Engineering Mathematics Learning in a Singapore Polytechnic: A Grounded Theory Approach

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DECLARATION

This thesis is my own work and no part of it has been submitted for a degree at this, or any other, university.

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ABSTRACT

This study generates a substantive theory of how engineering students approach engineering mathematics learning in a polytechnic in Singapore. This thesis adopts a symbolic interactionist perspective and engages grounded theory methodology in its investigation. The main source of data comes from a series of in-depth face to face interviews with a group of 21 engineering students in the case Polytechnic. This is supplemented by data gathered from the students' reflection journals and informal interviews with their teachers.

The first major outcome of this study is the generation of the theory of Selective Intentionality in engineering mathematics learning that describes how engineering students approach mathematics learning through a series of socio-psychological processes. The core category in this study is the category of intending that is surrounded by the other four categories of gathering, analysing, actualising and regulating. Another major outcome that arises from this study is the development of a typology of students with regards to how they experience and manage mathematics learning in their engineering courses in the case Polytechnic. The typology is based on the predominant distinctions among the participants according to their responses in the analysing, intending, actualising and regulating processes in the theory of Selective Intentionality. Accordingly, the students may be broadly classified into five types of learners: idealistic learners, competitive learners, pragmatic learners, fatalistic learners and dissonant learners.

In short, this study provides a fresh perspective on how engineering students approach mathematics learning that is very important in their courses. At the same time, it has implications for the development of theory, practice and future research.

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CHAPTER ONE

STATEMENT OF THE PROBLEM

Introduction

The greatness of mathematics lies in its ability in providing utilitarian solutions to problems presented in human societies (Putnam, 1986). The uses of mathematics to cater to the needs of any modern society became more pronounced in the 1900s, resulting in an estimate of 95% of all known mathematical theories, concepts and procedures produced since then (Berlinghoff & Gouvea, 2004). Consequently, occupations related to technology and sciences such as engineering, life sciences, information technology, computing, biotechnology and e-commerce, are very important in modern societies. And these occupations rely significantly on the mastery of mathematics.

Singapore is one such modern society that relies significantly on technology and sciences in its economic and political survival and development. The Singapore Government emphasises the necessity of maintaining an educated workforce to ensure the proper functioning of the society. All Singaporean students have to undergo 10-11 years of compulsory secondary education. Upon completion of their secondary education, 90% of each student cohort is channelled into postsecondary education that is relevant to the present needs of the society. Publicly funded junior colleges, polytechnics and institutes of technical education provide postsecondary education choices to these students after their secondary education. Students who excel academically in their secondary education (typically the top 25% of each student cohort) would usually enrol in junior colleges that prepare them for university education (Law, 2007). On the other hand, the next 40% of each student cohort would be provided with the opportunity of polytechnic education that aims “to train middle-level professionals to support the technological and economic development of Singapore” (Ministry of Education, 2006). The lower 25% of the student cohort would be channelled into institutes of technical education that “ensure its graduates have the technical knowledge and skills that are relevant to industry” (Ministry of Education, 2006). Top performers from polytechnics are given the opportunity to acquire university education, while strong performers in institutes of education can advance to polytechnic education. These publicly funded universities, junior colleges, polytechnics and institutes of technical education provide a range of courses such as engineering, life sciences, business, information technology, computing, nursing, biotechnology, design and e-commerce that are also highly relevant to the global economy in the 21st century.

It is the polytechnic context of engineering courses in which I work as a mathematics lecturer that provides the background for this research. The unique relationship between mathematics and engineering provides the foundation for this study. Mathematics is important to engineers as it is "a tree of knowledge: formulae, theorems, and results hang like ripe fruits to be plucked" (Steen, 1988:611) or "a well stocked and vital warehouse" (Peterson, 1996:1) where the formulae, theorems and results are at the disposal for their uses in their work solving engineering problems. As a lecturer teaching mathematics to engineering students in one of the five polytechnics in Singapore, I observe that not all engineering students approach this mandatory subject in the same embracing manner as expected of engineers.

From the interaction with my engineering students, I find that some of them like mathematics, see it as an important subject and embrace it as engineers would. They also claim that they feel fulfilled and motivated in studying mathematics as they are always able to get good grades in mathematics modules. However, I know some engineering students who respond to mathematics negatively, such that they dislike and even fear the subject, but are resigned or forced to study it as it is compulsory and examinable.

Many students study engineering courses because they are not able to study their preferred courses (such as life sciences, social sciences, accountancy and business). This is because they have not been able to satisfy the more stringent enrolment criteria that are based on their Singapore-Cambridge General Certificate of Education (Ordinary Level) Examination (termed as GCE "O" level in short) results, for these courses. The limited quota of vacancies for these popular courses further reduces their chances as these vacancies are taken up by students with better GCE "O" level results than them. According to some of them, they have to work extra hard in studying engineering mathematics as mathematics has always been difficult to them since their secondary school years. Thus, they divulge that they feel miserable, pressurised and unmotivated when studying engineering mathematics. On the other hand, some of these engineering students are calm and philosophical about studying mathematics as they adopt a relaxed attitude and do not bother to put in the extra hard work as required. They believe that external factors such as luck, lenient grading and divine intervention will have the final say in their engineering mathematics examinations.

It is also interesting to note that some of the academically weaker students (judging from their poorer GCE "O" level results and their slower pace of understanding concepts during lectures) have stated that engineering courses are in fact, their preferred choices. However, they are faced with the mixed feelings of despair and joy as they have to handle mathematics which they may not be proficient in although they like the practical aspects of the engineering discipline. Nevertheless, as engineering students, they have no choice but to at least achieve some mastery of mathematics in order to understand the engineering concepts. Thus, some of these students claim that they try to motivate themselves and strive to put in more effort in mathematics modules.

As a mathematics lecturer, I do believe that mathematics may also elicit other varieties of engineering students' experiences that are not discussed above. This stems from the context that mathematics is an indispensable part of engineering where its presence in any engineering course cannot be diluted or removed. This becomes a significant implication in a scenario where engineering students have to learn and master mathematics in order to understand engineering concepts and obtain their diplomas that are essential in their future work careers. From such a context, engineering students may form different perspectives in studying mathematics. From a lecturer's point of view, I can see some potential problems arising from their different perspectives in studying engineering mathematics.

First, I have seen some academically weaker students performing very well, and their academically stronger counterparts performing below expectations, in engineering mathematics tests or examinations. I observe that academically weaker students who show more positive elements in their perspectives in studying mathematics usually adopt more useful and effective actions in approaching it. Thus, they are able to fulfil their academic potential. They will also perform acceptably well or better in most engineering modules that are mathematics based. Some of them even surpass their academic potential and become the top few percentages of academic achievers in their engineering course cohort. However, I also notice students who show positive perspectives in studying mathematics but yet their subsequent actions are ineffectual in approaching it as they still cannot perform up to expectations in their engineering mathematics assessments. Similarly, some of those academically stronger students have also failed to fulfil their academic potential and obtained mediocre grades in their final engineering mathematics examinations. This may also result in them scoring badly for most engineering modules that are mathematics based. This may suggest that their previously proven academic competence may not reflect their level of performance in studying engineering mathematics. From my experience above, I believe that their level of performance may be influenced more significantly by the consequences of their actions that they have utilized in studying engineering mathematics instead. And these actions result from their perspectives of studying engineering mathematics. Thus, if the students fail to see their own perspectives of, and resultant actions towards, studying engineering mathematics influencing their academic attainment, they may not be able to learn effectively and fulfil their academic potential. This gives rise to the first problem where some students do not learn effectively and fulfil their academic potential due to their perspectives of studying engineering mathematics. And the failure to fulfil their academic potential usually affects their future academic or work careers.

The second issue that arises from the different perspectives of the students in studying engineering mathematics originates from the mathematics lecturers themselves. I have heard many of my colleagues lamenting the poor attitudes, undesirable behaviours and under performance of their students in their engineering mathematics lessons. Some of them may not attempt to rectify the above problems faced as they believe that the students are already in tertiary education and should be responsible for their own studies. Thus, many of their students' attitudes and behaviours towards engineering mathematics learning remain negative and impeding. As a result, the students cannot learn effectively and their performances in examinations are mediocre. Nevertheless, some lecturers do attempt to rectify the above problems by employing different teaching strategies with the students, but they are usually ineffectual. Therefore, they become frustrated and disappointed as their strategies cannot help their students to learn effectively. These lecturers also lose confidence in their teaching ability. However, I do have a few successful colleagues who are able to teach their students effectively. According to them, they usually make efforts to understand their students' thoughts and feelings about engineering mathematics learning. Thus, they generally spend a substantial amount of time in communicating with them. After understanding their students better (in terms of their perspectives and needs in engineering mathematics learning), they apply customised teaching strategies on them. This may indicate that if the lecturers are able to understand how these students view mathematics learning, they can appreciate the rationale behind their attitude, behaviour and performance in it. Consequentially, the lecturers will be in a better position to help their students in fulfilling or surpassing their academic potential through more customised teaching strategies or remedial efforts. For example, if a lecturer recognizes that some students perceive engineering mathematics to be frightening and are avoiding it, he/she can always seek to change or overcome their perspectives of studying engineering mathematics and help them improve their learning. If the lecturers can teach their students effectively through such customised teaching strategies, their confidence in their pedagogies can increase too. This also means that there would be more effective and confident engineering mathematics lecturers for the benefit of the learning community. In short, because of the lack of understanding of the students' perspectives of, and their subsequent actions towards, studying engineering mathematics, the lecturers may not be able to teach the students competently. This will then result in the students not learning effectively.

Lastly, if engineering students are not able to learn mathematics effectively and mathematics lecturers are not able to teach them competently because of the lack of understanding of their perspectives in studying engineering mathematics, the quality of engineers produced in the society may be compromised. This is because mathematics is the fundamental of all engineering principles and failure to master it means the engineering skills learnt will not be of acceptable or high quality. And this may be a very serious implication at a macro level as the Singaporean society relies significantly on technological and scientific skills in her economic and political survival.

To summarise, the research problem here is the lack of understanding of the students' perspectives or experiences of studying engineering mathematics in polytechnics that gives rise to the possible consequences of students' ineffective learning or/and lecturers' incompetent teaching and the eventual compromising of the quality of future engineers in Singapore. Thus, this thesis will centre on understanding the students' perspectives or experiences of studying mathematics as part of their engineering diploma courses in a polytechnic in Singapore.

1.1 Research Aims and Objectives

The overall aim of this thesis is to develop a substantive theory of the students' perspectives of studying mathematics as part of their engineering diploma courses in a polytechnic in

Singapore using grounded theory methodology. This theory aims to describe and explain how engineering students understand, experience and interpret mathematics in their own perspectives. At the same time, it also helps to shed light on the strategies engineering students use in studying mathematics and their consequences on their learning. With the research problem and aims of the thesis defined, the research questions of this study will be derived and discussed.

Grounded theory methodology is utilised in this study. In grounded theory, there is often no preconceived research question (Glaser, 1992). However, Strauss & Corbin (1998) proposed that technical literature and personal or professional experience can set the initial research question to guide the data collection. Charmaz (2006) too suggested that a literature review prior to the data collection can serve as the theoretical framework for a study. The research question is fluid and is not final as it may be modified as the data collection and analysis processes are in motion. In congruence with Strauss & Corbin (1998) and Charmaz (2006), a main research question is formulated to address the research problem which centres on the students' perspectives of studying mathematics as part of their electrical and/or electronic engineering diploma courses in a polytechnic in Singapore. Answering this main research question can fulfil the aim of the study in generating a substantive theory of the students' perspectives of studying engineering mathematics. Then, from the main research question, a number of manageable specific research questions will be constructed to guide the research process.

1.2 Key Research Questions

This thesis aims to answer the main research question:

> **"What are the students' experiences of studying mathematics as part of their electrical and/or electronic engineering diploma courses in a polytechnic in Singapore?"**
>
> This main research question will be further fragmented into more manageable specific research questions. The four specific research questions are:

a. **What are the societal factors that influence the students' experiences in studying engineering mathematics?**
b. **How are the students' intentions in engineering mathematics learning formed?**
c. **What strategies will the students use in realising their intentions and why are they used?**
d. **What are the expected consequences of the strategies on the students in engineering mathematics learning?**

These specific research questions are formulated in consideration of the desirable characteristics of good research questions proposed by Fraenkel & Wallen (1996). First, they are feasible to investigate in terms of time, effort and money. They are also clear and focused. Besides, they contribute to the current lack of such research locally as a search of research and thesis database of the only teacher training institution (National Institute of Education) and its subsidiary research centre (Centre for Research in Pedagogy and Practice) where most local educational research is done, yields no similar studies. Lastly, as the research questions do not concern sensitive personal issues and the research subjects are free to leave the study at any time, no psychological harm will be inflicted on them.

1.3 The Importance of This Study

Putnam (1986), Berlinghoff & Gouvea (2004), Steen (1988), Peterson (1996), De Lange (1996), Stanic (1989), Lane (1999) and Ernest (2004) have underlined the fact that mathematics education has become indispensable in the social needs and economic survival of any modern society. The engineering domain impacts the function of a society significantly and mathematics is crucial in mastering it. The importance of mathematics is especially evident in Singapore as Singapore must build on her only resource – people, due to its lack of natural resources and limited human resources (MariMari, 2003). Scientific and technological education thus plays an important role in the economic and national development of Singapore, as the government has to deploy precious and limited human resources efficiently according to the industry's needs. Engineering is one of the domains that is always emphasised. Thus, at a macro level, this study is important in the Singaporean society as it aims to examine the beginning education of engineers, a group that is vital to the Singapore economy. Specifically, this study will help understand why some engineering students thrive and others struggle with mathematics which is the important link in ensuring the high proficiency of engineers (Steen, 1988; Peterson, 1996; Shaw & Shaw, 1999). Ultimately, the Singapore economy may gain from this type of study.

At a micro level, this study is important to the effective teaching and learning of mathematics in engineering courses. According to Pekrun et al. (2002:1), the ways that a student perceives a subject "are significantly related to students' motivation, learning strategies, cognitive resources, self-regulation, and academic achievement..." This is supported by Schoenfeld (1992) and Franke & Carey (1997) who stated that the manner by which students understand and interpret mathematics can influence the mathematical behaviours they engage in. Thus, a clear and in-depth understanding of the students' perspectives of studying mathematics as part of their engineering diploma courses is important to the students themselves, their mathematics lecturers, and engineering and other related professions reliant on mathematics. From the teaching viewpoint, the mathematics lecturers may be able to adjust their instructional strategies accordingly to ensure their students learn effectively. At the same time, the students can also alter their learning strategies usefully through understanding their own, and others' experiences in engineering mathematics learning. The fact that there is a lack of such research in Singapore further emphasises the importance of this study in allowing practitioners (such as engineering students, teachers, researchers and policy makers) to understand the perspectives of students in engineering mathematics learning.

Another basis to justify the importance of this study is methodological. Grounded theory is a useful qualitative research method that allows a researcher to understand the experience of humans from their perspectives within their social environment (Charmaz, 2006; Grbich, 1999; Strauss & Corbin, 1998; Glaser, 1992). However, it is seldom used in educational research in Singapore as the absence of grounded theory research in the research and thesis database of National Institute of Education and Centre for Research in Pedagogy and Practice, shows. Thus, this study serves as an important contribution in local educational research using grounded theory methodology which has seldom been utilised in Singapore.

In summary, this study is important in three areas. First of all, at a macro level, it contributes indirectly to the economic and social survival of the Singaporean society as it seeks to understand the study habits of its future engineers, who form an important part of the economy. Secondly, at a micro level, it enhances the teaching and learning of engineering mathematics.

Lastly, it serves as an important contribution to grounded theory educational research that is presently lacking in Singapore.

1.4 Research Design

There are two main research paradigms employed in social research. They are the positivist research paradigm and the interpretive research paradigm (Cohen et al., 2000). Both paradigms have their own assumptions about the nature of knowledge and reality. They also set out to achieve different goals through their methods.

The positivist research paradigm is positivistic or realistic such that it believes that there is one external reality which represents the only truth for any phenomenon investigated. It is concerned with objectivity, prediction and generalization of events (Cohen et al., 2000; Shaughnessy & Zechmeister, 1997). The positivist research paradigm aims to establish causal relationships between data collected, based on factual or statistical evidence.

The interpretive research paradigm is concerned with the human understanding of events and their behaviours within a given context (Cohen et al., 2000; Shaughnessy & Zechmeister, 1997). The presence of multiple realities of an investigated phenomenon is commonly believed in the interpretive research paradigm. Therefore, the interpretive research paradigm is usually known as anti positivistic or idealistic.

Judging from the research questions presented above, the interpretive research paradigm serves the aims of this study more aptly as it seeks to understand and interpret the students' perspectives of studying engineering mathematics instead of seeking causal relationships between variables in it. Besides, interpretive research is suited for the study of phenomenon that is little known with no or few existing theories to explain it (Nassar, 2001; Cohen et al., 2000). And the study of the students' perspectives of studying engineering mathematics in Singapore is hardly researched at all. Thus, interpretive research methods will address the research problem of this study more effectively.

In this study, the interpretive methodology of grounded theory is selected as the research approach for this thesis. Byrne (2001:2) stated that "The foundations of grounded theory are embedded in symbolic interactionism, which assumes that one's communications and actions express meanings". Symbolic interactionism attempts to understand human behaviours in terms of their social interactions and shared meanings. Dimmock & O'Donoghue (1997) further added that, in symbolic interactionism, humans assign meanings to the actions of others and their own actions in social interactions. These assigned meanings are then processed and adjusted accordingly through one's own internal interpretive mechanisms.

This study attempts to investigate the experiences of students studying engineering mathematics in Singapore and this means understanding their thoughts, feelings and emotions, and thus recognizing the reasons behind their actions, as affected by social factors around them. Therefore, the symbolic interactionist aspect of grounded theory suits it well. The research design for this study will be further elaborated in Chapter Three.

1.5 Limitations of Research

There are some limitations foreseen in this study too. They are:

- The limited ability of this study to generalize its results beyond the investigated students to the main population of engineering students in Singapore.
- As an "insider" researcher in this study, my sensitivity, prejudices and bias regarding mathematics learning may affect its credibility to some extent.

These limitations will be further elaborated, together with ways to reduce their liabilities to the minimum, in Chapter Three.

1.6 Outline of Thesis

This thesis consists of seven chapters. Chapter One has provided the background, aims and significance of this study, the main research questions and a brief description of the research design and its limitations. A literature review that covers the pertinent aspects of the study will be provided in Chapter Two. Chapter Three defines and justifies the research methodology underpinning the study. Chapter Four gives a summary of the findings of this thesis, while Chapter Five and Chapter Six elaborate on them. Lastly, Chapter Seven consists of the discussion, implications and recommendations that arise from the study's findings.

CHAPTER TWO

LITERATURE REVIEW

Introduction

This literature review is framed by the main research question in this study, which is **"What are the students' experiences of studying mathematics as part of their electrical and/or electronic engineering diploma courses in a polytechnic in Singapore?"** Students may have their own views and intentions of learning as affected by societal factors (such as government, schools, teachers, peers and families) around them. These intentions may result in the planning and actualisation of certain strategies to achieve them. Furthermore, the consequences of the strategies may influence their original intentions of learning. Thus, in this study, the students' experiences of studying engineering mathematics will consist of their views, intentions, strategies and their consequences as influenced by the various societal factors. Consequently, four specific research questions are formed below to understand the students' experiences of studying engineering mathematics:

a. **What are the societal factors that influence the students' experiences in studying engineering mathematics?**
b. **How are the students' intentions in engineering mathematics learning formed?**
c. **What strategies will the students use in realising their intentions and why are they used?**
d. **What are the expected consequences of the strategies on the students in engineering mathematics learning?**

First of all, this literature review will serve to rationalise the significance of this study through the critical evaluation of those relevant studies done (Hart, 1998). At the same time, it will establish the context of the research problem (Hart, 1998) through the discussion of the societal factors that may influence mathematics learning in Singapore. As there are few studies (such as Shaw & Shaw, 1999; Jaworski, 2002; Ee & Wong, 2005) that address the students' experiences of studying mathematics in the context of tertiary students studying engineering mathematics, this literature review will focus on other relevant studies in general educational settings such as primary or secondary levels. Although the students' experiences of mathematics learning at primary or secondary level may differ from the experiences of engineering students at tertiary level - due to the differences in social, economic and personal contexts - by conducting a literature review in such contexts, there may be useful insights to be gained.

First, given the scarcity of previous studies of the experiences of mathematics learning in tertiary engineering education, the theoretical framework for the study can be constructed by relating to studies based on the experiences of mathematics learning in other primary and secondary mathematics learning contexts (Charmaz, 2006). Moreover, the students' experiences of learning mathematics in primary and secondary years may influence their experiences in studying engineering mathematics if they choose to embark on engineering careers later and thus this should not be ignored. Besides, these reviewed findings may be useful in the data collection stage to stimulate questions in the initial interviews and for theoretical sampling (Strauss & Corbin, 1998). Furthermore, they may also help to increase my theoretical sensitivity, as a researcher, since their similarities or differences can sensitise me in the analysis of the properties of the categories through the process of constant comparison in the grounded theory approach adopted in this study (Glaser & Strauss, 1967; Strauss & Corbin, 1998). Lastly, this literature review may help in confirming the study's findings and gaps in the present literature may also be answered by the outcomes of the study (Strauss & Corbin, 1998; Charmaz, 2006). Thus, this literature review is divided into five sections which address the four specific research questions:

2.1 Societal Factors Influencing Students' Experiences of Mathematics Learning;
2.2 Formation of Students' Intentions in Mathematics Learning;
2.3 Strategies Resulting from Students' Intentions in Mathematics Learning;
2.4 Consequences Resulting from the Strategies of Students in Mathematics Learning;
2.5 Preliminary Theoretical Framework.

The students' experiences of mathematics learning are usually influenced by various societal factors around them. Societal factors can manifest themselves politically, economically or socially. These societal influences include the government, schools, teachers, parents and peers. Thus, the first section, "Societal Factors Influencing Students' Experiences of Mathematics Learning", reviews the societal factors that influence the students' experiences in mathematics learning. This will help to address the relevant literature linked to the first specific research question of this study: **What are the societal factors that influence the students'**

experiences in studying engineering mathematics? At the same time, it will set the specific research context that influences the formation of engineering students' views, intentions and strategies in mathematics learning.

As influenced by the societal factors around them, the students will form intentions in the learning of engineering mathematics. Thus, the second section of literature review, "Formation of Students' Intentions in Mathematics Learning", will shed some light on the second specific research question: **How are the students' intentions in engineering mathematics learning formed?**

With their intentions in studying mathematics, the students may start to plan strategies in achieving them. However, not all students will use the same strategies. Therefore, this part of the literature review, "Strategies Resulting from Students' Intentions in Mathematics Learning", can help address the third specific research question: **What strategies will the students use in realising their intentions and why are they used?**

Current intentions can be modified, removed or new ones may be created due to the consequences of the strategies. Thus, the section "Consequences Resulting from the Strategies of Students in Mathematics Learning", will aim to understand the consequences of the strategies used by the students and the effects on their mathematics learning. This will address the fourth specific research question: **What are the expected consequences of the strategies on the students in engineering mathematics learning?**

Lastly, a **theoretical framework** will be proposed in addressing the four specific research questions in the research context of engineering students. This provides the guidance in the data collection and analysis stages.

2.1 Societal Context Influencing Students' Experiences of Mathematics Learning

The students' learning experiences are influenced by the political, economic and social milieu in which they live. At a macro level, the government's social, education and economic policies may significantly affect the students' learning experiences. At a micro level, students interact with their peers, parents, teachers and others. Such interactions can significantly affect their learning experiences too. Thus, in this section, I will argue that a number of contextual issues are created in influencing the experiences of mathematics learners here. However, there is a need to qualify that there may be more contextual issues arising as this study progresses. These initial issues can serve to improve my theoretical sensitivity and direct the early data collection and analysis stages. The contextual issues in the setting of Singapore are related to the:

- Perceived socio-economic values of mathematics education;
- Perceived socio-political influences of mathematics education;
- Successes in mathematics education;
- Gender issues in mathematics learning;
- Affective aspect of the Singapore Mathematics Curriculum Framework;
- Emphasis given to engineering education in the economy;
- Indispensability of mathematics in engineering;
- Influences from social agents – teachers, peers and parents.

2.1.1 Socio-Economic Values of Mathematics Education in Singapore

Mathematics plays an important role in providing utilitarian solutions to the problems created by the needs of science, business, technology and other aspects of daily life in the society (Lane, 1999; Putnam, 1986). The importance of mathematics is more distinct in modern societies as they rely heavily on science and technology. The uses of mathematics also became more crucial with the invention of computers as this has allowed mathematicians to test conjectures and discover new results through simulating and visualizing mathematical problems (Berlinghoff & Gouvea, 2004). Thus, applied mathematics has become very important in the world of technological advancement (De Lange, 1996).

As mathematics is the basis of science and technology, this inadvertently and explicitly leads to mathematics education being a heavy-weight gatekeeper to employment in many modern societies. In the modern society, most of the occupations need mathematics to different extents. There are occupations such as engineers, physicists, computer scientists and economists who use mathematics extensively. In other occupations such as statisticians, actuaries, accountants and operations research analysts, they use specialised branches of mathematics in their domains too. Even for other non-mathematics related occupations such as sociologists, business associates, chemists and sales executives, a reasonable amount of mathematics knowledge is needed in their work. And most important of all, everyone in the society needs to know some simple mathematics in performing important functions such as doing banking transactions, calculating daily expenses and totalling of bills, in their daily lives. In short, mathematics influences the economic and social well being of the society. The government may then implement policies that favour mathematics education extensively to create that ready pool of workers in the technological and scientific sectors. This thus results in the importance of mathematics and its education being deeply embedded in the culture of the society. Therefore, in a society that emphasises mathematics and its education, a unique set of perspectives about mathematics learning is endorsed by the society, espoused by the majority of its people and embedded into its culture. As a result, excellence in mathematics education may also become a form of high social status in such societies (Kloosterman, 2002; Zhang et al., 1990).

The economy of Singapore has to build on its people due to its lack of natural resources (MariMari, 2003). Thus, the education of its people becomes a significant deliberate process of transmitting important parts of the culture (in terms of beliefs, values, skills, facts and attitudes) of the society to the young (Hurn, 1985; Meighan & Siraj-Blatchford, 2003). More importantly, education trains and compartmentalises people into different occupations to support the economic needs of the society (Meighan & Siraj-Blatchford, 2003; Ballantine, 1997). Therefore, the Singapore Government tailors its educational system to support the requirements of the economy, which is oriented towards science, technology and business (Ashton & Sung, 1997). This means that the Singapore Government needs to emphasise the importance of mathematics learning as an indispensable component of a technological, scientific and business driven community.

The Singapore Government realises it must adopt an effective mathematics education system to maintain a body of highly skilled scientists and engineers who can ensure the social, economic and political well being of the society. Mr Goh Keng Swee who was one of the founding fathers of modern Singapore and the chief architect of the country's economic development in the 1960s and 1970s, stated in Goh (1996), that it was a deliberate economic move by the Singapore Government to transform its education system in order that Singapore could rival the most advanced countries in the 1960s in technological and scientific expertise. The Singapore Government’s strong focus on science and technology has continued into the 21st century, as shown by Singapore’s 2nd position out of 125 countries in the measurement indicator of technological readiness (this measures the scientific level of information and communication, and other technologies that enhance productivity of its industries) in "The Global Competitiveness Report 2006-2007, World Economic Forum". Thus, mathematics, which provides the foundation for science and technology, becomes an important and compulsory subject that is learnt and tested in schools. All Singaporean students have to go through the compulsory national mathematics curriculum which is examinable in their first ten years of formal education and is given more academic weighting as compared to other subjects. Eventually, the postsecondary education paths taken by them are significantly affected by their mathematics results in the GCE "O" level examination. Thus, a student has to score well in mathematics in order to advance far in the educational system of Singapore. And students who do well in mathematics in Singapore are usually accorded more respect and status among their teachers and peers in schools and the society.

From the above, I believe there may be a unique relationship between the Singapore Government's strong reliance on mathematics education and the formation of students' experiences of mathematics learning. This national emphasis on mathematics seems to be deeply embedded in the culture of the Singaporean society. For example, Singaporean students may be inadvertently led into believing that mathematics and science education is more important than humanities and arts education or their mathematical abilities determine their status in the society. Thus, cultural beliefs about mathematics education in the Singaporean society can play a significant role influencing students' experiences in mathematics learning. This study can further explore such relevant cultural beliefs in the context of engineering mathematics learning.

Evaluation is very important in the Singapore Government's education policies and may affect students' experiences in mathematics learning too. National mathematics examinations have become highly stressful and competitive as good grades in mathematics education are highly sought after in order to advance far in the educational system of Singapore. Therefore, I foresee that this stressful mathematics examination system may have a strong impact on how students perceive and approach mathematics learning here. This, in turn, shapes their overall experiences of mathematics learning. As there are no local studies that have examined this issue, this uncharted area can be uncovered in this study.

2.1.2 Socio-political Aspect of Mathematics Education in Singapore

There are three domains of mathematics competencies in mathematics education as proposed by Skovsomose (1994) - mathematical competence, technological competence and reflective competence. Mathematical competence is the proficient understanding of the concepts and computations of school mathematics, while technological competence refers to the proficient applications of mathematics in technological projects. Reflective competence emphasises on reflecting and evaluating the just and unjust uses of mathematics and its education. The emphasis on mathematics education in a society may surface its unjust social aspects if the reflective competence of its students is just as enthusiastically pursued by its government as compared to the other two competencies. This is supported by Valero & Skovsmose (2002) and D'Ambrosio (1985), who claimed that the side effect of relying on mathematics education economically is the generation of a discriminatory educational system that puts mathematics as authoritarian with undemocratic pedagogical practices. Consequently, a government may not want to incur unnecessary criticism from its people and jeopardise its political reputation by promoting reflective competence in mathematics education. This also means that students who are academically weaker in mathematics may be socially disadvantaged by such education policies that favour mathematics.

The Singapore Government's education policies seem to favour those who do well in mathematics to some extent. However, there is no overt indication from students about such possible unjust social treatment from mathematics education here. There are also no local scholars who have investigated this issue. This may be because Singaporeans are known to be apolitical and obedient citizens. Other possible reasons may be that there exists no such injustice or the Singapore Government consciously discourages reflective competence in mathematics education. Therefore, this study may help in understanding how the unjust social aspects of mathematics education affect students' learning experiences, if they do exist.

2.1.3 Success of Mathematics Education in Singapore

In Singapore, mathematics education is centralised and high regulated. And it has proven to be effective as compared to other countries. This is shown in the International Mathematics Report of Trends in International Mathematics and Science Study 2003 (TIMSS 2003), which uses a questionnaire with different sections to measure different aspects of mathematics learning for both fourth and eighth graders. One section of the questionnaire measures the mathematics achievement score that determines the overall position of the respective countries. This section covers a series of items (it tests the mathematical content areas of numbers, algebra, geometry, data and measurement) answered by the respondents. It is this score in the questionnaire that enables Singapore to emerge as the top country with the highest average achievement in mathematics learning for both fourth graders (out of 25 participating countries) and eighth graders (out of 46 participating countries). Singapore has also outperformed most countries in similar reports of TIMSS 1999 and TIMMS 1995.

The achievement of Singapore mathematics education is also believed to be significant to the economy of Singapore as its science and mathematics education was ranked first in terms of the ability to meet the needs of a competitive economy in the "The Global Competitiveness Report 2006-2007, World Economic Forum". In short, the effectiveness of mathematics and science education may have catered successfully to the economic well being of Singapore.

I foresee the success of the mathematics education in Singapore having further implications on the students who are studying mathematics. Firstly, this will then heap more academic stress on them in learning mathematics as it may become an accepted societal belief that Singaporean students always do well in mathematics education. Such academic stress can be further reinforced on them by the government, schools, teachers, parents and peers. On the other hand, other students who are weak in mathematics may face more pressure or even resent and resist this commonly accepted belief as they cannot meet the national standards set. Therefore, I believe that these contextual conditions above can also influence the unique experiences of students learning mathematics in Singapore. However, this area has not been studied before locally. This study will help in filling up such gaps in the present literature.

2.1.4 The Singapore Mathematics Curriculum Framework

The types of mathematics curricula in schools can influence the students' perceptions of mathematics (Thompson, 1984). Due to its reliance on mathematics education, the Singapore government's economic and political policies influence and shape the type of mathematics curriculum found in schools, which support the aim of high proficiency of students in mathematics. Since 1990, in Singapore, pre-tertiary mathematics education has been guided by The Singapore Mathematics Curriculum Framework where the students learn branches of mathematics that include geometry, algebra, statistics and numbers. This is a pentagon model where mathematical problem solving is the main aim. The five sides (domains) forming the pentagon that support this main aim are concepts, skills, processes, attitudes, and meta-cognition. This pentagon model is shown below.

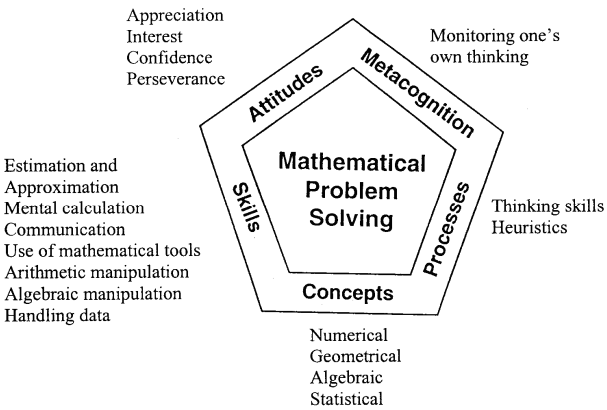


Figure 2.1 The Singapore Mathematics Curriculum Framework

The model encompasses the content to be taught (concepts), its methods (processes, skills, meta-cognition) and the affective aspects of mathematics learning (attitudes). It works towards assisting students in acquiring mathematical problem solving capabilities through the cultivation of the five domains concurrently. All primary and secondary mathematics teachers in Singapore are centrally trained (in the National Institute of Education) to implement this model in their lesson delivery with the support of some standard nationwide endorsed mathematics textbooks. Students in the primary and secondary education systems are centrally examined by the Ministry of Education Examination Board and Cambridge General Certificate of Education Examination Board, respectively.

However, there are some differences between the curriculum approaches of pre-tertiary mathematics and polytechnics' engineering mathematics. Unlike the primary and secondary education systems, each polytechnic is the examining authority for the course modules that make up its diplomas. In addition, engineering mathematics education may not follow the designated approach in the above model adopted in primary and secondary mathematics education. This is because polytechnic lecturers are not centrally trained by the National

Institute of Education. Each polytechnic has the autonomy to train its lecturers and tutors. Therefore, the engineering mathematics curricula may differ to some extent among the five polytechnics' engineering courses.

