encouraging students' active and assessment-related approaches. Researchers have pointed out the importance of teaching materials, particularly teacher guides, in providing quality education (Ball and Cohen, 1996; Braskén et al., 2020; Davis and Krajcik, 2005; Hemmi et al., 2017).

8.3.4 Addressing the challenges in teaching mathematics

The data findings regarding the challenges in teaching mathematics show that some challenges need to be addressed to leverage current level of achievement. The most prominent challenges include improving the quality of teaching mathematics, boosting students' performance and attitude, finding the best approaches for teaching mathematics, addressing the lack of diagnostic testing, and understanding learners' current mathematical level.

The review of the literature sections provides some clues on how schools and educators can cope with these challenges. For example, to improve the quality of teaching mathematics, schools should foster a mathematics culture among EIT students. They should ensure that students have access to education technology tools to enhance their learning (Peng et al., 2010); Schools should also implement the approach of problem-based learning and focus on enhancing a strong evidence-based educational system (Prodromou and Lavicza, 2017b).

Furthermore, researchers provide insights into how to address students' mathematics learning challenges. (Hadjerrouit, 2017) suggested building a SimReal+ tool as an interactive learning tool and focusing on visualising mathematics concepts. To address the lack of diagnostic testing and improve learners' current mathematics recommendations, the implementation of diagnostic testing methodologies is recommended level (Yang et al., 2016).

Researchers presume that addressing these challenges through the TRU-Lesson Study Framework will be affordable and feasible. Rather than postulating any specific approach to teaching, the TRU emphasises teachers' priority to provide mathematics support to students. It is an ongoing inquiry cycle that involves teacher learning communities (TLCs) grounded on the development model of professional learning (DosAlmas and Lewis, 2017; Schoenfeld, 2013, 2020a, 2020b; Schoenfeld et al., 2019; Schoenfeld, Floden, et al., 2018; Schoevers et al., 2020). In comparison, Lesson Study's advantages derive most from teachers' collaborative efforts to understand the wealth and complexity of mathematical ideas and practices and assist students in interacting with teachers. Teachers' shared views about the problems are exposed when engaging in striving pedagogy (Li and Schoenfeld, 2019; Suh et al., 2019).

8.4 Summary

This chapter discussed the findings obtained from qualitative and quantitative data and elaborated on the answers to the three research questions. The relationship between the variables in the first research question is quantified and statistically tested in isolation. Even though the MANOVA analysis outcome states that there is a significant impact on students' collaboration affected by the teaching method, it is plausible to be sceptical due to many unanswered questions. For instance, is the teaching method the only factor that affects collaboration or are there any confounding factors simultaneously affecting collaboration that the quantitative study did not measure? The analogical flow of logic is applicable to the second research question. This question includes one dependent variable of motivation and twelve independent variables. While the multiple regression analysis implies that multiple relationships exist between a dependent variable and some independent variables, the relationship between the dependent and the independent variable was technical. Hence, the relationship between the modelled variables in the multiple regression analysis is isolated. The qualitative part elaborated on answering the first and second research questions but addressed more the third research question.

9 Conclusion

This chapter highlights the findings and contributions of this study and discusses the study’s implications, limitations, and suggestions for future work.

9.1 Contribution to Research Knowledge

The study contributes to a growing body of research on system theory and social constructivist perspectives of teacher/student development through learning and teaching mathematics subject. I argue, based on the findings in this study, that effective pedagogies for teaching mathematics to EIT students at UC still need to be improved. For instance, there is a need to shift the effectiveness of the current practice of teaching and learning to one that enables not only students, teachers, and stakeholders in the organisation to solve each obstacle to effective learning. This pedagogical shift has the potential to outperform the current achievement in core mathematical skills, improve learning outcomes and boost the mathematics performance of UC students.

This study of mathematics teaching practices at UC and the literature on mathematical teachings allow schools to understand different mathematical learning opportunities and explore the impacts of various teaching practices as they unfold in the classroom. This study’s research on mathematics teaching uses close interaction analysis between teachers and students to show how teaching practices evolve in congruency with learning practices and provides new insights into the interrelationship between teaching and learning in schools. This study also suggests that teachers’ teaching and students’ learning are two equally essential parts of combined pedagogical practice. In mathematics teaching settings, a teacher’s teaching style shapes the learning practices available to students, and it consequently shapes learners’ mathematics performance. Similarly, a student’s learning style shapes the teaching styles available to teachers.

Furthermore, this study shows how teachers employ various teaching practices to achieve specific aims and achieve specific goals of learning practices and learning. Teaching practices are pedagogical and dialogic in nature, thereby enabling learners to create their learning styles and improve them over time as they communicate and interact with students in the classroom. I argue that good teaching is not entirely a matter of techniques. The practice of mathematics teaching is not sui generis; it is itself fashioned by other practices in addition to students' practices of learning—by practices of professional learning, practices of leadership, and practices of researching and reflecting. Moreover, teachers teach under various circumstances that are beyond their control. Sometimes, policies are enforced by the university or the state. Good pedagogical practices, however, are contingent not just upon teachers' practice but also upon what students carry to the classroom from their homes and communities. Students' state of mind from home influences their rapport with schools and teachers, and it shapes their readiness to engage with their peers in the classroom. Simply put, the mathematics performance of students rests on the commitment of students and teachers' ability to participate in collaborative classroom practice with optimism, authenticity, and a readiness to adapt to students' dynamic pedagogical needs.

I also found in this study that there was shared awareness of the importance of collaboration among students and teachers at UC, either classroom collaboration or professional development research collaboration between educators. This collaboration is needed to create circumstances to leverage mathematics understanding and achievement and nurture a higher motivation level for students interested in learning. However, public awareness will not be enough to drive the idealised practice into day-to-day practice in the classroom. A cyclical process (to practice, to reflect, and to research) should be applied consistently. An example of the process is the Lesson study framework, which is a collaborative teacher-learning program that engages teachers in inquiry and reflection around important problems of practice through the inquiry cycle of studying, planning, enacting, and reflecting (Huang et al., 2019).

To address this study's research questions, I employed the complex systems theory and focused on the core elements of teachers, students, and classroom practices as well as the peripherals elements of teaching, learning style, and macro-structure of the organisation (UC). All elements are equally important to function in the system regardless of whether it is a focal or peripheral elements. They create an ecosystem that is required for effective teaching and learning to function. This approach takes into account the complexity of mathematical teaching and learning at UC as a subset of national educational systems, where students are nested within classes that are nested within units, where variables within and across these levels can be directly and indirectly related, and where changes happen.

I tend to view the relationship between teaching methods and students' engagement, collaboration, and achievement in an interrelated network rather than in a bidirectional network between a dependent variable and some independent variables. In the statistical model, such as linear regression or the analysis of variance, a variable is constrained to specific variables that have a relationship with other variables, while ignoring the possibility of the confounding variable within the model. The rich data analysis of this mixed method can be used to overcome this challenge.

In the following section, we enumerate the main findings of the study. The main findings are as follows:

- The stakeholders (student, teacher, and educator expert) involved in the learning processes have the same perception regarding what constitutes effective mathematical learning.
- The stakeholders are receptive to the ever-changing social-cultural situation and the advancement of education technology.

- Each dimension of the teaching method is interrelated and interdependent. They cannot be functional in an isolated setting. In other words, each dimension demands balanced attention during a learning session.
- Learning and teaching sessions in the classroom within a specific time frame can be identified as a system taking some inputs processed by these interrelated dimensions of teaching methods to generate a set of outputs (student achievements) through some processes.
- The TRU-Lesson Study offers a learning processes-oriented framework that ignores any teaching style. It focuses on how the processes can increase the likelihood of effective teaching attainment.
- Students' achievement in learning is a function of teacher development in which a zone of proximal development (ZPD) is applicable for both students and teachers.

This study explored several perceived learning activities that occur in everyday interactions between students and teachers. It considered the different ways used by students and teachers to communicate with one another in the learning environment. The original aim of this study was to contemplate how teachers construct their professional identities through the learning and teaching process. Nevertheless, the variability of teaching methods may produce different outcomes for teachers. Hence, regardless of the teaching style implemented, the study is more about exploring *the processes* rather than the magnitude of relationships among constructs that are within the context of teaching methods at UC.

Another important point to note is the everyday reality happening in the classroom, especially in light of the rapid changes caused by the Covid-19 pandemic. This problem has challenged psychological theories of learning, such as the Vygotsky's Zone of Proximal Development. Moreover, using the assumption of entropy of system theory, learning and teaching processes in day-to-day reality are unpredictable.

9.2 Implication of Main Findings

This study provides insights into mathematics teaching approaches and explores what factors may affect mathematics learning at UC. It also shows how students' perceptions of mathematics play a crucial role in mathematics learning. One implication for mathematics curricula and syllabus development is that mathematics learning largely concentrates on objective analysis, even though subjective analysis, thinking processes, and mathematics communication also contribute to students' learning performance.

Another implication of this study is that mathematics is a highly effective subject and that students' perceptions of mathematics influence their engagement with the subject. The effectiveness of learning and teaching mathematics is not just a matter of choosing specific teaching methods, manipulating psychological factors, or selecting the best theoretical approach or the best pedagogical and technological element to apply. Beyond these matters, the key point lies within the day-to-day processes in which learning processes are often being disrupted. While the heavier burden is on the teachers' shoulders, the institution's leadership plays a considerable role in imparting knowledge in the classroom.

Within the setting of mathematical learning practice at UC, the fact that the stakeholders (students, teachers, and experts) share the same view concerning what constitutes effective mathematical learning means the weak mathematics foundation of students can be improved. For example, improvements can be made by adopting the action processes stipulated in the lesson study (TRU-Lesson Study) framework. The key message of this research finding is that teachers have the "biggest impact" on students' mathematics performance. Mathematics is a highly effective subject, and there are many variables that significantly influence students' engagement with mathematics, such as their goals, previous emotional experiences with mathematics, and expectations, among others. Students develop mathematical self-efficacy in schools and universities when they discover that they solve mathematical problems. They then carry this knowledge and confidence to universities.

Concerns about mathematics learning include students' attitudes towards mathematics. Students may develop anxiety when mathematics is presented as a "difficult" subject. Their mathematics performance may also decline due to the lack of recognition of self-success, lack of encouragement (where students "feel they can't do mathematics"), failure to communicate the value of mathematics, emphasis on learning through memorisation rather than through comprehensive understanding, difficulty in communicating mathematics, and inability to link mathematics topics to real-world applications.

According to the findings in this study, students need to carry out more tasks that encourage them to value and enjoy mathematics. Students in this study agreed that the curriculum should emphasise the applications of mathematics. In addition, there is strong evidence that mathematics learning requires a social environment in which students benefit from group discussion and peer learning. The ability to interconnect mathematics and its relevance is the major characteristic of a good mathematics education system. Educators and curriculum developers, therefore, need to engage with students in mathematics discussions and subjective analysis to help them improve their mathematics performance.

9.3 Limitations

This study uses a cross-sectional study design that can capture only a snapshot of an event at a particular time and in a specific social setting. Particularly, the study explores the perceived experience of learning and teaching among the stakeholders (students, teachers, and educator experts) and investigates the emerging themes that can be further analysed by implementing an analytical lens commonly implemented in educational research. The study is not observatory in nature, and it does not directly gauge the practice of learning and teaching implemented at UC.

The foci of this study are limited only to several dimensions of learning and teaching, such as teaching methods, collaboration, motivation to engage in learning mathematics, achievement and multidisciplinary approach. This limitation may negatively affect the richness of this research results and provide little insight into the vastness and complexity of mathematical teaching.