In the case Polytechnic, all students, most of whom, are aged between 17 and 20 years old, undergo two years (two semesters per year) of compulsory engineering mathematics learning (comprising of four modules) as part of their engineering courses. Students have to complete a coursework component (15% of the final module's grade) that consists of a problem based learning assignment, two e-quizzes and class participation for each of the mathematics modules. They are also required to take a written and closed-book test (25% of the final module's grade) in the middle of the semester. These components are followed by a written and closed-book final examination (60% of the final module's grade) at the end of the semester. The students require a minimum overall grade of 50% to pass the engineering mathematics modules. They learn mathematics concepts that include algebra, trigonometry, complex numbers, calculus, Laplace transforms, statistics, methods of integration, differential equations, infinite series and Fourier series. Then the students need to apply all these mathematics concepts extensively in their other compulsory engineering modules required in the completion of their engineering diploma courses. At the same time, these mathematics concepts tend to be more difficult for the students to master than those they learnt in secondary mathematics education, due to their mathematical complexity and relationships to engineering. Also, the focus of engineering mathematics education centres on the component of skills (in the above model) in relation to engineering theories. The other components of concepts, processes, attitudes and meta-cognition have not been explicitly specified in the engineering mathematics curricula. Such a unilateral approach to the engineering mathematics curricula can influence the students' perspectives of engineering mathematics learning in other ways. However, there is a need to note that there may be other lecturers who adopt the other components not mentioned in the engineering mathematics curricula, in their lesson delivery. In short, in the context of this research, the unique features of the engineering mathematics curricula justify investigation if they affect the experiences of the students. As this has not been investigated in Singaporean research before, this study can help to shed some light on this area.

2.1.5 Engineering Education in Singapore

In Singapore, most of the students are channelled into publicly funded junior colleges, polytechnics, institutes of technical training (ITEs) or universities after their secondary school education. Post secondary education trains the students in specific occupations to support the social and economic aims of the Singaporean society (Law, 2007). The differences between these educational institutions in the context of Singapore are described by Law (2007: 12-13):

> "Depending on their academic achievements (students' performance in GCE "O" level examinations), aptitude and interests, about 90% of a student cohort would progress to the Junior Colleges, Polytechnics or Colleges of ITE. Today, the Junior Colleges provide an academic high school education for the top 25% of a school cohort for a university education. The next 40% of school leavers would enter the Polytechnics for a wide range of practical-oriented three-year Diploma courses in preparation for middle-level professions and management. The lower 25% of a school cohort, in terms of academic abilities, are oriented towards vocational technical education in ITE Colleges."

However, it has to be qualified here that students who do well in their ITE courses can still advance to polytechnic education. Likewise, strong performers in polytechnic education are given opportunities to acquire university education.

As this study is focused on the learning of engineering mathematics at polytechnic level, more background information on polytechnic engineering education in the context of Singapore is provided below. Polytechnic education was first started by the Singapore Government in 1960s to provide technical and engineering education for its people, with the aim of industrialising the nation. This was planned in response to the nation's economic needs as its traditional commerce, trading and service domains were deemed insufficient to sustain the economy at that time (Goh, 1996). Thus, polytechnic education became the major avenue to support engineering education that was deemed to be very important in the nation's new industrialisation plan (Goh, 1996; Law, 2007). As the economic needs of Singapore change through the decades, polytechnic education has responded swiftly and flexibly by diversifying courses from its original focus on engineering to other disciplines such as life sciences, business, information technology, computing, nursing, biotechnology, design and e-commerce that are also highly relevant to the global economy in the 21st century. In spite of the presence of these new disciplines, engineering education still remains a national priority till now.

The Singapore Yearbook of Manpower Statistics provides very useful data to support the above conclusion. The statistics below do not include those students who enrol in engineering courses in private institutions. As the above statistics only refer to public tertiary institutions funded by the government in which the bulk of Singaporean students are enrolled, it is a better representation of the extent of the emphasis the government places on engineering expertise. The figures from the Singapore Yearbook of Manpower Statistics (2006:131-154) showed about 60% (6207 out of 9374 graduates) of graduates from the public institutions of technical training, 32.9% (6095 out of 18485 graduates) of graduates from the four public polytechnics and 24.6 % (4296 out of 17455) of graduates from the three main universities are engineering trained. In fact, a total of 22.3% of the 424,191 university graduates produced since 1960s, are from the engineering field (Ang, 2006). The overall data above also clearly showed that graduates from the engineering field form the bulk of the students trained by the Singapore Government. This has been the trend for the past 10 years (Ministry of Manpower Statistics, 2007). Thus, this is strong evidence that the government values engineering education.

The above statistics is largely influenced by the engineering of the education policies by the Singapore Government. As these educational institutions are publicly funded, the Singapore Government has the flexibility to decide the enrolment numbers for each course to meet the future economic and social demands of the society. One of the training areas that is always emphasised in Singapore is post secondary engineering education. Engineers in all fields (electrical, electronic, mechanical, civil, chemical, biological, aeronautical, marine and other sciences) are very important to Singapore in meeting technologically and scientifically driven needs within a global economy. Thus, every year, a substantial number of students are routed into engineering education in tertiary institutions by the Singapore Government.

However, I do foresee an issue here in understanding the students' experiences of engineering mathematics learning. The strong governmental emphasis in engineering will raise its economic value in the eyes of some students. In a perfect scenario, all academically stronger students (especially in mathematics) will opt for engineering courses. However, nowadays, engineering careers may not be attracting the best students in Singapore. This is supported by a trend that arises recently in engineering education here which is highlighted in Singapore's main English newspaper, "The Straits Times" on 16 June 2006, titled "Engineering 'boring'? Get the young excited." It was shown in the report that science and engineering related courses are being shunned by students here. Most of the academically stronger students prefer to choose other courses such as business, social sciences, humanities and mass communication. Nevertheless, in maintaining the economic well being of the country, the Singapore Government has to enrol a large percentage of students in engineering courses yearly. As a result, there may be a substantial number of academically weaker students (especially in mathematics) who are unwillingly enrolled in them as they cannot get into the courses of their preference. This is because the vacancies in their preferred courses are taken up by other students who have better GCE "O" examination results. Although these students can choose to enrol in their preferred courses in private institutions, most of them cannot afford their high fees (as compared to the fees of publicly funded polytechnics that are heavily subsidised by the government). Consequently, most of them have no other choices but to reluctantly enrol in their current engineering courses that have a surplus of learning places. This happens in spite of the fact that most of such students have little or no interest in engineering and are weak in mathematics. And the irony is that a strong secondary mathematics education is a pre-requisite in entering engineering careers. However, nowadays, students who are very weak in mathematics are also enrolled in engineering courses. This will possibly result in another set of students' perspectives that are different from others who are voluntarily enrolled in engineering courses. As there are no known local studies that address this issue, this area is worth exploring in this study.

2.1.6 Mathematics in Engineering Education

Engineering education depends significantly on the mastery of mathematics. Engineering students understand that mathematics is the foundation of engineering (Graves, 2005). In the specific context of engineering students, this becomes an extra academic load for them as mathematics is an indispensable part of engineering. Therefore, I anticipate this unique relationship between mathematics and engineering further skews students' perspectives of learning engineering mathematics as compared to other non-engineering courses that require some mathematics knowledge too. The importance of mathematics in engineering may be especially prominent for engineering students who are academically weaker in mathematics as it will create more academic stress for them. As there are no local studies that address this issue, this study can help in investigating this aspect. Although, this study can help in understanding how the importance of mathematics affects engineering students, it is not within its scope to compare it between engineering and non-engineering students. However, it does serve as an interesting option for further relevant studies.

2.1.7 Social Agents of Engineering Mathematics Education

The students' experiences of studying mathematics are further influenced by social agents such as teachers, peers and parents. The social context of the schools in which the students interact with their peers and teachers may influence their beliefs about mathematics learning (McLeod, 1992). At a micro level, mathematics teachers' beliefs about mathematics education play an important role in influencing the students' perspectives of mathematics learning. Some teachers may aim to help students understand the logical proofs of mathematical concepts to allow them to appreciate the beauty of mathematics (Hiebert & Lefevre, 1986). On the other hand, other teachers may believe that it is more important to help students solve mathematics problems to achieve the pragmatic purpose of passing examinations (Cooney, 1992; Hiebert & Lefevre, 1986). The teachers' beliefs about mathematics education in turn influence the types of pedagogies used by them. These pedagogies can be teacher-centred or student-centred. Some teachers may relate the learning of mathematics concepts to solving problems in real world contexts. This can be achieved through the use of computer simulations of these real life problems (Habre & Grundmeier, 2007). On the contrary, other teachers may emphasise mechanical "drilling" to familiarise the students with different types of mathematics questions that may be tested in examinations (Cooney, 1992). These differences in pedagogies used by the teachers in turn have an effect on the students' views of mathematics learning.

At the same time, the constraints of the context of the school, such as curriculum, pedagogical or time constraints, may dictate the teachers' perceived aims of mathematics education and their pedagogies used (Jaworski, 2003, 2004; Ernest, 1989; Lerman, 1986). In the case Polytechnic, each engineering mathematics module is made up of two hours of lectures and two hours of tutorials every week for one semester (15 weeks). Each lecture is usually conducted in a lecture theatre of 60 to 80 students, while tutorial classes are limited to a maximum of 20 students each in seminar rooms. New mathematics concepts are taught during lectures and students need to solve a stipulated number of mathematics questions during tutorials. As mathematics lecturers have to handle a substantial number of students of 60-80 at a time, this may constrain the types of pedagogies they can utilise. Besides, the amount of mathematics content (as defined by the curriculum of each module) to be taught may well be huge as commonly opined by the mathematics lecturers. This can put further strain on the lecturers' limited teaching hours. The shortage of teaching time is usually exacerbated by the diversity of students' mathematical abilities in each class. This may result in the lecturers needing to spend more teaching time on certain topics for the academically weaker students. Coupled with these pedagogical, time and curriculum constraints, the institution sets a minimum of a 95% pass rate for all academic modules as part of its key performance targets. This target needs to be collectively achieved by all the lecturers and tutors teaching each of the engineering mathematics modules. Thus, lecturers may face further pressure in fulfilling the high passing rate set for their classes. Such curriculum, pedagogical or time constraints and institutional expectations may well change the lecturers' beliefs about engineering mathematics education and their pedagogies. Therefore, it would be fruitful to investigate how such teaching and learning contexts, as influenced by the various constraints, shape the perspectives of engineering students (and staff) as it has not been investigated in Singapore.

Besides imparting mathematics knowledge to their students, teachers may also influence their attitudes towards mathematics learning through the social and affective support they provide to them. As mentioned earlier, the Singapore Mathematics Curriculum Framework also aims to cultivate desirable personal characteristics or feelings such as appreciation, interest, confidence and perseverance (Attitude domain) in mathematics learning and this important job is tasked to the teachers. I have experienced and seen mathematics teachers who work purely in imparting knowledge to their students, ignoring the Attitude domain totally. On the contrary, there are also teachers who attempt to influence their students' attitude in mathematics learning through their social interactions with them. They may attempt to know their students personally, set academic expectations for them and provide different types or levels of affective support for them.

In the context of this study, lecturers usually treat the students as mature students (as they are at least 17 years old) and concentrate on imparting content knowledge to them. The inculcation of the desirable attitudes in mathematics learning may not feature prominently in this polytechnic context as lecturers typically believe that the students are mature enough to be independent in their learning. All these may yet create different sets of students' experiences in mathematics learning. However, it is a research area that is neglected in Singapore.

In summary, pedagogical, affective and social influences from teachers, in mathematics learning, may come in the form of their class management strategies adopted (*management of learning*), affective strategies used (*sensitivity to students*) and the levels and types of cognitive tasks they posed to the students (*mathematical challenge*) (Jaworski, 2002). I would conclude that it is important to understand how the students' experiences of mathematics learning (in terms of their views, intentions and strategies) are affected by their teachers' beliefs about mathematics education, pedagogies and affective influence on them in terms of learning engineering mathematics. This study can thus help to fill up these gaps in the local literature.

Peer influence is a very powerful force in young people looking for identity endorsement and approval from their peers. Studies have stressed the positive effect of peer interactions on students' performances in mathematics learning especially those of higher ability students on the lower ability students (Ballantine, 1997; Perret-Clermont & Schubauer-Leoni, 1988; Sternberg & Wagner, 1994; Zimmer & Toma, 2000). This is supported by Vygotsky (1978) who believed that social interactions are powerful in promoting learning of lower ability student if he/she is interacting with a more competent peer. However, Hanushek (1992) argued that there is no effect on the achievement of lower ability students through interactions with higher ability ones. Davidson (1990) also stated that co operative, collaborative or group learning in mathematics can be effective for students' learning. In summary, I feel that these reviewed studies may be of limited applicability in this research as they are mostly statistical and have investigated the correlation between the students' academic ability in mathematics and peers' influence. In this study, it is more important to understand how peers, especially in the context of polytechnic education, influence the students in their views, intentions and strategies in mathematics learning. However, this is found lacking in the local literature. Hence, this study can help to uncover this neglected area.

Studies also showed that parents' educational standards, beliefs and expectations about mathematics have effects on students' attitudes and aspirations towards mathematics learning (Armstrong & Price, 1982; Cain-Cason, 1986; Cai et al., 1997). There is also a positive correlation between mother's attitudes and the children's attitudes, towards mathematics learning (Cain-Caston, 1986). Moreover, Cai et al. (1997) reported that positive parental support is related to positive attitudes towards mathematics and higher mathematics achievement by the children. However, the research of Balli et al. (1997) showed that there is no improvement in mathematics achievement despite increased intervention by parents. It is also shown that the socio-economic status of the parents plays a part in influencing students' experiences of learning mathematics (Hao, 1995). There are divides in studies' results in investigating the influence of parents on students' mathematics learning. However, the studies above do show parents' educational standards, socio-economic status, expectations, beliefs and support, influence the experiences of the students in learning mathematics. Nevertheless, these studies do not describe how these factors affected the students' experiences in terms of their views, intentions and strategies in mathematics learning as they are mainly survey based. More importantly, in the context of this research, the students are learning a more specialised form of mathematics that is related to engineering. Thus, it would be interesting to see if parents can play a significant part in affecting the students' experiences in engineering mathematics learning through this research.

2.1.8 Conclusion

Summarising from all the studies in this first main section, they enable me to conclude that the importance of mathematics education has become a cultural norm for the Singaporean society, which values the social, economic and political benefits that flow from it. This thus affects the experiences of students in mathematics learning as influenced by the government, schools, teachers, peers and parents. The government can influence the experiences of engineering mathematics learners through education and economic policies that favour mathematics learning. At the same time, negative social aspects of mathematics education may surface. The characteristics of the engineering mathematics curriculum and the demanding institutional academic targets can play significant adverse roles in affecting the students' perspectives in engineering mathematics learning. Besides, mathematics lecturers and tutors, as constrained by the macro factors mentioned above, may influence the students' learning socially, pedagogically and affectively. Lastly, peers and parents, through their social interactions with the students, can also shape the students' views in engineering mathematics learning. In short, all these socio-economic-political background factors provide the contextual conditions for this study of engineering students' experiences of studying mathematics. However, a major concern I foresee here is that the influence of these background factors are not substantiated in local studies. Nonetheless, by conducting of this study, these gaps in the local literature can hopefully be filled.

2.2 Formation of Students' Intentions in Mathematics Learning

Students form views related to learning. More specifically in mathematics learning, Kloosterman (2002) conducted a comprehensive study of the views of mathematics students. He found that their views are so diverse that it is difficult to generalize from them. Besides, students also report that their views of mathematics learning often change as they advance from lower levels to advanced levels of mathematics (Kloosterman, 2002). This study does not attempt to describe and generalize all the views (only a range of such views) of engineering students studying mathematics. Instead, in grounded theory tradition, this study focuses on the dimensions of conditions, processes and consequences in understanding the experiences of engineering mathematics learning. Thus, understanding the various views of mathematics learners through the studies below is vital to this research as they allow me to be theoretically sensitive to a huge diversity of students' views of mathematics learning. This will aid me in my data collection and analysis and in the task of developing a theory about engineering students' experiences of studying mathematics.

2.2.1 Students' Views of Studying Mathematics

In some societies, students may perceive mathematics learning to be difficult and abstract (Ernest, 1996). On the other hand, other societies may view mathematics as valuable and challenging and see those who do well in it as well respected and intelligent (Zhang et al., 1990). Students may believe that mathematics is useful and important in the societies they are in (Presmeg, 2002). Furthermore, effort is viewed by students as the key to good performance in mathematics in many Asian societies (Zhang et al., 1990; Chen, 1995). But in many other societies, students believe that mathematics learning is dependent on one's ability more than one's effort (Chen, 1995; McLeod, 1992; Kloosterman & Gorman, 1990). In short, students' experiences of mathematics learning are influenced by the beliefs of the societies they are in.

Students seem to hold a variety of views of mathematics in the classroom too. Across the academic levels, elementary students see that effort, regardless of ability, is the key to learning mathematics, but when they advance to high school level, they see the lack of ability as a significant impediment in mathematics learning (Kloosterman & Cougan, 1994). In the classroom, some students may believe that a good grade is important in mathematics assessment, while others may not (Hurn, 1985). Some students view mathematics learning as interesting, others may believe that it is a form of tedious and monotonous work (Cotton, 1993;

Cooney, 1992). Others may even see mathematics as a subject that causes them negative emotions such as fear, anxiety and anger during lesson (Hoyles, 1982). Some students feel that they learn mathematics because of their intrinsic interest in it (Kloosterman, 2002). At the same time, some students may view mathematics learning as being forced on them by schools and teachers (Ainley et al., 2005; Cotton, 1993). These students may possibly feel that they do not understand the "purpose" of the mathematics tasks assigned to them and thus see no meaning in doing these exercises (Ainley & Pratt, 2002). Students may also feel that some of the so called real world contexts used by teachers to relate to mathematics concepts may not be interesting to them and even create confusion in their problem solving (Ainley, 2000; Silverman et al., 1992). In terms of learning mathematics effectively, Kloosterman (2002) reported that students view procedures as more important than concepts. They also feel that memorisation is an important part of mathematics learning (Kloosterman, 2002). In relation to social influences in mathematics learning, some students may believe that teachers make learning mathematics difficult to understand and give little guidance to their mathematics learning (Kloosterman, 2002). On the other hand, other students may view mathematics as a subject where failure to achieve the right answers is usually met with disapproval and criticism by their teachers (Ernest, 2004). At the same time, some students may recognize that peers can help or impede them in their mathematics learning (Perret-Clermont & Schubauer-Leoni, 1988; Sternberg &Wagner, 1994; Zimmer & Toma, 2000). Specifically, Shaw & Shaw (1999) provided an interesting description of the types of engineering students learning mathematics. They classified them into five groups: Ambivalent with poor pre university teaching, Downhillers, Haters, Ambivalent with good pre university teaching and High fliers. These students perceive engineering mathematics differently in terms of its difficulty, the helpfulness of the teachers and lecturers, their level of liking and enjoyment of it, motivation in studying it and keenness in improving their mathematical capability (Shaw & Shaw, 1999).

The various studies above lead me to presume in this study that students can hold a huge diversity of views about mathematics learning at personal, social, conceptual, procedural, cognitive and emotional levels. However, the types of views discussed above are not exhaustive and cannot be representative of all mathematics students. Moreover, my belief is that most of these views are only representative of primary and secondary mathematics students and may not fully characterize those of tertiary students studying engineering mathematics. While the above literature is generally not representative of tertiary students, I still consider them important in this research as it can help to depict the possible changes in the students' views of mathematics learning as they move from pre-tertiary to tertiary levels. At the same time, they serve as a reference database for the interview questions to be developed for the data collection stage in this study. Another issue here is that most of these studies do not attempt to further explore how students' views of the discipline affect their intentions regarding the study of mathematics. Such investigation is important as students' intentions can affect their level of expectation and desire to do well in it eventually (Huang & Waxman, 1997). Thus, this study may help fill the missing gaps in the present literature.

2.2.2 Views of Singaporean Students in Studying Mathematics

Although there are few such studies in Singapore, two recent large scale studies did investigate on Singaporean students' views of mathematics learning. Fan et al. (2005) conducted a study of more than 1000 secondary 1 (Grade 7) students' attitudes towards mathematics learning and showed that they generally like it, understand its importance, put effort into learning it but do not perceive it to be useful in their adult life.

Another source in regard to students' views in mathematics learning is the International Mathematics Report of Trends in International Mathematics and Science Study 2003 (TIMSS 2003). It showed that most Singaporean students view mathematics as important to them due to its prominence in their daily lives, learning of other school subjects, getting into their preferred universities and working in their preferred occupations.

There is a disagreement between Fan et al. (2005) and TIMMS 2003 in students' perception of the usefulness of mathematics in their adult life. This can be further investigated in this study. In both studies, there is a minority of students who pose opposite views of mathematics learning as compared to the majority of the investigated population. Thus, I can foresee the question of how these opposite views influence their experiences regarding mathematics learning. This may be the side effect of the extra academic stress in mathematics education as mentioned earlier. However, this is not addressed in TIMMS 2003 and Fan et al. (2005) as they use closed questionnaire based surveys with pre-determined questions. Therefore, both studies have limited exploratory power in this aspect. Besides, due to the lack of such relevant studies in the local Singapore context, I think that there may be other possible students' views of mathematics learning that affect their experiences. Thus, this study, being grounded theory based, can help to fill this gap in the present relevant literature.

In summary, the above studies provide some useful insights about the views of students on studying mathematics. But the study of the students' intentions in mathematics learning which is important in this study is not catered to in these studies. Knowing the students' intentions is vital in understanding their actions and interactions in mathematics learning. In this study, I would hypothesize that certain views of significance or value of mathematics learning to the students personally can influence their intentions in it considerably. Thus, this area needs to be extensively investigated in this study. Another issue here is that these students' views of mathematics learning in secondary and primary levels may be different from the tertiary level of engineering mathematics learning. Consequently, this study may help fill the gap in the present literature by linking the students' views of mathematics learning to their intentions in studying it, in the local context of engineering mathematics learning.

2.2.3 Significance of Mathematics Learning to Students

The students' views of learning may influence their intentions - that is, what they hope to gain from it. These intentions are aims set by them in satisfying their needs or desires as identified in their learning. Generally, human needs can be classified as according to Maslow's Hierarchy of Needs and Murray's Taxonomy of Needs (Maslow, 1954 & Murray, 1938 in Schunk, 2008). I believe that students' learning needs can be possibly found in the above typologies and they may affect their intentions in learning significantly.

Specifically in learning, students form intentions or aims in learning if they can envisage tangible or intangible rewards (these rewards satisfy their individual needs) for themselves by engaging in it (Pintrich & De Groot, 1990; Grouws & Lembke, 1996). Therefore, in the case of mathematics learners, I assume that they will form intentions in mathematics learning if they believe that it is of certain value or significance in their lives. Thus, by understanding the significance of mathematics learning to the students, it helps to address the second specific research question: **How are the students' intentions in engineering mathematics learning formed?**

Some students believe that mathematics learning is significant to them as they enjoy it and see it as a form of intellectual challenge (Kloosterman, 2002). Thus, their intention in mathematics learning is to fulfil their personal intellectual satisfaction. On the other hand, the importance of mathematics learning to other students may be socially influenced. Students may believe that mathematics learning is significant to them because it enhances their social status in societies, especially in those where people who do well in mathematics learning are highly respected (Zhang et al., 1990). Therefore, their intention in mathematics learning is related to the accomplishment of respectable social status in their society. At the same time, other students' intention in mathematics learning may be more pragmatic when they believe that it may affect their future working careers in technologically driven societies (Presmeg, 2002). Thus, they feel that mathematics is very vital for their future livelihood and this becomes their intention in mathematics learning. The significance of mathematics learning to some students can be established at a micro level as influenced by their parents and teachers instead of being influenced by the society at a macro level. Mathematics learning is important to some students as it may elicit praises or materialistic rewards from their parents or teachers if they meet their expectations in it (Kloosterman, 2002; Cotton, 1993; Ernest, 2004). Such acknowledgement from the parents and teachers is important in the maintenance of their self worth in mathematics learning and personal materialistic satisfaction. The students' self worth in mathematics learning is important to them as it determines their academic and social standing in their mathematics class (Hicks, 1997). Being financially dependent, they also need their parents' financial backing to satisfy their materialistic needs through excelling in learning. On the contrary, punishments such as reprimand or privilege deprivation are imposed on some students by their parents or teachers as they cannot do well in mathematics learning (Ernest, 2004). And, since they cannot excel in mathematics learning, their intention is to avoid or minimise punishment from their parents and teachers (Kloosterman, 2002). At the same time, other students may not see any significance of mathematics learning to them at all as they believe that it is uninteresting and monotonous or a chore forced onto them by schools and parents (Cotton, 1993; Ainley et al., 2005; Cooney, 1992). Thus, they may form intentions of resisting or avoiding mathematics learning instead.

After examining the above studies, I see them as relevant to this research because they acknowledge that the significance of mathematics learning to the students plays a part in determining their intentions in mathematics learning. At the same time, I presume that these studies can provide useful guidance in data collection and analysis. However, I believe that an open mind in data collection has to be maintained as the above studies do not provide an exhaustive list of the reasons behind the significance of mathematics learning to students as there may be other possible reasons behind it. Besides, this data analysis process must take in account of the contextual issues presented earlier too. Lastly, the above studies have been done in the context of primary and secondary mathematics learners in Western societies. They are not representative of the local context of studying mathematics. Therefore, I see their relevance in this study being questioned to some extent. The present study can help to fill these gaps in the present literature.

2.2.4 Possible Categorisation of Students' Intentions in Mathematics Learning

From the above, it is hypothesised that the students' intention of mathematics learning is strongly influenced by its significance to them. It is also shown that mathematics learning can be important to students either personally or socially, at both macro and micro levels. Examining studies such as Elliot & Harackiewicz (1996), Diener & Dweck (1978), Hoyenga & Hoyenga (1984), Maehr & Braskamp (1986), Middleton & Midgley (1997) and Kloosterman (2002), I found that the intentions proposed by the earlier studies can fit into three general types: mastery-oriented, ego/performance-oriented or work avoidance-oriented.

Firstly, if the students view that studying mathematics is for the pure joy of learning and gaining knowledge, their intention of learning is mastery-oriented (Diener & Dweck, 1978; Kloosterman, 2002). Thus, such mastery-oriented intentions are intrinsically motivated and not influenced by external factors. Secondly, the students' intention in mathematics learning is ego/performance-oriented if they aim to gain acceptance or rewards from external sources such as society, teachers, peers or parents, or be superior to others through academic comparison (Hoyenga & Hoyenga, 1984; Maehr & Braskamp, 1986; Kloosterman, 2002). Lastly, the students' intentions in mathematics learning can be work avoidant if they intend to avoid or minimise mathematics learning (Middleton & Midgley, 1997; Elliot & Harackiewicz, 1996). Such ego/performance-oriented and work avoidance-oriented intentions are dependent on external factors and are usually extrinsically motivated.

Working on the basis of the categorisation of intentions in terms of mastery, ego/performance and work avoidance, based on the above authors, I believe that it helps in providing a focused direction in the initial data analysis stage. However, there is a need to be cautious that this direction may not be the final one as new developments can occur during data analysis. Besides, I also anticipate three other problematic issues in this study. Firstly, I notice that these studies do not specifically take into account the context of students studying engineering mathematics in the social, economic and political milieu of Singapore. Thus, their relevance to this study is questionable. Secondly, my thought is that students can have more than one intention in their mathematics learning in contrary to the above studies. And this is supported by Hannula (2006) who stated that the types of intentions may not be mutually exclusive, but instead complementary or hierarchical. Thirdly, Klein (2002) argued that a student may have certain intentions in learning that are not congruent with the cultural norms in the society or classroom. Thus, they cannot actualise their intentions (Buzeika, 1996). To me, this means that a student may have to hide or change their original intentions and possibly apply strategies congruent with the cultural norms of the society instead. This is possibly because of their aim of gaining acceptance or rewards from the society by being compliant (Hoyenga & Hoyenga, 1984; Maehr & Braskamp, 1986). Thus, I would ensure that all these three issues are consciously taken care of during the research process in this study.

In short, students form views in mathematics learning. From some of these views, students understand the significance of mathematics to themselves. I agree with Grouws & Lembke (1996) and Vroom (1964) that the significance of mathematics to the students can be either tangible in the form of external social, academic and materialistic rewards or intangible in the form of personal satisfaction and stress removal. Such significance of mathematics learning will be thoroughly investigated in this study. The students will form intentions in mathematics learning to support their perceived significance of mathematics learning to themselves. This study will initially adopt the basis that intentions may be mastery-oriented, ego/performance-oriented or work avoidance-oriented.

2.2.5 Intentions of Engineering Students in Mathematics Learning

Specifically in the domain of mathematics learning, the significance of mathematics learning to engineering students may be different from primary or secondary school students. Engineering students understand that mathematics is the foundation of engineering (Graves, 2005; Steen, 1988; Peterson, 1996). Therefore, engineering students usually believe that mathematics learning is vital to them as it allows them to understand engineering concepts and solve engineering problems. They also understand that the mastery of engineering mathematics is essential in performing their engineering skills competently in their future work careers. On the other hand, failure in mathematics modules will impede their completion of their engineering diplomas or degrees for some academically weaker engineering students. Thus, mathematics learning becomes significant to this group of students in completing their engineering courses. Although there are few studies that substantiate such probable conclusions of the significance of mathematics to engineering students, I expect them to be useful in this study in improving my theoretical sensitivity as a researcher. However, it should not be assumed that they are the only reasons behind the significance of mathematics learning to engineering students as there may be others not uncovered due to the lack of such studies. Besides, in understanding this significance, there is a need to take into account both macro and micro factors in the unique context of mathematics learning in Singapore as mentioned earlier. Thus, the present proposed study can contribute significantly to such relevant literature on mathematics learners in tertiary engineering courses.

2.3 Strategies Resulting from Students' Intentions in Mathematics Learning

This section of the literature review can help address the third research question: **What strategies will the students use in realising their intentions and why are they used?** Students' behaviours are directed by the intentions they have (Ajzen & Fishbein, 1980; Cooney, 2001; Hoyles, 1982; Yackel & Cobb, 1996; Franke & Carey, 1997). Thus, strategies are formulated by the students to actualise their intentions in mathematics learning. In this study, I would term all forms of behaviours as strategies if they are purposive processes and actions intended in achieving the students' intentions in mathematics learning. In mathematics learning, these strategies may be cognitive, meta-cognitive, affective and external resources management-oriented (Anthony, 2005; Gonzalez Lopez, 2005). As mathematics is usually considered certain, ahistorical, value free and culture isolated (Ernest, 1991; Bishop et al., 2000), most of the present studies in mathematics learning had focused on the detailed cognitive and meta cognitive processes of problem solving in different fields of mathematics such as arithmetic, algebra, geometry or calculus (Gutierrez & Boero, 2006; Kieran, 2006). However, this study does not attempt to adopt their cognitive and mathematical process based approach. This is because I believe that along with cognitive factors playing an important part in how the students cope with mathematics learning, social factors also feature prominently in their coping strategies. This study will attempt to understand how the students cope with learning engineering mathematics as influenced by the social factors around them.

2.3.1 Types of Coping Strategies in Mathematics

Mathematics learning can be considered as a stressful event due to the socially imposed demands and expectations on Singaporean students, as pointed out earlier. This source of stress worsens for many students who find mathematics difficult and problematic (Jackson & Leffingwell, 1999; Burns, 1998; Misra & McKean, 2000). Therefore, I see it appropriate to look into the coping literature on how students manage stressful events in order to understand how they cope with mathematics learning. In coping literature, Lazarus & Folkman (1986) first categorised coping strategies in stressful situations into either problem focused (taking behavioural action to alleviate problematic event) or emotion focused (alleviating the expected emotional or physiological distress of the problematic event through controlling or discharging emotions). Later, Carver et al. (1989) divided coping into active and avoidant strategies while Higgins & Endler (1995) grouped it into three categories: task-oriented, emotion-oriented, and avoidance-oriented. Cartwright & Cooper (1996) instead perceived coping strategies as being categorised into adaptive and maladaptive ones.

Examining studies that have investigated coping strategies in learning, they draw similar conclusions to the above coping literature. There are strategies that are positive, self regulatory and consciously displayed by students to improve their learning (Zimmerman, 2001; Boekaerts, 1993). They are termed as approach strategies (Covington, 1992; Newman & Goldin, 1990). Scrutinizing these approach strategies, they are synonymous with the problem focused coping suggested by Lazarus & Folkman (1986), active coping proposed by Carver et al. (1989) and the task-oriented coping in Higgins & Endler (1995). They are also adaptive as suggested by Cartwright & Cooper (1996). On the other hand, if students do not have successful approach strategies, they turn to exhibiting negative coping strategies such as refusing to seek help, avoiding the tasks (avoidant behaviours) or disrupting the class (disruptive behaviours) as they do not know how to, or do not want to, perform the learning tasks allocated to them (Covington, 1992; Newman & Goldin, 1990; Woods, 1980, 1984). These negative coping strategies are termed as avoidant or disruptive strategies (Covington, 1992; Newman & Goldin, 1990). I would place avoidant or disruptive strategies in the same category as the avoidant coping strategies in Carver et al. (1989) and Higgins & Endler (1995). And they are usually maladaptive as suggested in Cartwright & Cooper (1996). As for the emotion-oriented strategies as proposed by Lazarus & Folkman (1986) and Higgins & Endler (1995), I would perceive them as present in both approach and avoidant strategies. For example, a student can improve in his/her mathematics learning by trying to maintain relaxed and positive, while another can vent his/her anger on mathematics learning so as to avoid it. However, academic emotions are seldom researched on in educational psychology, especially in subjects like mathematics and science (Pekrun et al., 2002). I believe this is due to the common perception that mathematics is a pure cognitive endeavour that is out of bounds to emotional responses. This study will attempt to explore this area but, at the same time, caution will be taken not to enter too much into the psychology of mathematics learning that is outside the scope of this study.

Eventually, there is a need to relate students' intentions in mathematics learning to their coping strategies. Ryan et al. (2001) and Midgley et al. (2001) reported students who have mastery- and ego/performance-oriented intentions usually employ lesser avoidance and disruptive learning behaviours than those who espouse work avoidance-oriented or disruptive-oriented intentions. However, there are no studies that investigate the relationship of the students' intentions and strategies in engineering mathematics learning. Thus, this study can help to explore this area.