9.4 Suggestion for Future Work

Future studies should include the overall cycle of a learning process. The cycle may begin with an assessment of students' initial mathematical skills and learning stage and then end with a formative assessment to gauge whether there is a shift in student skills. A longitudinal design should be performed in future research. Future research should also implement the TRU-Lesson Study based on the rationale that this framework is receptive to various pedagogical approaches. Moreover, TRU-Lesson Study is flexible to conduct cyclically with no prescribed timeframe. Lastly, future research can focus on the roles in learning institutions.

9.5 Summary and Recommendations

This study examined the effectiveness of the pedagogical approaches used by teachers in addressing the Mathematics challenges faced by first-year EIT students at UC. At the core of this thesis is the assumption that teachers play a significant role in improving students' mathematics performance at UC. Table 9.1 recapitulates the aims of the study and their respective findings.

Table 9.1 Research's aims and finding summary

Aims	Findings
To understand what the impacts of the UC mathematics teaching approach on the first-year EIT students' collaboration, understanding, and achievement in mathematics courses are.	In the quantitative phase, the impact of teaching approaches on collaboration, understanding, and student achievement was found to be statistically significant. And in the qualitative phase, collaboration emerges within the theme of teaching method, while creating robust understanding is part of teaching methods. Hence, a teaching method is closely perceived to be associated with collaboration, understanding, and achievement. Therefore, the later phase corroborates the first phase's findings.
To know what factors, motivate EIT students to engage or lose interest in mathematics are.	In the quantitative phase, factors that motivate EIT students to engage or lose interest in mathematics were found to be statistically significant. In the qualitative phase, more insight into engagement was gained, i.e., that students' mathematical engagement is driven by their self-interest, personal goals, goal proximity, affect, and self-efficacy, and student senses that engagement will produce some valuable knowledge, skill, or social standing.
To assess whether implementing a multidisciplinary pedagogical approach enhance the effectiveness of student mathematics learning for UC's EIT students.	In the qualitative phase, the insight of multidisciplinary approaches was identified concerning the actors involved in the teaching and learning at UC having a multidisciplinary mindset. This mindset means incorporating a mathematical learning system into a wider system comprising other interconnected disciplines. Simply put, it is recommended to integrate a multidisciplinary approach to mathematics learning.

The findings of this research confirm that this assumption is valid. All the participants (teachers, students, and educator experts) of this study agreed that teachers could help students to address their mathematical skill deficits. However, an examination of the learning styles adopted by students, teachers, and educator experts in the past could not capture the everyday dynamics essential to students' development in mathematics. By focusing on these dynamics, researchers will understand mathematics education and effective learning styles that can aid student mathematics performance. Students' weak performance in mathematics may be because they come from disadvantaged families. To help such students, policymakers need to organise pre-university mathematics programmes. While helping students to address their mathematics challenges is quite challenging, what is even more difficult is identifying those students struggling with mathematics. In this light, university administrators should administer mathematics tests to all first-year students in the EIT department. The tests should be mandatory for all new students in this department. That way, students with mathematics difficulties can be identified and provided learning support quickly.

Appendices

Appendix I: Questionnaire form

Questionnaire Form

Survey (An Evaluation of Mathematical Teaching Pedagogies to Tertiary Engineering and Information Technology Students at the University of Canberra)

Please click next to read the participant information form and consent form. Then, the survey's questions will begin.

Participant Information Form:

Project Title
An Evaluation of Mathematical Teaching Pedagogies to Tertiary Engineering and Information Technology Students at the University of Canberra

Project Aims and benefits This research project aims to:

- Make engineering and IT (EIT) students at UC more motivated and successful in mathematics learning;
- Enhance our understanding of the impact of the current applied mathematics teaching approaches at UC on the first year EIT students' collaboration, understanding, and achievement in mathematics courses;
- Shed light on the problem of mathematics anxiety amongst new EIT students.; and
- Provide suggestions and recommendations that will make teaching mathematics for EIT students more effective.

General Outline of the Project
The project will study and evaluate the pedagogies that are used in mathematics teaching to tertiary engineering and IT students at UC.

Participant Involvement
Participants who agree to participate in the research will be asked to:

1. Provide basic personal information and answer an online survey,
2. Be interviewed to allow for more detailed answers,
3. Grant permission to be recorded in video and audio format, and

4. Allow for accessing their test/exam results.

Participation in the research is entirely voluntary, and participants may, without any penalty, decline to take part or withdraw at any time or may choose not to answer a question without providing an explanation.

Confidentiality

Only the researcher/s will have access to the individual information provided by participants. Privacy and confidentiality will be assured at all times. The research outcomes of this project may be presented at conferences and written up for publication. However, in all these instances, the privacy and confidentiality of individuals who participated will be protected.

Anonymity

All reports and publications of the research will contain no information that can identify any individual and all information will be kept in the strictest confidence.

Data Storage

The information collected will be stored securely on a password protected computer throughout the project and then stored at the University of Canberra for the required five year period, after which it will be destroyed according to university protocols.

Ethics Committee Clearance

The project has been approved by the Human Research Ethics Committee of the University of Canberra (HREC – 2009).

Queries and Concerns

Queries or concerns regarding the research can be directed to the researcher and/or supervisors. Their contact details are at the top of this form. You can also contact the University of Canberra's Research Ethics & Integrity Unit via phone 02 6201 5220 or 02 6206 3916 or email humanethicscommittee@canberra.edu.au.

If you would like some guidance on the questions or about your participation, please refer to the Participants' Guide located at http://www.canberra.edu.au/ucresearch/attachments/pdf/a-m/Agreeing-toparticipate-in-research.pdf

Consent Statement

I have read and understood the information about the research. I am not aware of any condition that would prevent my participation, and I agree to participate in this project. I have had the opportunity to ask questions about my participation in the research. All questions I have asked have been answered to my satisfaction.

1. Please indicate whether you agree to participate in each of the following parts * of the research (please indicate which parts you agree to by putting a cross in the relevant box):

- ☐ Complete a questionnaire.
- ☐ Participate in an interview with the researcher.
- ☐ Allow retrieving of your academic results.
- ☐ Be audio and video recorded.
- ☐ Be observed during lectures.
- ☐ All above.

2. A summary of the research report can be forwarded to you when published. If you would like to receive a copy of the report, please include your email address below.

____

Personal and Background Information

3. What are the initials of your name?

4. What is your degree program?

5. What is your gender? Are you ...?

- ◯ male
- ◯ female
- ◯ other
- ◯ prefer not to say

6. Year of birth (Four digits e.g. 2001)

7. Is English your native language?

- ◯ Yes
- ◯ No

8. Write your study unit number. (e.g. 6698)

9. Write your study unit name. (e.g. Discrete Mathematics)

10. I am ...

- ◯ Undergraduate student
- ◯ Graduate student

11. I am ...

- Domestic student
- International student

12. What was your Mathematics course at high school?

- Advanced course
- Basic (Standard) course

13. Did you attend a mathematics pre-course?

- Yes
- No

14. How do you pay for your studies?

Check all that apply.

- [ ] Parents
- [ ] Job
- [ ] Savings
- [ ] Scholarship
- [ ] loan (e.g. HECS-HELP)
- [ ] Other

15. How many hours per week do you dedicate to:

Mark only one oval per row.

	0	1-5	6-10	11-15	16-20	> 20
Employed work	⬭	⬭	⬭	⬭	⬭	⬭
Study (including time spent in class)	⬭	⬭	⬭	⬭	⬭	⬭
Co-curricular activities e.g. Sports or other hobbies	⬭	⬭	⬭	⬭	⬭	⬭
Looking after family	⬭	⬭	⬭	⬭	⬭	⬭

16. How important were the following reasons in deciding your path of study?

Please indicate importance as follows:

	Very important	Important	Slightly important	Not at all important
Personal preferences and talents	⬭	⬭	⬭	⬭
Good earning potential	⬭	⬭	⬭	⬭
Advice from parents or friends	⬭	⬭	⬭	⬭
Advice from academic and professional consultants	⬭	⬭	⬭	⬭
General interest in the subject since school	⬭	⬭	⬭	⬭
Professional development	⬭	⬭	⬭	⬭

Learning Environment and Behaviour:

For each activity described below (17-49), please indicate how often this happens to you. You can grade your answers from very frequent to very rare as follow: 1. Very Frequently, 2. Frequently, 3. Occasionally, 4. Rarely, 5. Very Rare.

17. I make tables, diagrams or graphs in order to structure the material in a way that makes sense to me.

18. I try to plan in advance the parts of a certain topic which I have to learn.

19. If I encounter difficult material, I adapt my learning technique (e.g. by slower reading or doing more practise examples or seeking further help from educators/colleagues).

20. I work on assessments together with my classmates.

21. I have regular study sessions with my classmates.

22. I look for more material if I'm not clear about some of the content.

23. When I have a certain amount of study to do, I make an effort to do it.

24. I'm easily distracted.

25. My concentration does not last long.

26. I set specific times to study and I stick to it.

27. I study in a place where I can concentrate well on the material.

28. If I do not understand something while reading, I try to highlight the gaps and then review the material.

29. I make brief summaries of the main content to support my understanding.

30. I take the time to discuss the subject with my classmates and if something is not clear to me, I ask a classmate for advice.

31. For missing information or if I do not understand a technical term, I search for it, e.g. in a textbook or on the Internet.

32. I read my notes/lecture notes successively several times.

33. I push myself to study even when I do not like the material.

34. I try to relate new concepts or theories to those already familiar to me.

35. I memorize key terms to better remember the important content for the exam.

36. I do not give up, even if the material is very difficult or complex.

37. I try to organize the material so that I can memorize/understand it well.

38. I have a classmate who asks me questions and answers my questions about the material.

39. I study late at night and on weekends, if necessary.

40. I seek others’ help when I have serious understanding problems.

41. I ask myself questions about what I learnt to make sure I understand everything.

42. I memorize rules, technical terms or formulas.

43. In order to identify knowledge gaps, I recapitulate the most important contents without using my documents

44. Before the test, I take enough time to go through the whole material again.

45. I work on additional tasks to see if I have really understood the material.

46. I create my own lists of important technical terms and definitions.

47. I think about whether the subject matter is also important for my everyday life.

48. I study until I'm sure I can pass the exam well.

49. I maintain a good balance between study/work/life activities.

Teaching and Learning Methods:

For each item described below (50-76), please indicate your opinion. You can grade your answers from Strongly agree to Strongly agree as follow: 1. Strongly agree, 2. agree, 3. Neutral, 4. disagree, 5. Strongly disagree.

50. I think I am learning a lot (more than my capacity).

51. Students work together so everyone can learn.

52. We often move onto a new topic before we really understand the current one.

53. When students ask questions, it slows us down.

54. I have to compete to get good grades.

55. It is OK to spend extra class time on a difficult topic.

56. Our teacher thinks mistakes are OK, as long as we learn from them.

57. After class, I usually feel satisfied with what I have learned.

58. Only the smartest students can get a good grade.

59. Our teacher wants us to work cooperatively with each other.

60. Our teacher wants us to understand why things happen the way they do.

61. Students often have trouble keeping up with the work.

62. Our teacher has to cover all the material in this course, even if we don't understand it all.

63. To get a good grade, I have to memorize a lot of facts/formulas/rules.

64. Our teacher tries to get us to think for ourselves and solve problems on our own.

65. In this unit, it is more important to get the right answers than to understand why they are right.

66. Our teacher helps us see how what we learn relates to the real world.

67. My aim is to pass the course while doing as little work as possible.

68. Our teacher encourages us to ask questions when we don't understand something.

69. I feel that if a clear objective in class was presented, it would help me focus on the concept(s) being learned.

70. Our teacher facilitate discussion to increase our understanding.

71. The assessments align with the unit learning objectives.

72. If technology were incorporated into math classes, (i.e. smart boards, computers, graphing calculators) then I would be more focused during those classes.