2.3.2 Singaporean Students' Strategies for Coping with Mathematics Learning

There are few studies that investigate the strategies utilised by Singaporean students in mathematics learning. Fan et al. (2005) showed that Singaporean students utilise the strategies of practice and revision in mathematics learning in secondary schools. In his study of avoidant and disruptive strategies used by a class of secondary two students in their mathematics learning in Singapore, Khiat (2006) suggested the categories of procrastinating behaviours, delusive behaviours and resistant behaviours. However, both studies were done in the context of secondary school students which might not be relevant in the context of tertiary settings in this study.

In the domain of engineering mathematics, Ee & Wong (2005) also mentioned a repertoire of behaviours students exhibited during lectures. They include both approach strategies and avoidant or disruptive strategies. However, Ee & Wong (2005) used a closed questionnaire for the single scenario of an engineering mathematics lecture. Therefore, my view is that Ee & Wong (2005) did not depict the possible wide repertoire of strategies used by students in all possible situations in engineering mathematics learning.

2.3.3 Summary

In short, there is hardly any literature on the strategies employed by students in engineering mathematics learning. Therefore, my belief is that it would be useful to understand the various strategies (approach, avoidance or disruptive) displayed as influenced by the social, political and economic milieu the students are situated. This will then help to fill the relevant gaps in the current literature.

2.4 Consequences Resulting from the Strategies of Students in Mathematics Learning

The fourth research question will be addressed here: **What are the expected consequences of the strategies on the students in engineering mathematics learning?** In this study, I shall argue that the consequences of the students' strategies can strengthen or modify their original views, intentions and strategies in studying mathematics. For example, two students may initially view that mathematics is important in their future work careers and utilise approach strategies in achieving their intention. One of them does well in mathematics examinations, thus retaining his/her original intention and strategies in studying mathematics. This will then make up his/her eventual experience of mathematics learning. The other student may keep on doing badly in mathematics examinations and begin to view mathematics as detestable, thus change his/her original intention of getting good grades into avoiding mathematics learning. This will result in new avoidant strategies in learning mathematics. This may finally result in a permanent negative experience of learning mathematics. However, the above scenarios are only my own presumptions and the study's findings may verify or disconfirm them later.

The consequences resulting from the strategies of a student's intention in studying mathematics learning can be tangible or intangible. In tangible form, a student can earn incentives such as materialistic and verbal rewards or sanctions such as reprimand and privilege withdrawal, from external sources like teachers, parents, schools and society. In intangible form, a student can experience emotions or influence their personal characteristics such as self worth, persistence and confidence.

2.4.1 Consequences of Approach Strategies

Successful approach strategies usually mean better mathematics achievement, self fulfilment, praise from teachers and parents, and acknowledgement from peers. This will help the students improve their internal characteristics such self confidence and persistence in mathematics learning, gain materialistic rewards and elicit positive emotions such as joy and pride (Covington, 1992; Ingleton, 1999; Turner et al., 2002; Stipek et al., 1998). On the other hand, other students may only perceive mathematics learning a route to acquiring materialistic rewards. In summary, I would picture them as possible consequences of the experiences of mathematics learning of some students who utilise approach strategies successfully.

2.4.2 Consequences of Avoidant or Disruptive Strategies

Students' work avoidant intentions can dictate their behaviour with powerful and usually negative consequences (Schoenfeld, 1992). By avoiding tasks or being disruptive in class (self handicapping), they can safely attribute their lack of success in the tasks allocated by giving the excuse that they do not perform the task at all, thus it is not constituted as a failure (Covington, 1992). This also allows the students to retain their feelings of self worth and avoid negative emotions in mathematics learning (Covington, 1992; Ingleton, 1999). However, they are still required to take school and national examinations eventually and may face failures in them. Through experiencing such continuous failures in mathematics examinations, they may fall into a state of learned helplessness where they make negative evaluations of their abilities in mathematics learning and strongly believe that they can never do well in it (McLeod & Ortega, 1993; Boekaerts, 1993). Others may even blame other external factors, such as teachers, peers, society for their failure in learning (Covington et al., 1980; Covington, 1992). Consequently, these students may display permanent negative and pessimistic views towards the mathematics learning. The above scenarios can possibly depict the consequences of mathematics learning suffered by students who use avoidant or disruptive strategies.

In summary, the consequences of mathematics learning can be tangible or intangible and they may affect the internal characteristics of the students. However, I would caution that there may be other possible consequences of different strategies in mathematics learning. Besides, these studies were not conducted in the context of engineering students studying mathematics. Therefore, this study will attempt to uncover other consequences of their strategies previously not explored.

2.5 Preliminary Theoretical Framework

The main research question in this study is **"What are the students' experiences of studying mathematics as part of their electrical and/or electronic engineering diploma courses in a polytechnic in Singapore?"** Its four specific research questions are:

a. **What are the societal factors that influence the students' experiences in studying engineering mathematics?**
b. **How are the students' intentions in engineering mathematics learning formed?**
c. **What strategies will the students use in realising their intentions and why are they used?**
d. **What are the expected consequences of the strategies on the students in engineering mathematics learning?**

In order to answer the four specific questions above, a theoretical framework is proposed. As defined in this study, the students' experiences of studying engineering mathematics are made up of their views, perceived significance, intentions, strategies and the resultant consequences of studying it. The theoretical framework below is used to represent the students' overall experience of studying engineering mathematics.

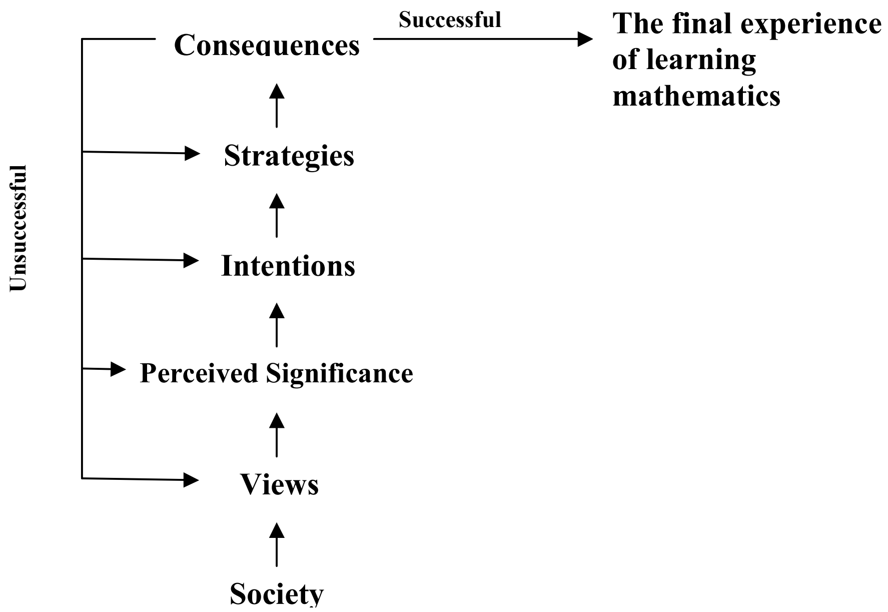


Figure 2.2 Proposed theoretical framework

As social beings, the students' views are influenced by societal factors which are political, economic or social. These societal factors may be linked to the government's policies, teachers, parents and peers. This means that society is the fundamental context to the students' experience of mathematics learning. As affected by societal factors, students may form their own views about studying engineering mathematics. Some of their views may eventually influence how they perceive the significance of mathematics learning to themselves. This significance will then influence their intentions of studying engineering mathematics. These intentions may be mastery-, ego/performance- or work avoidance-oriented. Then these intentions of studying engineering mathematics may result in the planning and actualisation of certain strategies to achieve them. These can be approach, avoidant or disruptive ones. Eventually, some of the strategies may be actualised and it is hypothesised that their consequences can further reinforce or modify their original views, perceived significance, intentions or strategies of studying engineering mathematics. Thus, these factors constitute the students' overall experience of studying engineering mathematics. In short, this theoretical framework allows this study to explore the students' experience of studying engineering mathematics in terms of their views, intentions, perceived significance and strategies as influenced by societal influences politically, economically and socially.

CHAPTER THREE

METHODOLOGY

Introduction

The aim of this study is to develop a substantive theory of the students' perspectives of studying mathematics in a polytechnic in Singapore. This study is framed by the research question, "**What are the students' experiences of studying mathematics as part of their electrical and/or electronic engineering diploma courses in a polytechnic in Singapore?**" Grounded theory methodology is used as the research design in this study to answer main research question above. Grounded theory which is consistent with symbolic interactionism, aims to build a theory or theories from the conceptualisation of data in explaining a phenomenon that can be an event, problem or issue affecting the participants (Glaser & Strauss, 1967; Strauss & Corbin, 1998; Glaser, 1992; Charmaz, 2006). Hence, grounded theory methodology is suitable for this study. In this chapter, the use of grounded theory methodology is justified through the description and discussion of the research paradigm it is positioned in and its methodological assumptions, methods, limitations and ethical issues in relation to the main research question. This methodology chapter is divided into eight sections:

3.1 Two Main Research Paradigms in Social Research;
3.2 Methodological Assumptions of Grounded Theory;
3.3 Data Collection;
3.4 Data Analysis;
3.5 Rigour of Study;
3.6 Ethical Issues;
3.7 Limitations of Methodology;
3.8 Conclusion.

3.1 Two Main Research Paradigms in Social Research

The term "paradigm" represents the epistemological foundation of a research design in social sciences (Guba, 1990). In other words, the paradigm underpinning a research design consists of the beliefs, values and principles that rationalise and justify its existence and subsequently help to direct its methodological assumptions and methods.

3.1.1 Positivist Research Paradigm and Interpretive Research Paradigm

There are two main research paradigms employed in social research (Cohen et al., 2000; Shaughnessy & Zechmeister, 1997). They are the positivist research paradigm and the interpretive research paradigm (Cohen et al., 2000; Shaughnessy & Zechmeister, 1997). Both paradigms have their own assumptions, beliefs and values about the nature of knowledge and reality. They also set out to achieve different goals through their methods.

The positivist research paradigm believes that there is one external reality which represents the only truth for any phenomenon investigated. Owens (1982:4, as cited in Kember et al., 1990) stated that in the positivist paradigm, "certain parts of the real world, which are called 'variables' may be singled out from reality for study or treatment while controlling other parts of the setting." Hence, the positivist research paradigm aims to establish causal relationships between data collected, based on factual or statistical evidence and is concerned with objectivity, prediction and generalization of events (Cohen et al., 2000; Shaughnessy & Zechmeister, 1997). It is deductive and theory testing. It uses quantitative methods of data collection such as surveys and experiments that are statistically friendly.

The presence of multiple realities of an investigated phenomenon is commonly believed in the interpretive research paradigm. Owens (1982:6, as cited in Kember et al., 1990) stated that in the interpretive paradigm, "in the real world, events and phenomena cannot be teased out from the context in which they are inextricably embedded, and understanding involves the interrelationships among all of the many parts of the whole." Therefore, the interpretive research paradigm is concerned with the human understanding of events and their behaviours within a given context (Cohen et al., 2000; Shaughnessy & Zechmeister, 1997). It is usually inductive and theory generating. The interpretive research paradigm normally uses qualitative methods of data collection such as open ended or semi structured interviews, diaries or other documents and observations that are useful in exploring the uniqueness of a given situation.

3.1.2 Why the Interpretive Research Paradigm and Grounded Theory are Preferred in This Study?

The specific research questions presented in this study are:

a. **What are the societal factors that influence the students in studying engineering mathematics?**
b. **How are the students' intentions in engineering mathematics learning formed?**
c. **What strategies will the students use in realising their intentions and why are they used?**
d. **What are the expected consequences of the strategies on the students in engineering mathematics learning?**

The interpretive research paradigm can answer these four specific research questions more appropriately as compared to the positivist research paradigm as the questions aim to understand the students' perspectives of studying engineering mathematics within a context instead of seeking causal relationships among variables related to it (Cohen et al., 2000; Shaughnessy & Zechmeister, 1997; Donmoyer, 2001). Besides, few if any study of students' perspectives of studying engineering mathematics has been conducted in Singapore and the inductive nature of the interpretive paradigm is best suited for such studies with no or few existing theories (Nassar, 2001; Cohen et al., 2000).

There is a wide selection of approaches in the interpretive research paradigm to use in this study (such as grounded theory, ethnomethodology, life history, inductive analysis, phenomethodology and case study). In the selection of any research methodology in a study, Field & Morse (1985) highlighted the importance of its methodological relevance to the research problem and the congruence of the researcher's epistemological focus with it. On the other hand, Nassar (2001) emphasised the type of training a researcher has and his/her research experience also influence the choice of the research methodology in a study.

This study attempts to investigate the experiences of students studying engineering mathematics through understanding their thoughts, feelings and actions/interactions as influenced by the social, political and economic conditions around them. Therefore, the symbolic interactionist aspect of grounded theory which assumes that one's communications and behaviours express meanings as influenced by social conditions and interactions around them, suits it well (Grbich, 1999; Mead, 1964; Blumer, 1969). In short, grounded theory allows processes, meanings and relationships in the phenomenon of studying engineering mathematics to be investigated. On the other hand, there are few if any theories that are associated with the students' experiences of learning engineering mathematics. As grounded theory is known for building theories inductively from data in under-researched areas, it is suitable for the exploratory nature of this study (Grbich, 1999). Besides, as a researcher who prefers to work within clearly determined processes, grounded theory suits me as it is more rigorously systematic in its data collection and analytical procedures. In addition, I have always been more familiar and confident with grounded theory methodology due to my postgraduate training in it. Thus, in line with Field & Morse (1985) and Nassar (2001), I have chosen to use the grounded theory methodology in this study.

3.2 Methodological Assumptions of Grounded Theory

Grounded theory belongs to the interpretive paradigm as reflected in its methodological assumptions. The methodological assumptions of a research design provide a philosophical and logical justification in the operation of its research processes. They define, delimit and substantiate the ways that a research design operates.

3.2.1 Symbolic Interactionism and Grounded Theory

Byrne (2001:2) stated that "the foundation of grounded theory is embedded in symbolic interactionism, which assumes that one's communications and actions express meanings." Symbolic interactionism is strongly influenced by pragmatism which believes that human beings are constantly adapting to the changing society through the contemplation of occurring events through their minds (Jeon, 2004). Pragmatic positions (such as those of Dewey, Cooley, Pierce and James) are usually non realistic or anti positivistic such that they do not believe in an external reality as the only truth (Kirkham, 1995, cited in Lomborg & Kirkevold, 2003). Therefore, pragmatism believes in the presence of multi realities. To trace the conception of symbolic interactionism, Mead provided its philosophical justification while Blumer further advanced it as a sociological theory and research method (Jeon, 2004).

Symbolic interactionism arises from Mead's (1964) tenets of "Self", "I" and "Me" that are found in a person. A person's "Self" will determine the behaviour one displays in reaction to an object/person/event within a social context. "Self" is made up of two parts – "I" and "Me". "I" is the subjective part that is natural, reflects one's personal opinions and subsequently one's individuality. On the other hand, "Me" is the objective counterpart that recognizes the perspectives of others of the object/person/event that one is responding to. "Me" helps one to understand the social expectations, norms and corresponding social responses required of him/her. Both “I” and “Me” are constantly communicating and negotiating (termed as inner conversation) before an action is exhibited in reaction to an object/person/event within a social context (Mead, 1964). Thus, Mead (1964) believed that human beings are products of the society, moulded through their social experiences, interactions and interpretations. In short, symbolic interactionism works on the basis that human beings interpret their various conditions posed by their environment and act upon them with the information of their interpretations (Morrison, 2002). Through their interpretations, they assign meanings to the actions of others and their own actions as influenced by social conditions or interactions around them (Dimmock & O’Donoghue, 1997). These assigned meanings are then processed and adjusted accordingly through one’s own internal interpretative mechanisms that result in his/her interaction/action in response to the relevant phenomenon (Dimmock & O’Donoghue, 1997; Mead, 1964; Morrison, 2002). Such interpretation is achieved with the aid of their common language and other symbolic tools that they utilise to communicate (Crotty, 1998).

With its philosophical root set in place by Mead (1964), symbolic interactionism is further extended into a set of research methodological assumptions by Blumer (1969). Blumer (1969:2) put forward three premises of symbolic interactionism in the operation of its corresponding research methodology. They are:

1) Human beings act towards things on the basis of the meanings that the things have for them.
2) The meaning of such things is derived from, or arises out of, the social interaction that one has with one's fellows.
3) These meanings are handled in, and modified through, an interpretive process used by the person in dealing with the things he/she encounters.

Thus, Blumer (1969) assumed that a phenomenon can be understood and analysed in symbolic interactionist term, through the participants’ interpretations of the object/person/event and their resultant action/interaction within a particular social context.

From the above, the experiences of mathematics learners in this study can be described suitably in symbolic interactionist term. Through their social interactions with people around them, engineering students may form their own subjective meanings about mathematics learning (their "I"). However, they also recognise the effect of social factors on their possible intention and action/interaction that have resulted from their own perspectives about mathematics learning (their "Me"). Thus, they have to go through an internal interpretative process that negotiates between their personal interests and the intervening social conditions around them (their "Self") before carrying out the action/interaction. As a result, taking these tenets of social interactionism (Mead, 1964; Blumer, 1969) as the basis, this study aims to understand the meaning of studying engineering mathematics to the students, their internal negotiation process and the subsequent action/interaction that arises and their consequences on them.

With its symbolic interactionist foundation, grounded theory first originated from sociologists, Barney G. Glaser and Anselm L. Strauss who used it in their qualitative studies of the phenomenon of dying in hospitals (Charmaz, 2006). They have developed systematic grounded theory methodological strategies in their book "The discovery of grounded theory" published in 1967. With its humble beginnings in sociological research, grounded theory research methodology has become popularly applicable in many other areas of research such as education, psychology, business, information technology, medical science and cultural studies by the twenty first century (Clarke, 2005).

As grounded theory is popularised, differences in its methodological assumptions and methods arise. There are different variations of grounded theory methodology 40 years after its birth (Mills et al., 2006). Currently, there are three main groups of grounded theorists – Glaser (1992, 1998), Strauss & Corbin (1990, 1998) and the social constructivists such as Charmaz (1990, 2006) and Annells (1996). However, it is not feasible to discuss their differences here due to space constraint. Nevertheless, notwithstanding the differences in the methodological assumptions and methods among the different schools of grounded theory, its philosophical roots and main canons remain the same (Creswell, 1998). In this study, I used the methods proposed by Strauss & Corbin (1990, 1998) because its detailed and systematic methods are more user friendly to me.

3.2.2 The Aims of Grounded Theory

Grounded theory studies the social process of a major problem faced by a specific social group and it is termed as a basic social problem (Glaser, 1992). The basic social problem faced by the group can be understood through comprehending their thinking processes, feeling their emotions and thus understanding the reasons behind their actions and interactions (Glaser & Strauss, 1967; Glaser, 1978; Strauss & Corbin, 1998; Charmaz, 2006). In methodological terms, grounded theory research is about conceptualising data and eventually resulting in the emergence of a theory or theories from the data itself in explaining a basic social problem faced by a specific group (Glaser & Strauss, 1967; Strauss & Corbin 1998; Glaser, 1992).

The theory developed from grounded theory can be substantive or formal. A substantive theory explains how specific subjects manage their experiences. Grounded theory can further advance theoretical research by creating formal theories (Strauss & Corbin 1998; Grbich, 1999). By conducting similar studies in different contexts, it is possible to change a set of substantive theories into a formal theory. A formal theory, which makes up of a number of substantive theories, attempts to provide a framework to explain the experiences of a number of social groups (Strauss & Corbin, 1998).

3.3 Data Collection

This section will detail the various stages of data collection in this study.

3.3.1 The Setting and Participants

This research was conducted in a polytechnic in Singapore. As there are many types of engineering courses (with different mathematics syllabi) in this polytechnic, any attempt to investigate all courses is futile due to the possible extensive range of experiences that cannot be adequately covered within the confines of time and space of this study. Thus, the sample for this study was drawn from selected courses in the School of Electrical and Electronics Engineering. The sampled students in the four diploma courses – Electrical Engineering, Aerospace Engineering, Bioelectronics Engineering and Communication Engineering, needed to take a centralised programme (that consists of 3 modules) in engineering mathematics. Although the students' experiences of mathematics learning in other engineering disciplines are not covered in this study, they should serve as possible areas of inquiry in forming more substantive theories in future.

3.3.2 The Sampling Method

In grounded theory, sampling is conducted according to the principle of theoretical sampling where sampling choices are dictated by the categories of the emerging theory. In theoretical sampling, the researcher jointly collects, codes and analyses his/her data. He/she then further decides what the data to be collected next are and where to find them, so as to develop the theory as it emerges (Glaser & Strauss, 1967; Strauss & Corbin, 1998). Thus, the function of theoretical sampling is to aid in the selection of participants who will yield data that produce categories of a phenomenon until no new categories are found. At the same time, it also helps to develop, elaborate and refine existing categories through searching their other uncovered properties and dimensions, until none is found. In other words, the researcher is "sampling along the lines of properties and dimensions, varying the conditions." (Strauss & Corbin, 1998:202) Therefore, theoretical sampling is not searching for repeatedly occurring properties or dimensions of a category (Charmaz, 2006). In short, theoretical sampling increases the range of variation and analytic density of the categories and puts them on firmer and stronger theoretical grounds (Strauss & Corbin, 1998). In this study, three types of sampling were involved: open sampling, relational and variational sampling and discriminate sampling (Strauss & Corbin, 1998).

3.3.2.1 Open Sampling

At the start of any study, open sampling has to be employed as no theoretically relevant categories are as yet uncovered (Strauss & Corbin, 1998). Open sampling aims to discover initially emerging theoretically relevant categories that may serve as the basis for theoretical sampling later. In open sampling, the participants are selected based on their expert knowledge of the phenomenon to be studied, that is, students who can share information about their perspectives of studying engineering mathematics in this study. There are different variations in open sampling (Strauss & Corbin, 1998). In this study, the initial open sampling of engineering students was based on the literature review and my professional experience. I observed that proficiency in mathematics can significantly determine the types of experiences of mathematics learning. Proficiency in mathematics is especially relevant in the Singaporean context where mathematics education is a highly competitive and stressful journey which affects the students academically, economically and socially in their future lives (Fan et al., 2005; TIMMS, 2003).

During the initial open sampling, I was not presuming “mathematical ability” as a category yet as it had not evolved from the data. Instead, its status as a possible category depended on the resulting data analysis (“mathematical ability” eventually emerges as a category in this study). Although from the literature review, other factors such socio economic level, types of peers and teachers may also influence students’ perspectives about mathematics learning, they were not considered in the initial sampling as they had not been proven in local studies. However, they could still emerge as possible categories for further theoretical sampling.

I involved three of my colleagues in this study and enlisted their help in recommending students who satisfied the initial sampling criteria. Thus, the selected students were not my current or former students. At the same time, I would not have a chance to teach them as they had either completed their three compulsory mathematics modules recently or were doing their last mathematics module when I interviewed them. This greatly reduces the power imbalance between the interviewer and interviewee which can affect the trustworthiness of the study (Wengraf, 2001). This should also enable them to speak openly and honestly without the fear of affecting their current or future grades, or offending me. In this study, 8 students were initially selected according to their differences in academic abilities in mathematics (good [A-C grades] and mediocre [D-F grades] in their past engineering mathematics modules) across the four diploma courses. This enabled maximum variation in the initial open sampling in this study.

Before the next round of interviews was carried out, data transcription and analysis were completed for the previous interviews. This is to prevent the researcher from missing the chance to sample and collect more information regarding new emerging concepts (Strauss & Corbin, 1998). There were two more groups of interviewees that consisted of 8 and 5 students respectively. The profiles of the 21 students interviewed in this study are shown in Appendix A.

3.3.2.2 Relational and Variational Sampling

After concepts have been discovered during the open coding stage (described in Section 3.4.3), there is a need to understand the relationships between them (Strauss & Corbin, 1998). This is done through variational and relational sampling in the axial coding stage (described in Section 3.4.4). It aims to maximise the differences between different categories and examine the interrelationships between them. As the categories are differentiated clearly, their salient interrelationships are uncovered (Charmaz, 2006). Such maximisation of differences further allows the dense development of the properties of categories and thus delimits the scope of the emerging theory (Glaser, 1978). However, there is a need to understand that new categories can also be uncovered in relational and variational sampling. The analysis of the data of the initial group of students provided a source of possibly theoretically relevant categories that served as the basis for further variational or relational sampling. For example, analysis of the initial interviews yielded the category of "understanding" that provided the basis for uncovering more of its properties and their dimensions in the second batch of interviewees.

3.3.2.3 Discriminate Sampling

In selective coding (described in Section 3.4.5), discriminate sampling is practised where specifically selected participants, new or old, are selected or reselected to further refine categories and validate their interrelationships. At the same time, discriminate sampling allows the verification of information through different sources. This is a form of data triangulation that contributes to the rigour of the grounded theory research. It also acts as an avenue where the development of a basic process is followed as it allows a researcher to uncover new experiences of the subjects (Charmaz, 2006). In this study, I returned to 5 previous interviewees to clarify and validate present categories and their relationships.

3.3.2.4 Theoretical Saturation

The most important theoretical sampling criterion in grounded theory is that the data collected must be able to achieve the theoretical completeness of the whole phenomenon. This is achieved when theoretical saturation is attained and data collection stops. Theoretical saturation is where no additional data are found whereby the researcher can form new categories or develop new properties and dimensions of any present category (Strauss & Corbin, 1998). Therefore, sample size in theoretical sampling is not an important issue as long as theoretical saturation is reached (Glaser & Strauss, 1967). There is a need to be aware of the danger of proclaiming saturation of categories when they are not. This may be due to "uncritical and limited analytic treatment" of data (Charmaz, 2006:114). Besides, theoretical saturation can also be seen as a form of triangulation of data. Therefore, "false" saturation of data may affect the rigour of research itself. In this study, theoretical saturation was reached after I had interviewed my 21st participant.

3.3.3 The Data Collection Methods

Potential participants were first briefed on the purpose of the study - to understand their experiences of learning engineering mathematics. They were also told that the consequences of the research could improve teaching and learning of engineering mathematics and at no time, their grades or performance in their study here would be affected by it. They were then informed that the interviews would be confidential and they were allowed to discontinue at any point of the interview without giving any reason. These measures thus ensure the ethics of interview research (informed consent, confidentiality and its consequences on the participants) are adhered to (Kvale, 1996). Each participant was given a week to consider if he/she wanted to take part in this study. A total of 24 students were invited to participate in this study and 21 students agreed to take part. The 3 students who did not wish to participate in the study cited that they did not have the time for the interviews.

The interviews of these 21 students served as the main source of data for this study. Data were collected through interviews that centred on the four fragmented specific research questions for this study. These questions were based on the concepts derived from the literature review and my personal experience relevant to the phenomenon studied. However, as these concepts did not evolve from the data, they were considered as provisional and could be discarded if they were not theoretical relevant eventually (Strauss & Corbin, 1998). During the initial open sampling stage, a semi structured interview guide that focused on the four fragmented specific research questions about learning engineering mathematics at tertiary level was used. The initial interview guide changed four times for the purpose of theoretical sampling (Strauss & Corbin, 1998). The initial and final interview guides are shown in Appendix B.

All interviews were conducted in the privacy of soundproof classrooms or library special rooms. Throughout the interviews, I conscientiously attempted to improve my interviewing skills by following the desirable qualities (knowledgeable, structuring, clear, gentle, sensitive, open, steering, critical, remembering and interpreting) of an effective interviewer as suggested by Kvale (1996). A digital voice recorder was used in recording each interview. Each interview lasted from 15 minutes to 35 minutes. There was a total of 499 minutes of interviews in all. All interviews were recorded, transcribed verbatim and stored in a computer database. There were also 5 follow up interviews which were done through email correspondence. They were conducted to clarify and validate certain categories and their relationships. Email correspondence was used as it was considered more efficient than fixing another face to face interview with them.

Besides being interviewed, the 21 participants were requested to pen their thoughts electronically with regards to context specific scenarios – before, during and after a mathematics examination. There was a set of questions to guide their responses. These electronic records that served as another source of data were organised in the computer database. A sample of the questions used for the students' own reflections is provided in Appendix C.

Another source of data was obtained through the informal conversational sessions (each lasting less than ten minutes) with the 21 interviewed students' tutors. Two tutors who were approached in the study did not agree to be involved in the sessions. I did not ask them their reasons of declining the interviews. In the end, a total of six tutors (three of them were the ones who recommended me the interviewees) were involved in these sessions. Some of them were either the current or former tutors to a few of the interviewed students. Questions asked in such sessions were essentially related to their perceptions of their students' attitudes in engineering mathematics learning. These sessions were not audio-taped as four of them were uncomfortable about the recording. However, this should not affect the rigour of this study as the information obtained was considered complementary since this study focuses primarily on the perspectives of the students. Thus, this source of data from the tutors was mainly used to triangulate the main sources of data collected through the students' interviews and reflection journals. Information obtained was also summarised by the researcher retrospectively after each session within a day to minimise the loss of data and its inaccuracy. An illustration of a retrospective report is provided in Appendix C.

The literature review conducted for the study was also an important source of data (Strauss & Corbin, 1998). Other data collected included the retrieved profiles of the students that comprised of their "O" level results and current GPA (General Point Average) in their courses. Other sources of data consisted of the students' engineering modules' course materials and past years' examination papers.

The collection of data from the different sources above would allow triangulation of the data and ensure the rigour of the study. In total, there were 278 pages of transcripts obtained from the students' interviews, their online reflections and the tutors' feedback.

3.4 Data Analysis

The eventual generation of original and yet justifiable theories depends on the rigorous operationalisation of the data analysis phase in grounded theory. The data analysis phase is the stage where the data are broken down, conceptualized and creatively put back in new ways. From there, new concepts are built from the data that contribute to the absolute creation of new theory or theories. Data analysis is achieved through the process of coding (Glaser 1992; Strauss & Corbin, 1998; Charmaz, 2006). There are three types of coding, namely open coding, axial coding and selective coding (Strauss & Corbin, 1998). It is not necessary for the coding to move strictly from open through axial and finally selective coding in a successive manner as the process of coding in grounded theory is not sequential. This means that, at all times, there is a need to revisit any section of the cycle (to find new data through theoretical sampling, reorder new data, analyze new and old data in creative ways) till theoretical saturation is attained. Therefore, grounded theory method is also branded as the method of constant comparison as the data interacts through comparison where analysis then arises (Pidgeon & Henwood, 1996, cited in Robson, 2002).

3.4.1 Constant Comparative Method

In the constant comparative method, each piece of relevant data is continually compared with every other piece of relevant data to generate theoretical concepts that encompass as much behavioural variation as possible (Glaser & Strauss, 1967). It involves four stages: a) comparing incidents applicable to each category; b) integrating categories and their properties; c) delimiting the theory and d) writing the theory (Glaser & Strauss, 1967:105). It is important to compare every incident and category with one another. This is done through asking questions of the information provided by each incident or category to ensure if any two are similar. Through this comparison process, the collection, coding and analysis phases work in tandem from the start to the end of the investigation. This allows the gradual development of the data from the lowest level of abstraction to a higher one of theoretical conception. For example, in this study, the categories of "understanding" and "practising" in engineering mathematics learning can be subsumed under the higher conception of the process of "actualising". At the same time, theoretical sensitivity, which is important in the data analysis stage, is fostered in the constant comparison phase.

3.4.2 Theoretical Sensitivity

Theoretical sensitivity is very important in the analysis stages. Theoretical sensitivity is the ability of the researcher to identify the important features of the collected data, perceive the concepts, categories, properties and their interrelationships that arise and finally give meanings to them (Glaser & Strauss, 1967; Glaser, 1992; Strauss & Corbin, 1998). In the initial stage of data analysis, certain events may be overlooked, but as theoretical sensitivity increases, they can be recoded and reanalysed (Strauss & Corbin, 1998). Glaser & Strauss (1967) suggested that the researcher's personal inclinations and experience are helpful in creating theoretical sensitivity to the ongoing research. In this study, I was able to draw on my former experiences as a former secondary school mathematics teacher and in my current appointment as a polytechnic lecturer teaching engineering mathematics. This helped me to attain an acceptable level of theoretical sensitivity in dealing with the initial data collection and analysis. At the same time, the reading of literature also helps in enhancing the theoretical sensitivity of the researcher (Glaser, 1978). Thus, the literature review conducted with respect to the four specific research questions was very helpful in developing my theoretical sensitivity. As the study progressed, the data analysis phase became another source for increasing my theoretical sensitivity (Strauss & Corbin, 1998).

Although it is recognised that pre-existing perspectives and knowledge can develop theoretical sensitivity to enhance theory development, their meanings may also be forced into the data and delimit theory development (Glaser, 1978; Charmaz, 2006). This is because a researcher's background perspectives and knowledge play the role of "points of departure" (Charmaz, 2006:17) where they set the grounds for asking interview questions, the way that the data is collected, organised and analysed. Because of the presence of pre-existing conceptions from his/her background perspectives and knowledge, certain data may be filtered out consciously or subconsciously. Then the researcher will not be able to identify some of salient features of the data. This will result in an inaccurate portrayal of the phenomenon investigated.

To prevent any filtering of data through such pre-existing conceptions, I have constantly evaluated the fit between my pre conceptions and the emerging data by looking at data from multiple angles, making constant comparisons, going towards any possible new directions and building on any feasible ideas (Charmaz, 2006). This is also known as the process of theorising (Strauss & Corbin, 1998).

3.4.3 Open Coding

Open coding involves the labelling and categorization of the phenomenon as indicated by the data. Coding does not entail the mini descriptions of the different blocks of data but it works in capturing the meanings of theirs instead (Strauss & Corbin, 1998; Charmaz, 2006). The end products are concepts which are the building blocks that will help build up the grounded theory or theories. The comparative method that employs the procedures of asking questions and making comparisons is being utilized in this process (Glaser 1978). By asking simple questions such as who, why, what, how, when, where etc, every word, phrase or sentence in each line of data is analyzed. Each analyzed line is then broken down microscopically into different discrete events called codes. All codes are assigned individual incident labels. Such line by line microscopic analysis serves to prevent researcher from making biased analysis due to preconceived idea about the data or theory as it forces the researcher to be exposed to the complete range of the data (Strauss & Corbin, 1998). It then progresses to the platform where the codes are compared and similar codes expressing the same incidents are grouped together under the same conceptual label. Each such group thus becomes a concept. These conceptual labels are then contrasted again and further clustered into a higher and more abstract level known as categories. After a category is formed, there is a need to identify its properties and dimensions (Strauss & Corbin, 1998). The properties of a category can be obtained from the same principle of asking who, why, what, how, when, where questions within the category. The dimensions of the category include the range of situations with such properties that have occurred for the subjects. In addition, Charmaz (2006:46) stressed the importance of language in the coding process as "specific use of language reflects views and values." Thus, it is very important to examine the hidden assumptions and meanings behind the participant's use of language in open coding stage (Charmaz, 2006). Some examples of the open coding process in the data generated from the interviews with the participants, their online reflections and their tutors' feedback on the participants are shown in Appendix D.