73. Our teacher provides a timely and constructive feedback on assessments.

74. I find if the math lessons were filled with lots of practice problems on the math concept(s) taught, I would be able to understand the concept better.

75. Our teacher wants us to learn to ask questions about mathematics.

76. I do not find my course very interesting, so I keep my work to a minimum.

Feelings and Anxiety:

For each item described below (77-84), please indicate the occurrence level. You can grade your answers from Usually to Never as follow: 1. Usually, 2. Often, 3. Sometimes, 4. Seldom, 5. Never.

77. I do not feel confident enough to ask questions in my mathematics classes.

78. I get tense when I prepare for a mathematics test.

79. I believe I cannot do well on a mathematics test.

80. I worry that I will not be able to use mathematics in my future career when needed.

81. I worry that I will not be able to get a good grade in my mathematics course.

82. Working on mathematics assessments is stressful for me.

83. I worry that I do not know enough mathematics to do well in future mathematics related courses.

84. I worry that I will not be able to complete every assignment in a mathematics course.

Please do not hesitate to add any comments

....

....

....

Thank you

End of the questionnaire.

Appendix II: Interview questions form

An Evaluation of Mathematical Teaching Pedagogies to Tertiary Engineering and Information Technology Students at the University of Canberra

INTRODUCTION

- Time allocation 30-60 minutes
- Digital recording

PURPOSE OF STUDY

This research project aims to:

- assist and support educators to make engineering and IT (EIT) students at the University of Canberra (UC) more motivated and successful in mathematics learning;
- enhance our understanding of how UC EIT students currently perceive applied mathematics teaching approaches at UC;
- shed light on the problem of mathematics anxiety among new EIT students at UC; and
- provide suggestions and recommendations that will enhance UC EIT students learning experience with mathematics units.

USE OF RESULTS

It is anticipated that findings from this study will help:

- to identify possible causes for students having trouble in learning mathematics.
- to suggest approaches that may assist in students learning mathematics.
- to foster a collaborative arrangement between researchers and the teaching staff to help advance efficient educational approaches in these rapidly changing times.

The findings will be presented in the researcher's final thesis and will also be reported in research publications and conference proceedings.

Table II.1 Interview Questions

	Participants Groups		
Q No.	**Mathematics Teachers**	**Education Experts**	**EIT Students**
1	From your experiences, what do you feel are the biggest hurdles for EIT students to learn mathematics at UC? - Please give 5 examples in order of importance and outline why.	What do you feel are the biggest hurdles for EIT students to learn mathematics at UC? - Please give 5 examples in order of importance and outline why.	From your experiences, what do you feel are the biggest hurdles for you to learn mathematics at UC? - Please give 5 examples in order of importance and outline why.
2	What are the activities you feel mathematics teacher could additionally use to help students better understand mathematics?	What are the activities you feel mathematics teacher could additionally use to help students better understand mathematics?	What are the activities you feel mathematics teacher could additionally use to help you better understand mathematics?

3	What are the ways you feel students can add to face to face learning environments to be more involved in discussions for collaborative and active learning of mathematics? Does this apply to the online learning environments as well? Or there are other ways?	What are the ways you feel students can add to face to face learning environments to be more involved in discussions for collaborative and active learning of mathematics? Does this apply to the online learning environments as well? Or there are other ways?	What are the ways you feel you can add to face to face learning environments to be more involved in discussions for collaborative and active learning of mathematics? Does this apply to the online learning environments as well? Or there are other ways?
4	Is it necessary to describe clear objectives of each lesson to the students? Why?	Is it necessary to describe clear objectives of each lesson to the students? Why?	Is describing clear objectives of each lesson necessary to you? Why?
5	How do you stay abreast of current teaching trends in mathematics teaching and have you applied them in the recent past? Examples would be great.	How does mathematics teacher stay abreast of current teaching trends in mathematics teaching?	How do you think mathematics teachers stay abreast of current teaching trends in mathematics teaching?
6	Do you think arranging meetings with other teachers (e.g., external teachers) can lead to help you improve student learning? And to	Do you think arranging meetings with other teachers (e.g., external teachers) of the same subject can lead to help improve student learning?	Do you think arranging meetings with other teachers (e.g., external teachers) of the same subject can lead to help improve student learning? And to what extent do you think it is important?

	what extent do you think it is important?	And to what extent do you think it is important?	
7	Do you think a different grading approach to the one we currently use can help students in learning mathematics?	Do you think a different grading approach to the one we currently use can help students in learning mathematics?	Do you think a different grading approach to the one we currently use can help you in learning mathematics?
8	What strategies can be taken to relate mathematical concepts with future mathematics related courses and with the real life?	What strategies can be taken to relate mathematical concepts with future mathematics related courses and with the real life?	What strategies can be taken to relate mathematical concepts with future mathematics related courses and with the real life?
9	Do you feel it is important to encourage the creativity of students in mathematics? How and Why?	Do you feel it is important to encourage the creativity of students in mathematics? How and Why?	Do you feel encouraging your creativity is important in mathematics subject? How and Why?
10	Would students be more focused if latest technology were incorporated into math classes, (i.e. virtual and augmented reality (VR/AR), wearable technology, game-based and Artificial intelligence (AI) tools)?	Would students be more focused if latest technology were incorporated into math classes, (i.e. virtual and augmented reality (VR/AR), wearable technology, game-based and Artificial intelligence (AI) tools)?	Would students be more focused if latest technology were incorporated into math classes, (i.e. virtual and augmented reality (VR/AR), wearable technology, game-based and Artificial intelligence (AI) tools)?
11	Do you think the implementation of a	Do you think the implementation of a	Do you think the implementation of a multidisciplinary

	multidisciplinary pedagogical approaches can enhance the effectiveness of student mathematics learning? E.g., blended approaches (online and face to face) for example.	multidisciplinary pedagogical approaches can enhance the effectiveness of student mathematics learning? E.g., blended approaches (online and face to face) for example.	pedagogical approaches can enhance the effectiveness of your mathematics learning? E.g., blended approaches (online and face to face) for example.
12	In order to help identify the students' knowledge gaps, what should they and you do?	In order to help identify the students' knowledge gaps, what should they and their teachers do?	In order to help identify your knowledge gaps, what should you and your teachers do?
13	To what degree do you think student/student collaborations can facilitate lessons discussion and increase students understanding?	To what degree do you think student/student collaborations can facilitate lessons discussion and increase students understanding?	To what degree do you think you and your classmates collaborations can facilitate lessons discussion and increase your understanding?
The following questions are based on the student survey results: (a summary of the conducted survey will be introduced at this point)			
14	In your view, why do you think more than one third[2] of the students have serious concentration issues? - What should they do to get less distracted?	In your view, why do you think more than one third of the students have serious concentration issues? - What should they do to get less distracted?	In your view, why do you think more than one third of the students have serious concentration issues? - What should they do to get less distracted?

[2] Chart No.1

15	About 62%[3] of the students have trouble keeping up with what they are learning and about 69%[4] of the participants think they usually move to a new topic before they really understand the one in hand. - Why do you think this is happening? - What can be done to resolve this issue?	About 62% of the students have trouble keeping up with what they are learning and about 69% of the participants think they usually move to a new topic before they really understand the one in hand. - Why do you think this is happening? - What can be done to resolve this issue?	About 62% of the students have trouble keeping up with what they are learning and about 69% of the participants think they usually move to a new topic before they really understand the one in hand. - Why do you think this is happening? - What can be done to resolve this issue?
16	About half[5] of the students aim just to pass the course while doing as little work as possible. - What reasons could be behind their lack of motivation? - How can they get more motivated while learning mathematics? - What factors motivate EIT students to engage, or not engage, with mathematics?	About half of the students aim just to pass the course while doing as little work as possible. - What reasons could be behind their lack of motivation? - How can they get more motivated while learning mathematics? - What factors motivate EIT students to engage, or not engage, with mathematics?	About half of the students aim just to pass the course while doing as little work as possible. - What reasons could be behind their lack of motivation? - How can they get more motivated while learning mathematics? - What factors motivate EIT students to engage, or not engage, with mathematics?

[3] Chart No.2
[4] Chart No.3
[5] Chart No.4

17	More than 44%[6] of the participants get frequently tense when they prepare for a mathematics test, about 30%[7] consider working on mathematics assessments is stressful for them, and about 22%[8] worry that they might do not know enough mathematics to do well in future mathematics related courses. Apparently, some students have a high level of anxiety and lack of confidence in their learning. - Why do you think is that? - How can this be lessened?	More than 44% of the participants get tense when they prepare for a mathematics test, about 30% consider working on mathematics assessments is stressful for them, and about 22% worry that they might do not know enough mathematics to do well in future mathematics related courses. Apparently, some students have a high level of anxiety and lack of confidence in their learning. - Why do you think is that? - How can this be lessened?	More than 44% of the participants get tense when they prepare for a mathematics test, about 30% consider working on mathematics assessments is stressful for them, and about 22% worry that they might do not know enough mathematics to do well in future mathematics related courses. Apparently, some students have a high level of anxiety and lack of confidence in their learning. - Why do you think is that? - How can this be lessened?

[6] Chart No.5
[7] Chart No.6
[8] Chart No.7

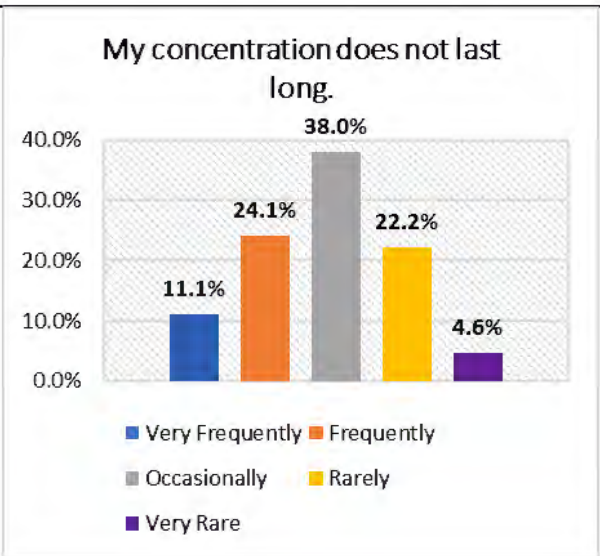


Chart No.1

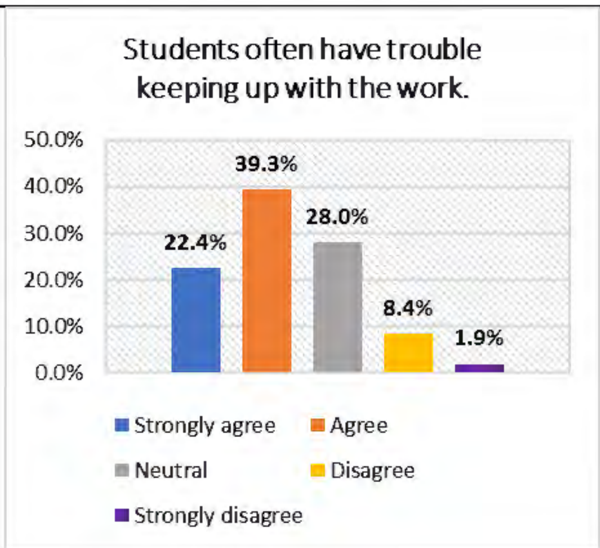
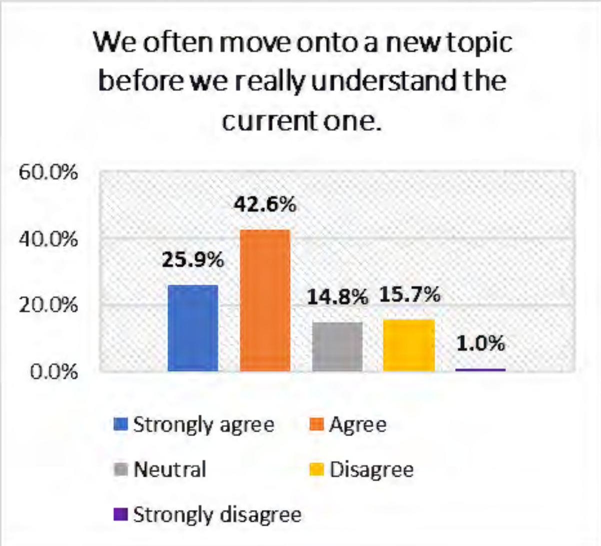