3.4.4 Axial Coding

As for axial coding, those assembled data are put back together in fresh ways by making associations between a category and its subcategories. This is to bring together the categories and subcategories in explaining the phenomenon that is embedded in the data. The development of main categories and subcategories is central to the process. There are four steps in axial coding (Strauss, 1987). The first step is the identification of the properties and dimensions of each category or subcategory. It is followed by the exploration of the relationships between them and uncovering the conditions, actions and consequences for the phenomenon through these relationships. The fourth involves using a paradigm to represent and link up the various relationships. An example of a category and its subcategories in the types of family support provided for engineering students in the mathematics learning is shown below.

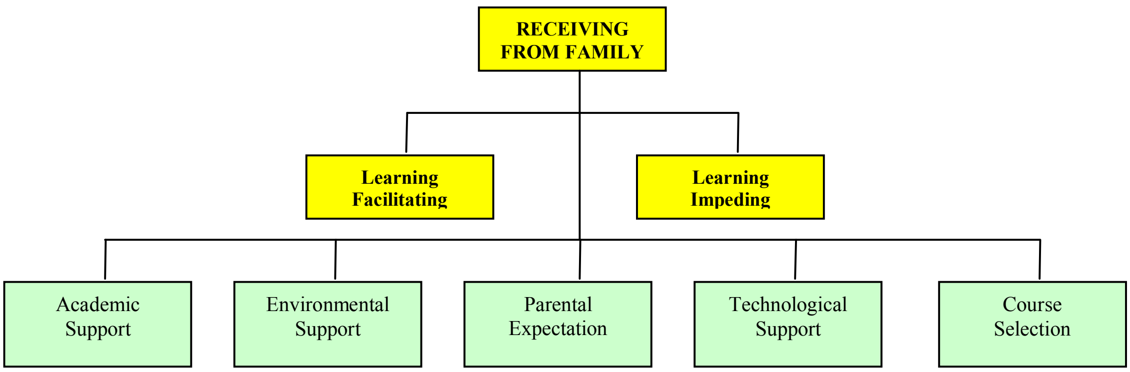


Figure 3.1 An example of a category and its subcategories

3.4.5 Selective Coding

Selective coding refers to the integration of the categories to structure the initial theoretical framework so as to analytically come up with the grounded theory from the data. The first step involves the identification of the core category. Strauss & Corbin (1998:146) stated that the core category "is a conceptual idea under which all the other categories can be subsumed." The core category is, in fact, the conceptualization of the storyline about the central phenomenon of the research study. The core category is the main theme of the data such that it can explain the whole phenomenon investigated. It is also important that the other categories must be able to relate to the core category in the description or explanation of the whole phenomenon.

Therefore, the auxiliary categories may be linked to the core category in complex and intertwining ways. There is a need to note that there may be more than one core category that represents the phenomenon investigated. At the same time, the data form each category must not be forced into forming a relationship with the core category/categories. There are four methods to identify a core category, namely writing a storyline, conceptualization, use of diagram and review of memos (Strauss & Corbin, 1998). The core category for this study is the category of "Intending" in engineering mathematics learning and the methods used in identifying it are conceptualisation, review of memos and use of diagrams.

3.4.6 Conditional / Consequential Matrix

In all the three stages of data analysis, the use of a conditional/consequential matrix is essential. The matrix allows the researcher to analyse "the relationships between macro and micro conditions/consequences both to each other and to process" (Strauss & Corbin, 1998:181), serving as a conceptual guide. It also enables the researcher to develop explanatory hypotheses that can be further verified or modified through further data collection and analysis (Corbin & Strauss, 1996, cited in Strauss & Corbin, 1998). At the same time, the matrix provides direction for the research in theoretical sampling too. An example of the conditional/consequential matrix is shown below.

Table 3.1 An example of a conditioned matrix

Core process		**GATHERING**		
Sub-processes	Active Passive	**Receiving**	**Experiencing**	**Recalling**
Causal conditions		Society Family Others (such as ex teachers and classmates and recruitment officers)	Lectures Tutorials Self learning Assessment Teachers Peers	Pre-tertiary school days in learning mathematics
Context where information is gathered		Influences from external sources	Personal learning process in current course	Remembering own prior mathematics learning experiences

3.4.7 Memos and Diagrams

Glaser (1978:83) defined memoing as "the theorizing write up of ideas about codes and their relationships as they strike the analyst while coding". Strauss & Corbin (1998) introduced writing memos as a system for keeping track of the categories, properties, hypotheses, and generative questions that evolve from the analytical process. These memos are constantly engaged in the formulation and revision of the theory during the research process. Memos thus help to raise the data to conceptual level, develop its properties and connect the concepts together to form the grounded theory ultimately. Memos, too allow the researcher to keep track of his thought processes throughout the research proper. In other words, memos enable the researcher to be clear and reflective about his/her thought processes of what is happening to the data. Furthermore, in the triangulation of data in the research process, the memos used can help to corroborate the data collected.

Three categories of memos were drawn on for this research study. **Code memos** are used for conceptual labelling. Code memos are usually created in the open coding stage. **Theoretical memos** relate mostly to axial and selective coding and are analysed according to the paradigmatic diagram that shows the process of axial coding as below.

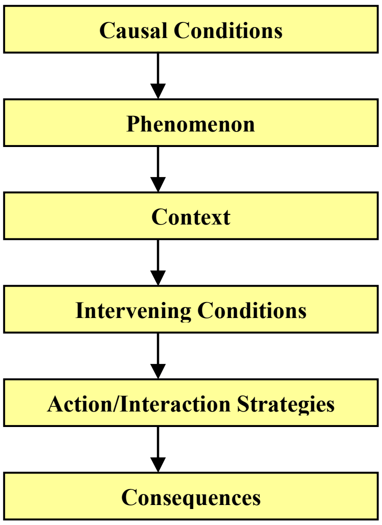


Figure 3.2 Process of axial coding

Causal conditions are the events that lead to the development of the phenomenon (the core category). Context refers to the particular set of conditions of intervening conditions, within the broader set of conditions, in which the phenomenon is couched. Action/interaction strategies are the actions and responses that occur because of the phenomenon. Finally, the outcomes, both intended and unintended, of these actions and responses are referred as the consequences (Strauss & Corbin, 1998; Pandit, 1996). This process facilitates the researcher to think analytically and relate data in multifarious approaches, through the proposal of linkages and the examination of data for validation. **Theoretical memos** focus on the researcher's thoughts on the paradigm features, processes, properties, dimensions and variations of the categories (Strauss & Corbin, 1998). Usually, theoretical memos will lead to operational memos. **Operational memos** contain thoughts on the directions and procedures relating to the evolving research design. There are a total of 107 pages of memos (A4 size) produced in this study. Some examples of these three types of memos created in this study are shown in Appendix E.

Diagrams can also be used to depict relationships between concepts. Therefore, they are more useful during axial and selective coding stages. In axial coding, diagrams may be used to depict "relationships between a category and its subcategories or among several categories" (Strauss & Corbin, 1998:235). As a researcher who thrives on visual representations than words, diagrams helped me significantly in my analysis. The example below shows an earlier diagrammatic conceptualisation of the relationships between the different forms of intentions in engineering mathematics learning in axial coding. This diagram was eventually improved and refined in this thesis.

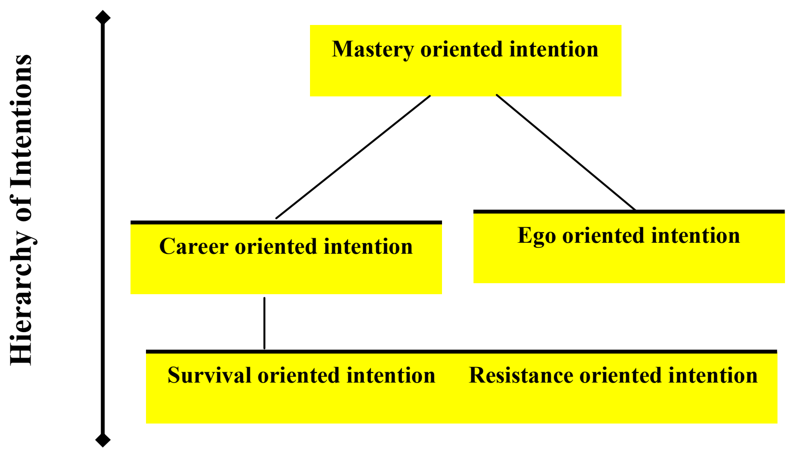


Figure 3.3 An example of diagrams utilised in axial coding

As the analysis gets more in depth, the diagrams usually get more complex and integrative as in selective coding (Strauss & Corbin, 1998). In selective coding, **diagrams** help in presenting the density and complexity of the evolving theory. Below is the final integrative diagram that represents the final theory that has evolved from the study.

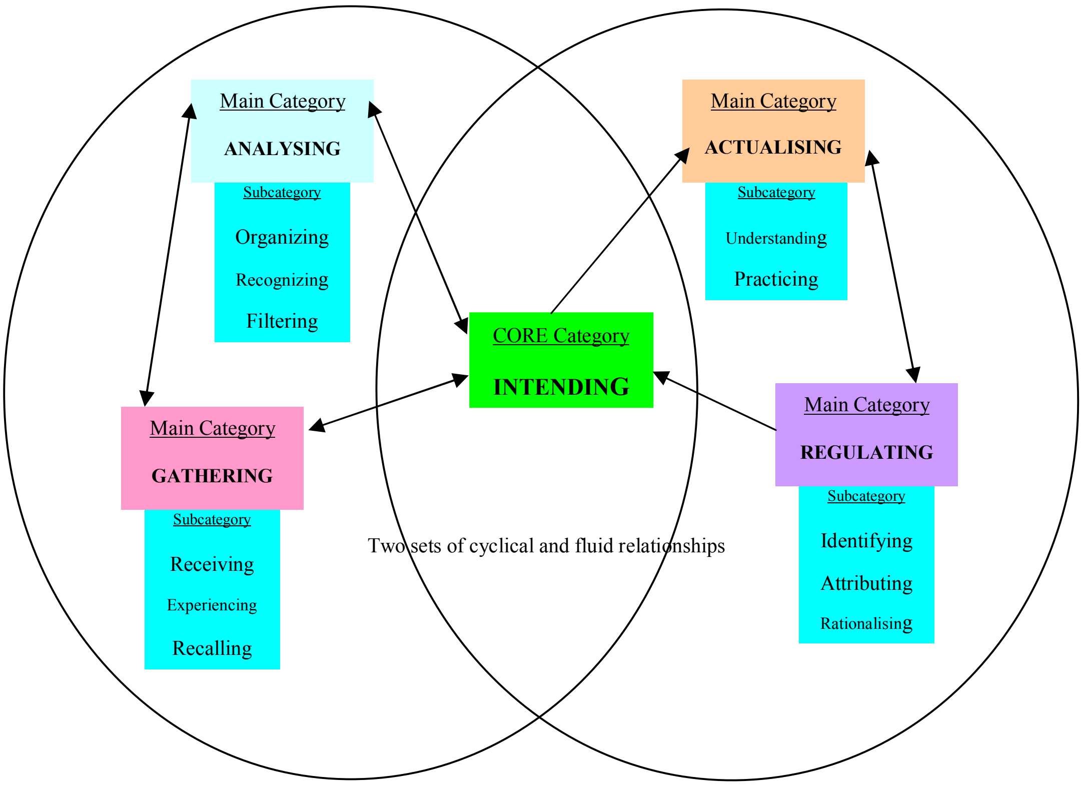


Figure 3.4 The theory of Selective Intentionality with the category of intending as the core category

3.5 Rigour of Study

According to Lincoln & Guba (1985:290), the basic question addressed by the notion of rigour in interpretive research is "How can an inquirer persuade his/her audiences that the research findings of an inquiry are worth paying attention to?" This means that the results of the data analysis phase must be able to withstand any external test or scrutiny presented. The rigour of an interpretive study is examined by the notion of trustworthiness instead of reliability and validity in positivist studies. Trustworthiness is defined as the conceptual soundness of the research results and is influenced by the notions of credibility, transferability, dependability and confirmability (Lincoln & Guba 1985; Guba & Lincoln, 1989).

Strauss & Corbin (1998) set the criteria for judging the rigour of a grounded theory as plausibility, reproducibility, generalizability, concept generation, systematic conceptual relationships, density, variation, and the presence of process and broader conditions. These criteria translate into eight conceptual questions to judge the trustworthiness of the study (Strauss & Corbin, 1998:270-272):

1) Are concepts generated?
2) Are concepts systematically related?
3) Are there many conceptual linkages and are the categories well developed? Do categories have conceptual density?
4) Is variation within the phenomena built into the theory?
5) Are the conditions under which variation can be found built into the study and explained?
6) Has process been taken into account?
7) Do the theoretical findings seems significant and to what extent?
8) Does the theory stand the test of time and become part of the discussions and ideas exchanged among relevant social and professional group?

These criteria in determining the rigour of a grounded theory can be complemented by ensuring the credibility, transferability, dependability and confirmability of the study are satisfied (Guba & Lincoln, 1989).

3.5.1 Credibility

In terms of interpretive inquiry, internal validity is almost impossible to achieve (Lincoln & Guba 1985). This is because one needs to know the one objective reality that represents the phenomenon that is investigated, which is unattainable in interpretive research. Therefore, an interpretive study will not set to prove if this represented reality of the phenomenon is the one objective truth in positivist tradition. Instead, it should strive to describe accurately the reality of a phenomenon it intends to represent within the research context. This is thus known as the credibility of the study.

Theory/perspective triangulation in this study was achieved through the literature comparison stage as proposed by Glaser (1992). This was done in Chapter Seven. By tying the emergent theory with extant literature after the analysis, the credibility of the theory building can be enhanced (Glaser, 1992). Triangulation of sources was achieved here through ensuring maximum variation in the sampling of interviewees and types of data sources (Patton, 1990; Hammersley & Atkinson, 1995). This also improves the credibility of the study.

3.5.2 Transferability

Transferability refers to the applicability of the research findings to other similar settings (Marriam, 2002; Lincoln & Guba, 1985). It is equivalent to the issue of external validity of a quantitative study. In this study, its transferability was achieved through thick descriptions (Geertz, 1973) of how engineering students perceived and coped with mathematics learning in the context of a polytechnic (Lincoln & Guba, 1985). This will allow others to make accurate and informed judgements if the findings of this study are applicable to their contexts.

3.5.3 Dependability

Dependability refers to the consistency between the data collected and the findings (Marriam, 2002; Lincoln & Guba, 1985). This is similar to the reliability of the data in a quantitative research (Seale, 1999). However, the replicability of the findings in quantitative research is nearly impossible to emulate in qualitative research. Nevertheless, there is still a need to account for the whole research process and convince the readers of the consistency of the data to the findings for the particular research setting.

An audit trail that consisted of a detailed documentation of the methods and the collection and analysis of data was maintained to ensure the dependability of this study (Merriam, 2002; Seale, 1999). This audit trail included the list of interviewees, interview guide, audio records and transcripts of interviews, data collection and analysis procedures, memos and results. The audit trail for this study is shown in Appendix F.

3.5.4 Confirmability

Confirmability refers to the degree the findings can be corroborated by other researchers (Marriam, 2002). It is equivalent to the issue of objectivity in a quantitative research (Seale, 1999). In interpretive research, it is impossible for a researcher to remain objective and "outside" the investigated phenomenon (Nightingale & Cromby, 1999; Charmaz, 2006). The values, experiences, interests and epistemological and methodological beliefs of the researcher can affect the construction of meaning in the data. A researcher can improve confirmability of a study by being reflexive (Marriam, 2002). Reflexivity is a process of conscious self awareness where a researcher continually appraises the subjective responses and intersubjective relationships within the data in relation to his/her values, experiences, interests and beliefs (Finlay, 2002; Nightingale & Cromby, 1999). My reflexivity was maintained by being consciously aware of my epistemological preferences, beliefs, values, theoretical orientations, bias, experiences and recording them in my memos as shown in Appendix E. In addition, the audit trail mentioned above helped in enhancing the confirmability of this study.

3.6 Ethical Issues

Bogdan & Biklen (2003) stated that the relationship between the researcher and the participants in interpretive research is more like having a friendship than contract. This results in the lack of a written code of ethics. Nevertheless, there are still some guiding principles that a researcher should take note of. Bogdan & Biklen (2003: 44-45) provided a code of ethics in interpretive research.

> "Avoid research sites where the informants may be coerced to participate in your research.
>
> Honour your informants' privacy.
>
> Unless otherwise agreed to, the subjects' identities should be protected so that the information you collect does not embarrass or in other ways harm them.
>
> Treat the participants with respect and seek their cooperation.
>
> In negotiating permission to do the study, you should make it clear to those whom you negotiate what the terms of the agreement are, and you abide by that contract.
>
> Tell the truth when you write up and report your findings."

Ethical issues should be discussed early in the research and incorporated in all stages of the research at all times (Bogdan & Biklen, 2003). This study followed all salient ethical issues mentioned above. Below are the elaborations of some of them.

3.6.1 Informed Consent

Before the start of the interview process, there is a need to let the participants know the purposes and implications of the research (Kvale, 1996; Bogdan & Biklen, 2003). Therefore from there, it is only possible to get the informed consent of the participants. Evans & Jakupec

(1996) and Kvale (1996) perceived informed consent as one of the most critical issues in interpretive research although there are others such as Fine (1992) who felt that covert research is acceptable as long as the participants are not harmed. I do not agree with Fine (1992) as it is the rights of the participants to be in the know. There is a need to confirm informed consent during the different stages of the research (Bartunek & Louis, 1996). As the events unfold during different stages of research, the participants need to be consulted for consent if it is deemed that any new development may harm them. Lastly, participants must be given ample opportunities to withdraw from the research proper without any explanation.

In this study, the participants were informed of the research's purposes and implications. They were then asked to consent to the study without coercion. They were given one week to consider the request. During the interview process, they were allowed to terminate it anytime without reasons. At the same time, I ensured that the content and analysis of the interview transcript of a participant go through him/her for checking before being released to others. If the participant did not agree to release the analysis for any reason (his/her reason would not be asked), his/her decision would be respected unconditionally. In this study, no participants terminated the interviews halfway or objected to my analysis in the report.

3.6.2 Confidentiality

The confidentiality of the participants must always be protected (Fraenkel, 1990; Bogdan & Biklen, 2003; Kvale, 1996). In this study, no participant was identified without their approval. The interview transcripts were returned to the participants and the subsequent analysis report were sent to them for review in case that any part of the analysis might identify them (Rowling, 1994). This protects the participants from any form of embarrassment or harm (Bogdan & Biklen, 2003). However, Berg (1998) stated that maintaining the anonymity of the participants may not be able to protect the confidentiality of their identities if other information provided may identify them indirectly. Therefore, I took care in not revealing other information that may divulge their identities in my report. In this aspect, I had given pseudonyms to the participants' school, courses, names and gender. Their tutors were not identified too.

3.6.3 Emotional Protection

The researcher has to be aware about the issue of sensitivity when dealing with emotional research questions (Bogdan & Biklen, 2003). In short, the interview process must not cause any emotional distress to the participants. The researcher must actively watch out for signs of such emotional distress and terminate the interview when necessary.

The nature of this study will not cause any physical harm to the participants directly from the interview process or the release of the research findings. However, it may elicit memory of bad experiences of mathematics learning. Therefore, in this study, I constantly watched for such emotional distress from the participants and would terminate the interview sessions when necessary. However, there was no instance where I needed to terminate the session due to the interviewee's emotional stress.

3.7 Limitations of Methodology

The methodological limitations of this study can be approached from both macro and micro levels. At the macro level, the methodological limitation is related to the issue of the generalizability of the findings of this study. At the micro level, the methodological limitations that arise come from the limitations due to insider research and issues in the interview process during data collection (Foddy, 1993; Wengraf, 2001; Kvale, 1996; Hall & Callery, 2001; Neill, 2006; Finlay, 2002; Brannick & Coghlan, 2007; Mercer, 2007). Such micro issues are especially important in the social constructivist form of grounded theory research which emphasises on the influences of researcher-participant interaction on data collection and analysis (Charmaz, 1990, 2006; Annells, 1996). This form of social constructivist grounded theory is in contradiction with the positivist fundamentals of grounded theory where the researcher has to take an unbiased stance (Glaser & Strauss, 1967; Glaser, 1992; Strauss & Corbin, 1998). However, in this study, I took a social constructivist stand and was mindful of the limitations presented by it. While acknowledging the limitations due to insider research and issues in the interview process during data collection can never be totally eradicated, I took steps to minimise them so as to improve the rigour of this study's findings. Below are the discussions of these methodological limitations and the steps I took to minimise them in this study.

3.7.1 Generalizability of The Findings

Grounded theory aims to understand important issues in people's lives through building a theory from data collected from the investigation of the issue or phenomenon (Glaser & Strauss, 1967; Glaser, 1978; Strauss & Corbin, 1998; Charmaz, 2006). From here, a substantive theory that explains how specific subjects manage their experiences is formed. Thus, the result of a grounded theory research study demonstrates its explanatory power of a phenomenon in specific conditions or a given context (Strauss & Corbin, 1998). This means that grounded theory does not attempt to use its results to make context free generalizations on any other population experiencing the same phenomenon, as in the positivist research paradigm. However, it still has some useful but limited form of generalization. It can generalize its findings to any other population in similar contexts experiencing the same phenomenon. The context of this study is students in the field of electrical and electronic engineering studying engineering mathematics in a polytechnic in Singapore. Thus, the results of this study may not be applicable to other engineering students in other tertiary settings such as institutes of technical education and universities or courses such as mechanical engineering, civil engineering and bio-engineering in Singapore or elsewhere. However, its results may be still applicable to other polytechnics' engineering students in the same engineering field in Singapore if the contexts of their students' make up and their engineering curriculum are similar to those of this study.

While the generated theory has limited generalizability, by conducting similar research in different contexts, it is possible to change a set of substantive theories in a formal theory. A formal theory, which can be made up of a number of substantive theories, attempts to provide a framework to explain the experiences of a phenomenon of a number of social groups in different contexts (Strauss & Corbin, 1998). Thus, although one substantial theory has limited generalization power, a formal theory can explain a phenomenon more effectively for a larger community. However, it can never achieve the generalization power of grand theories as in the positivist paradigm. In short, multiple grounded theory studies can advance theoretical research by creating formal theories (Grbich, 1999). Thus, this study can serve as one of the substantive theories of students' perspectives in studying engineering mathematics that can be combined with other studies of the same phenomenon into a formal one.

3.7.2 Standpoint of The Researcher

As I am a lecturer in the department in which students are the participants for this study, I am able to observe the different ways they approach engineering mathematics learning. In other words, I have prior views on the subject. I have my own perspectives about how engineering students think and feel about mathematics learning and, their subsequent behaviours towards it due to my proximity to the participants in my position as a lecturer. Although such preconceived conceptions about the participants can help in enhancing my theoretical sensitivity, they can bias data collection and analysis too. At the same time, due to our lecturer-student relationship, some of the students are more apprehensive and reserved in sharing with me about their experiences in mathematics learning. I believe our unique lecturer-student relationship might have created a power imbalance between us. Therefore, the participants may not want to divulge honest information to me in fear of affecting their academic progress or offending me. Such power imbalance may bias the data collection and analysis stages too. In conclusion, as an insider researcher in this study, I have to acknowledge the methodological limitations caused by my preconceived conceptions about the participants and the power imbalance between us. While recognising such methodological limitations due to my proximity to the participants could not be totally eliminated, I took steps to minimise them so as to improve the rigour of the findings.

3.7.2.1 Limitations Posed by Insider Research

Insider research is very useful for teachers in exploring and developing their own practices in mathematics education (Jaworski, 2004; Jaworski & Goodchild, 2006). However, there are some research limitations that come with it. These limitations need to be tackled effectively to improve the rigour of this study. The first important limitation of insider research that was addressed here is the pre-understanding/familiarity of the researcher in the research setting (Brannick & Coghlan, 2007; Mercer, 2007). As I have been teaching in this polytechnic for a number of years, I have experience in dealing with different types of mathematics students and their behaviours. This is beneficial as it makes me more theoretically sensitive and I am also able to elucidate the meanings of data analysed more effectively. However, such pre-understanding/familiarity can create preconceptions about the researched phenomenon and this can bias the study (Brannick & Coghlan, 2007; Mercer, 2007). Such bias can be created in the data collection and analysis stages through the researcher's failure to probe areas outside their scope of research knowledge, unsubstantiated assumptions of the types of data to be collected and unwillingness to reframe their current thinking in data analysis (Brannick & Coghlan, 2007; Mercer, 2007).

To reduce such limitation, I was consciously aware of my beliefs, values and possible biases due to my familiarity with, and experiences in, the research context in the data collection and analysis processes by recording them in my memos. By being constantly reflexive, I maintained a self awareness of such pre-understanding bias by continually appraising the subjective responses and intersubjective relationships within the data analysed in relation to my potentially biasing experience (Brannick & Coghlan, 2007; Finlay, 2002; Nightingale & Cromby, 1999). By maintaining self reflexivity, the researcher can also improve the confirmability of the study as shown earlier in Section 3.5.4.

The next limitation discussed here is the power imbalance between the insider researcher and the participants. As a lecturer in the same polytechnic as the students, I have ready access to potential student participants. Besides, I am also able to build rapport with them more easily (Mercer, 2007). However, disadvantages in terms of power and trust relations between the participants and the researcher may be created as a result of such proximity (Mercer, 2007; Wengraf, 2001). Power imbalance between them may result in the reluctance of the participants to divulge important information or to question the validity of the research and its analytic framework and results (Hall & Callery, 2001). This is because they may not want to offend the researcher and/or affect their academic progress due to the researcher's higher authority in academic settings. Thus, the participants may not trust the researcher with information that they feel may disadvantage them. As a result, some participants may not want to divulge information that is against the social norms and may instead give socially desirable responses. This might well greatly affect the rigour of the research. Therefore, to remove such limitations caused by power and trust relations, I ensured that the participants were not my former students, nor would they be my future students. This helped prevent any bias due to role duality (the situation where I teach and research on the same set of students) in the research process (Brannick & Coghlan, 2007). At the same time, I shared my personal and professional values with the participants so as to gain their trust, which in turn, enabled more honest disclosures from them. They were also assured that the research would not affect them academically or personally in any way. Such honest communication is known as the processes of relationality and reciprocity (Mercer, 2007; Mallory, 2001; Hall & Callery, 2001).

3.7.3 Issues Arising from the Interview Process

This section will discuss the methodological weaknesses posed in the interview process. Through his symbolic interactionist model of a question-answer sequence, Foddy (1993) argued that conversational interaction that occurs in an interview is problematic. This is because both the interviewer and interviewee are encoding and decoding each others' questions and answers on the basis of their own purposes, presumptions/knowledge about each other and perceptions of the presumptions/knowledge of the other party on himself/herself. In simpler terms, Foddy (1993) meant that different interviewees will attend to different clues in a question, come up with different interpretations of it and end up with different responses to it. This is supported by Wengraf (2001) who claimed that the question of "Referent" (or known as the topic) is important as both the interviewer and interviewee may interpret it differently. Thus, Charmaz (2006) stressed that it is very important to examine the hidden assumptions and meanings behind the participant's use of language in interviews. Besides, experimental results also showed that the expectancies of both the interviewer and interviewee may unintentionally influence the result of the interview too (Kvale, 1996). Although, this weakness in the question-answer sequence can be reduced through good interviewing skills, it can never be totally removed. There will still be some elements of misinterpretation from the interviewer and interviewees. In order to minimise this limitation in this study, I constantly checked with the interviewees whether they had the same understanding of the interview questions as me. At the same time, I also regularly followed up and clarified the meanings of the relevant aspects of the interviewee's answers in the course of the interview (Kvale, 1996).

Another limitation in this study is that I was not able to capture the effect of social cues in data analysis. Social cues (such as body language, intonation, voice) are important in data collection especially when investigating the participants' attitude to a phenomenon (Wengraf, 2001; Opdenakker, 2006). The interviews in this study were not videotaped due to budget constraints. Therefore, I was not able to capture the participants' body language. Besides, I am not trained to interpret social cues. Hence, inaccurate analysis may result if I use social cues as part of my data analysis. Thus, I did not attempt to enhance the data collection and analysis through observing social cues in this study. However, verbal data in this study was sufficient enough to provide the bulk of the data required to produce robust findings.

3.8 Conclusion

This chapter had a number of objectives. First, the suitability of the interpretive paradigm coupled with the symbolic interactionist perspective and their links to the grounded theory approach, were explained and justified. Methods of data collection and analysis, involving theoretical sampling, open, axial and selective coding, were also discussed. Subsequently, the methods used to maintain the trustworthiness of the study in terms of credibility, transferability, dependability and confirmability were detailed. At the same time, ethical issues such as informed consent, confidentiality and emotional protection which are important in social research were defined. In addition, the limited generalizability of findings in this study was acknowledged. Besides, weaknesses of face to face interviews and power and trust issues, and above all, the insider position of the researcher, were detailed .Ways in which some of these limitations were overcome or mitigated, were also discussed. In summary, the use of grounded theory methodology in this study was justified through the description and discussion of the research paradigm within which it was located and positioned and its methodological assumptions, methods, limitations and ethical issues in relation to the main research question.

Grounded theory methodology enables a substantive theory of the students' perspectives of studying mathematics as part of their electrical/electronic engineering diploma courses in a polytechnic in Singapore to be formed. This substantive theory depicts and explains how engineering students perceive the study of engineering mathematics, construct personal intentions in it and form strategies to achieve their intentions. At the same time, it also provides an understanding of the consequences of the strategies on the students. An overview of the substantive theory of Selective Intentionality that describes the experiences of student in engineering mathematics learning will be presented in the subsequent chapter.

CHAPTER FOUR

THE THEORY OF "SELECTIVE INTENTIONALITY" IN ENGINEERING MATHEMATICS LEARNING

Introduction

This study aims to understand the learning experiences of engineering students studying mathematics in a Singapore polytechnic. It is designed to improve understanding of the teaching and learning of engineering mathematics – from the student viewpoint - about which little published research exists in Singapore. The main research question of the study is as follows:

> **What are the students' experiences of studying mathematics as part of their electrical and/or electronic engineering diploma courses in a polytechnic in Singapore?**

The above main research question that is addressed can be answered by the theory of Selective Intentionality generated in this study. This chapter first, provides an overview of the categories and processes in the theory of Selective Intentionality in engineering mathematics learning. Second, it explains the selection of the core category (a key feature of grounded theory studies) of "Intending". Third, the outline of the typology of engineering mathematics learners resulting from the theory of Selective Intentionality will be presented.

In most theses, this chapter would usually come after the data analysis and findings sections. However, in view that this is a grounded theory study, it is placed before these chapters in order to present a general overview of the categories and processes in the theory of Selective Intentionality and its resultant typology to help readers engage with the detailed conceptual development and interpretation in the chapters that follow.

A key finding of the study is that engineering students in a polytechnic in Singapore approach mathematics learning through a series of socio-psychological processes. First, engineering students gather information about engineering mathematics through the interactions with their families, teachers and peers in the different contexts of home, lecture, tutorial and examination. The students' own thoughts and emotions about engineering mathematics learning are thus formed through multiple influences in and outside education. Through such influences, the students clarify their intentions in regard to engineering mathematics as a subject to learn. After clarifying their intentions in regard to learning engineering mathematics, students set their personal aims. They then formulate and operationalise strategies to achieve their learning aims. Consequently, the failure or success of the strategies in achieving their learning aims can further diminish or fortify their motivation and strategies towards future learning of engineering mathematics. Utilising grounded theory research methodology, this series of processes leads to the substantive theory of Selective Intentionality in engineering mathematics learning.

A further important outcome of this study is the conception of a typology of students as learners of engineering mathematics based on their differences in their intentions and subsequent processes in the theory of Selective Intentionality. The typology recognises the following learner types - idealistic learners, competitive learners, pragmatic learners, fatalistic learners and dissonant learners in engineering mathematics learning. In summary, this chapter will be presented as below:

4.1 The Overview of the Categories in the Theory of Selective Intentionality;
4.2 Relationships and Processes between Categories;
4.3 Typology of Engineering Mathematics Learners;
4.4 Conclusion.

4.1 The Overview of Categories in the Theory of Selective Intentionality

The aim of this study is to generate a substantive theory with respect to factors that have influenced the mathematics learning journey of engineering students in a Singapore polytechnic. It describes the basic socio-psychological process by which engineering students manage their mathematics learning.

To achieve this aim, the data were primarily obtained from a series of face to face interviews with 21 engineering students in the case Polytechnic. The data were supported by the literature review, students' reflective journals completed online, retrieved students' bio-data and academic results and informal discussions with their tutors. From these primary and secondary raw data, concepts, categories and processes related to the students' engineering mathematics learning were formed. All categories in this chapter were generated through the process of systematic coding (open coding, axial coding and selective coding) utilised in grounded theory research. From the raw data, initial concepts were generated during the open coding phase. Through further conceptualisation, these initial concepts were classified and reduced into a manageable number of categories and subcategories that are also more encompassing conceptually. The relationships between these categories and subcategories in terms of their conditions, actions/interactions and consequences were then investigated in the stage of axial coding. Eventually, the core category was determined during the selective coding stage. These subsequently led to the formation of the substantive theory of Selective Intentionality and its resultant typology of engineering mathematics learners in the case Polytechnic. The diagram below gives an overview of the categories in the theory of Selective Intentionality.

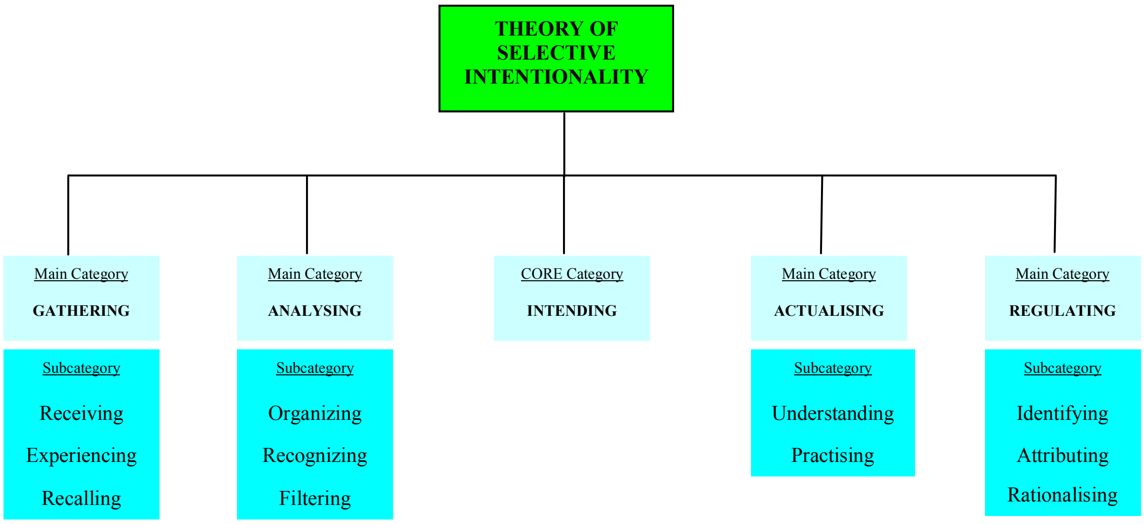


Figure 4.1 Categories in the theory of Selective Intentionality

The core category in the theory of Selective Intentionality is "**Intending**". It is supported by four other main categories of "**Gathering**", "**Analysing**", "**Actualising**" and "**Regulating**". More distinct subcategories are subsumed under each main category as shown in Figure 4.1. These subcategories or properties allow each main category to be illustrated more comprehensively in width and depth. Subsequent sections will provide an outline of each category and its subcategories.