Chart No.2



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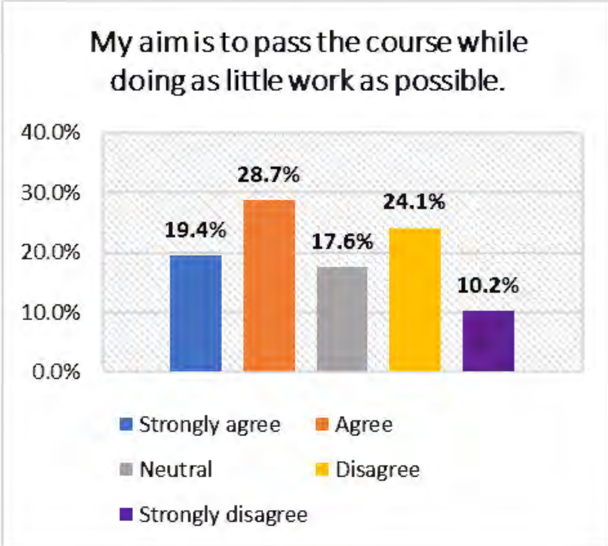


Chart No.4

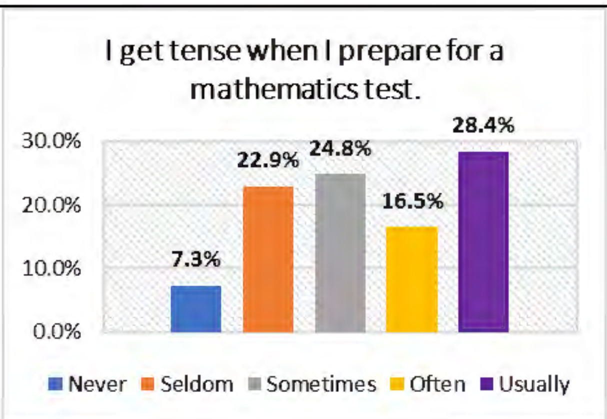


Chart No.5

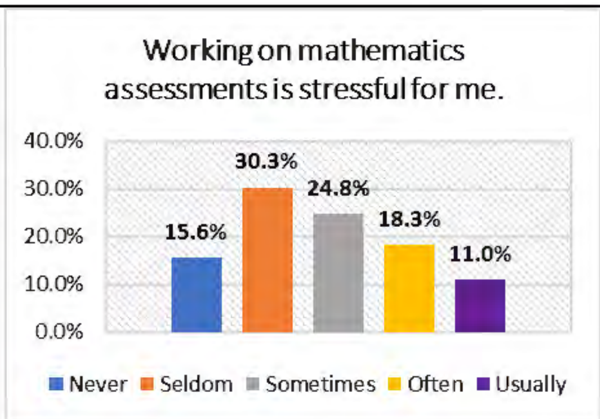
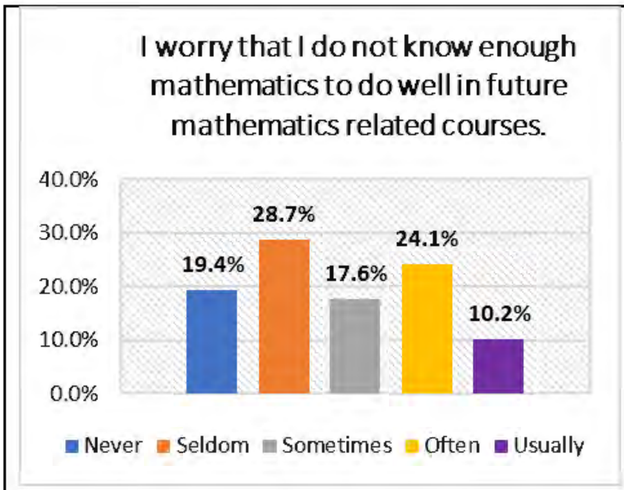


Chart No.6

I worry that I do not know enough mathematics to do well in future mathematics related courses.
40.0%
30.0%
20.0%
10.0%
0.0%
19.4%
28.7%
17.6%
24.1%
10.2%
Never
Seldom
Sometimes
Often
Usually	
Chart No.7	

Appendix III: Interview consent form

Consent Form

Project Title

An Evaluation of Mathematical Teaching Pedagogies to Tertiary Engineering and Information Technology Students at the University of Canberra

Consent Statement

I have read and understood the information about the research. I am not aware of any condition that would prevent my participation, and I agree to participate in this project. I have had the opportunity to ask questions about my participation in the research. All questions I have asked have been answered to my satisfaction.

Please indicate whether you agree to participate in the research interview by ticking the following boxes:

_ Participate in the research interview.

_ Be audio and/or video recorded during the interview.

Name……………………………………………………………….…………………….........…

Signature…………..…………………..……

Date ………………………………….

A summary of the research report can be forwarded to you when published. If you would like to receive a copy of the report, please include your email address below.

Name…………………………………………………………….……………….....……….

Email Address……………………………..……………………………………….…………

Appendix IV: Sample of the measures of the questionnaire

Table IV.1 Sample of the measures of the questionnaire

Measure	Items from the questionnaire
Learning Style (Behaviour)	- I make tables, diagrams or graphs in order to structure the material in a way that makes sense to me. - I try to plan in advance the parts of a certain topic which I have to learn. - I make brief summaries of the main content to support my understanding. - I read my notes/lecture notes successively several times. - I try to relate new concepts or theories to those already familiar to me. - I memorise key terms to better remember the important content for the exam. - I try to organise the material so that I can memorise/understand it well. - In order to identify knowledge gaps, I recapitulate the most important contents without using my documents. - I create my own lists of important technical terms and definitions. - I ask myself questions about what I learnt to make sure I understand everything.
Collaboration	- I work on assessments together with my classmates. - I have regular study sessions with my classmates. - I take the time to discuss the subject with my classmates and if something is not clear to me, I ask a classmate for advice. - I have a classmate who asks me questions and answers my questions about the material. - I seek others' help when I have serious understanding problems. - Students work together so everyone can learn.

General Understanding	- I work on additional tasks to see if I have really understood the material. - If I do not understand something while reading, I try to highlight the gaps and then review the material. - I look for more material if I'm not sure about some of the content. - If I do not understand something while reading, I try to highlight the gaps and then review the material. - We often move on to a new topic before we really understand the old one. - I find if the math lessons were filled with lots of practice problems on the math concept(s) taught, I would be able to understand the concept better. - Students often have trouble keeping up with the work. - I feel that if a clear objective in class was presented, it would help me focus on the concept(s) being learned.
Teaching	- Our teacher wants us to work cooperatively with each other. - Our teacher thinks mistakes are OK, as long as we learn from them. - Our teacher has to cover all the material in this course, even if we don't understand it all. - Our teacher tries to get us to think for ourselves and solve problems on our own. - Our teacher helps us see how what we learn relates to the real world. - Our teacher wants us to learn to ask questions about mathematics. - Our teacher encourages us to ask questions when we don't understand something. - Our teacher facilitate discussion to increase our understanding. - Our teacher provides a timely and constructive feedback on assessments.
Anxiety	- I do not feel confident enough to ask questions in my mathematics classes. - I get tense when I prepare for a mathematics test. - I believe I cannot do well on a mathematics test. - I worry that I will not be able to use mathematics in my future career when needed. - I worry that I will not be able to get a good grade in my mathematics course. - I worry that I do not know enough mathematics to do well in future mathematics related courses. - I worry that I will not be able to complete every assignment in a mathematics course.

Appendix V: Descriptive statistics of the demographic variables

Table V.1 What is your gender?

	Frequency	Percent
male	54	53.5
female	47	46.5
Total	101	100.0

Table V.2 Is English your native language?

	Frequency	Percent
yes	55	54.5
no	46	45.5
Total	101	100.0

Table V.3 Are you international or domestic student?

	Frequency	Percent
international student	43	42.6
domestic student	58	57.4
Total	101	100.0

Table V.4 What was your Mathematics course at high school?

	Frequency	Percent
advanced course	42	41.6
basic course	59	58.4
Total	101	100.0

Table V.5 Did you attend a mathematics pre course?

	Frequency	Percent
Yes	26	25.7
No	75	74.3
Total	101	100.0

Table V.6 How do you pay for your studies?

	Frequency	Percent
Parents	26	25.7
Parents & Jobs	3	3.0
Parents & Jobs & Loan	3	3.0
Other	3	3.0
Parents & Savings	1	1.0
Parents& Loan	1	1.0
Jobs	7	6.9
Jobs & Scholarship	1	1.0
Jobs & Loan	7	6.9
Savings	5	5.0
Savings & Loan	1	1.0
Scholarships	26	25.7
Loan	17	16.8
Total	101	100.0

Table V.7 How many hours per week do you dedicate to Employed work?

	Frequency	Percent
"0"	44	44.4
"1-5"	13	13.1
"6-10"	10	10.1
"11-15"	14	14.1
"16-20"	15	15.2
">20"	3	3.0
Total	99*	100.0

* Two students did not answer this question.

Table V.8 How many hours per week do you dedicate to Co-curricular activity?

	Frequency	Percent
"0"	3	3.0
"1-5"	57	57.0
"6-10"	20	20.0
"11-15"	17	17.0
"16-20"	3	3.0
">20"	0	0.0
Total	100*	100.0

* One student did not answer this question.