4.1.1 Gathering

The process that depicts how the participants collect information about engineering mathematics is termed as **gathering** within the theory of Selective Intentionality. **Gathering** can be achieved through three distinct sub-processes – **receiving**, **experiencing** and **recalling**. **Receiving** is the process where the participants gather information about engineering mathematics from external sources such as the society, their families, ex-teachers, ex-classmates, polytechnic course recruitment officers and informational materials. **Experiencing** is a process where the participants personally collect such information through their learning experiences in four avenues – lectures, tutorials, self learning and assessments. **Recalling** refers to the recollection of their previous beliefs and learning experiences in mathematics during their pre-tertiary mathematics learning years.

4.1.2 Analysing

The participants then undergo the process of **analysing** the gathered information. They analyse the information gathered through the sub-processes of **organising**, **recognising** and **filtering**.

Organising consists of three sub-processes which are not sequential – **perceiving**, **relating** and **comparing**. **Perceiving** is the process where the participants form personal perceptions of engineering and engineering mathematics education. **Relating** refers to the process where the participants relate their personal beliefs about engineering mathematics education to the discipline of engineering. **Comparing** is the process where the participants look at the similarities and differences between pre-tertiary mathematics education and their current engineering mathematics education. From these processes, the participants form **personal**, **relational** and **comparative** beliefs of engineering and engineering mathematics education. Based on their beliefs about engineering and engineering mathematics education from the process of **organising**, the participants tend to identify the various contexts where engineering mathematics learning is important through the process of **recognising**. Although the participants may see the significance of engineering mathematics in different contexts, they have to recognize the context that is most important and relevant to them. In this regard, the process of **filtering** aims to discover the participants' personal significance of engineering mathematics learning in their own contexts.

4.1.3 Intending

Through the processes of organising, recognising and filtering, the participants are aware of the significance of engineering mathematics learning to them in their present conditions. From here, the participants begin to form their intentions. Their intentions in engineering mathematics learning tend to be related to the amount of mathematical knowledge gained (mastery-oriented intention), the level of social status attained (ego-oriented intention), level of assurance of a good diploma and academic future (career-oriented intention), level of assurance of passing examinations (survival-oriented intention) and level of resistance or avoidance towards education policies (resistance-oriented intention). This process forms the category of **intending**. The category of **intending** is the core category within the theory of Selective Intentionality, in this study.

4.1.4 Actualising

Actualising is the process whereby the participants try to achieve their intentions in engineering mathematics learning. All the strategies in engineering mathematics learning mentioned by the participants aim to achieve the two main "in vivo" categories of "**understanding**" and "**practising**" that are commonly mentioned by all the participants.

Understanding is made up of four different categories: **conceptual**, **functional**, **procedural** and **associational** understanding. **Conceptual understanding** refers to the participants' ability to comprehend how the mathematical formulae are derived. **Functional understanding** is achieved if the participants know the functions of the mathematical formulae and procedures that are being taught. To achieve **procedural understanding**, the participants need to know how to model the steps of the mathematical formulae in solving mathematical problems. On the other hand, **associational understanding** refers to the participants' ability to relate and utilise the mathematical formulae in the engineering problems they are tackling.

Practising is made up of three components – **procedural training**, **simple procedural competence** and **complex procedural competence**. **Procedural training** involves hands-on mathematics problem solving that includes the uses of mathematical formulae and procedures. **Simple procedural competence** refers to the participants' ability to compute basic mathematics questions while **complex procedural competence** is needed to compute engineering applied mathematics questions. A number of strategies are employed in the process of practising.

There is a repertoire of strategies used by the participants to achieve the various forms of understanding and practising mentioned above. They are grouped into **approach** or **avoidant** and **cognitive**, **affective** or **behavioural** types.

4.1.5 Regulating

Regulating is the management of the emotions and thoughts that arise from the consequences of the participants' mathematics understanding and practising strategies. The regulating process is made up of the sub-processes of **identifying**, **attributing** and **rationalising.**

After the implementation of their strategies in the process of actualising, the participants **identify** the consequences that have resulted. These consequences come in the form of work done in the participants' actualising process, their engineering mathematics examination results, social sanctions or rewards from external sources, avoidant or resistant behaviours in mathematics learning and academic emotions. **Attributing** is the process where the participants attach explanations to the success or failure of the accomplishment of their intentions in mathematics learning after they have implemented their actualising strategies. These attributional explanations can be **external** or **internal** and **controllable** or **uncontrollable**. After attributing explanations to their experiences and the consequences of their behaviours, the participants tend to reframe their thoughts in relation to their future motives and actions in mathematics learning through the process of **rationalising**.

4.1.6 Conclusion

The concise presentation of the concepts, categories and processes in the theory of Selective Intentionality has been provided above. However, there is a need to note that the core category and the main categories are not independent entities by themselves. On the contrary, they are closely associated with one another through important relationships and processes. The following section will link up the relationships and processes between these categories and explain why the category of "**Intending"** is the core category.

4.2 Relationships and Processes between Categories

The theory of Selective Intentionality starts with the process of **gathering**. Through gathering, potential engineering participants in the polytechnic collect relevant information about engineering mathematics through external sources (such as society, family, teachers and peers), related experiences in engineering mathematics learning contexts (such as lectures, tutorials, assessments and self study), and their prior mathematics learning experiences in pre-tertiary education. Such gathered information are then utilised in the subsequent process of **analysing** where the participants form personal, relational and comparative beliefs about engineering and engineering mathematics education. Subsequently, the participants recognize and appreciate the various significant aims of engineering mathematics education.

When they have internalised their personal significance of engineering mathematics and its relevance in their contexts, the participants then form their intentions in engineering mathematics learning. This is where the core category of **intending** is created. In short, the main categories of **gathering** and **analysing** give rise to the core category of **intending**. However, the process of **intending** can also influence future **gathering** and **analysing** activities by the students. With their intentions in mind, the participants set their levels of achievement.

They begin to formulate beliefs and strategies in achieving their intentions. This process is the category of **actualising**. When the process of actualising is completed, the participants start to assess if their strategies are successful in achieving their intentions. They also adjust their strategies or conceive new strategies in relation to their engineering mathematics learning in future. This is achieved through the process of **regulating**. Thus, the relationship between the processes of **intending**, **actualising** and **regulating** is cyclical. The diagrammatic relationship between the core category and its main categories is illustrated below:

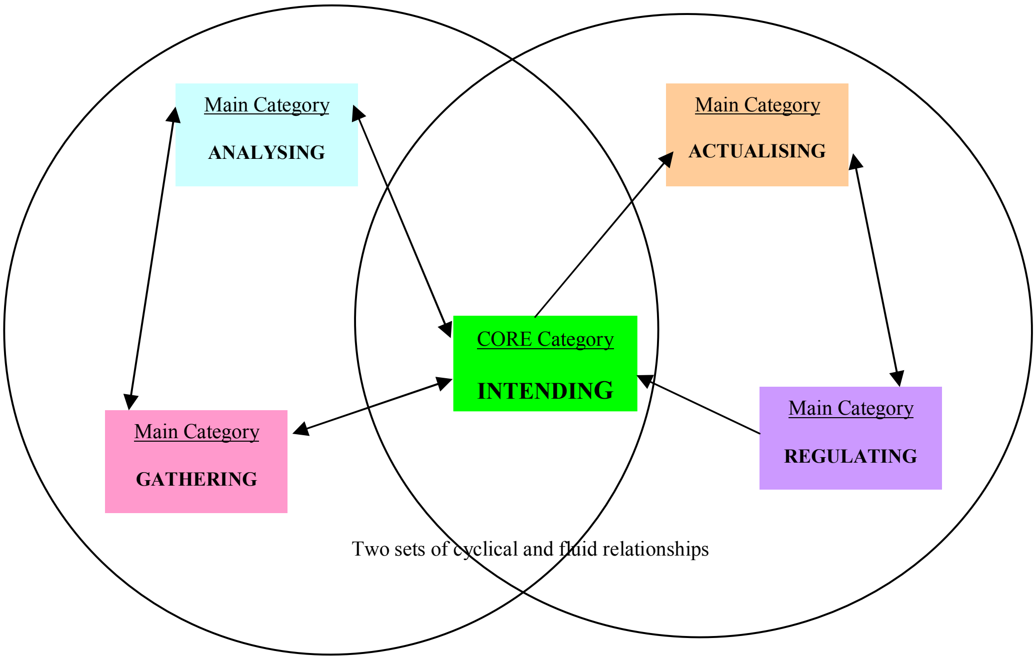


Figure 4.2 Relationships between the categories in the theory of Selective Intentionality

In summary, there are two sets of cyclical relationships which both involve the core category of intending. One of them is the cyclical relationship between the processes of intending, gathering and analysing, while the other set of such relationship is related to the processes of intending, actualising and regulating. Thus, the category of intending operates as the centre of the theory of Selective Intentionality with the other four main categories "orbiting" around it. Without the category of intending, the other main categories may not be relevant or even exist in the participants' engineering mathematics learning journey. Therefore, the category of intending is the core category in the theory of Selective Intentionality.

Different engineering students may not have the same intentions in engineering learning. They make their personal selection on the types of intentions they may subscribe to in their engineering mathematics learning as affected by events and people around them. Their intentions in mathematics learning may also appear to be fluid in the earlier part of their engineering courses before they stabilise and become permanent. They approach engineering mathematics learning differently as affected by their own perceived intentions in it. Therefore, the concept of "Selective Intentionality" – created from the core category of intending – can best encompass the presence of the students' own "selected intentions" in engineering mathematics learning that significantly determines their unique learning experiences in engineering mathematics.

4.3 Typology of Engineering Mathematics Learners

A major outcome that arises from this study is the development of a typology of students with regard to how they approach mathematics learning in their engineering courses. The typology is based on the predominant distinctions made among the participants in the manner they have responded in the analysing, intending, actualising and regulating processes in the theory of Selective Intentionality. In this study, the participants can be broadly classified into five types of learners: **idealistic learners**, **competitive learners**, **pragmatic learners**, **fatalistic learners** and **dissonant learners**.

4.3.1 The Idealistic Learner

Idealistic learners have generally shown great interest in electrical and electronic gadgets since they were young. After they have understood that it is the domain of engineering they have always been interested in, they tend to accept the significance of engineering mathematics in mastering the discipline of engineering. Thus, the intention of the idealistic learners is to gain mastery understanding of mathematical formulae used in engineering.

With their intention in engineering mathematics learning, idealistic learners are usually self driven, interested, optimistic, internally motivated, independent, self assured, consistent and persevering in the learning process itself. They are generally well liked by their lecturers and tutors. At the same time, they help their peers in engineering mathematics learning. They usually put in a substantial amount of academic effort (spending time in tutorials on past years' examination questions) and aim to achieve all types of understanding – conceptual, functional, procedural and associational. In terms of academic emotions in engineering mathematics learning, they feel satisfied if their intention is achieved. If their intention in engineering mathematics is not achieved, they become more determined and interested in the subject.

4.3.2 The Competitive Learner

The competitive learners are driven by their egoistic nature. They want to perform better than their peers in academic domains, including mathematics – which is usually their forte in learning. Thus, they internalise the importance of engineering mathematics as a form of social comparison with their peers. This results in their intention of gaining higher social status among their peers in mathematics learning.

Competitive learners – according to the data – are typically competitive, egocentric, highly confident, persevering, interested, and have a strong sense of pride in engineering mathematics learning. Their intention in engineering mathematics learning usually sets them in competitive relationships with their peers. They spend a substantial amount of academic effort on learning, and aim to achieve functional, procedural and associational understanding in engineering mathematics learning. Competitive learners generally feel proud whenever they do well in engineering mathematics learning. In contrast, they are overwhelmed by anger if they lose out to their peers.

4.3.3 The Pragmatic Learner

Pragmatic learners are influenced by the materialistic Singaporean society that embraces consumerism. They internalise the importance of education in being a passport to fulfilling their future materialistic needs in the society. Thus, engineering mathematics, being an important part of their engineering courses, becomes essential in their intention of gaining higher education and good careers. There are two groups of pragmatic learners – Type I and Type II. Both types can be subsumed under the "umbrella" of pragmatic learner, as they share the same intention, which is the core category, in engineering mathematics learning.

Type I pragmatic learners enrol in their engineering courses voluntarily and have strong foundations in mathematics, while Type II pragmatic learners are enrolled in their current engineering courses out of no choice as their "O" level results (including mediocre mathematics grades) are not good enough to get them into their preferred non-engineering related courses. They hope to take their current courses as a stepping stone to study other non-engineering related courses they prefer, at university level in future. As for their psychological characteristics, both subgroups are pragmatic and materialistic in nature. There are also other differences. Type I pragmatic learners are confident, persevering, interested and possess high self efficacy in engineering mathematics learning. On the contrary, Type II pragmatic learners are realistic, resigned, compromising and under-confident in engineering mathematics learning. Both types of learners predominantly have cooperative relationships with their peers. They also regularly seek the assistance of their lecturers and tutors in their learning. The amount of academic effort in engineering mathematics put in by Type I pragmatic learners tends to be more than their Type II counterparts. Type I pragmatic learners may also experience more positive emotions and less negative feelings, as compared to their Type II counterparts in engineering mathematics learning.

4.3.4 The Fatalistic Learner

Fatalistic learners are academically handicapped by their prolonged multiple failures in mathematics learning since pre-tertiary education. They tend to be weak academically. Fatalistic learners are resigned to the fact that they are not going to do well in their current engineering courses, in which they are placed due to their poor “O” level results. They respond with setting their intention of obtaining only a minimum pass in their diploma courses.

Due to their low level of intention in engineering mathematics learning, fatalistic learners are typically fatalistic, unmotivated, pessimistic, procrastinating and passive and have low self efficacy and determination in engineering mathematics learning. They typically spend the minimum academic effort that is deemed sufficient to help them pass the examinations. They also rely extensively on their peers and tutors. Most of the time, fatalistic learners are affected by their fear of failing engineering mathematics examinations. If they pass their examinations, they usually feel relieved.

4.3.5 The Dissonant Learner

Dissonant learners are placed in the engineering courses because of their poor “O” level results – similar to Type II pragmatic and fatalistic learners. While Type II pragmatic learners aim to postpone their academic interest and fatalistic learners are resigned to their academic incompetence, dissonant learners blame the unfair educational system for their predicament. They perceive that the Singaporean education system is unfairly predisposed towards mathematics and science. Thus, their intention in engineering mathematics learning is to show their displeasure towards the education authorities by avoiding or resisting “the system”. They hardly put in any academic effort in engineering mathematics learning as they usually skip lectures and tutorials. Dissonant learners are also reproachful, distrustful, resistant, unmotivated, uninterested, relenting and under-confident in engineering mathematics learning. Their relationships with their peers and tutors are generally avoidant and resistant. At the same time, dissonant learners do not experience any positive emotions in engineering mathematics learning as they are overwhelmed by their dislike of the education system they have perceived as unfair.

4.4 Conclusion

This chapter has given a concise overview of the concepts, categories and processes in the theory of Selective Intentionality in engineering mathematics learning in a polytechnic in Singapore. At the same time, it has outlined the distinction between the various types of learners in the typology, developed from the theory of Selective Intentionality. Following this chapter, the theory of Selective Intentionality will be explained in detail in Chapter Five and the resultant typology will be elaborated in Chapter Six.

CHAPTER FIVE

THE CONCEPTS AND CATEGORIES OF THE THEORY OF SELECTIVE INTENTIONALITY

Introduction

Chapter Four has presented the theory of Selective Intentionality through the concise presentation of its concepts, categories and resultant typology of students in engineering mathematics learning. This chapter will further depict how these concepts and categories interact to create the theory of Selective Intentionality with reference to the data collected from the 21 participants. It describes the basic socio-psychological process by which engineering students manage their mathematics learning. In summary, this chapter will be structured into seven main sections, in accordance to the main processes and sub-processes of the theory of Selective Intentionality in engineering mathematics learning (as shown in Figure 5.1):

5.1 Gathering;
5.2 Analysing;
5.3 Intending;
5.4 Actualising;
5.5 Regulating;
5.6 The Theory of Selective Intentionality;
5.7 Conclusion.

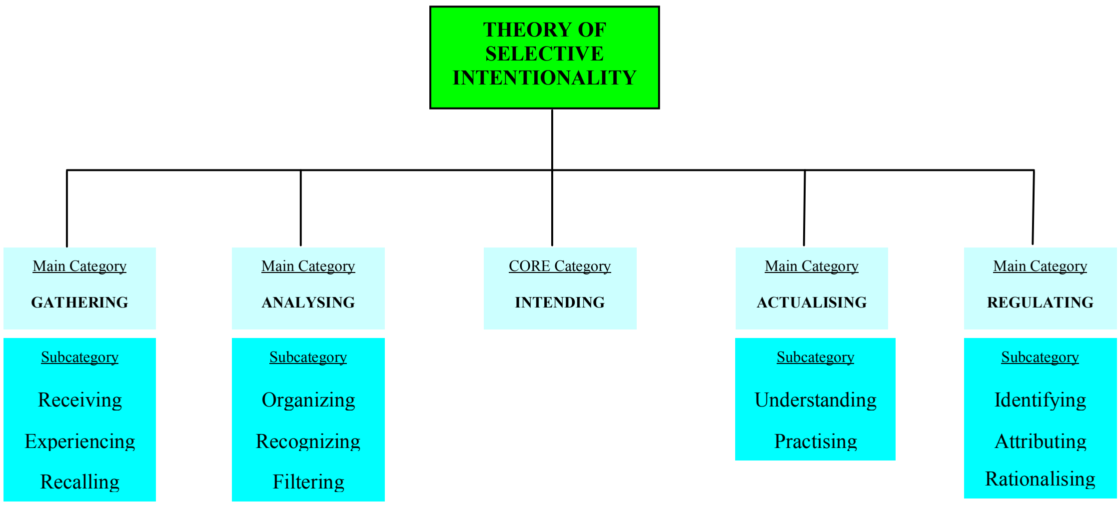


Figure 5.1 Theory of Selective Intentionality and its categories

This study investigates how engineering students approach mathematics learning in a polytechnic in Singapore. The four specific research questions in this study have been addressed by forming concepts and clustering them into various categories and processes explained in the theory of Selective Intentionality:

a. **What are the societal factors that influence the students' experiences in studying engineering mathematics?**
b. **How are the students' intentions in engineering mathematics learning formed?**
c. **What strategies will the students use in realising their intentions and why are they used?**
d. **What are the expected consequences of the strategies on the students in engineering mathematics learning?**

All categories in this chapter have been generated through the process of systematic coding (open coding, axial coding and selective coding) utilised in grounded theory research. From the raw data that are generated from the 21 students' interviews and reflective journals and their tutors' feedback, a total of 1782 concepts have been generated during the open coding phase. Through further conceptualisation, these initial concepts have been classified and reduced into a manageable number of categories and subcategories that are also more encompassing conceptually, each of which has properties and dimensions. The relationships between these categories and subcategories in terms of their conditions, actions/interactions and consequences, have then been investigated in the stage of axial coding. This is also the stage where the main categories of gathering, analysing, intending, actualising and regulating have been formed. Their properties and dimensions are also further developed in depth and width at this point. At the same time, the relationships between the above five categories have been formed. Eventually, the core category of "Intending" has been determined during the selective coding stage. In this study, the core category of "Intending" serves as the central explanatory category with the other main categories and subcategories being organised around it and interacting with it, in terms of their conditions and processes. Thus, the integration of the core category with the other categories results in the formation of the theory of Selective Intentionality in engineering mathematics learning in this study.

5.1 Gathering

The process that depicts how the participants collect information about engineering mathematics is termed as gathering within the theory of Selective Intentionality. The process of gathering usually takes place before or during the first year of their engineering courses. Through the process of axial coding, the means of collecting information about engineering mathematics may be achieved through three distinct sub-processes within gathering – receiving, experiencing and recalling. These three sub-processes can be active, passive or both. The table below represents the main process of gathering, its sub-processes and their related causal conditions in the context of engineering mathematics learning.

Table 5.1 The category of gathering and its subcategories

Core process		**GATHERING**		
Sub-processes	Active	**Receiving**	**Experiencing**	**Recalling**
	Passive			
Causal conditions		Society Family Others (such as ex teachers and classmates and recruitment officers)	Lectures Tutorials Self learning Assessment Teachers Peers	Pre-tertiary school days in learning mathematics
Context where information is gathered		Influences from external sources	Personal learning process in current course	Remembering own prior mathematics learning experiences

These three sub processes of receiving, experiencing and recalling are distinct as shown by their respective unique causal conditions illustrated in the table. At the same time, they are not sequential as they may occur concurrently. Lastly, the information obtained from the main process of gathering significantly influence the subsequent main process of analysing.

5.1.1 Receiving

Receiving is the process where the participants gather information about engineering mathematics from external sources such as the society, their families, ex-teachers, ex-classmates, polytechnic course recruitment officers and informational materials. Below are the in depth descriptions of these external sources.

5.1.1.1 Society

The participants do not receive information about engineering mathematics directly from the society. However, the deeply rooted societal beliefs about mathematics learning in the Singaporean society influence the participants' beliefs about engineering mathematics learning. There are three sets of predominant societal beliefs about mathematics that are constantly mentioned by the participants. Firstly, it is commonly believed that the government emphasises the importance of mathematics, science and technology (besides the importance of the domain of finance) in the economy of Singapore. Second, the participants clearly understand that mathematics is needed in all aspects of life. Lastly, mathematics is one of the most emphasised subjects in primary and secondary schools in Singapore as a pass in it is compulsory for a student to advance into tertiary education. Thus, the Singaporean society sets high standards and expectations when it comes to mathematics learning. Such commonly espoused societal beliefs play an important role in influencing the participants' subsequent beliefs about mathematics learning in their engineering courses. Below is the table that summarises the three predominant beliefs received by the participants from the society. The number of participants mentioning each of these beliefs is shown too to highlight how deep these beliefs are rooted in the Singaporean society. Illustrations of some of the participants' comments about these beliefs are provided in the table.

Table 5.2 Predominant types of received information

Received information from Singaporean Society		Number of participants mentioning item (N=21)	Illustration
Mathematics is important here.		18	**E02:** *I know that the world also revolves around maths.*
Mathematics is needed in all aspects of life.		16	**E15:** *Because maths is used in our daily life. Without maths we cannot do a lot of things.* .
Mathematics education is important here.		15	**E01:** *Because like people said you can fail anything but do not fail maths. Because if you fail maths, you cannot enter poly…*

5.1.1.2 Families

Receiving information about engineering mathematics from the participants' families comes from three predominant areas, namely course selection, expectation and support.

Course selection is not directly related to the learning of engineering mathematics. However, family members, especially parents, may play a part in influencing the participants in the selection of courses in tertiary education. On the contrary, the parents may also leave the selection of courses solely to the participants themselves. Such parental influences are captured by the comments made by E18 and E03:

> *Why did I join Engineering? It is also because my dad is an engineer; he's a Marine Engineer… And… actually all my other relatives are mostly all engineers, SI Engineers, Marine Engineers… (E18)*

> *For my parent side, they never really stress me out. They leave it up to me to decide what I want to study. (E03)*

Receiving information in the form of parental expectation in performing for engineering mathematics or engineering learning can also play an important part in influencing the participants' beliefs in engineering mathematics learning. In this aspect, E02 divulged:

> *My parents stress me to get into the university. They want me to do my best not only in engineering mathematics but also any other modules in the course…*

At the same time, receiving technological, environmental and academic support from their family tends to affect the participants' engineering mathematics learning. Technological support may come in the forms of personal computers, laptops, internet access and other technological gadgets at home. Such technological equipment is important due to the technical nature of the discipline of engineering. In terms of the participants' studying conditions, participants' families may provide a conducive and non-threatening study environment for them. On the other hand, participants' families may also provide an uncaring and unsupportive learning environment for the participants. In addition, some of the family members can be academically competent to assist the participants in the learning of engineering mathematics. However, other participants may not get such academic support due to the low educational level of their family members. With regard to the above, E19 and E10 commented:

> *No, they (her parents) don't really care. They just make sure I get the notebook and broadband connection at home required for my course. They are busy with work. When they are at home, they are always quarrelling, making it difficult for me to study also, so it is better they are not around.(E19)*

> *Because my father is also from this course, so he studied engineering mathematics before. Therefore so he also understands…He can help me. I feel safer selecting this course. (E10)*

Therefore, consequentially, the type and level of support given by the participants' families are likely to have different effects on their engineering mathematics learning. With further axial coding, the types of families' support for the participants are found to be generally divided into two main groups - learning facilitating (as from the concepts of "academically and technologically supportive", "encouraging", "concerned", "realistic expectations" and "interested") and learning impeding (as from the concepts of "disruptive", "technologically disadvantaged", and "uncaring"). The diagram below represents the categories of receiving information about engineering mathematics from the participants' families.

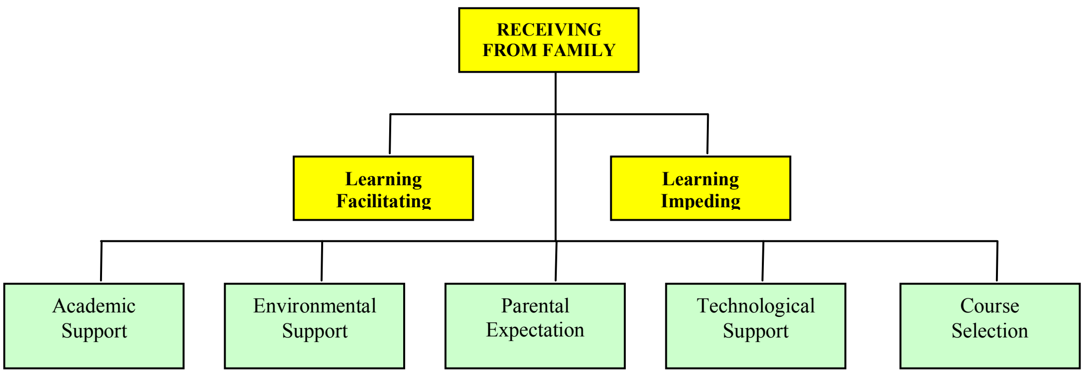


Figure 5.2 Forms of support received from families

5.1.1.3 Others

Other groups of people who can provide substantial information about engineering mathematics to the participants are their ex-teachers or classmates in their pre-tertiary years and polytechnic course recruitment officers. Provided that their ex-teachers are engineering trained, the participants may receive information about engineering mathematics from them.

The participants may also discuss with their former classmates in the selection of courses in polytechnics. Course recruitment exercises conducted by the polytechnics are also a source of such information received by them. At the same time, there are other participants who actively seek information about the engineering subjects they are studying through informational materials such as engineering books, brochures and articles. The participants' comments made below exemplify the category of receiving information from the above sources:

> *In fact, I know it (engineering mathematics) from my secondary school teachers. (E05)*

> *… they (polytechnic recruiters) came to conduct the talk and they said this course will be pretty much useful for me, pretty much to my benefit if I go out to work next time. (E12)*

> *…from young I have come in touch with those stuff (engineering related books), touch those things (electronic equipment)…(E21)*

5.1.2 Experiencing

Experiencing is one of the sub-processes where engineering participants gather information about engineering mathematics. It is a process where the participants personally collect such information through their learning experiences in four avenues – lectures, tutorials, self learning and assessments. At the same time, in these four avenues, two groups of people feature prominently in the process of experiencing – peers and teachers.

5.1.2.1 Peers

Through social interaction during lectures, tutorials and self study, peers influence the participants' engineering mathematics learning process. Coupled with the presence of engineering mathematics examinations and other related assessments in their courses where the participants are aware of their academic abilities as compared to their peers, the phenomenon of academic comparison arises. From this academic comparison process, six types of peer relationships as shown below are formed among the participants during engineering mathematics learning.

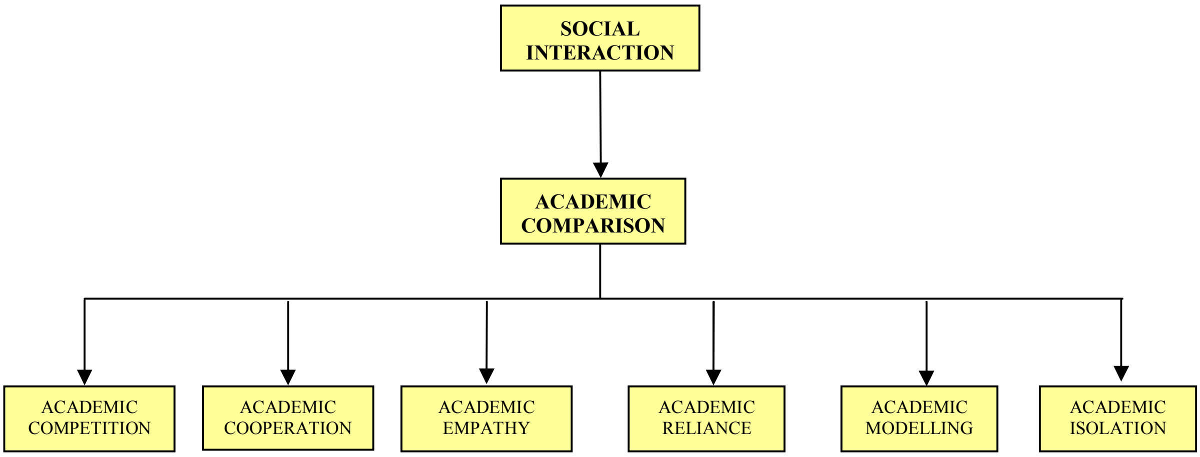


Figure 5.3 Types of peer relationships in the process of experiencing

Firstly, participants may see academic competition between them and their peers as a motivating factor in mathematics learning. This is also due to the emphasis placed on the need to pass engineering mathematics in their courses. This is typified by E02:

> *For peers, competition also motivates us in some way (in engineering mathematics). Nobody likes to lose.*

However, cooperation amongst the peers in engineering mathematics learning is also possible. Such cooperation enables the participants to provide academic and social support for one another in the learning process. Such support can be beneficial or negative to engineering mathematics learning. E20 voiced his thought on such positive support with the following:

> *We have actually this group of friends where we have to stick together and study.*

On the other hand, such cooperation can also result in the participants taking their peers' behaviours as excuses to engage in negative mathematics learning behaviours. Such behaviours are illuminated by E20:

> *They (peers) down there take out their handphones, mp3, PSP to play, make a lot of noise ...you cannot learn....Then you join them and so might as well don't go to class....*

Thirdly, if participants do as badly as their peers in engineering mathematics learning, they can identify with one another and thus find solace among one another. This may greatly alleviate their negative emotions they may experience. This is termed as academic empathy. E17 stated:

> *Then if I can't solve the number ten questions and every one else can't solve it, I feel better…*

Academic reliance happens when the participants are much weaker academically as compared to their peers. These academically weaker participants have to seek the assistance of their peers in mathematics learning extensively. The following is E03's comment:

…most of the time I will go back to my friends and ask them for tips, solutions and how they carry out their methods.

On the contrary, peers may set high expectations for participants who are academically superior to them in engineering mathematics learning. These academically superior participants are also expected to help their weaker peers when needed. Thus, they become role models for their peers in engineering mathematics learning. This is known as academic modelling. The following is E16's judgement regarding academic modelling:

> *Peers… when I get about two or three test good grades…Then they expect me to get good grades for the rest of the course…*

Finally, participants who have no interest in engineering mathematics learning often intentionally isolate themselves from their peers. They feel that they cannot communicate with their peers due to their lack of a common intention in mathematics learning. E07 felt that academic isolation served him better with the comment below:

> *…, but later when they (peers) teach me, I also don't understand. So I don't approach them after some weeks. Anyway, I don't think I am on the same frequency as my peers so I avoid them after this. I don't need their help.*

With regard to these six types of peer relationships, there is a need to note that a participant may engage in more than one of them in their learning process. For example, E16 wanted to set a good example for his peers in learning (academic modelling), studied with them (academic cooperation) and aimed to maintain his supremacy over others (academic competition) in his engineering mathematics assessments. In summary, through such relationships, peers can significantly influence the participants' beliefs, emotions, aims and strategies in engineering mathematics learning.

5.1.2.2 Teachers

Lecturers and tutors are very important in imparting engineering mathematics to the participants in lectures and tutorials. In lectures, the participants learn about the various mathematical concepts, formulae and calculations used in engineering, from their lecturers. They include the use of mathematical concepts such as differentiation, integration, vectors, algebra and statistics. They also learn about the applications of mathematics in engineering situations. During tutorials, participants have first hand experiences in solving engineering mathematics problems with the assistance of their tutors. The tutors may also go through past years' examination papers where the participants learn about the types of assessment questions they have to tackle. The comments below made by some of the participants illustrate the learning of engineering mathematics as assisted by their lecturers and tutors:

> *…usually I feel a bit intrigued by the numerous ways there are to see a particular problem from a lot of different angles (as demonstrated by lecturers). (E03)*
>
> *Teacher say integration and differentiation, even the basic formula learnt in lessons like sine cosine waves we also use, like for example, in principles of electronic engineering we also make use of the sine wave to calculate things, like our AC curve, AC power supply, the components that make the AC supply ….(E08)*
>
> *The lecturer suggests I do the simple questions in section A (examination format) first. As section C requires more thinking, I do them later. (E13)*

Participants also receive information in the types of teaching pedagogies used by their teachers (concepts generated include lecture style, cooperative, interactive, rote training, teacher-centred and student-centred) and the affective aspects of their teachers' instruction (concepts generated include concerned, encouraging, interesting, extra, uninterrupted, strict, unconcerned, insensitive and minimal) in engineering mathematics learning. Such pedagogical and affective teaching can be either facilitating or impeding. Another important aspect of receiving information about engineering mathematics is the expectation level of the lecturers or tutors on their learning. Some lecturers or tutors may set high expectations for the participants' learning while others may not. This may significantly affect their learning strategies and level of effort in learning engineering mathematics. As for academic support from lecturers and tutors, it usually comes in the form of the amount of time rendered for assistance and their willingness to help the participants. Participants are able to gauge how much academic support they can get by considering these two factors. This is important as lecturers play significant part in assisting the participants in understanding engineering mathematics. If the participants perceive that the level of academic support from the lecturers is low, they have to seek alternative ways to get help in engineering mathematics learning. These comments made by the participants show the teachers' types of influences on them:

> *Lecturers, some of them are just go through the syllabus, do not really bother what we do. For others, they actually put in a lot of efforts insisting on we have to do well in the modules especially engineering maths. (E02)*
>
> *The lecturer is teaching very fast, and I don't understand what is he now rushing? (E14)*
>
> *I think my lecturers do not emphasise on getting good grades. They just want us to do our best and do what we can. (E08)*
>
> *The teacher is really very concerned for us in our learning. (E01)*

In summary, the table below shows how the participants receive information from their lecturers or tutors in engineering mathematics learning.