Learning Style:

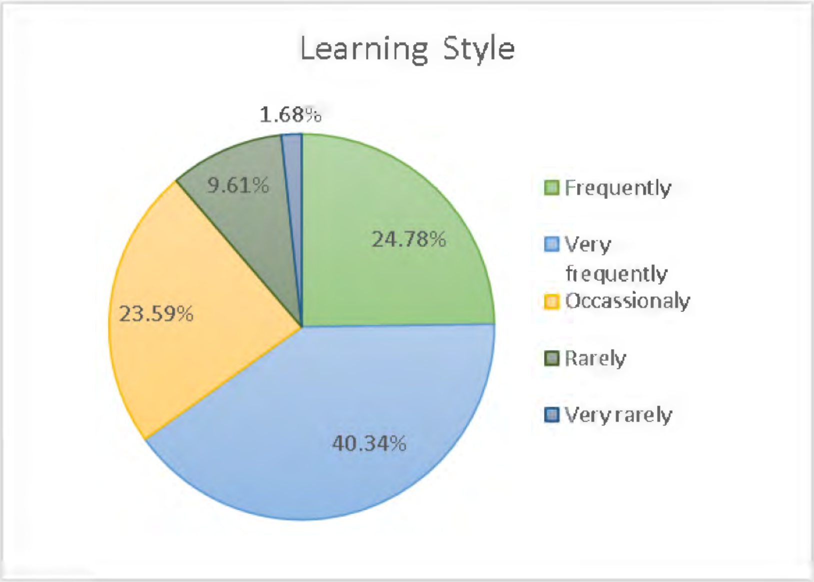


Figure V.1A

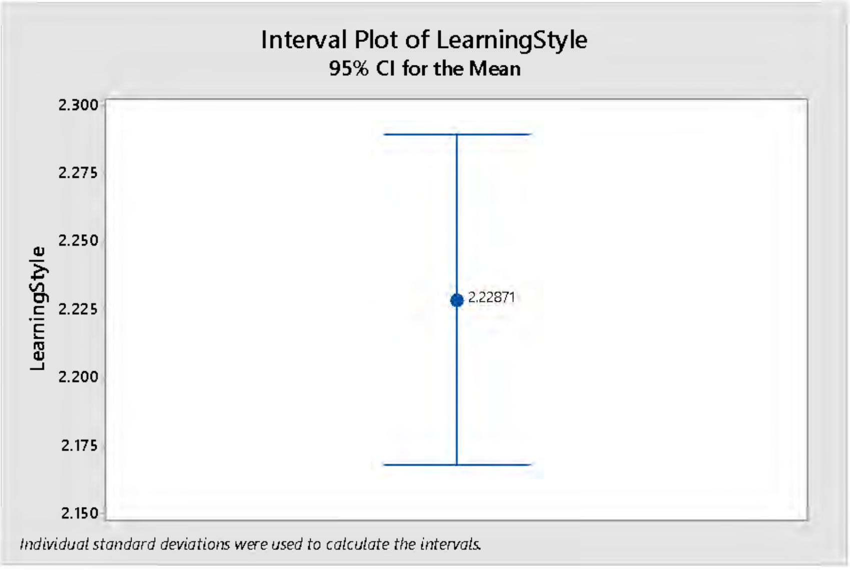


Figure V.1B

Collaboration

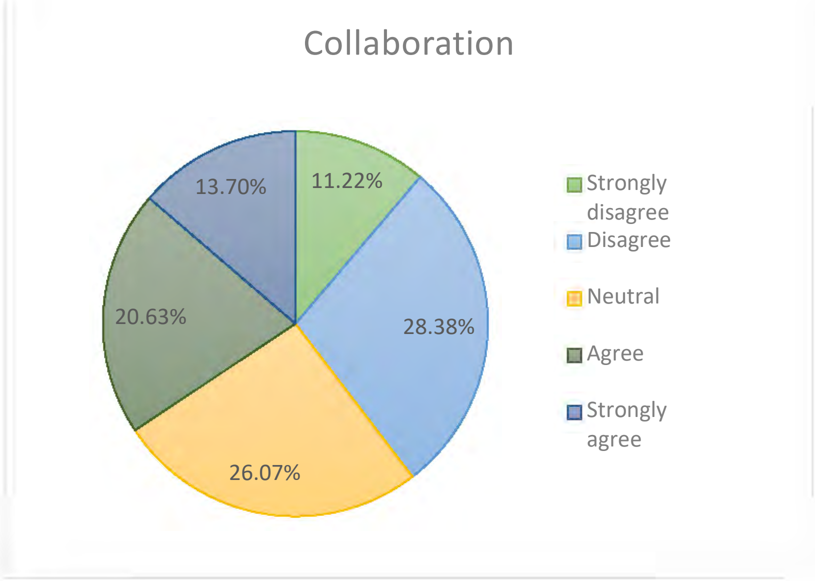


Figure V.2A

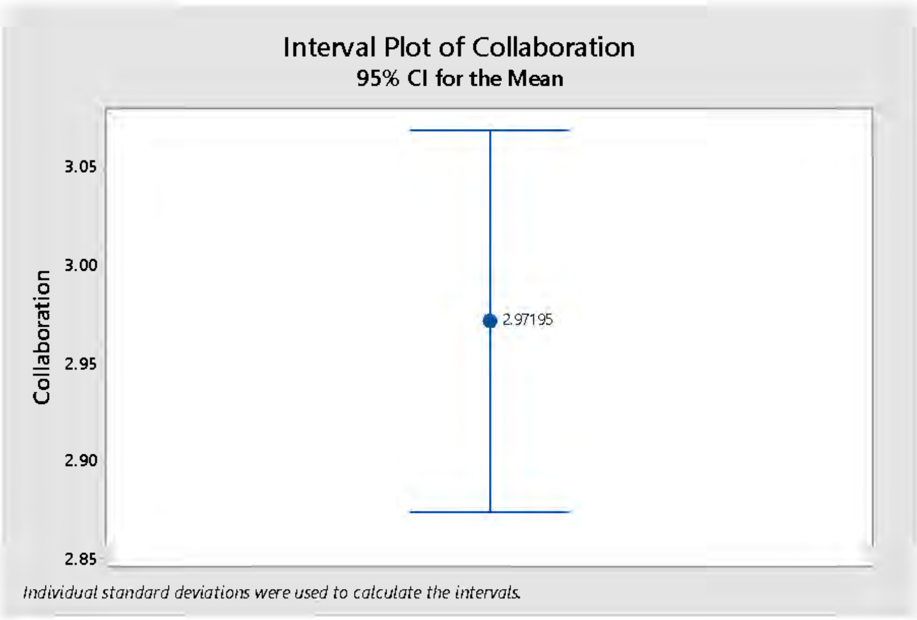


Figure V.2B

Understanding Related

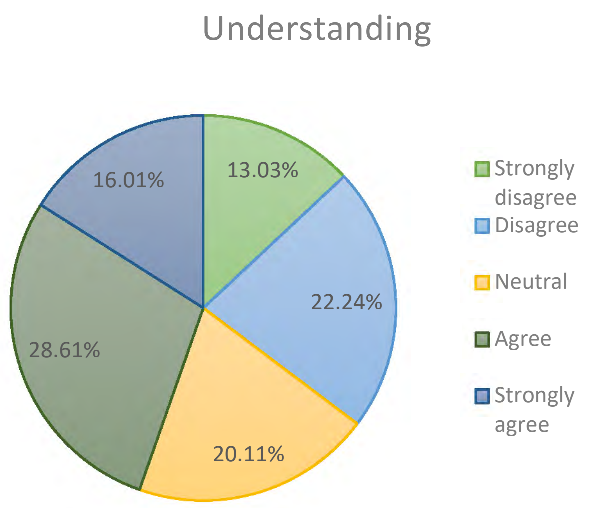


Figure V.3A

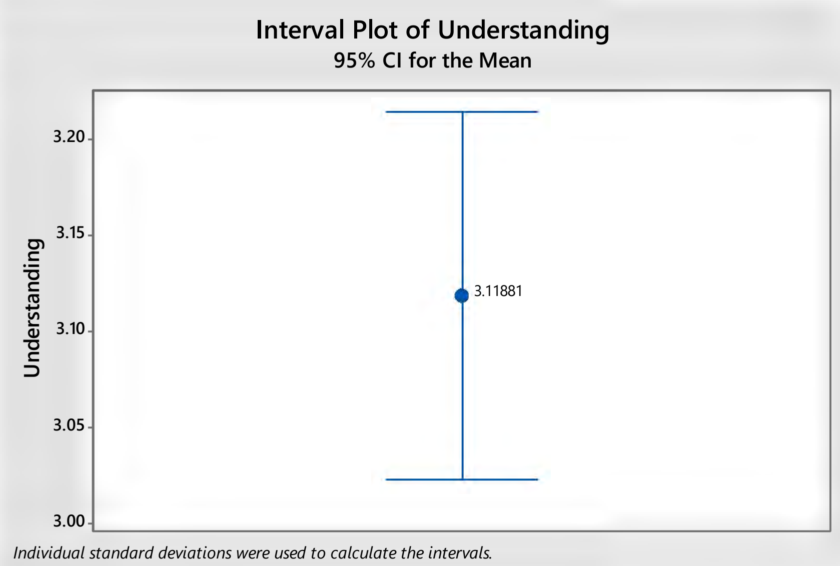


Figure V.3B

Time Management

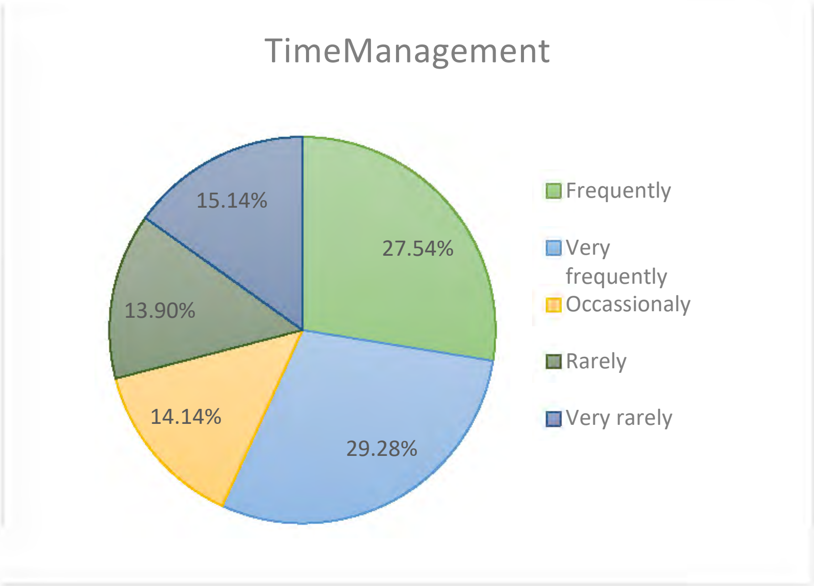


Figure V.4A

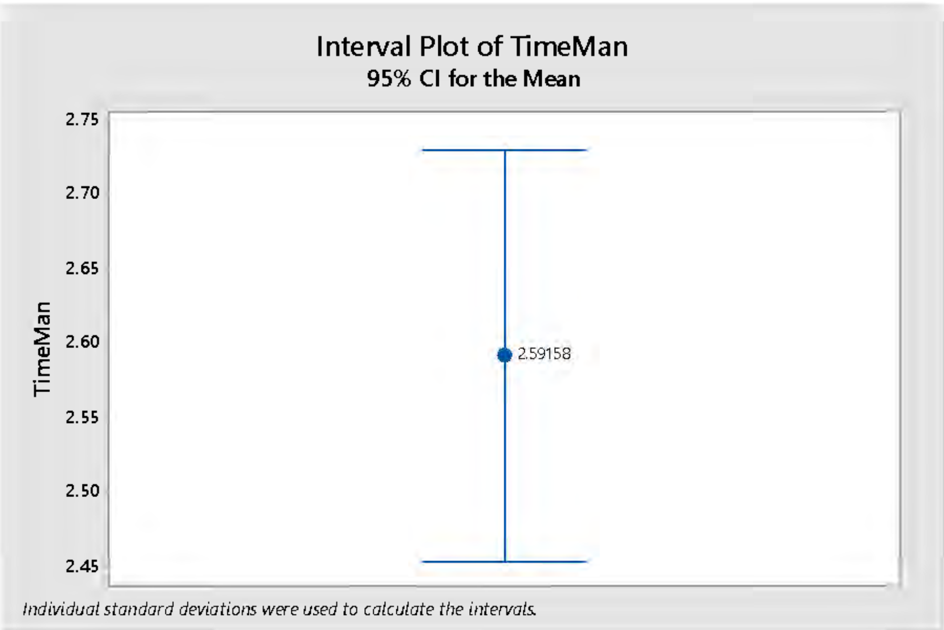


Figure V.4B

Teaching

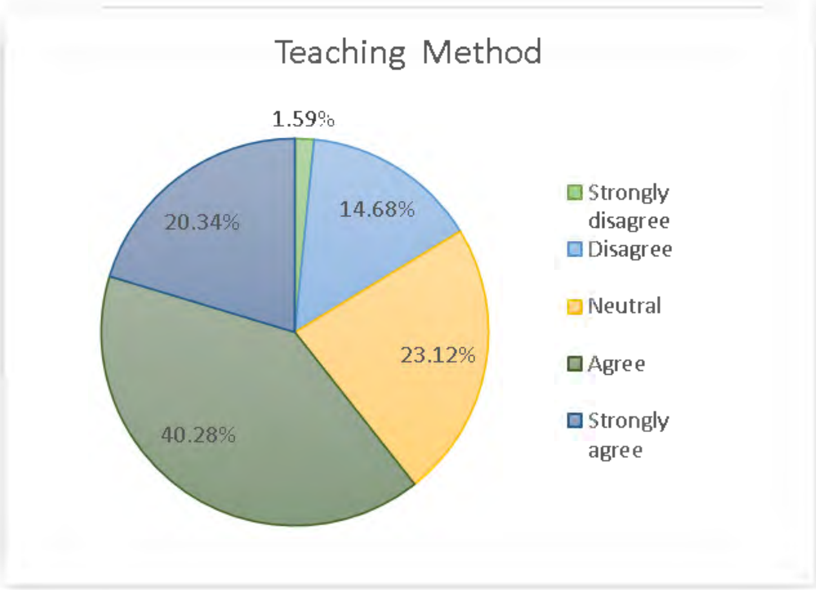


Figure V.5A

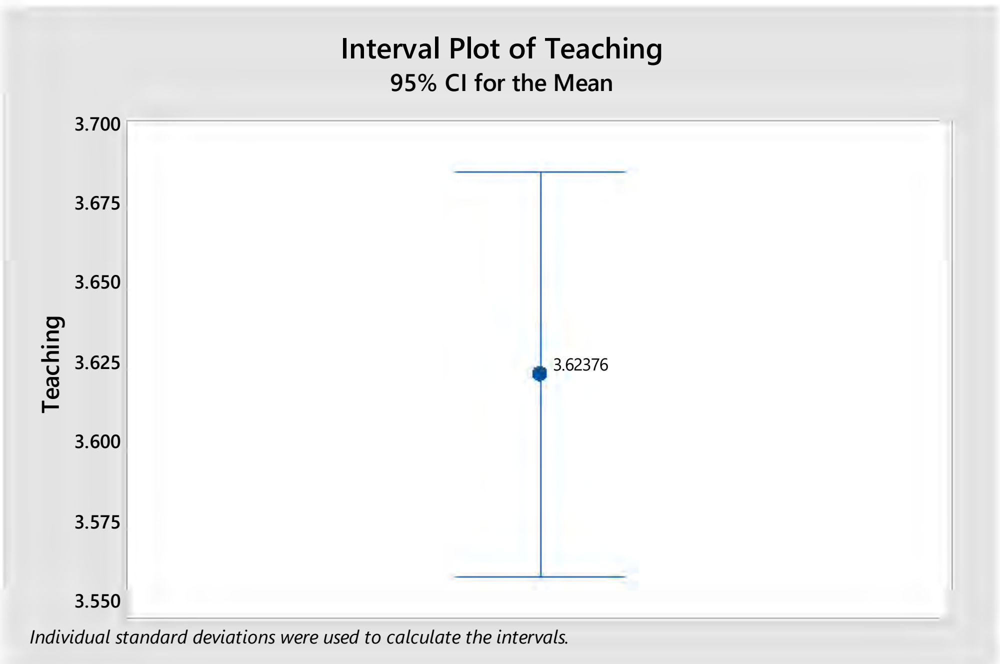
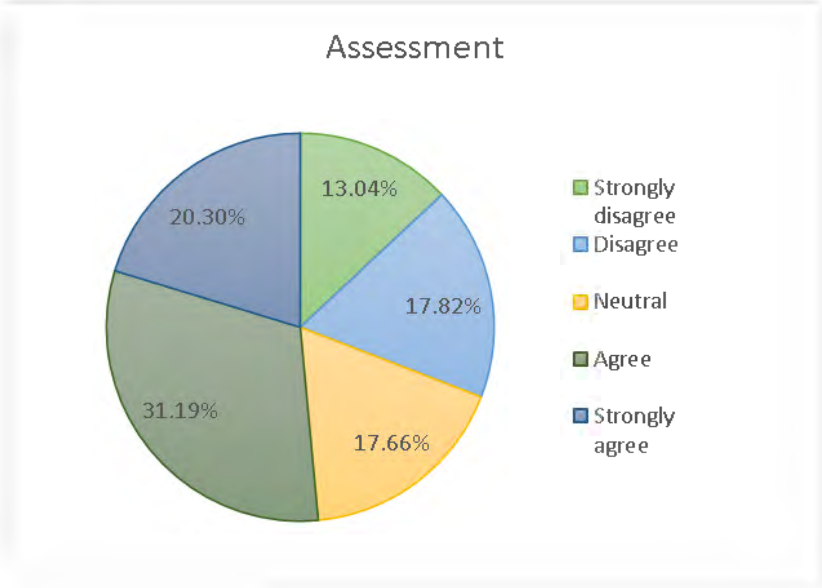


Figure V.5B

Assessment Related



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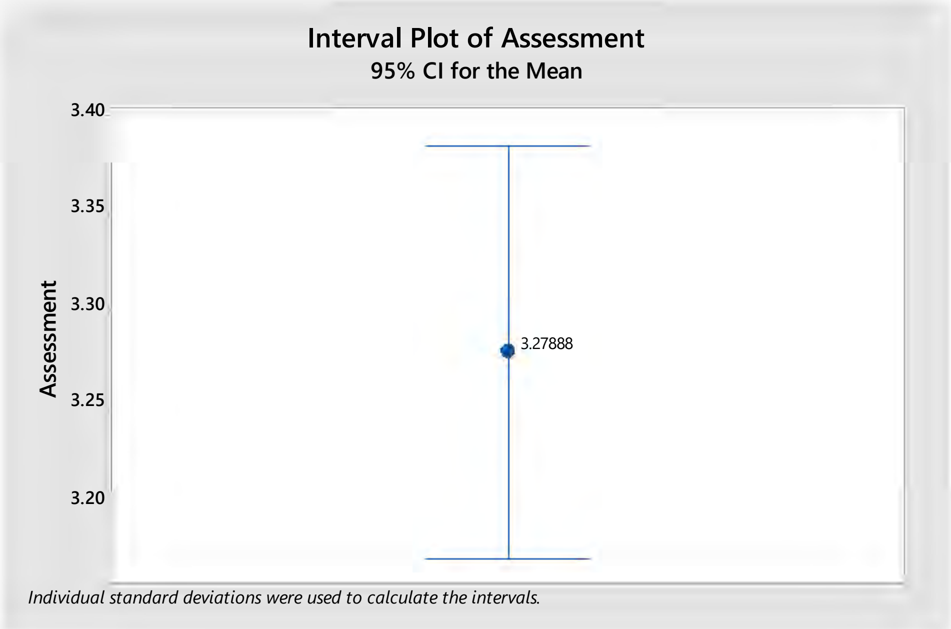
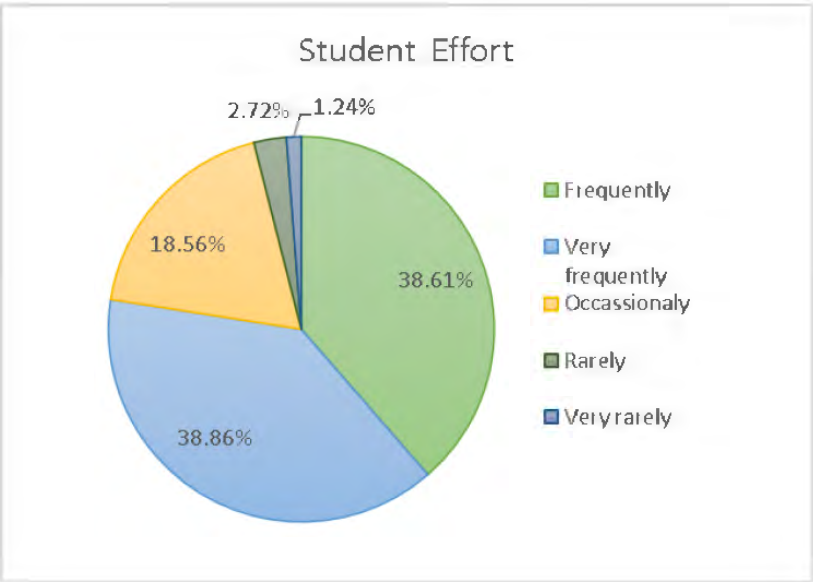


Figure V.6B

Student Effort



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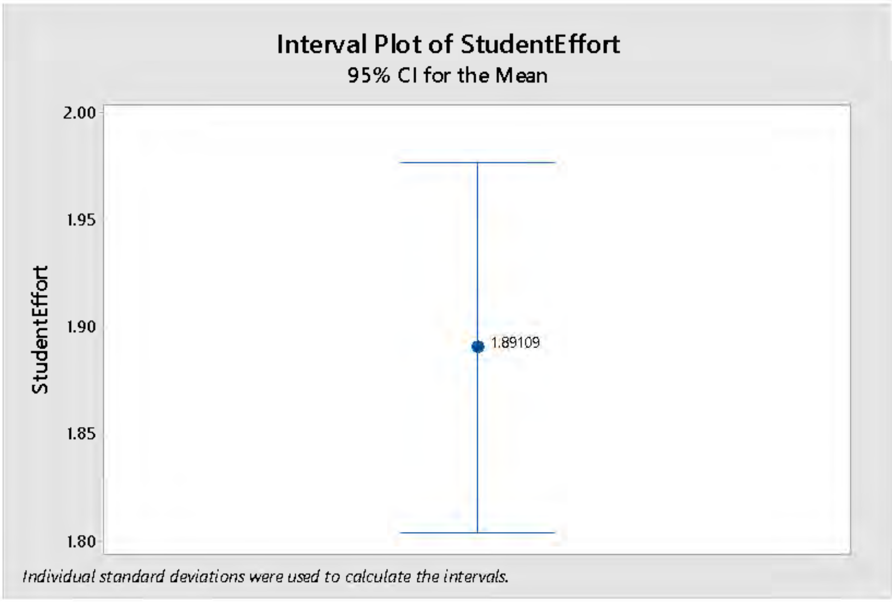