Table 5.3 Teachers' types of influences on students' mathematics learning

Process	Properties	Dimensions
Receiving information from lecturers/tutors	Conceptual knowledge	▪ Types of mathematical concepts ▪ Uses of mathematical formulae ▪ Types of mathematical calculations ▪ Types of mathematical applications in engineering ▪ Variations of mathematics problems ▪ Ways of solving mathematics problems ▪ Types of examination/test questions
	Teaching pedagogies	▪ Types of lesson delivery ▪ Levels of effectiveness of lesson delivery
	Affective Teaching	▪ Facilitating or impeding ▪ Types of affective support
	Expectation level	▪ High or low
	Academic support	▪ Amount of time rendered ▪ Level of willingness of lecturer/tutor to help

5.1.3 Recalling

Recalling refers to the recollection of their previous beliefs and learning experiences in mathematics during their pre-tertiary mathematics learning years. Although such prior experiences and beliefs do not provide any information about engineering mathematics learning, they do play an important part in the formation of their future approach towards it. First of all, their prior, pre-tertiary mathematical knowledge may serve as a conceptual foundation where they learn engineering mathematics. Second, their recalled emotions and beliefs in mathematics learning during their pre-tertiary years tend to set as the basis where they form their attitudes towards engineering mathematics. Lastly, their strategies in engineering mathematics learning are often strongly influenced by their prior beliefs of how mathematics should be learnt in primary and secondary mathematics learning. As such, the recalled information in terms of pre-tertiary mathematics education consists of three categories – concepts, attitudes, and strategies.

In terms of concepts, the participants may recall the mathematical knowledge that they have obtained in pre-tertiary level. This is important as it serves as a basis where they learn engineering mathematics. As E16 put it:

> *In secondary school I learn those basic concepts say basic Calculus, just like integrating or differentiating…But in polytechnic I learn more on application of these basic such as finding voltage or the charge or current.*

Academic emotions and beliefs in pre-tertiary mathematics learning experiences seem to play an important part in forming the participants' attitudes towards their present engineering mathematics learning experiences. These recalled academic emotions and beliefs can be positive or negative. The participants' comments below capture such attitudes towards engineering mathematics learning:

> *I like mathematics because since young my mathematics has been quite good. (E01)*

> *I don't know what is engineering and it needs maths which is my weakest and most hated subject in secondary school. (E19)*

> *… during secondary school, I was very frustrated that I could not do maths. Therefore, I might as well quit doing as after taking any maths test, it was like as good as failing one. (E14)*

Lastly, participants tend to recall their strategies in mathematics learning in pre-tertiary years. They usually attempt to replicate those pre-tertiary tried strategies in their present engineering mathematics learning. The following illustrations from the data demonstrate this:

> *I was taught to do it in primary school as well as in secondary school and that's what I learnt is that maths is a practicing subject... (E12)*
>
> *I will calm myself down and think of other ways to solve the problem (in secondary school) ... (E03)*
>
> *For me, if I understand, I can teach my friends, then by teaching my friends I can learn more about it (in secondary school). (E10)*

In summary, recalling is a process where the participants recollect their prior conceptual knowledge of, attitudes towards and previous strategies used in, pre-tertiary mathematics learning. They usually serve as an important source of information for their current engineering mathematics learning.

5.2 Analysing

After gathering information about engineering mathematics through the processes of receiving, experiencing and recalling, the participants undergo the process of analysing the gathered information. They analyse the information gathered through the sub-processes of organising, recognising and filtering. These sub-processes are sequential. They are shown as below.

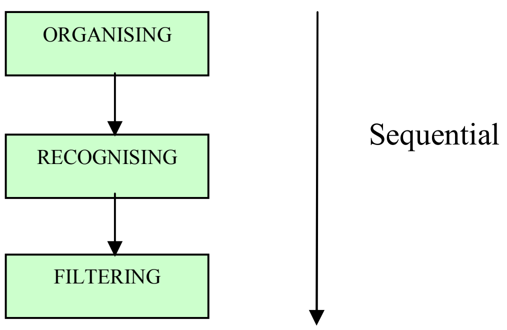


Figure 5.4 The sequential nature of the process of analysing

5.2.1 Organising

Organising consists of three sub-processes which are not sequential – perceiving, relating and comparing. These three processes allow the participants to organise their obtained information about engineering mathematics into three main types of beliefs – personal, relational and comparative beliefs.

5.2.1.1 Perceiving

Perceiving is the process where the participants form personal perceptions of engineering and engineering mathematics education. In this study, these are termed as personal beliefs. Below is the table that shows the various subcategories of personal beliefs formed in the process of perceiving.

Table 5.4 Types of personal beliefs in engineering and engineering mathematics education

	Engineering education	**Engineering mathematics education**
	Externally influenced	Personally experienced
Personal Beliefs	○ Importance in societal technological needs ○ Emphasis on engineering by government ○ Economic value ○ Stepping stone to other occupations ○ Attitude	○ Mathematical formulae ○ Calculation ○ Problem solving ○ Understanding and practising ○ Attitude

There is a set of beliefs of engineering and engineering mathematics learning that is commonly accepted by the participants. In the domain of engineering education, these beliefs are mainly influenced by external sources such as society, schools, parents and peers as in the process of gathering. It is commonly believed that engineering is very important in fulfilling the technological needs of the modern Singaporean society. Engineers help to maintain the comfortable and modern lifestyle of Singaporeans. The participants can also see the great emphasis the government puts on engineering in Singapore through the presence of engineering courses dominating tertiary education. Another aspect that is commonly agreed by the participants is the economic value of engineering in the Singaporean society. Engineering is known to be a stable job that commands a comfortable salary. More importantly, a versatile engineering education is recognised as a stepping stone to a variety of more attractive non-engineering based occupations. They may also form different levels of affection for the discipline of engineering. Such beliefs are illustrated by the participants' comments below:

> *Engineering is also important in this society because everything in every day life (technological gadgets) needs maintenance and when it comes to maintenance, it is the engineers who do it. …So I think the Government try to produce more engineers in Singapore because there are a lot of engineering course in the polytechnics. (E06)*

> *Engineering in polytechnic right, is the biggest field…And most of them would take Engineering because they say getting an engineering job in future is easy… (E20)*

> *My uncle said that, now people are taking up business course, why not you for Engineering first? It is because engineers learn the basics of all disciplines. Therefore, if one still wants to go into business, it is can be done easily…. actually a lot of businessmen now right graduated from engineering. (E14)*

> *….since young I actually like electronics gadgets…I do enjoy mathematics learning… (E05)*

In the domain of engineering mathematics education, participants form their beliefs about it in accordance with its content. And these personal beliefs about engineering education are primarily formed through the participants' own experiences in lectures and tutorials. Selected comments below explain the types of such beliefs formed:

> *…it is more of formula application. (E12)*

> *Engineering mathematics is doing calculations with certain formulae. (E18)*

> *In engineering mathematics, we need new angles to create solutions to problems. (E03)*

> *In engineering mathematics, there are many ways to approach a problem…it is about understanding all the theories and the formulae and it is not a subject whereby you is memorise one, it requires practice and practice. (E06)*

> *I felt excited when I could not solve a mathematics problem (in engineering mathematics). I want to solve it more because it is challenging. (E16)*

To summarise the participants' personal beliefs about engineering mathematics education, they tend to believe that engineering mathematics is predominantly made up of mathematical formulae and calculations. They usually perceive it as a form of problem solving where multiple approaches can be employed. And, to the participants, the best method to master engineering mathematics is to understand its concepts and formulae. Practising its procedures and calculations is also deemed as essential in doing well in engineering mathematics education. Lastly, they may form learning attitudes such as levels of affection or confidence towards it. Some students may like engineering, while others cannot see the reason why they need to study it.

5.2.1.2 Relating

After forming personal beliefs about engineering and engineering mathematics education, the participants may relate these two groups of beliefs together. These are termed as relational beliefs of engineering mathematics learning. This is especially important as engineering mathematics learning may be seen as a meaningless theoretical process by the participants if it exists as a solitary entity by itself. Through axial coding, the relationship between engineering and engineering mathematics education, as perceived by the participants, may be categorised into two distinct groups as shown in the diagram below.

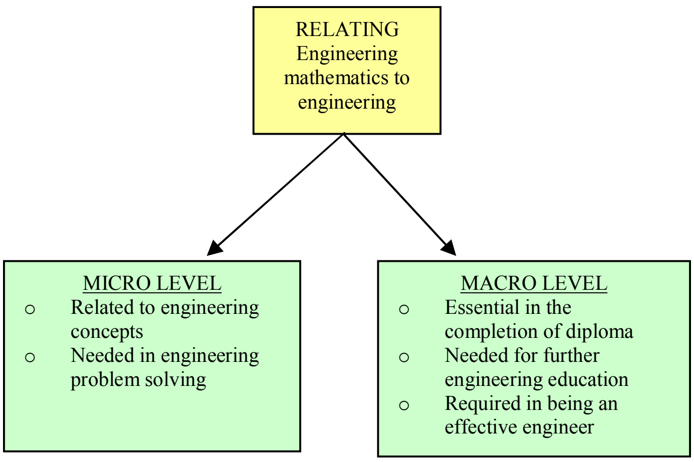


Figure 5.5 The process of relating at micro and macro levels

The first group of categories is content based at a micro level. First of all, engineering mathematics is seen as a component required in understanding engineering concepts. Without engineering mathematics, many engineering concepts cannot be operationalised. Second, the formulae in engineering mathematics are needed in computing real life engineering problems, which is very important in the discipline of engineering. These two categories are exemplified by the participants' remarks below:

> *…you know engineering concept like current, we need concepts like differentiation, integration to understand it… (E13)*
>
> *After all, in electronics, it still covers things like complex numbers covered in mathematics. This allows us to have a clearer picture of what we studied in electronics, sine waves, cosine waves etc. (E01)*
>
> *We have engineering mathematics calculations in electronics so whatever maths learnt is a must if you are doing electronics so as to enter the digital world. (E12)*
>
> *…I saw some engineering mathematical formulae used in engineering lesson… (E07)*

The next group of categories is at a macro level with a view to their future work and academic careers. First of all, in order to perform effectively as an engineer, a sound foundation in engineering is needed and engineering mathematics is part of it. E03 supported this view:

> *…a lot of formulae at our fingertips are needed to do whatever project we are doing as part of our jobs in future.*

To obtain their diplomas, the students need to pass a substantial number of engineering modules where engineering mathematics is an important part of them. Thus, to pass these modules, the participants need to have a strong foundation in engineering mathematics. In this aspect, E11 said:

> *…..the importance is I need the grade (in engineering modules) to progress on in my course and mathematics is important in them.*

On the other hand, participants may also understand the relationship between engineering mathematics and their future engineering education at university level. E10 stated in this respect:

> *Next time you go to university or higher study you can make use of engineering mathematics. Diploma is just a basic foundation for degree.*

In summary, the participants' ability to relate engineering mathematics to engineering education allows them to attach meaningful connotations to engineering mathematics.

5.2.1.3 Comparing

As mathematics learning takes up 12 to 13 years of their pre-tertiary years, the participants tend to see differences and similarities between engineering mathematics and pre-tertiary mathematics. These are termed as comparative beliefs. They may use their pre-tertiary experiences of mathematics learning as the basis in forming beliefs about engineering mathematics learning.

First of all, they usually observe that there are differences in the content of both subjects. Engineering mathematics is believed to be more narrowly scoped, in depth and application based as compared to pre-tertiary mathematics. This is noted by E05 and E21 who stated:

> *I find that secondary school mathematics is a bit different, we study the basics. When we study engineering mathematics, we study more difficult ones, apply it in the circuits. (E05)*
>
> *Then… secondary maths is very general and wide… basic…Engineering is about application, deeper and you find it useful in engineering… (E21)*

Secondly, the participants tend to agree that engineering mathematics learning requires more independent learning from them as compared to secondary mathematics. This is because they are seen by the lecturers and tutors as mature students who should take more ownership of their learning. Regarding this aspect, E12 said:

> *Because we are not so bound to the rules in polytechnic….It's like I have my own time, I have to do it, if I don't do it, it's my loss. So I just plan out the schedule and I'll just go into studying.*

As for the similarities, one of them is the belief that mathematics is about understanding and practice. They bring this strong belief of theirs into their tertiary education and it may significantly determine their future strategies in engineering mathematics learning. E07 and E19 stated:

> *We must understand and practise a lot so that we can do well in all mathematics. (E07)*

> *Everyone tells me that since primary school, for mathematics, practise and practise then it will be fine. (E19)*

Lastly, the participants have always believed mathematics as a problem solving tool since they were first introduced to it in pre-tertiary education. E13 put in:

> *I believe, maths is very important as long as whether you working, or whether you are staying at home or whatsoever you are doing, maths is be applied everywhere and every minute ….Engineering Mathematics, I think is also very important especially when you have to go out to the working world where a lot of calculations you have to do as the technological advances will not have come about without maths.*

In summary, the process of the comparison of pre-tertiary and engineering mathematics allows the participants to see differences in their content in terms of width, depth and scope. The differences in the level of personal ownership in learning are also noted between pre-tertiary and engineering mathematics learning. The comparison process also enables the participants to appreciate the similarities in learning strategies and aims, of pre-tertiary and engineering mathematics learning. As together with the participants' personal and relational beliefs about engineering and engineering mathematics education, such comparative beliefs are essential in the subsequent process of recognising.

5.2.2 Recognising

Based on their personal, relational and comparative beliefs about engineering and engineering mathematics education, the participants tend to identify the various contexts where learning engineering mathematics is important through the process of recognising. It is important in this study to note that the participants may recognise a number of instances where engineering mathematics is significant. However, this does not mean that all such recognised instances may play a predominant role in their intentions in engineering mathematics learning. These contexts where engineering mathematics is important, as deemed by the participants, are represented as below.

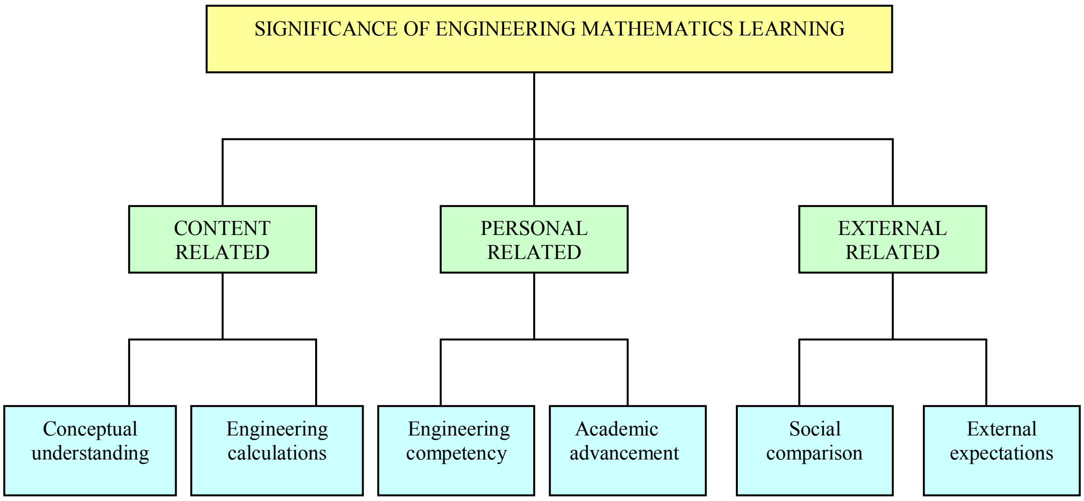


Figure 5.6 The significance of engineering mathematics learning

The first group of contexts where engineering mathematics is deemed significant is content related. Firstly, all participants understand the importance of engineering mathematics in understanding engineering concepts. Second, they also realise the value of mathematical formulae in computing engineering calculations. E13 and E06 emphasised the significance of engineering mathematics at content level:

> *So basically a lot of mathematics is involved, unless you have a strong foundation in this, if not, it is very difficult to proceed on with understanding of this structure (engineering concepts)…(E13)*

> *Understand how this formula can be used, where it should be used, and later when we given a scenario (engineering problem), we can use this formula to help you in that scenario to get the answer. (E06)*

Personal-based contexts where engineering mathematics is important are concerned with the participants' personal aims in learning it. One of its sub-categories is based on the participants' understanding that engineering mathematics education is important in performing effectively as an engineer in the future. The other sub-category of such personal-based significance stresses the importance of engineering mathematics learning in terms of the participants' academic promotion in their diploma courses and advancement to higher education. These are supported by E18, E02 and E20 in their comments:

> *My intention of studying engineering maths is to make use of maths in my working life. (E10)*
>
> *Basically to obtain an engineering course, engineering maths is one of the requirements…. Engineering maths, when we use it most of the time when we are in our job. (E02)*
>
> *If you work as an engineer, you obviously have to use engineering mathematics. Actually, a lot of people tell me that a good engineering diploma is just a stepping stone to university. (E20)*

The contexts where engineering mathematics learning is essential may be external-based as they are related to social factors such as society, parents and peers. Some participants see the importance of engineering mathematics learning as a form of academic and social comparison with their peers. There are also others who understand the significance of engineering mathematics as fulfilling their parents', lecturers' or peers' expectations. E08 and E02 mentioned such external-based significance in their interviews:

> *And only 5 % of the cohort can get distinction, it serves as a motivation for me to study harder and revise for the subject (engineering mathematics). (E08)*
>
> *My dad influences me in doing well for this course so as to get my diploma. (E12)*

In summary, the participants may recognize the different contexts where engineering mathematics is significant, but only some of them may provide the foundation where the participants form intentions in mathematics learning. The process of filtering will help the participants to sieve out the context, among the above mentioned ones, where engineering mathematics is most important and relevant to their current circumstances.

5.2.3 Filtering

The participants have their own beliefs about the significance of engineering mathematics in different contexts as shown in the category of recognising. However, not all of these recognised contexts may form the basis of their eventual intentions in learning engineering mathematics. In this respect, the whole interview transcript of E20 revealed a number of contexts where engineering mathematics is deemed significant:

> *And most of them would take Engineering because it is easier to get a job with it…Actually, they a lot of people tell me a good engineering diploma is just a stepping stone to university….if you work as a engineer, you obviously have to use engineering*

> *mathematics….If you disregard or cannot take maths, you have no chance of passing it (engineering diploma) at all…*

It is clear from E20's thoughts above, that the participants may recognise the importance of engineering mathematics in facilitating a versatile future working career, positioning as a stepping stone to university education, producing a competent engineer and passing their current diploma course. However, not all of the relevant contexts may form the basis of students' intentions in mathematics learning. Only one of these contexts where engineering mathematics is important has the most important personal consequences on them. They are able to relate this particular context where learning engineering mathematics is significant, to their present state. From there, they internalise the fact that this particular context is significant to them in engineering mathematics. In short, their internalised personal significance of engineering mathematics learning may then form the basis of their intentions in it. In this regard, the process of filtering aims to discover the participants' own internalised personal significance of engineering mathematics learning.

The process of filtering is influenced by a number of intervening factors. The first few factors are mentioned in the earlier sections: the presence of their personal, relational and comparative beliefs that are formed in the process of organising and the recognition of the contexts where engineering mathematics learning is essential, in the process of recognising. Another important intervening factor is related to the occurrence of a critical event and its consequential effect that can be traced back to their pre-tertiary life or current engineering course experiences. It is termed as the "critical trigger" in this study. Together, all these intervening factors determine the participants' eventual intentions in engineering mathematics learning.

5.2.3.1 Critical Trigger

A critical trigger helps the participants to appreciate how engineering mathematics is significant to them in their present state. It consists of the critical event and its consequential effect. A critical event is an unique occurrence in the participants' pre-tertiary experiences or their first year in their engineering courses, that serves as one of the determining factors in their internalisation of the personal significance of engineering mathematics learning among the different contexts where engineering mathematics is deemed important as recognised by them.

This critical event often leads to a consequential effect that may form the basis of their intentions in mathematics learning.

One of the critical events that may occur is the participants' development of a keen interest in electronic, electrical and other scientific gadgets since their younger days. Consequentially, they love the discipline of engineering in their current diploma courses. From there, they recognize the importance of mathematics in acquiring such engineering knowledge that they are actively pursuing, regardless of their affection and ability level of mathematics. To illustrate the above, E21 who has done very well in engineering mathematics stated:

> *I like those items that can support human daily and I like to find out how they come about… When I'm young, I would open like those toy guns to see what makes it operate………At first I think that the modules - principles of electrical and electronic engineering (PEEE) and digital engineering (DE) are interesting but maths which I have to count on is troublesome and also not very interesting, thus I have to force myself to like it so that I can do better in PEEE and DE questions…*

Next, the participants' low self efficacy in engineering mathematics learning triggered off by critical events in their previous mathematics experiences can also influence their intention of learning. The participants' self awareness of their ability in engineering mathematics usually develops during their pre-tertiary mathematics learning period or even during their polytechnic years. They may have suffered multiple failures in mathematics learning since pre-tertiary education or during the first year of their engineering courses. This has resulted in them forming perceptions that they have limited ability in their mathematics learning and subsequently they set low goals in it. This may also result in them disliking mathematics. In this regard, E15 gave a candid response:

> *I aim to get more than a pass enough… Because my maths is very lousy… In secondary school I always fail maths. I don't really like maths.*

Participants may also see the importance of gaining social status among their peers. As a result, they want to do better than their peers in education, including engineering mathematics learning, in order to gain their respect. Consequentially, such participants are usually good in engineering mathematics learning. They also like mathematics since it allows them to score better than their peers in assessments. At the same time, this often seems to result in the competitive and egoistic nature of such participants. E8 is such an example and he commented:

> *Mathematics is my strongest subject. Only 5 % of the cohort can get distinction, it serves as a motivation for me to study harder and revise for the subject. I force myself to do well and be better than the others. I feel satisfied when I scored better than the others.*

Lastly, the societal standards set with regards to mathematics learning may also create the basis for the participants' intentions in mathematics learning in the process of filtering. As influenced by the Singaporean society that embraces consumerism, participants may engage in the pursuit of their materialistic desires since their younger days or when they become more mature during their tertiary education. They perceive that they can have better career prospects and advancement to higher education (tools to reach their materialistic desires) if they can do well in their courses. Sometimes, such societal expectations are reinforced by other significant external agents such as parents and teachers. Accordingly, they may internalise the significance of engineering mathematics in achieving engineering competency, advancing into university education and fulfilling significant persons' expectations. E14 who hopes to carve out a good career for himself in engineering is a good example of such participants.

At times, the failure of the participants to get into their choice of study may also be set as an important critical event. This means that they do not fancy their current engineering courses at all, but they have to compromise in this case. Therefore, they may postpone their current learning interest and plan to pursue their course of interest eventually at university level by doing well in their current course. In this regards, E04 whose "O" level results were not good enough to put her in her first choice of study explained:

> *Ah…this is my seventh course so I never do care about it … hehe… at least I can go to polytechnic ….so I decide to study hard in order to go university, then I change a course I am interested in there.*

However, some of these participants may instead form resentment against the educational system which they perceive it as being unfair to them. They do not like their current courses at all as they have no interest in them. This is what E07 protested in his interview:

> *Not everyone can do mathematics, this is not fair in Singapore. I got no interest in mathematics…I have no motivation (in this course).*

In summary, there are different critical events that may influence the participants' eventual internalisation of the significance of mathematics learning unique in their own situations. Such critical events in engineering mathematics learning include affection for engineering, low self efficacy in their mathematical ability, competitive nature, meeting future societal materialistic needs, failure to get into courses of choice and the lack of interest in their current courses. Another important point to take note is the possibility of a learner being influenced by more than one critical trigger at the same time. The presence of these concurrent critical triggers in a participant's learning experience is usually complementary in his/her filtering process. For example, E09 was affected by both her materialistic pursuit and failure to get into her preferred course in forming her final intention in engineering mathematics learning. Her current intention involves the postponement of her academic interest. She will try to do well enough in the current engineering course to pursue her preferred discipline at university level. This will still be in congruence with her pursuit of future materialistic needs through a good career.

Together with their personal, relational and comparative beliefs (in the process of organising) and perceived importance of engineering mathematics learning (in the process of recognising), the consequential effects of these critical events tend to influence the participants in the formation of their intentions in engineering mathematics learning. This is termed as the process of filtering and it is very essential in the subsequent process of intending. More importantly, through the process of filtering that is made up of the organising and recognising processes, and the critical trigger, the participants become aware of, and internalise, the significance of engineering mathematics learning to them at their present state.

5.3 Intending – The Core Category

After the process of filtering, the participants begin to form intentions in it. This process forms the category of intending. The participants' intention in engineering mathematics learning in this study is based on their internalised personal significance of mathematics learning in the process of filtering. In this study, the participants' intentions in engineering mathematics learning consist of the following components: **their own internalised significance of mathematics learning**, **aims**, and **perceived intention-related consequences**. The participants' **own internalised significance of mathematics learning** in engineering mathematics learning is jointly influenced by their organised personal, relational and comparative beliefs, recognised contexts where engineering mathematics learning is important and critical trigger. The participants may accept and internalise their personal significance of engineering mathematics learning in terms of conceptual understanding, academic and career advancement or social comparison. After recognising and accepting their personal significance of mathematics learning, they create their aims in engineering mathematics learning.

These **aims** are built on the basis of the participants' personal significances of mathematics learning. They can be related to the amount of mathematical knowledge gained (mastery-oriented intention), the level of social status attained (ego-oriented intention), level of assurance of a good diploma and academic future (career-oriented intention), level of assurance of passing examinations (survival-oriented intention) and level of resistance or avoidance towards education policies (resistance-oriented intention) as perceived by the participants. Having aims in engineering mathematics learning lead the participants in setting self perceived tangible or intangible targets in judging the level of success of their aims. Such targets are termed as their **perceived intention-related consequences**. These targets include examination grades in engineering mathematics modules or the courses, amount of time spent in understanding or practising, recognition from peers or family and level of avoidance from learning.

There is a need to note that the failure to achieve their perceived intention-related consequences can create new critical events for the participants, especially during the first few months of their engineering courses. This possibly results in a new critical trigger that may change a participant's original intention. An example of participant's intention in engineering mathematics learning being altered due to change in critical events is shown below:

> *E12 has decided not to disappoint his father by securing a good future for himself through his course* **(original critical trigger)**. *Thus, building up a good future for himself became important to him* **(original internalised personal significance)**. *He then aimed to get a good diploma when he first started the course* **(original aim)**. *However, during the first year of his course, he was struggling for a pass in those relevant mathematics assignments and assessments* **(failure to achieve original intention-related consequences)**. *He felt that he was just not good enough to achieve good grades for a good diploma* **(new critical trigger)**. *He thought that being able to secure a pass diploma was more important and realistic to him at this moment* **(new internalised personal significance)**. *Therefore, he had to fight for "survival" in engineering mathematics learning* **(new aim)** *and target a minimum pass in his examinations* **(new intention-related consequences)**.

Such changes of critical events that eventually cause the change of intentions in engineering mathematics will be further elaborated in Chapter 6.1.6. Below is the flowchart that summarises the relationships between the processes of organising, recognising, filtering and intending, as according to the timeline of the participants' academic journey.

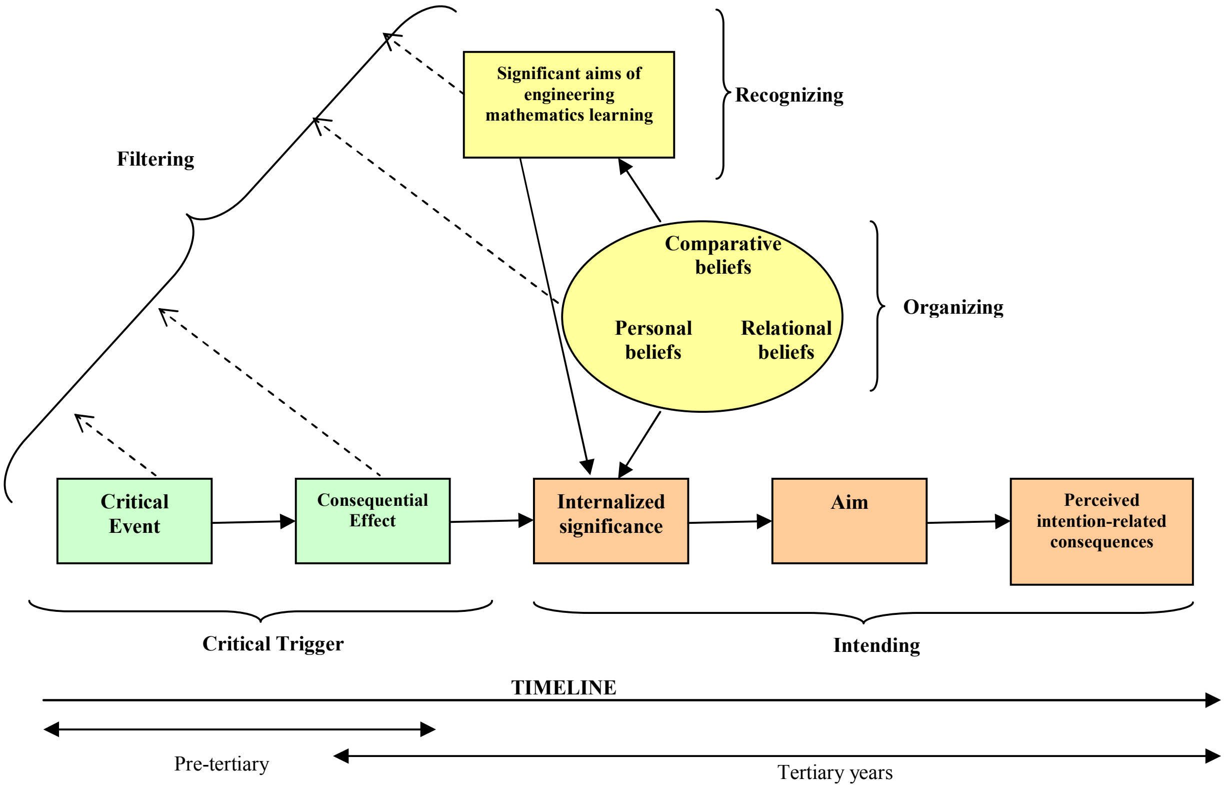


Figure 5.7 The relationship between the core category of intending and other categories

An example of the process of intending as influenced by the process of filtering is shown in the case of E05:

> *Since young, E05 has been fascinated by how electronic gadgets work* **(filtering: critical event)**. *He liked to open up such gadgets to discover how their components functioned. As he grew older, he came to understand that it is the domain of engineering that captivated him* **(filtering: consequential effect)**.*At the same time, as affected by the society, family and peers, he believes that engineering is important in the country's economy* **(filtering: personal belief, seeing significance)**, *mathematics is significantly related to engineering* **(filtering: relational belief, seeing significance)** *and more practical than secondary mathematics* **(filtering: comparative belief)**. *Therefore, he opted for the course of engineering as his tertiary education. Through his love of engineering, he understands the importance of mathematics in understanding engineering is more important than other*

> *significant aims* **(intending: seeing personal significance of engineering mathematics)**. *Therefore, he takes engineering mathematics learning as the process of gaining engineering knowledge* **(intending: aim)**. *To gauge whether he has achieved his aim in engineering mathematics learning, he sets himself targets in mathematics examination, evaluate if he can apply the mathematical knowledge in engineering modules and ensure targeted invested time in understanding and practice is attained* **(intending: perceived intention-related consequences)**.

The category of intending is the core category in this study. In this study, the other four main categories formed (gathering, analysing, actualising and regulating) are related to this state of having an intention in engineering mathematics learning. The processes of gathering and analysing set the basis for the formation of the participants' intentions in mathematics learning. At the same time, the process of actualising is related to the strategies utilised in achieving the participants' intentions in mathematics learning. Lastly, the process of regulation where the participants analyse the consequences of their use of strategies in accomplishing their intentions, in turn, affects the participants' further intentions and strategies in engineering mathematics learning. Thus, the category of intending operates as the centre of the theory of Selective Intentionality with the other four main categories "orbiting" around it. This will be further described in Section 5.6 where all the categories integrate with the core category of intending to create the theory of Selective Intentionality.

In summary, with clearer intentions in their engineering mathematics learning, as created through the process of filtering, the participants begin to form strategies to achieve them in the subsequent process of actualising.

5.4 Actualising

Actualising is the process whereby the participants try to achieve their intentions in engineering mathematics learning. All the strategies in engineering mathematics learning mentioned by the participants aim to achieve the two main "in vivo" categories of "understanding" and "practising" that are commonly mentioned by all participants. This is due to the participants' unanimous belief that understanding and practice are the keys to success in engineering mathematics learning as influenced by their own personal learning experiences and external factors such as society, teachers, peers and parents. The process of actualising occurs in three contexts in engineering mathematics learning: lectures, tutorials and self learning. Participants use a repertoire of strategies to achieve their understanding and practice of engineering mathematics. Below is the elaboration of the processes of understanding and practising.

5.4.1 Understanding

The concept of understanding first emerged during the open coding process of the first batch of interviews. These students perceived understanding ("in vivo") of engineering mathematics as important in their learning. However, the properties and dimensions of the concept of understanding were not well explored and defined due to the lack of relevant data in this first batch of interviews. Therefore, through theoretical sampling, students in the second batch of interviews were specifically probed on the concept of understanding. This was achieved through presenting them with some mathematical formulae or equations such as $\frac{d}{dx}\left[x^5\right] = 5x^4, \int\left[\cos x\right]dx = \sin x, 1 + j = \sqrt{2}\left[\cos(\frac{\pi}{4}) + j\sin(\frac{\pi}{4})\right]$ and eliciting their perspectives of what they understood about them. From the analysis of the data collected in the second batch of interviews, the properties and dimensions of the concept of understanding were further enhanced and developed. The concept of understanding was eventually elevated to the status of a category that consists of four different subcategories: conceptual, functional, associational and procedural understanding.