Figure V.7B

Technology Role

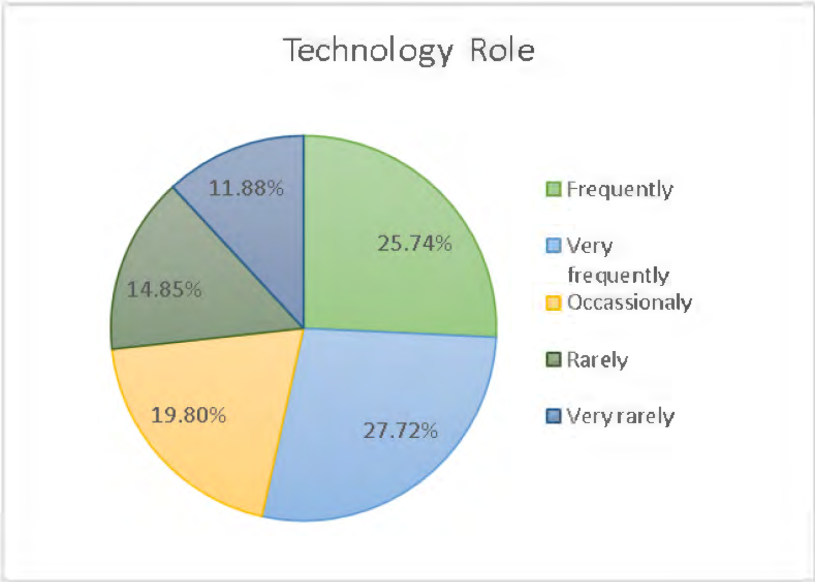

Figure V.8A

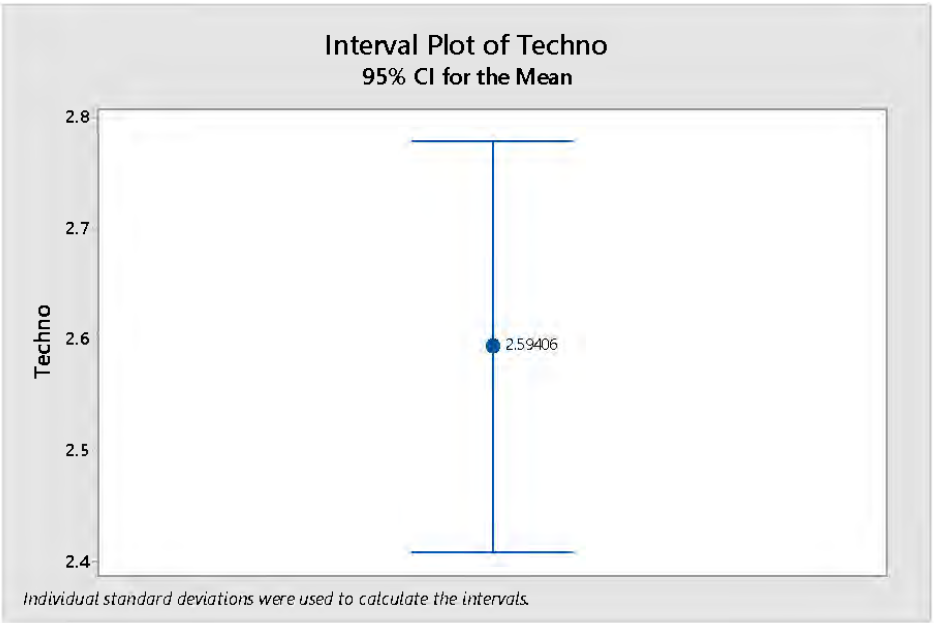

Figure V.8B

Emotional Role

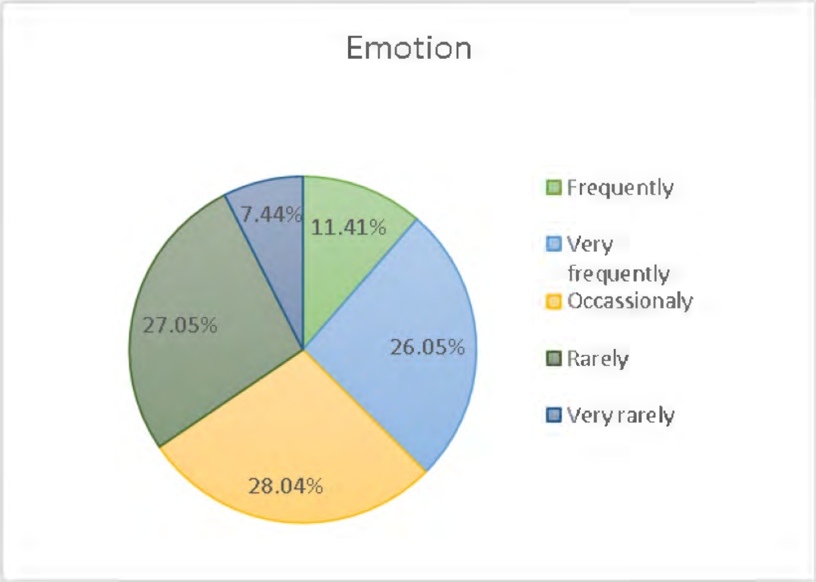

Figure V.9A

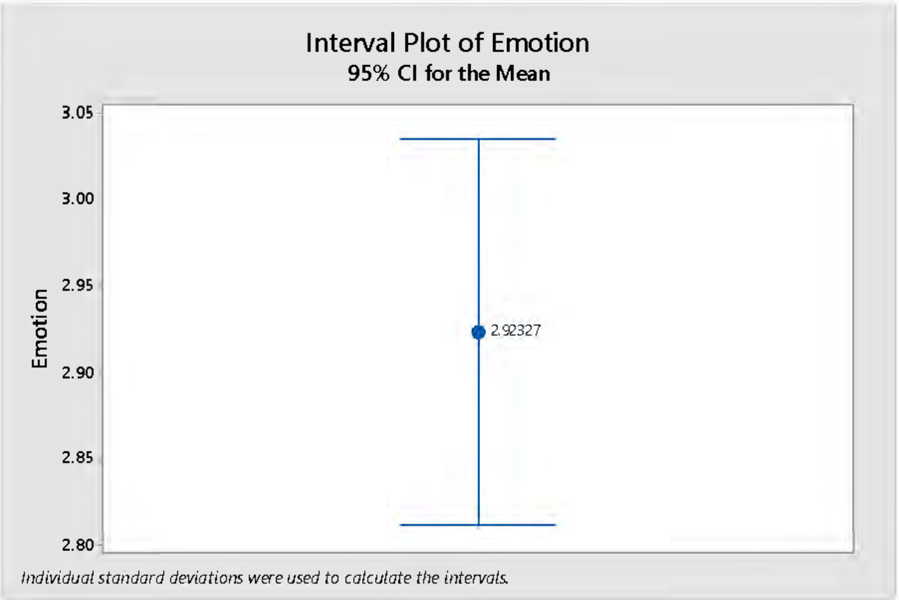

Figure V.9B

Motivation

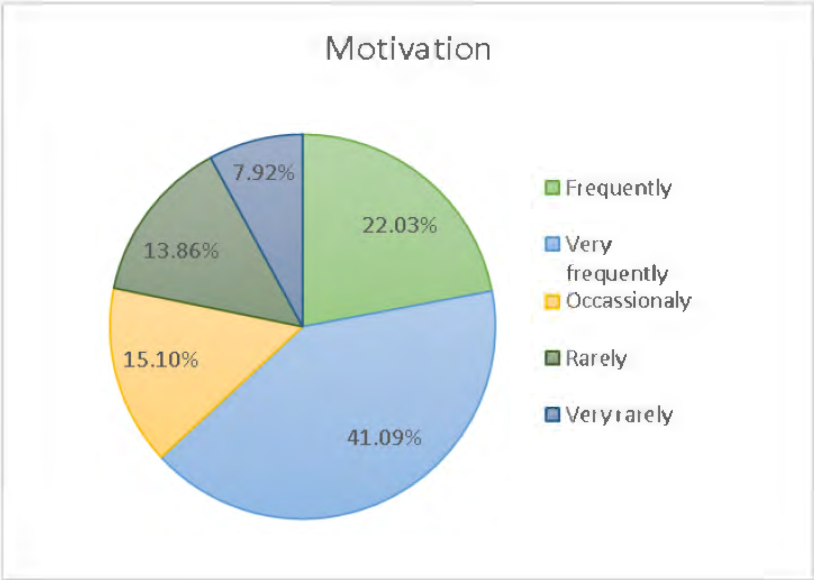

Figure V.10A

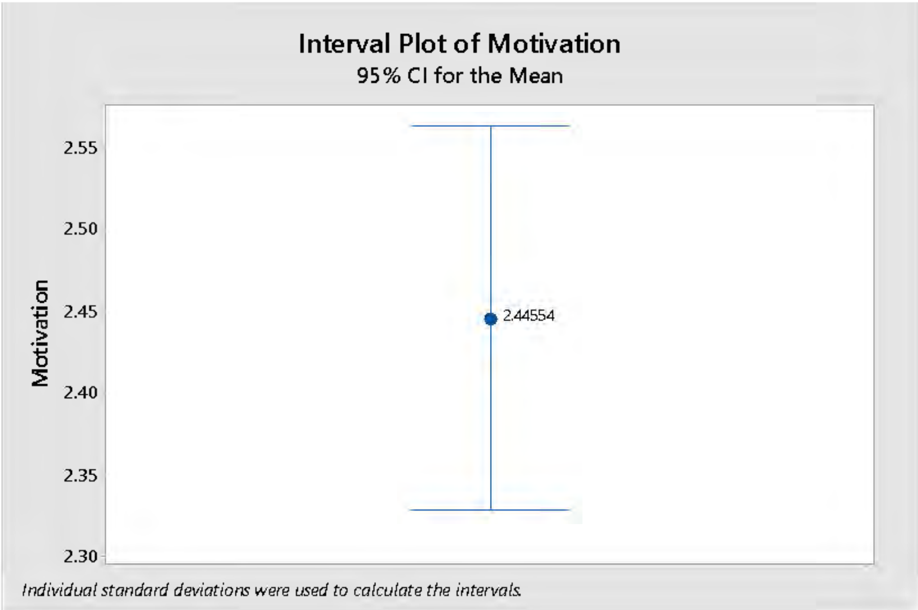

Figure V.10B

Satisfaction

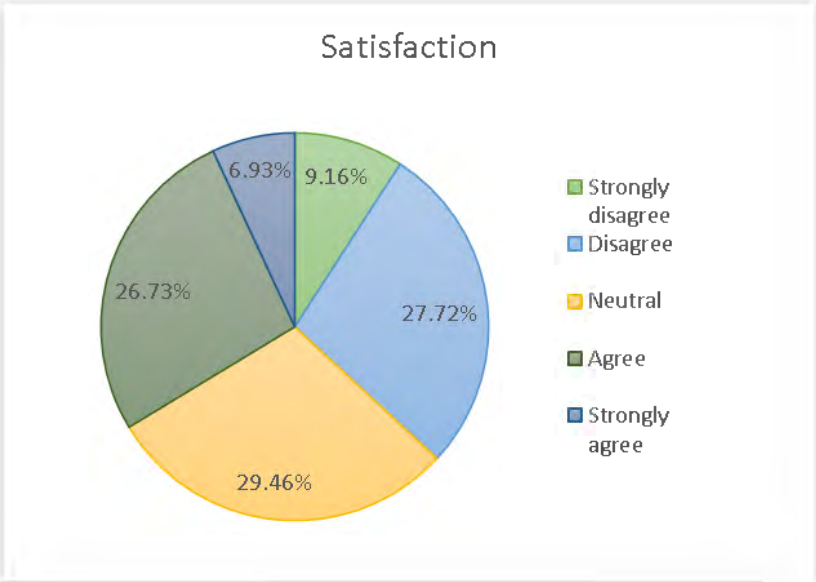

Figure V.11A

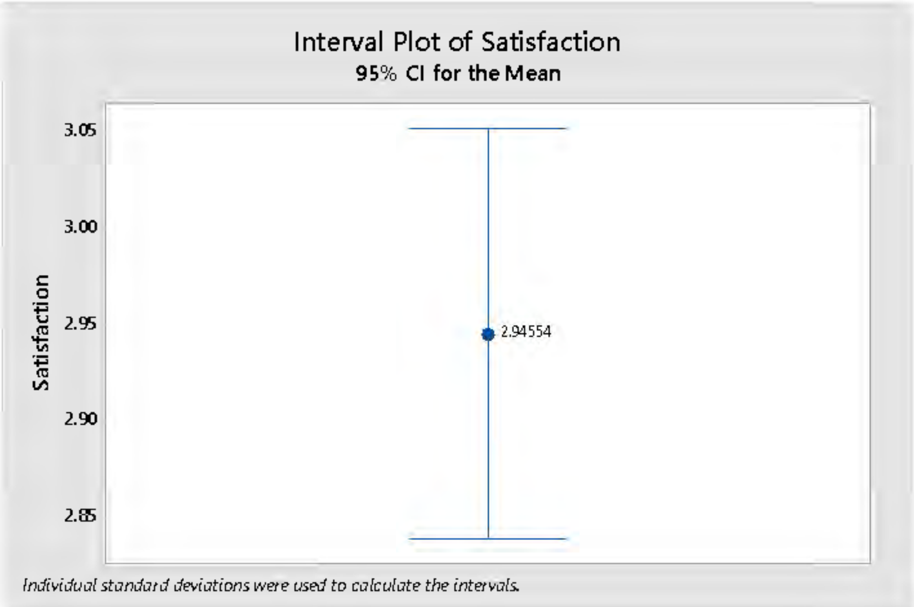

Figure V.11B

Anxiety

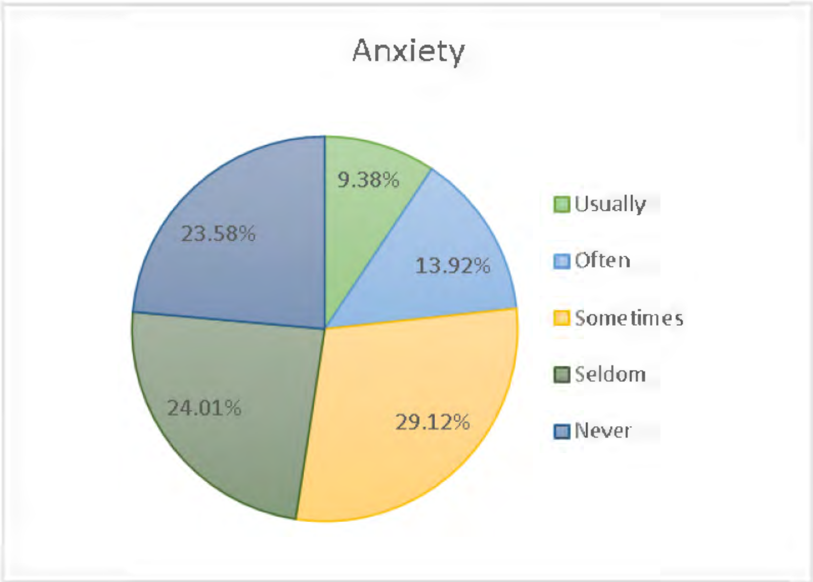

Figure V.12A

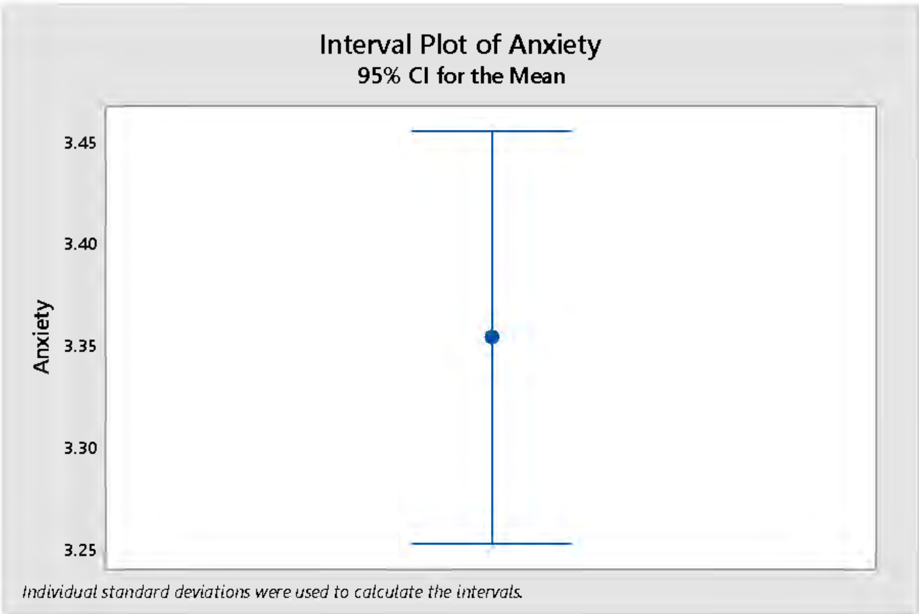

Figure V.12B

Reliability Scale of the Variables

Table V.9 Reliability Scale of the Variables

Variable	Cronbach's Alpha	Dijkstra–Henseler's ρ_A	Composite Reliability	AVE
Anxiety	0.82	0.84	0.87	0.49
Assessment	0.28	0.51	0.54	0.25
Collaboration	0.62	0.85	0.78	0.55
Emotion	0.27	0.48	0.66	0.41
Learning Style	0.81	0.82	0.85	0.37
Motivation	0.39	0.48	0.35	0.36
Satisfaction	0.15	0.27	0.27	0.29
Student Effort	0.55	0.60	0.75	0.44
Teaching	0.85	0.87	0.88	0.44
Technology	0.24	-11.37	0.56	0.51
Time Management	0.05	-0.20	0.26	0.25
Understanding	0.16	0.56	0.16	0.22

Discriminant Validity using Fornell-Larcker Criterion

Table V.10 Discriminant Validity using Fornell-Larcker Criterion

	Variable	1	2	3	4	5	6	7	8	9	10	11	12
1	Anxiety	**0.70**											
2	Assessment	0.26	**0.50**										
3	Collaboration	-0.10	-0.15	**0.74**									
4	Emotion	0.49	0.23	0.01	**0.64**								
5	Learning Style	-0.49	-0.41	0.27	-0.44	**0.61**							
6	Motivation	0.11	0.22	-0.26	0.09	-0.29	**0.60**						
7	Satisfaction	-0.50	-0.24	0.10	-0.45	0.44	-0.37	**0.54**					
8	Student Effort	-0.43	-0.43	0.09	-0.35	0.69	-0.05	0.27	0.66				
9	Teaching	0.49	0.47	-0.03	0.30	-0.41	0.18	-0.34	-0.31	**0.66**			
10	Technology	-0.31	-0.19	-0.03	-0.11	0.21	0.03	0.09	0.33	-0.45	**0.71**		
11	Time Management	-0.17	-0.13	0.30	-0.21	0.50	-0.21	0.25	0.35	0.05	0.06	**0.50**	
12	Understanding	-0.39	-0.43	0.26	-0.38	0.66	-0.36	0.42	0.46	-0.34	0.35	0.42	0.47

Discriminant Validity using Heterotrait-Monotrait Ratio (HTMT)

Table V.11 Discriminant Validity using Heterotrait-Monotrait Ratio (HTMT)

	Variable	1	2	3	4	5	6	7	8	9	10	11
1	Anxiety											
2	Assessment	0.4										
3	Collaboration	0.1	0.4									
4	Emotion	0.6	0.8	0.3								
5	Learning Style	0.6	0.7	0.3	0.6							
6	Motivation	0.5	0.7	0.4	0.5	0.6						
7	Satisfaction	0.9	1.0	0.4	0.8	0.9	0.8					
8	Student Effort	0.6	1.0	0.2	0.7	0.9	0.6	1.0				
9	Teaching	0.5	0.5	0.2	0.4	0.5	0.4	0.7	0.4			
1	Technology	0.6	0.9	0.6	0.6	0.5	0.7	0.7	0.8	0.8		
1	Time	0.6	0.8	0.4	0.6	0.8	0.5	1.0	1.1	0.5	0.9	
1	Understanding	0.7	1.2	0.4	0.8	0.8	0.9	1.1	0.9	0.8	1.3	0.9

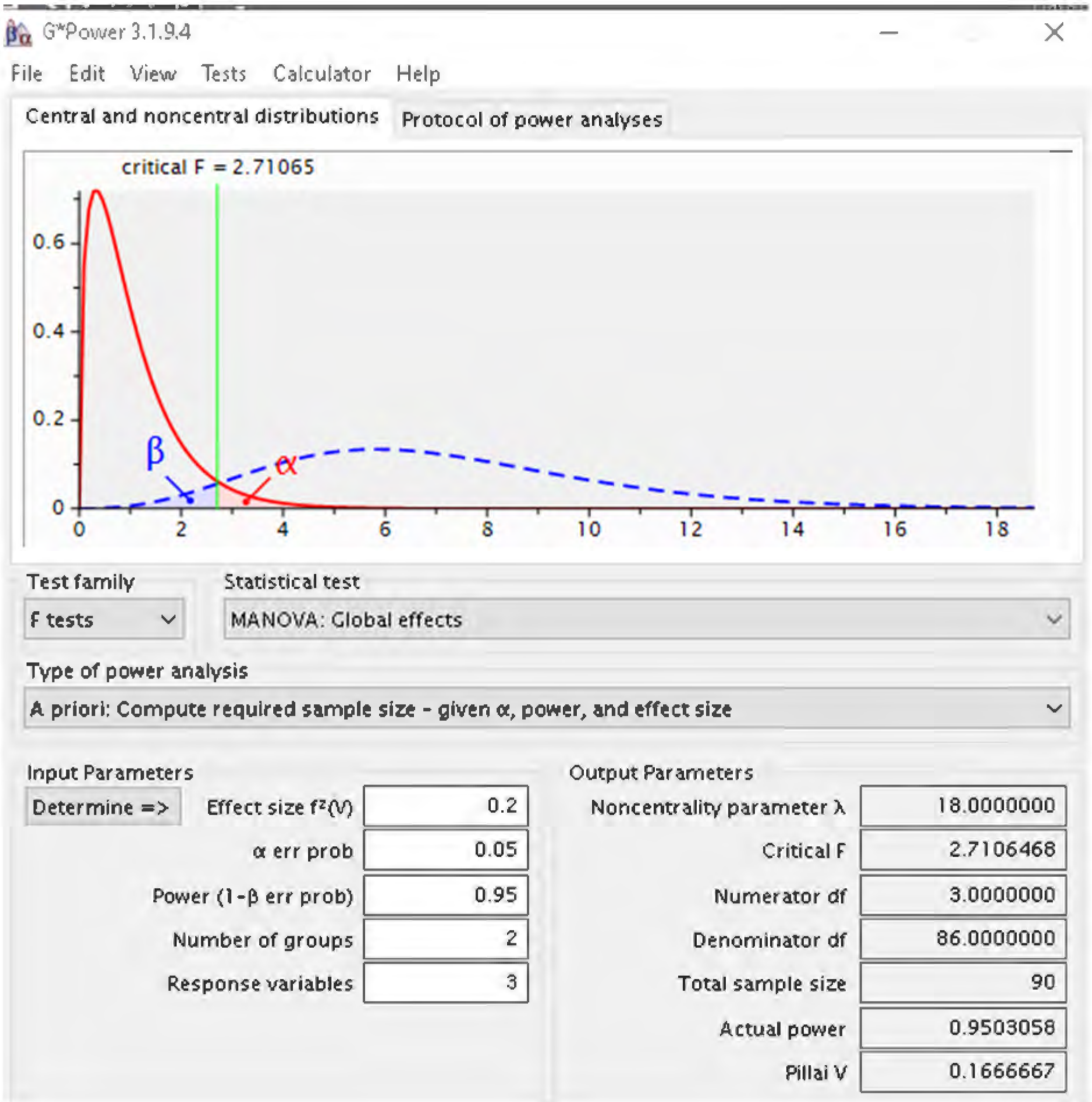
G*Power 3.1.9.4
File Edit View Tests Calculator Help
Central and noncentral distributions
Protocol of power analyses
critical F = 2.71065
β
α
Test family
F tests
Statistical test
MANOVA: Global effects
Type of power analysis
A priori: Compute required sample size - given α, power, and effect size
Input Parameters
Determine =>
Effect size f²(V) 0.2
α err prob 0.05
Power (1-β err prob) 0.95
Number of groups 2
Response variables 3
Output Parameters
Noncentrality parameter λ 18.0000000
Critical F 2.7106468
Numerator df 3.0000000
Denominator df 86.0000000
Total sample size 90
Actual power 0.9503058
Pillai V 0.1666667

Figure V.13

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