Before the various types of understanding are discussed, the meaning of theorems, formulae and procedures unique in engineering mathematics will be defined. Mathematical theorems are statements that can be proven on the basis of agreed mathematical assumptions and can be represented in the form of formulae. In engineering mathematics, theorems are usually represented as formulae. Procedures refer to the steps in operationalising the theorems or formulae.

Firstly, conceptual understanding refers to the participants' ability to understand how the mathematical formulae are derived. In other words, it indicates the basis of the mathematical assumptions and proofs of the mathematical formulae. The students' comments below describe the notion of conceptual understanding when they were asked about their perceptions of the formula, $\frac{d}{dx}\left[x^5\right] = 5x^4$:

It is good to know the theories or proof behind the formula and why it is like this. (E06)

If I know why this formula comes about (the proof), why it is put this way, I can understand it better. (E08)

Functional understanding refers to the participants' capacity to comprehend the functions of the mathematical formulae and procedures in the mathematics domain. The participants' remarks below demonstrate the meaning of functional understanding when they were probed about what they think of the formulae, $\frac{d}{dx}\left[x^5\right] = 5x^4$ and $\int\left[\cos x\right]dx = \sin x$ respectively:

...it shows how much x^5 changes when x is changing every second. (E13)

In maths, this also means we find the area under cos x if two points are given. (E06)

As perceived by the participants, procedural understanding refers to the capability to model the steps in the mathematical formulae in solving mathematical problems. The category of procedural understanding is shown by the participants' comments below with regards to the formulae, $\frac{d}{dx}\left[x^5\right] = 5x^4$ and $1 + j = \sqrt{2}\left[\cos(\frac{\pi}{4}) + j\sin(\frac{\pi}{4})\right]$ respectively:

Yes, this is the differentiate x^n thing, if I see it in exams, I just need to put in the formula and fill up the values, I think... (E07)

To get the answer (Right hand side) just got to key the values (Left hand side) into the calculator. (E19)

Lastly, associational understanding refers to the participants' ability to relate and utilise the mathematical formulae in the engineering problems they are tackling. This means that the participants convert mathematical formulae into engineering terms and apply them in solving engineering problems. Associational understanding is mentioned in the participants' accounts below with regards to the equations of $y = 2\sin\left[x + \frac{\pi}{3}\right]$ and $\frac{d}{dx}\left[x^5\right] = 5x^4$ respectively:

We make use of the sine wave to calculate our AC curve, AC power supply, the components that make the AC supply. (E08)

…(the formula) help you calculate in the design of circuit or stuff like that.… (E11)

From the analysis of the students' own perceived levels of accomplishment of the different forms of understanding, the relationship between conceptual, functional and procedural understanding is further conceptualised. Participants who have achieved conceptual understanding can naturally attain both functional and procedural understanding. On the other hand, participants who have attained functional or procedural understanding will not reach conceptual understanding as they do not understand explicit assumptions and proofs behind the formulae. Participants who have accomplished functional understanding will achieve procedural understanding. However, participants who have only achieved procedural understanding cannot accomplish conceptual or functional understanding as they do not understand the circumstances a formula is created and used.

As for the relationship between the above first three types of understanding and associational understanding, participants who achieve conceptual or functional understanding may be able to achieve associational understanding. This is because the pre-requisites needed in achieving associational understanding are the mastery of functional understanding and related engineering concepts. Thus, the absence of the mastery of such engineering concepts means that they may not be able to achieve associational understanding even if they are conceptually and functionally adept in the formulae learnt. However, participants with only procedural understanding will not be able to achieve associational understanding due to their lack of functional understanding in engineering mathematics.

To demonstrate the relationship between these four types of understanding, the example below is used as an illustration:

Differentiation is an important mathematical concept and is represented by the formula: $\frac{dy}{dx}=\lim_{h\to 0}\frac{f(x+h)-f(x)}{h}$*. The participants who achieve* ***conceptual understanding*** *are able to understand the explicit assumptions and proof behind this formula. They also know that this formula measures the rate of change of y with respect to x and they will be usually utilised when rate of change is concerned in any mathematical problem* ***(functional understanding)****. More importantly, they are able to compute a mathematical problem using the procedures involved in this formula such as* $\frac{d}{dx}\left[x^n\right]=nx^{n-1}$ *if the* *value of n is given (**procedural understanding**). The differentiation formula can be applied in engineering scenario where the relationship between current and capacitance in an electric circuit is represented by formula, $i = C\frac{dv}{dt}$ (i, C and v represent current, capacitance and voltage respectively). If they know this formula, they have achieved **associational understanding** as $\frac{dv}{dt}$ is an engineering concept that is converted from a differentiation function.*

In summary, understanding can be conceptual, functional, procedural and associational in engineering mathematics learning. At the same time, these different types of understanding are closely related to one another in the students' understanding process.

5.4.2 Practising

Practising is one of the processes which are important in actualising the participants' intentions in mathematics learning. Through axial coding, practising is deemed to be made up of three components – procedural training, simple procedural competence and complex procedural competence. These three sub-processes are sequential and related. The diagram below illustrates these three components.

Figure 5.8 The components of practising

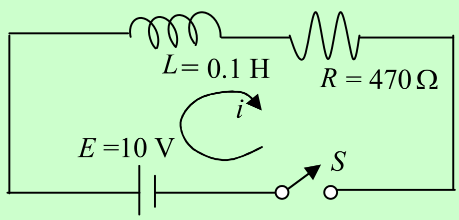
Procedural training is the first stage of practising. It involves hands-on mathematics problem solving that includes the uses of mathematical formulae and procedures. All participants are given a set of tutorial questions every week. This training process can take place during or outside tutorial sessions. The participants see these tutorial questions as their first step to practising. Besides tutorial questions, past year examination papers are the next significant source of procedural training. The presence of procedural training in the contexts of tutorials and self learning was mentioned by the participants below:

Practice in tutorials makes perfect for engineering mathematics. (E02)

> *...without practice in the past year papers, I guess there is no way I can pass it. (E19)*

Before simple and complex procedural competences are discussed, there is a need to create the context for the types of mathematics questions practised in the engineering mathematics modules. There are two categories of mathematics questions in both tutorial and past years' examination papers in the context of the case Polytechnic. The first type of problems consists of basic mathematics questions where the participants need a single formula and procedure to compute them. They typically require little conceptual or functional understanding and are considered easy to solve by the participants. The other group of problems are complex and applied in engineering scenarios. They are known as engineering applied mathematics questions. They need at least functional and associational understanding on the part of the participants and usually require more than one formula or procedure. Thus, they are considered tedious and difficult to solve by the participants. Below is a table that shows the basic and complex applied mathematical problems as retrieved from one of the engineering mathematics modules in the case Polytechnic.

Table 5.5 Basic mathematical problem and engineering applied problem

Example of a basic mathematics question	Example of a complex engineering applied mathematics question
Find each of the following Laplace Transforms: $L\left\{ t^2 + 3t + 7 \right\}$ (Questions modified from an examination paper in the case Polytechnic.)	In the *R-L* series circuit shown below, the switch *S* is closed at time $t = 0$. Show the current i (amperes) flowing through the circuit at time t (seconds) satisfies the differential equation $L\frac{di}{dt} + iR = E$.  Given that $i = 0$ when $t = 0$, find (i) the current i in the circuit at time t, (ii) the steady-state current, (iii) how long it will take for the current to reach 80% of its steady-state value?

In summary, there are two types of questions in engineering mathematics modules in the case Polytechnic: basic mathematics questions and engineering applied mathematics questions.

Simple procedural competence refers to the participants' ability to compute basic mathematics questions while complex procedural competence is needed to compute engineering applied mathematics questions. Both competences are mentioned by the participants below:

> *I make sure I am good with the simple questions (basic mathematics questions) that need easy and short steps. (E04)*
>
> *I do the simple questions in section A (basic mathematics questions) first. As section C (engineering applied questions) requires more thinking, I do them later. (E13)*

Since the process of practising is sequential, the lack of procedural training means the absence of both simple and complex procedural competence. The achievement of simple procedural competence needs the presence of effective and sufficient procedural training and procedural understanding attained by the participants. At the same time, the mastery of complex procedural competence entails the prior attainment of procedural training, simple procedural competence and the presence of functional and associational understanding on the part of the participants.

5.4.3 Relationships between Understanding, Practising and Examination Results

The acts of understanding and practising will usually lead to the process of taking the engineering mathematics examination as mentioned by all participants. Ultimately, understanding and practising will lead to the eventuality of examinations. Examination grades in engineering mathematics are important to all participants depending on their intentions. It is the final examination for the mathematics module that will determine how effective their understanding and practising processes are.

Although the results of the participants' mathematics examination confirm the effectiveness of their practising, they do not necessarily prove that they have achieved all levels of understanding. This is because the participants only need to achieve functional and associational understanding to do well in examination through effective practising (procedural training) where both simple and complex procedural competences are achieved. Conceptual understanding is not required at all in order for the participants to perform well in engineering mathematics examinations here.

5.4.3.1 "Actualising" Strategies

There are both positive and negative strategies utilised by the participants in the actualising process of engineering mathematics in the three contexts in engineering mathematics learning: lectures, tutorials and self learning. Although the strategies illustrate how the participants achieve understanding and practising in engineering mathematics learning, there is need to take note of some limitations in them. This study is unable to distinguish if any particular strategy is useful in any particular form of understanding or practising as this would require more systematic administrated tests and observational data in classrooms. At the same time, the strategies may also be used in any of the three contexts of engineering learning. This study does not aim to distinguish if any strategy is used more frequently in any of the contexts. Besides, the participants do not mention that these strategies are unique to engineering mathematics learning as they may use the same strategies in other non-mathematics modules. These limitations are outside the scope of this study. Nevertheless, this area provides more scope for investigation in future. Lastly, the use of any of these strategies may depend largely on each individual participant's intention in mathematics learning and preference or capability in employing them.

There is a repertoire of approach or positive strategies used by the participants to achieve the various forms of understanding and practising. The data shows that there is a wider range of positive strategies, as compared to negative strategies used in engineering mathematics learning. In this study, approach strategies are broadly categorised into: control, attitudinal and social. **Control strategies** are individual ones consciously utilised by the students in the management of their actualising process. Such control strategies are either cognitive or behavioural in nature. Cognitive strategies may include target setting, planning, focusing, memorising, self checking, self testing, progress tracking. Target setting is the conscious recognition of the type of understanding they aim to achieve. Planning involves the participants in deciding the amount of time they spend in their learning, their study schedule, the deadline they set in achieving the targets. Participants who practise self checking verify the knowledge that they have obtained and test their understanding periodically. Through self checking, they can also correct their own conceptual, functional or procedural misconceptions. Focusing is practised by participants during lectures and tutorials so that they will not miss any knowledge transfer by the teachers. They also memorise important formulae and procedures. Participants may also conduct self testing where they intentionally assess their level of understanding through self assessments. Lastly, participants may consistently monitor the progress of their strategies in relation to their targets through progress tracking. Through progress tracking, they can also adjust or change their current strategies if necessary so as to stay on track for their targets. There are also other behavioural approach strategies such as taking notes, reading relevant textbooks, doing stipulated tutorial questions, drilling on similar types of questions, doing extra questions found in other textbooks, doing past year examination questions and doing extra questions on weak topics. Below is the table that illustrates the above control strategies.

Table 5.6 Types of control strategies and their illustrations

CONTROL STRATEGIES	
STRATEGY	**ILLUSTRATION**
TARGET SETTING	*No when come to the tutorial, I just, my main mentality of tutorial is I must learn…(E18)*
PLANNING	*So I just plan out the schedule and I'll just go into studying. (E12)*
FOCUSING	*…focus and listen to what the teacher said. (E08)*
MEMORISING	*I am memorising steps. (E19)*
RELATING	*Those topics which we learned in Engineering Mathematics are linked in engineering life, where we calculate these circuit things. (E06)*
SELF CHECKING	*I must understand how to do first question, then I can logically go to the second and third question which is more difficult. (E17)*
SELF TESTING	*I did the past few years papers from the blackboard and the proper steps were provided clearly for question I didn't know how to do. (E16)*
PROGRESS TRACKING	*..if I make a mistake, I would learn from it and, try not to repeat the mistake again.(E09)*
READING TEXTBOOK	*In our own free time, we have to read through the topics to re-emphasise on our learning. (E02)*
TAKING NOTES	*I will write notes. (E09)*
DOING TUTORIALS	*My intention is to finish all the tutorial questions. (E08)*
DOING PAST YEAR PAPERS	*And I do all the past year papers. The minimum is that I must do all the tutorial questions first. (E14)*
ROTE TRAINING	*My strategy is just to do past year paper, do and do all over again. (E01)*
DOING EXTRA EXERCISES	*Let say if the tutors only ask us to do the odd numbered, I do the even numbered ones too. (E18)*

Attitudinal strategies are the conscious exercise of attitudes perceived by the participants to be useful in the implementation of their control strategies. These strategies are usually affective and influence the level of success of their control strategies. The success of the control strategies can reinforce the attitudinal strategies too. Thus, their relationships are bidirectional. These attitudinal strategies include the maintenance of discipline, self encouragement, persistence, interest, confidence, motivation and positive mentality in mathematics learning. The participants have to consistent in their learning and put in an effective amount of effort, in the application of their control strategies and this needs them to be self disciplined in their mathematics learning process. When the participants achieve their targets in understanding, they may encourage themselves psychologically through morale boosting thoughts or reward themselves with tangible entertainments such as movie treats, food, computer games etc. The ability to persist in understanding and practising will see the participants not giving up easily in their control strategies. Maintaining their interest in mathematics lessons will make them put in more effort in their control strategies. At the same time, participants' cultivation of their confidence in mathematics learning is a form of attitudinal strategies employed by them to improve the success of their control strategies. With their intention as the motivating force, the participants can execute their control strategies with more conviction. The participants also understand the importance of staying positive in mathematics learning as they know that negative emotions can impede the progress of their control strategies. Below is the table that illustrates the above attitudinal strategies.

Table 5.7 Types of attitudinal strategies and their illustrations

ATTITUDINAL STRATEGIES	
STRATEGY	**ILLUSTRATION**
SELF DISCIPLINE	*We have to constantly revise and practice in order for ourselves to become better. This is our responsibility. I always believe that … you just have to finish up the tutorials… by that week (E13)*
SELF ENCOURAGING	*Then I would tell myself that, continue this good progress in future, and do as well for other subjects…(E16)* *So after the test was done, I gave myself some break to release my stress. (E05)*
PERSISTENCE	*… just try to keep my mind calm then restudy again, read and read until I understand.* (*E14)*
INTEREST	*You're interested in this Engineering Mathematics right, definitely, the person will actually want to study hard. (E05)*
CONFIDENCE	*I was confident that I can solve the questions. (E02)*
POSITIVE MINDSET	*I think positive in learning….Like if this comes out and if I make a mistake; I would learn from it and, try not to repeat the mistake again. (E09)* *I also can't do those super tough questions, but at least I feel good, at least I can secure 8 and half questions… (E17)*

Besides control and attitudinal strategies in the process of actualising, participants also use **social strategies**. Social strategies can help in enhancing control and attitudinal strategies. Social strategies usually aim in eliciting academic support from external sources such as asking parents, peers and/or lecturers for assistance. These are termed as **supporting social strategies**. However, there are also **cooperative social strategies** where participants benefit from one another. These include teaching academically weaker peers and group study. Supporting and cooperative social strategies are usually behavioural in nature. Another form of social strategies is affective in nature. They are termed as **motivational social strategies**. Participants may take clues from the behaviours of their teachers, peers or parents as a form of motivation to enhance their control or attitudinal strategies. The table below illustrates these social strategies.

Table 5.8 Types of social strategies and their illustrations

SOCIAL STRATEGIES	
STRATEGY	**ILLUSTRATION**
SUPPORTING	*Most of the time I will go back to my friends and ask them for tips, solutions and how they carry out their methods. (E03)* *If I still don't understand, I ask the teacher to work out some examples. (E14)* *Sometimes… we consult friends… and then if really cannot… then we consult the lecturers…(E06)*
COOPERATIVE	*For me, if I understand, I can teach my friends, then by teaching my friends I can learn more about it.(E10)* *We have actually this group of friends where we stick together and study.(E20)*
MOTIVATIONAL	*But some how I saw people getting more than 3 (GPA), I would also feel like getting more than them. (E14)* *They (teacher) are all willing to teach me and, and you know, they're very patient, listen to my questions….so will work hard not to disappoint them. (E13)* *The teacher encourages me to think more and my father also encourages me not to give up, keep on trying, so I am more motivated. (E10)*

Participants also utilise **avoidant strategies** in the actualising process of their engineering mathematics learning. These negative strategies are by and large affective and behavioural. They can be generally classified into four different types – evasive, compromising, procrastinating and resistant. All these strategies aim to avoid mathematics learning to different extents. **Evasive strategies** are non-confrontational and usually include non-completion of assignments/tutorials, false compliance in front of teachers, skipping lessons with official reasons and deliberately avoiding teachers and peers. **Compromising strategies** aim at meeting only some of the teachers' requirements in assignments/tutorials or preparing lesser for assessments. **Procrastinating strategies** aim at delaying the completion of the teachers' requirements in assignments/tutorials or preparation for examinations. Lastly, **resistant strategies** which are generally confrontational in nature include arguments with peers or teachers, skipping lessons with no official reasons and open refusal to do tasks as directed by teachers. The table below demonstrates some of these negative strategies as divulged by the participants.

Table 5.9 Types of avoidant strategies and their illustrations

AVOIDANT STRATEGIES	
STRATEGY	**ILLUSTRATION**
EVASIVE	*Sometimes I pretend to do the questions in class so the teacher will not bother me. .... I don't click with them (peers). In fact, I and XXX (another friend of hers) tried to avoid them as much as possible. They don't understand us really. (E19)*
COMPROMISING	*...Because the questions are all about similar so why bother to do all the tutorial questions... Because my maths is very lousy one so work hard also useless. (E15)*
PROCRASTINATING	*If exam is here, you will study. If exam is not here, you can say many times that you want to study but you will never do it. (E11)*
RESISTANT	*One time I quarrel with my lecturer because he keeps forcing me to do the questions. (E07)*

In summary, actualising strategies in engineering mathematics learning can be approach or avoidant and cognitive, affective or behavioural. Approach strategies used by the participants are useful to them to different extents in their actualising process and can be control-based, attitudinal or social. On the other hand, avoidant strategies aim to avoid learning and can be evasive, compromising, procrastinating or resistant.

5.5 Regulating

Regulating is the process that occurs after the process of actualising is completed in the context of lectures, tutorials, self learning and assessments. The regulating process is made up of the sub-processes of identifying, attributing and rationalising. These three sub-processes are sequential. Below is a diagram that illustrates this sequential relationship.

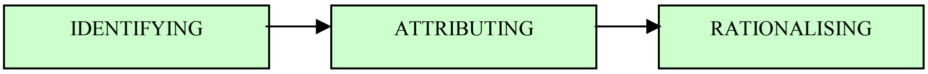


Figure 5.9 The components of the category of regulating and their sequential nature

5.5.1 Identifying

After the implementation of their strategies in the process of actualising, the participants identify whether their perceived intention-related consequences are achieved. There are intention-related consequences that come directly from the process of actualising. They come in the form of work done in the participants' actualising process, their engineering mathematics examination results and avoidant or resistant behaviours in mathematics learning. These perceived intention-related consequences contribute to the accomplishment of the participants' aims in engineering mathematics learning. Academic emotions and social sanctions or rewards from external sources are the next group of consequences that is formed. They do not arise directly from the process of actualising, but indirectly from the success or failure of their overall aims in engineering mathematics learning. In summary, the consequences identified after the completion of the participants' strategies can be tangible or intangible in nature and direct or indirect from the process of actualising. The diagram below shows the relationships between the consequences from the process of actualising.

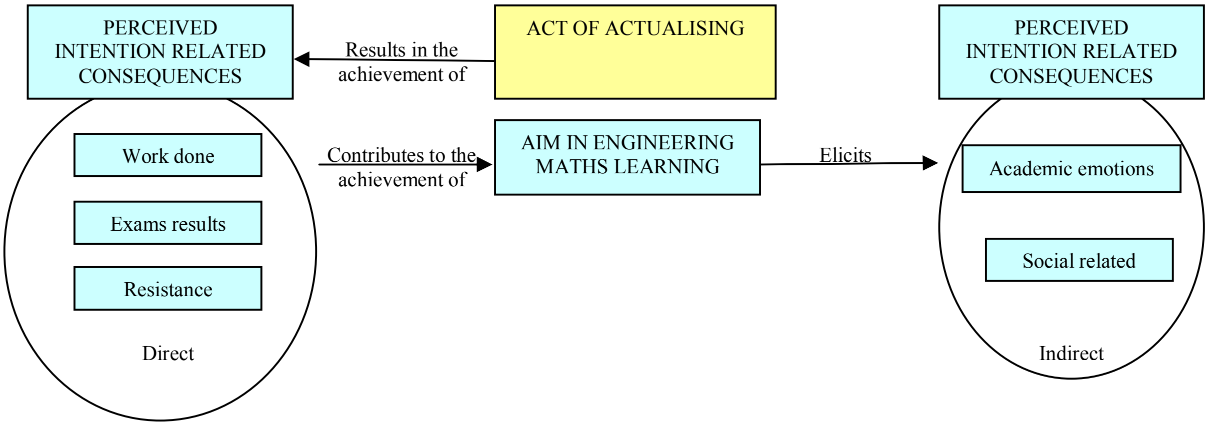


Figure 5.10 Consequences resulting from the process of actualising

5.5.1.1 Perceived Intention-related Consequences

Perceived intention-related consequences may come in the form of the level of completion of tutorial and past years' examination questions by the participants and the accuracy level of the participants' answers to the questions. These are reflected by E13 and E15 who commented:

I did the tutorials and past years papers about 3 times. (E13)

When exam comes, just doing the past years paper accurately should be sufficient. (E15)

They can also be reflected by the participants' results of engineering mathematics examinations. They may assess if their examination results are up to their own expectations which are influenced by their aims in mathematics learning. In this regard, E02 and E11 stated:

The result shows me that hard work does pay off. (E02)

When I got back my result, I did not do well. (E11)

They may also be undesirable behaviours such as avoidance or resistance in lectures or tutorials as typified by E19 who guiltlessly stated:

They (mathematics and lecturers) are a pain in the neck. We skipped school together.

The above consequences affect the achievement of the participants' aims in engineering mathematics learning. Aims in engineering mathematics learning, as discussed earlier, are related to the amount of mathematical knowledge gained (mastery-oriented intention), the level of social status attained (ego-oriented intention), level of assurance of a good diploma and academic future (career-oriented intention), level of assurance of passing examinations (survival-oriented intention) and level of resistance or avoidance towards mathematics learning (resistance-oriented intention) as perceived by the participants. For example, the perceived intention-related consequences of a participant who intends to gain mathematical knowledge may include indicators such as acceptable results in examinations, higher academic advancement and ability to achieve associational understanding. This will be further illustrated in Chapter Six.

The possible achievement of their aims will elicit another set of indirect perceived intention-related consequences. They can be socially related and may come in the form of praise, reward or reprimand for the participants, from their family or lecturers as typified by E02 and E14 who made the following comments:

I make my lecturer proud as I achieve his target set for me. (E02)

I see a lot of As. Finally, I made my parents proud. (E14)

The teacher counseled me for my bad results. (E01)

At the same time, these indirect intention-related consequences can come in the form of academic emotions. In these contexts, the regulation of the emotions that arise from the consequences of the participants' mathematics learning strategies is very important. This is because emotions can be beneficial or damaging to their overall psychological and physiological health. Thus, they may improve or disrupt their daily lives. Academic emotions are perceived to be the key motivating force in the process of regulating as their presence activates the subsequent sub-processes of attributing and rationalising.

5.5.1.2 Academic Emotions

Academic emotions occur in response to the success or failure of the students' aim of engineering mathematics learning. There is a need to note that there are also emotions that are experienced by the participants before their engineering mathematics learning process. Thus, academic emotions can be grouped into prior learning and post learning. The academic emotions experienced prior to the participants' experiences in engineering mathematics result from their mathematics learning experiences at pre-tertiary levels. Predominant emotions prior to engineering mathematics learning include the amount of interest and liking for mathematics learning in general. Although prior emotions do play a part in the filtering process for some participants, they will not be discussed in this section which is focused on academic emotions that arise from the engineering mathematics learning process. As the participants engage in the process of actualising in engineering mathematics learning, more emotions are formed as influenced by the achievement of their aims in engineering mathematics learning.

Such academic emotions can be measured **qualitatively** or **quantitatively**. There are fundamentally two qualitative categories of emotions that result from the consequences of the students' strategies in mathematics learning – positive and negative. Positive emotions experienced by the participants include: Interested Confidence Love Fun Satisfaction Excited Happy Contented. They have also experienced negative emotions that include: Disappointment Frustration Fear Stressed Anger Regret Dislike Disinterested Nervous Blaming. Such qualitative emotions can also be quantitatively measured in terms of their intensity and duration. Some participants can experience a certain emotion strongly for a very long period of time, while others may feel some weak emotions for a short while after identifying the consequences of their process of actualising in engineering mathematics learning. The following comment made by E03 indicates the emotional consequences experienced by him in engineering mathematics learning:

> *Then I feel motivated to come and find answers to the problem. Then sometimes I feel a bit frustrated if some methods do not work like I guess a certain method is efficient in dealing with the problem, then if it does not turn out correct, I feel a bit slightly frustrated...For tests, the first feeling I will feel is fear because I know I never put in much effort to study and practice… My feelings of relief after examination will be gone in a week.*

Although the participants may understand the types or intensities of their emotions felt during mathematics learning, they may or may not react to them. Academic emotions arise from the successful or unsuccessful achievement of the aims in engineering mathematics learning. From here, they may or may not influence the participants' subsequent process of mathematics learning. Those emotions that do not have any effect on their subsequent mathematics learning are pure emotional outputs which are either pleasurable or unpleasant to them psychologically and physiologically. These emotions are usually short term and may be removed once they are not in the same mathematics learning situations that elicit them. They are known as **gratifying or unrewarding emotions** in this study. However, emotions may influence the participants' subsequent mathematics learning process too. They can be motivating in the sense that they prompt or direct the participants to find out the underlying reasons that cause the success or failure in achieving their aims in engineering mathematics learning. These emotions are termed as **facilitating emotions** if remedial actions are formulated to improve, reinforce their present learning conditions or alleviate negative emotions formed. On the other hand, some emotions are termed as **impeding emotions** as they can slow down or obstruct the participants' mathematics learning process. They can even change the participants' intentions in mathematics learning. While gratifying emotions are positive and unrewarding emotions are negative, both facilitating and impeding emotions can be either positive or negative. E04 experienced the three kinds of emotions mentioned above after the process of actualising:

> *I am scared* ***(impeding emotions)*** *that I will fail the paper and I think that it is difficult when I do it. I felt relieved* ***(gratifying or unrewarding emotions)*** *that I can finally forget about math after the exams. I am very unhappy* ***(facilitating emotions)*** *with the results… but still it will end when the next paper result comes...depending if I had done better… I am going to be more hardworking...and learnt to solve the questions to the last step and not allow myself to give excuses...*

In summary, the properties and their dimensions of academic emotions are clearly represented in the diagram below:

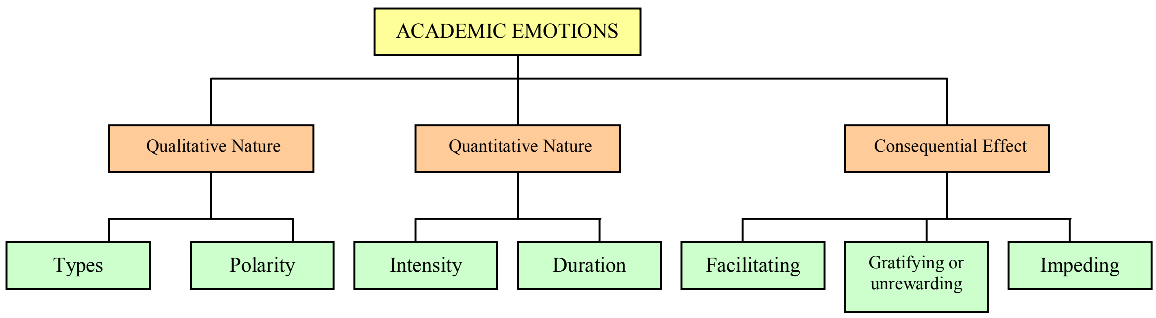


Figure 5.11 The properties and their dimensions of academic emotions in engineering mathematics learning

5.5.2 Attributing

After identifying both the tangible and intangible consequences of the participants' strategies in engineering mathematics learning, they set to discover cognitively the reasons behind them. This is especially important due to the presence of academic emotions that can be psychologically beneficial or detrimental. The participants react to these academic emotions by analysing the origins and contributing causes of the consequences experienced by them. This may enable them to regulate their academic emotions to their own perceived advantage. Regulation of academic emotions that occurred aims to reduce or remove psychologically detrimental emotions or leverage on the useful ones in their future engineering mathematics learning. In the regulation of the participants' academic emotions, the processes of attributing and rationalising are very important.

Attributing is the process where the participants attach explanations to the success or failure of the perceived intention-related consequences experienced by them after they have implemented their strategies in mathematics learning. These explanations are broadly categorised into two groups – internal and external. Internal reasons include the participants' own level of understanding and mathematical ability, and the amount of practising put in. Internal explanations are generally directed at the participants themselves. The participants' comments below typify such internal attributions:

I guess it is all in my fate, I am never good in maths. (E11)

It is due to my lack of practice or lack of understanding. (E14)

External explanations that are directed at external factors include the types of lecturers, the types of peers, school and governmental policies, non-school related interferences (include work, family or relationship problems outside the school) and the difficulty level of the examinations. With regards to external attributions, the participants below explained:

Busy with work…lesson too early, cannot wake up. Worked until very late at night. (E07)

…because the lecturer taught me very well. (E15)

There was one killer question that came out and I cannot do it. (E17)

The various attributions mentioned by the participants are also governed on the continuum of controllability. On the continuum of controllability, an explanation is controllable if the participants perceive that they have the ability to change its governing factors. On the contrary, an explanation is uncontrollable if participants perceive that they cannot change its governing factors. For example, the amount of practice put in by the participants is controllable, while the difficulty level of mathematics examination is not. Below is a table that shows the relationship between attributions by the participants on their experienced consequences in engineering mathematics learning and their controllability.

Table 5.10 A 2×2 matrix representing explanations for the consequences experienced by the participants in engineering mathematics learning

	Internal	External
Controllable	○ amount of practising ○ level of understanding ○ level of affection for course	○ types of peers
Uncontrollable	○ level of prior mathematical aptitude	○ difficulty level of examination ○ types of lecturers ○ non-school related interference ○ school / governmental policies

In summary, the success or failure of the participants' intentions induces the formation of their academic emotions. And academic emotions bring about the process of attributing. The types and controllability of the participants' explanations that are formed in the process of attributing are important in their subsequent rationalising process. This rationalising process, as shown in the section below, is essential in assisting the participants regulate their academic emotions.

5.5.3 Rationalising

After attributing explanations to their experiences and the consequences of their behaviours, the participants tend to reframe their thoughts in relation to their future motives and actions in mathematics learning through the process of rationalising. In this rationalising process, the participants' reactions to their own perceived attribution of their experienced consequences in engineering mathematics learning consist of four general types – **assuring acceptance, active acceptance, resigned acceptance and blaming defiance**.

In the case of **assuring acceptance**, the participants' perceived intention-related consequences in mathematics learning are achieved. Positive emotions are formed. They are gratifying or facilitating. They are assured that their current strategies in mathematics learning are effective in achieving their aims. These participants accept their attributions (maybe internal, external or both) for the accomplishment of their intentions. If the attributions are uncontrollable, the participants may let their strategies remain status quo. Thus, these positive emotions remain gratifying. On the other hand, they may also leverage on these positive academic emotions to reinforce their current intentions and strategies in engineering mathematics learning. Therefore, these positive academic emotions can be facilitating. Thus, these academic emotions can be both gratifying and/or facilitating if the attributions made are uncontrollable in the case where the participants' perceived intention-related consequences in mathematics learning are achieved. If their attributions made are controllable, they may consider modifying the strategies to improve their chance of attaining their intentions in mathematics learning. In such scenarios, academic emotions experienced are facilitating too.

With regards to the case of assuring acceptance, E06 was contented **(facilitating positive emotion)** whenever he got correct answers in mathematical problems **(success in achieving perceived intention-related consequence)**. This made him believe that he had the ability to solve any mathematical problem **(reinforce beliefs)**. He was also aware that he had put in a lot of hard work in mathematics learning to get such good results **(controllable internal attribution)**. He became more interested in mathematics learning and spent more time in it **(improving the chance of achieving perceived intention-related consequence)**.

If the participants' perceived intention-related consequences are not met, three scenarios arise. The first scenario is the case of **active acceptance**. In active acceptance, they experience unpleasant emotions. Such participants accept their attributions (maybe internal, external or both) for failing to attain their intention-related consequences. If the participants' attributions made are controllable, they may attempt to modify their strategies to improve their chance of attaining their intentions in mathematics learning in the future. This often helps them reduce or remove their unpleasant academic emotions. On the contrary, if the attributions are uncontrollable, participants may also attempt to reduce or remove their negative emotions through lowering their expectations of their intention-related consequences or changing their intentions totally as they perceive that there is no use in changing their strategies. In summary, in active acceptance, the participants' academic emotions experienced become facilitating in alleviating their negative emotions in mathematics learning through the modification of their strategies or intentions.

Active acceptance is demonstrated in the case of E04 who acknowledged her lack of practice **(controllable internal attribution)** resulted in her not getting the grades she aimed for **(failure in achieving perceived intention-related consequence)**. She was very unhappy **(facilitating negative emotion)** as a result. But she decided to work harder and spend more time in learning the difficult mathematical steps **(modifying the process of actualising)** so as to improve on her grade **(improving the chance of achieving perceived intention-related consequence)**. This helped to reduce her negative emotions. Another example of active acceptance is the case of E3 who started with the aim of gaining mathematical knowledge. However, he had not been able to achieve his perceived intention-related consequence of doing well in mathematics examination and other engineering modules. This resulted in him experiencing negative emotions such as fear and anxiety **(facilitating negative emotion)**. He attributed it to his lack of aptitude in mathematics **(uncontrollable internal attribution)**. Therefore, he prioritised his intention in engineering learning to that of achieving minimum pass in examinations over the original intention of gaining knowledge **(modifying aims)**. This greatly reduced his stress and thus alleviated the presence of other related negative emotions.
On the other hand, other participants who attribute uncontrollable factors to the failure in achieving their intentions may feel resigned to the fact that they cannot improve on their current situation. In such cases, their intentions and strategies remain status quo. They believe that their unrewarding and unpleasant emotions would be removed naturally through time. Such participants may even come to a stage where they are immune to such unpleasant academic emotions due to prolonged exposure to them. This is the case of **resigned acceptance**.

Resigned acceptance is aptly demonstrated in the case of E11. E11 always felt nervous and stressful **(unrewarding negative emotions)** during examination period. He knew that he was always weak in mathematics **(uncontrollable internal attribution)** and accepted that he would never score good grades in examination. However, he still aimed for an acceptable grade but he did not get it **(failure in achieving perceived intention-related consequence)**. He blamed it on poor teaching by the lecturers **(uncontrollable external attribution)**. He did not attempt to do anything to improve the situation as he believed that everything is fated **(maintaining status quo of the process of actualising)**.

However, some participants may refuse to accept their uncontrollable attributions in their failure in mathematics learning. They feel victimised and form blaming emotions against perceived sources that cause their failure. These academic emotions are impeding and remain as long as they are engaged in mathematics learning. The participants' strategies may change or remain status quo. They may even refuse to engage in mathematics learning in protest for their perceived victimisation. This scenario is termed as **blaming defiance**.
E19's behaviour in mathematics learning shows the meaning of blaming defiance. At first, she hated mathematics learning and did not know what she wanted from it. When she did not understand any mathematical concepts **(failure in achieving perceived intention-related consequence)**, she hated mathematics more **(impeding negative emotions)**. She also blamed the education system as being unfair and poor teaching by her lecturer **(uncontrollable external attributions)** for her predicament. She became totally disinterested **(impeding negative emotions)** in mathematics learning as she could not understand it. She felt victimised and eventually aimed to defy the education system in future mathematics learning **(modifying process of intending)**.

In short, the process of rationalising consists of the categories of assuring acceptance, active acceptance, resigned acceptance and blaming defiance. Below is a table that summarises the relationships between the various forms of rationalising and the participants' intentions, strategies and academic emotions.

Table 5.11 Relationship between the four categories of rationalising with the participants' intentions, academic emotions and strategies

Reaction / Action	Assuring acceptance	Active Acceptance	Resigned Acceptance	Blaming Defiance
Attainment of intentions				
Intention met	√			
Intention not met		√	√	√
Types of emotions produced				
Facilitating emotions	√	√		
Gratifying emotions	√			
Impeding emotions				√
Unrewarding emotions			√	
Actions in response to emotions formed				
Intentions strengthened	√			
New intentions formed		√		√
Intentions as status quo	√		√	
New strategies	√	√		√
Strategies as status quo	√		√	

Lastly, it is noted that the attainment of the participants' perceived intention-related consequences and the processes of regulating and actualising may be a pervasive process that occurs throughout their engineering mathematics learning process. This is because the participants may reach different levels of success at different periods of their engineering mathematics learning due to institutional, social and individual factors. This may thus result in them making different forms of attribution and rationalisation as the present intervening factors dictate. It is a fluid process.

5.6 The Theory of Selective Intentionality

This section will depict how all the categories mentioned earlier integrate to create the theory of Selective Intentionality through the process of selective coding. The core category in this study is the category of **intending**. The other four categories of **gathering, analysing, actualising and regulating** are closely related to it in important aspects, although the four of them may not be directly related to one another. As defined by The American Heritage® Dictionary (2000), intentionality is the state of having an intention. All the four categories are related to the state of having an intention in engineering mathematics learning. It is this state of intention that drives these four main categories in this study. Without this intentionality, these four main categories may not exist throughout the students' engineering mathematics learning experiences. Although the state of intention in engineering mathematics learning is present in all students, they may not have the same types of intentions. They may have different intentions in engineering mathematics learning as affected by events and people around them. From there, they make their personal selection on the types of intentions they may subscribe to in their engineering mathematics learning. Therefore, the concept of "**Selective Intentionality**" as created from the core category of intending can best encompass the presence of the students' different personally "selected" intentions in engineering mathematics learning that determines their learning process in engineering mathematics, as investigated by this study. The diagram below illustrates the theory of Selective Intentionality with respect to its core category of intending and the other four main categories and their subcategories.

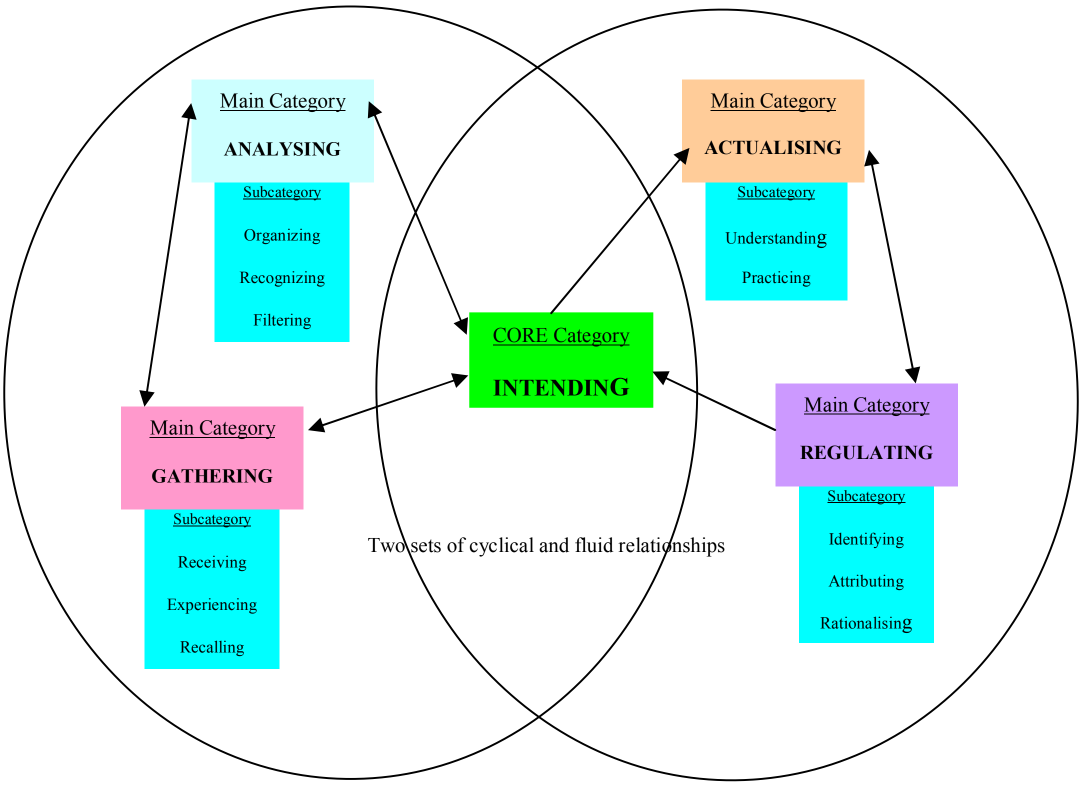


Figure 5.12 The theory of Selective Intentionality with the category of intending as the core category

The theory of Selective Intentionality first starts with the process of gathering. Through gathering, potential engineering students in the polytechnic collect relevant information about engineering mathematics through external sources such as society, family, teachers and peers, their learning experiences in engineering mathematics related contexts such as lectures, tutorials, assessments and self study, and their prior mathematics learning experiences in pre-tertiary education. Such gathered information are then utilised in the subsequent process of analysing where the students form personal, relational and comparative beliefs about engineering and engineering mathematics education. These beliefs then form the basis where the students recognize the various significant aims of engineering mathematics education. In combination with their unique critical events in their previous pre-tertiary learning experiences or the first year of their engineering courses, the students form their intentions in terms of their personal significance, aim and perceived intention-related consequences in engineering mathematics learning. This is where the core category of intending is created. In short, the main categories of gathering and analysing give rise to the core category of intending. This relationship among the categories of intending, gathering and analysing is cyclical and fluid as any further changes to the students' intentions can further influence their personal, relational and comparative beliefs in the process of analysing and experiences in the process of gathering. Thus, this is the first set of cyclical relationship that occurs in the theory of Selective Intentionality in engineering mathematics learning

The presence of an intention in engineering mathematics learning does not stop here. With an intention in mind, the students set to achieve it. They begin to formulate beliefs and strategies in achieving their intentions. This process is termed as the category of actualising. As the process of actualising is completed, the students start to assess if their strategies are successful in achieving their intentions. The success or failure of their intentions elicits academic emotions that can be psychologically useful or damaging to the students. Therefore, the students have to regulate their emotions to their academic advantage. Such regulation of academic emotions happens in the process of regulating. This is achieved through the strengthening or modification of their strategies and intentions. Therefore, while the process of regulating arises because of the category of actualising, it is also related to the categories of intending and actualising as its resultant effects influence the future intentions and actions of the students. Thus, the processes of intending, actualising and regulating also work in a cyclical manner. These three processes are always in flow as long as the students engage in engineering mathematics learning. This makes up the second set of cyclical relationship that occurs in the theory of Selective Intentionality in engineering mathematics learning.

In summary, there are two sets of cyclical relationships which both involve the core category of intending. One of them is the cyclical relationship among the processes of intending, gathering and analysing while the other set of such relationship is related to the processes of intending, actualising and regulating. Together, these two sets of cyclical relationships create the theory of Selective Intentionality in engineering mathematics learning.

5.7 Conclusion

This chapter has described all the categories and processes in the theory of Selective Intentionality. Furthermore, the emergence of the core category is explained. More importantly, the integration of all the categories in relation to the core category to create the theory of Selective Intentionality in engineering mathematics learning is also clearly illuminated. Another major outcome that arises from this study is the development of a typology of students with regards to how they experience engineering mathematics learning through the categories and processes of the theory of Selective Intentionality. This typology will be described in the next chapter.

CHAPTER SIX

A GROUNDED TYPOLOGY OF ENGINEERING LEARNERS STUDYING MATHEMATICS IN A SINGAPORE POLYTECHNIC

Introduction

A major outcome that arises from this study is the development of a typology of students with regards to how they experience and manage mathematics learning in their engineering courses in a polytechnic in Singapore. The typology is based on the predominant distinctions made by the participants according to their responses to the analysing, intending, actualising and regulating processes in the theory of Selective Intentionality. Accordingly, the participants may be broadly classified into five types of learners: idealistic learners, competitive learners, pragmatic learners, fatalistic learners and dissonant learners. The table below shows the 21 participants in this study being compartmentalised into the five distinct types of learners in engineering mathematics.

Table 6.1 The participants compartmentalised into the five types of learners in typology

TYPE OF LEARNERS	IDEALISTIC	COMPETITIVE	PRAGMATIC		FATALISTIC	DISSONANT
			TYPE I	TYPE II		
PARTICIPANT	E05 E06 E13 E21	E02 E08 E18	E14 E16 E17	E01 E04 E09 E10	E03 E11 E12 E15 E20	E07 E19

The main discriminating factors in the typology are the categories of analysing and intending, where the learners are distinguished in terms of their critical trigger, internalised significance, aim and perceived intention-related consequences in engineering mathematics learning. There is a need to note that it is shown in Chapter 5.3 the learners' intentions may be fluid due to changes in critical events as affected by the failure to achieve their perceived intention-related consequences during the first year of their engineering courses. However, their intentions usually stabilise and become permanent by the time they are in the second year of their courses. Therefore, the proposed typology is based on the stabilised intentions of the students after the first year of their engineering courses (this was achieved in this study as all 21 participants were either in their second or third year of their courses when they were interviewed). This is important because different students' intentions can activate different behaviours in the categories of actualising and regulating. Thus, the permanency of the students' intentions will then ensure consistency in their actualising and regulating processes that are representative of the different learner types.

In the category of actualising, the differences are reflected in terms of the students' understanding and practising processes. For the category of understanding, the learners are differentiated according to their involvement or non-involvement in conceptual, functional, procedural or associational understanding. The students' major behavioural differences in terms of procedural training and the types of procedural competence in the category of practising are also noted in the proposed typology. The students in each learner type also possess unique internal characteristics in the process of actualising. In addition, key differences in the students' social relationships with their peers in the typology with regards to the actualising process are noted.

In the process of regulating, the dominant types of academic emotions experienced by the different types of learners in the typology are described. Different types of learners also attribute different reasons for the achievement or non-achievement of their intentions in engineering mathematics learning. Lastly, they react in different ways to future mathematics learning in their rationalising process. The table below summarises the predominant variables that help discriminate between the characteristics of the different learners in the proposed typology.

Table 6.2 Summary of predominant variables in the typology

ANALYSING	INTENDING	ACTUALISING	REGULATING
❖ Critical event ❖ Consequential effect	❖ Internalised significance ❖ Aim ❖ Perceived intention-related consequences	Understanding ❖ Conceptual understanding ❖ Functional understanding ❖ Procedural understanding ❖ Associational understanding Practising ❖ Procedural training ❖ Simple competence ❖ Complex competence Attitude Relationships with peers	Identifying ❖ Dominant academic emotions Attributing ❖ Own level of understanding ❖ Amount of practising put in ❖ Level of prior mathematical ability ❖ Types of peers ❖ Education policies ❖ Types of lecturers ❖ Difficulty level of examination Rationalising ❖ Assuring Acceptance ❖ Resigned Acceptance ❖ Active Acceptance ❖ Blaming Defiance

Although each learner type consists of certain predominant attributes in their processes of analysing, intending, actualising and regulating, there is a need to take note that the learners in each type share a number of common features in some of the processes in the theory of Selective Intentionality. These common features may be found in the process of gathering where the participants collect information about engineering mathematics, the types of approach and avoidant strategies used in the process of actualising and their types of personal, relational and comparative beliefs about engineering mathematics formed in the process of analysing. After the comparative analysis of the characteristics of the different types of learners in this typology, two propositions are generated. These propositions may serve as useful guides for practitioners in dealing and intervening with engineering mathematics learners. They may also be useful for other educational researchers who choose to further explore or substantiate these propositions in engineering mathematics learning for the benefits of the academic community.

In short, this chapter will illustrate the five types of learners in the typology through a comparative analysis of the differences in their dominant attributes in the processes of analysing, intending, actualising and regulating. It will be structured into the following main sections:

6.1 Intentions and Typology;
6.2 Intentions and Actualising Approach;
6.3 Consequences of Actualising and Future Intentions;
6.4 Propositions Arising from The Typology;
6.5 Conclusion.

6.1 Intentions and Typology

The participants' intentions in engineering mathematics drive the other processes in the theory of Selective Intentionality. Therefore, the differences in the components of the participants' intentions in engineering mathematics learning inevitably play the most important role in distinguishing the different types of learners in the typology. The participants' intentions in engineering mathematics learning are determined by the categories of analysing and intending. The sections below cover the characteristic intentions of each learner type in the proposed typology.

6.1.1 The Idealistic Learner

The idealistic learners have been fascinated with electrical and electronic gadgets since their younger days. As they mature, they understand that their interest is closely related to the domain of engineering. Idealistic learners' strong interest in engineering has been nurtured over a period of time where they actively learn about it long before they are enrolled in their engineering diploma courses. At the same time, their interest may be reinforced by influences from their parents or siblings who may be engineering-trained. Through their interactions with the different aspects of engineering in real life and books, idealistic learners realise the importance of mathematics in understanding and operationalising engineering concepts. There is a need to note that idealistic learners love engineering but they may not like mathematics. This is exemplified by E21 who divulged that he finds engineering mathematics boring when it is studied as an isolated entity, without relating to engineering concepts. However, he knows that mathematics is important in engineering and works hard in mastering it.

Among the various social and personal contexts where engineering mathematics learning is important, idealistic learners internalise the importance of mathematics in engineering as the basis of their intentions. Because of their internalised significance of engineering mathematics, their aim in learning it is to master the mathematical formulae that are to be utilised in the discipline of engineering. Idealistic learners identify a number of intention-related consequences to support their aim. Firstly, their ability to relate and utilise engineering mathematics in their engineering modules is one of the yardsticks to gauge if their aim is accomplished. Second, their grades in engineering mathematics examinations, as part of their intention-related consequences, are also an essential measure they utilise. Thirdly, due to their love of engineering, idealistic learners generally aspire to apply engineering knowledge or learn more about it - after they have graduated from the polytechnic. Therefore, being able to secure an engineering career or advance their engineering study at the university level is also a component of their perceived intention-related consequences that determine the accomplishment of their aim of mastering the mathematical formulae used in engineering. Below is a table that illustrates the components and an example of idealistic learners in the category of intending.

Table 6.3 Components and illustrations of the intentions of idealistic learners

Intending	Idealistic	Illustration (E05)
Critical event	Like playing with electronic gadgets	*...since young I actually like electronics gadgets. I tend to play, play circuits around and, like to discover why things work.*
Consequential effect	Love learning engineering	*Going into electronics course is actually my first choice.*
Accepting significance of maths in	Understanding engineering	*Mathematics is the foundation for engineering.*
Aim	Gaining understanding of formulae used in engineering	*Actually I want to know more of the knowledge (of formulae used in engineering). I need mathematics modules to apply in my electrical modules.*
Perceived intention-related consequences	• Related engineering knowledge gained • Self targeted grade in exams • A good pass grade for academic or career advancement	*Mathematics modules right, I want to be able to apply this Engineering Mathematics module towards my electrical modules...if you're interested in Engineering Mathematics right, definitely, you will actually want to score good grades one. In the future, when I advance in my job, I will tend to use Engineering Mathematics.*

6.1.2 The Competitive Learner

Competitive learners have perceived the attainment of higher social status among their own clique of peers as very important since their younger days. They may be influenced by their parents or the culture of the competitive and egocentric Singaporean society. Through competition with their peers in different areas of life, they aspire to achieve their desired level of social status. As students, competitive learners understand the importance of education in achieving higher social status in the Singaporean society. This is because the Singaporean society places great emphasis in the education of its people, especially in science and mathematics, due to its lack of natural resources. Thus, competitive learners internalise the importance of education in achieving their desired social status in the society. This significance is supported by the fact that competitive learners are usually academically stronger than their peers in the domain of mathematics learning. As a result, their aim in engineering mathematics learning is related to the enhancement of their social status among their peers.

In terms of perceived intention-related consequences, competitive learners attempt to achieve their aim through obtaining better grades than their peers in engineering mathematics examinations. At the same time, they perceive respect from their peers as a gauge if their aim is achieved. As the prestige of being able to advance into university level can enhance their social status, competitive learners believe that academic advancement is also important in ascertaining the success of their aim in engineering mathematics learning. Below is a table that shows the components and an illustration of such competition oriented intentions of engineering mathematics students.

Table 6.4 Components and illustrations of the intentions of competitive learners

Intending	Competitive	Illustration (E18)
Critical event	Like to be better than peers	*And I always want to be better the rest…because I'm a perfectionist. So that's what motivates me.*
Consequential effect	Competing with others in their stronger academic area – mathematics	*I must beat them …I like maths and I want to do it…*
Accepting significance of maths in	Social comparison	*Mathematics is a subject that makes you better than the rest…*
Aim	Gaining social and academic status among peers	*I feel proud because I'm one of the thinking people (who can do mathematics in Singapore). I'm proud because I am one of those who can do it (engineering mathematics tests)….*
Perceived intention-related consequences	• Grade better than targeted peers • Respect from peers • A good pass grade for academic advancement	*I must at least be better than them (in mathematics)…I want to graduate with a diploma, followed by a degree. I am satisfied with the results as most of my classmates did worse than me. They said I am good and I think they envy me.*

6.1.3 The Pragmatic Learner

Due to the growing affluence of the Singaporean society, the pursuit of materialistic needs is increasingly perceived by its people as an unspoken cultural norm. The present generations are brought up believing the importance of pursuing materialistic wants in their lives. Pragmatic learners are one such group that is strongly aligned to this "rat race" phenomenon. As education is the most important life investment in Singapore, pragmatic learners perceive the successful completion of their current diploma courses as their passports to a better future. And, due to the importance of engineering mathematics in their current engineering courses, pragmatic learners have to accept its significance in achieving their future materialistic needs.

Although all pragmatic learners subscribe to the materialistic norms of the society and actively pursue such needs through their current diploma courses, there exists an important intervening condition, namely, their "O" level results, that may distinguish the pragmatic learners into two subgroups (Type I and Type II). There are some variations in the manner they approach engineering mathematics learning but they still share many important common traits in the category of intending. Therefore, in this study, these two subgroups of pragmatic learners will not be separated into two different types due to their common features in the typology's most important distinguishing category – Intending (it is the core category in the theory of Selective Intentionality).

The intervening factor of their "O" level results tends to determine whether they are able to pursue a course of their choice. Although pragmatic learners aim to improve their probability of accessing future higher education or career prospects, their "O" level results may not be good enough to achieve this in their preferred courses. This is an important intervening factor as there are different implications for the students when they study courses that either interest or irk them.

Type I pragmatic learners consist of those students who have chosen their current engineering courses as their preferred choice as they have done well in mathematics and science at "O" level examinations. They have based their decision in their course selection on their strong ability in mathematics and science. This results in them staying on track in meeting their future materialistic needs in the society through the accomplishment of a successful education or engineering career. Another consequential effect is that they have more confidence in learning engineering mathematics due to their strong ability in mathematics. From these, Type I pragmatic learners internalise the significance of engineering mathematic as being related to academic advancement in engineering-related university courses and achieving job competency in future. This will then lead them to fulfilling the materialistic expectations they aspire to achieve.

As for Type II pragmatic learners, they are not as fortunate as compared to the earlier subgroup. Type II pragmatic learners had chosen other non-engineering courses that interest them, but were placed instead in their current engineering courses as their “O” level results were not good enough to place them in their preferred courses. This is due to the increasing popularity of non-engineering related courses among the student applicants. There are a huge number of engineering-related courses offered in polytechnics due to the social engineering of the government in ensuring the effective functioning of a technologically reliant society. Type II pragmatic learners are channelled into these courses. As these learners have chosen not to retake their “O” level examinations and reapply for their preferred courses in a year’s time, they decided to postpone pursuing their academic interest by aiming to do well in their current engineering courses. This can hopefully allow them to advance into the original non-engineering related domains that interest them, at university level. Therefore, their current engineering courses become important to their future academic life that is non-engineering based. And mastering engineering mathematics becomes very important to them in doing well in their current engineering courses. In short, their internalised significance of engineering mathematics is similar to Type I pragmatic learners as it is also related to fulfilling societal materialistic expectations and academic advancement. This shared significance is internalised by both subgroups in the different contexts of whether their current diploma courses are their preferred courses and the careers or university courses they aspire to be in, after they have graduated from the polytechnic.

Both subgroups of pragmatic learners share the common aim of improving their chances in gaining access to higher tertiary education and good working careers. They generally perceive that their aims have to be achieved through acceptable grades in engineering mathematics (which constitutes a substantial number of credit units in the fulfilment of the courses) that is significant in the overall award of their current engineering diplomas. Below is a table that illustrates the similarities and differences between Type I and Type II pragmatic learners in the typology.

Table 6.5 Components and illustrations of the intentions of pragmatic learners

Intending	**Pragmatic**		**Illustration (E14-Type I, E04-Type II)**
	Type I	**Type II**	
Critical event	Influenced by societal standards and family Seeing importance of materialistic needs		*If I don't study hard, next time I think I would be like them (the lowly educated). I promised my parents that I need to go university. (E14)* *My mum tells me that maths is important in this society (in terms of career).This course I am in is my seventh course. (E04)*
	Course is preferred choice as they can score well in "O" level maths and science	"O" level result not good enough to get into preferred course	
Consequential effect	Pursing own future materialistic needs Subscribing societal norms		*I also earn money (if I do well in studies) ....I need maths to go to university… usually, I have confidence in doing maths. (E14)* *…at least can go poly. I decide to study properly, if I can go university, then I change course. (E04)*
	Confidence in doing well for engineering maths	Postponing personal academic interest Seeing current course as stepping stone for advancement in future non engineering academic courses	
Accepting significance of maths in	Academic advancement External societal materialistic expectations		*Because I need maths to go to university… My job would be engineering, and then I would need mathematics… So because of engineering mathematics, your other modules also improve. Finally, I made my parents proud with my results. (E14)* *My mother tells me mathematics is important. If I got good results, I can go university to study what I like. (E04)*
	Job competency	Academic interest postponement	
Aim	Gaining access to higher education or good working career		*I think of going university. (E14)* *If I got good results, I can go university (through my current course). (E04)*
Perceived intention-related consequences	• A good GPA pass grade for academic or career advancement		*End year I have to get 3 point 5 (GPA). (E14)* *I just think of having good results so as to go university to study the non engineering related courses that have interested me. (E04)*

6.1.4 The Fatalistic Learner

Fatalistic learners are aware of their weakness in engineering mathematics learning. They have experienced multiple failures in mathematics learning in their secondary and primary school years or during their first year in their engineering courses. Thus, mathematics, which they dislike to a great extent, has always been their Achilles' heel in their academic career. Their weakness in mathematics learning is exacerbated by the fact that they are enrolled in their current engineering courses – which they dislike – as they are not able to be admitted to their preferred courses due to their poor "O" level results. As they are already pessimistic about their ability to do well in engineering mathematics learning due to their learned helplessness in mathematics learning developed during their pre-tertiary years, they accept that engineering mathematics learning represents a form of perpetual academic survival to them. At the same time, they are resigned to the fact they are not expected to do well in their tertiary studies nor advance into university studies, due to their poor overall academic ability. Thus, they have internalised the significance of engineering mathematics in completing their diploma so as to start their future working careers. This also means that fatalistic learners aim to obtain a minimum pass in their current engineering courses as they are realistic about their chances of doing well in them. In terms of their perceived intention-related consequences, fatalistic learners perceive that a minimum pass in engineering mathematics is enough not to affect their final GPA score (General Point Aggregate) in securing their diplomas. An illustration of such fatalistic learners in the categories of analysing and intending is provided below.

Table 6.6 Components and illustrations of the intentions of fatalistic learners

	Fatalistic	**Illustration (E11)**
Critical event	Multiple failures in maths Poor results in "O" level	*Most of them (mathematics examinations in primary and secondary years) are failed or even if I passed it was a just pass. I don't have a choice (in course selection).*
Consequential effect	Having low self efficacy of mathematics Dislike for engineering Survival in mathematics learning Resigned to the fact that they are not able to advance to university level	*The first day I am in polytechnic, I know that I cannot do well for mathematics.* *It is not you like it or don't like it, it is that you must do well for your maths. No choice.* *I know my maths standard, I do not aim to score well. I just learn enough to help me scrape through.*
Accepting significance of maths in	Academic advancement in completing diploma	*Mathematics GPA (general point aggregate) is high so you must do well for maths if not your GPA will be pulled down. If your GPA is pulled down, your diploma will be affected.*
Aim	Gaining a diploma pass	*I just want to go well enough to get my diploma.*
Perceived intention-related consequences	• A minimum GPA pass grade	*My aim is to get D for maths. As long as I can scrap through my maths, the other subjects I can get As.*

6.1.5 The Dissonant Learner

Similar to their fatalistic counterparts, dissonant learners had bad experiences in mathematics learning in their pre-tertiary learning years. This is worsened by the fact that they are enrolled in engineering courses which they have no interest in. This is because their poor "O" level results are not good enough for them to get into the more popular non-mathematics related courses they like. This makes them dislike mathematics more as it is an important part of engineering. Unlike the Type II pragmatic and fatalistic learners, they eschew mathematics learning and are not willing to accept their current situation. They perceive that proficiency in mathematics learning determines the future careers of many people in the Singaporean society. They believe that students who are good in mathematics and science are usually well looked upon in the society. To these dissonant learners, such students also get the priority in selection of courses in polytechnics. Thus, they feel that such treatment meted out by the society and educational system in Singapore is unfair, a situation they find hard to accept. This increases their dislike for mathematics learning that is now an important component of their current engineering diploma courses. Therefore, they internalise the significance of mathematics in unfairly compartmentalising students in terms of mathematical ability and depriving them of their true academic interests. With such thoughts, they form resistance against engineering mathematics learning so as to register their discontent at the current educational system which they believe as being unfair to those academically weaker students in mathematics learning. This is achieved through missing lectures, tutorials and even examinations. They perceive successful avoidance from or resistance to engineering mathematics learning as their intention-related consequences. The characteristics of dissonant learners' intentions of engineering mathematics learning are presented below.

Table 6.7 Components and illustrations of the intentions of dissonant learners

	Dissonant	**Illustration (E19)**
Critical event	Hated mathematics since young Poor "O" level results	*I did not like this course and mathematics. This is selected as my sixth choice by my parents. I want to get into business but did not get in because of my poor "O" level results.*
Consequential effect	Perceiving education system as unfair Dislike for engineering and maths	*One cannot pass maths means that he cannot go most of the courses in poly. I think this is unfair to us who are not good in maths. Why can't the system be fairer to all of us?.....I don't know what is engineering and it needs maths which is my weakest and most hated subject in secondary school.*
Accepting significance of maths in	Unfairly compartmentalising students and depriving them of academic interest.	*I don't understand why maths must be so important here.*
Aim	Displaying discontent against education system	*But, at times, I do feel angry why I am in a course I am not interested in and cannot study what I like.*
Perceived intention-related consequences	• Avoidance from learning • Resistance to learning	*.....do I look motivated (in engineering mathematics learning)? I am just passing time. So might as well don't study at all.*

6.1.6 Conclusion

As shown above, the intention of each learner type in engineering mathematics learning differs qualitatively and quantitatively in the typology. These intentions can be mastery-oriented, ego-oriented, career-oriented, survival-oriented or resistance-oriented. From the analysis of the data, these intentions appear to be either solitary or hierarchically related as shown in the diagram below.

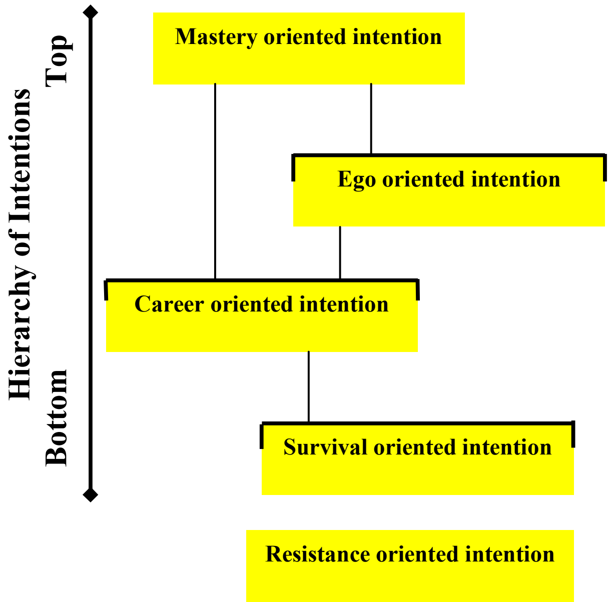


Figure 6.1 Relationships between intentions in engineering mathematics learning

A resistance-oriented intention in engineering mathematics learning tends to be solitary in nature. This means that dissonant learners who hold such intention do not have any other intention concurrently in their learning. They subscribe unfalteringly to their intention of resisting engineering mathematics learning. However, from the data, it is shown that the other four intentions may be hierarchically related. Idealistic learners perceive the achievement of the mastery of engineering mathematics as their main intention. Nevertheless, they may recognise social status (ego-oriented intention) and good future academic or work prospects (career-oriented intention) as the natural outcomes of the pursuit of their mastery-oriented intention. Similarly, competitive learners know that securing good future academic and work prospects (career-oriented intention) support their ego-oriented intention. However, they usually do not perceive gaining mastery understanding of engineering mathematics (mastery-oriented intention) as necessary. At the same time, pragmatic learners, especially Type II ones, are aware that obtaining a minimum pass in engineering mathematics examination (survival-oriented intention) is essential before they successfully achieve their own career-oriented intentions. And pragmatic learners generally do not mention the attainment of social status (ego-oriented intention) or mastery understanding (mastery-oriented intention) as part of their intention in mathematics learning. Similarly, fatalistic learners normally do not hope for a bright future academic or work career (career-oriented intention), respect from peers (ego-oriented intention) or mastery understanding (mastery-oriented intention) through engineering mathematics learning. In summary, a subscribed intention may encompass some of those intentions below it (in the hierarchy) in its “background” or as part of its perceived intention-related consequences. On the contrary, any subscribed intention will not usually incorporate those intentions above it in the hierarchy.

Another finding in this study is that some of the students’ intentions in engineering mathematics appear to be fluid during the early months of their engineering courses. Some students’ intentions in engineering mathematics remain similar as those of theirs in pre-tertiary mathematics learning years. These students may have been doing either satisfactorily or suffering repeated failures in mathematics learning since their pre-tertiary years. For example, E06 has always strived for conceptual mastery in mathematics learning (idealistic learner) and excelled in it since his pre-tertiary years, while E15 who has been experiencing repeated failures in mathematics learning, always aims for a minimum pass in it since his pre-tertiary years (fatalistic learner). There are also others who have attempted to maintain their pre-tertiary intentions in mathematics but have failed in the context of engineering mathematics learning. For example, E01 divulged that he has initially started with the intention of winning his peers (which he had successful experiences in his pre-tertiary years) in his engineering course (competitive learner). However, he discovered he was not as good as his course peers and suffered repeated negative experiences in his first few months of the course. Therefore, he has changed his previous ego-oriented intention into the current career-oriented one (pragmatic learner). On the other hand, others may have intentions in engineering mathematics learning which are different from those they have subscribed to in their pre-tertiary years. For instance, E05 has attempted to change his intention of a minimum pass in pre-tertiary mathematics learning (he did not know why he needed to study mathematics then) to the aim of mastery learning in his engineering mathematics education (idealistic learner). This is because he has managed to see the significance of mathematics in the discipline of engineering that interests him since young. Thus, he has proactively put in hard work in engineering mathematics learning. And he has done very well in engineering mathematics and other engineering modules since then. However, E12 who used to hope for a minimum pass in secondary mathematics has started with a career-oriented intention in engineering mathematics (pragmatic learner) but failed miserably. As at the time of interview, he has settled on a minimum pass in his engineering mathematics examination (fatalistic learner).

Although students' intentions in engineering may appear to be fluid in the earlier months of their engineering courses, it is observed that they usually stabilise and remain permanent by the time the students are in their second year of their engineering courses. The permanency of an intention depends substantially on the level of success in the achievement of its intention-related consequences that can induce new critical events, in the earlier months of the engineering course as shown in Chapter 5.2.3.1. This success depends significantly on the student's personal characteristics and external factors around him/her. The table below shows the change of the participants' intentions in mathematics learning from their pre-tertiary mathematics learning years to their current engineering mathematics courses.

Table 6.8 Change of Intentions

Participant	Pre-tertiary Mathematics Learning	First Year of Engineering Mathematics learning	Second Year of Engineering Mathematics learning
E01	Ego	Ego	Career
E03	Survival	Mastery	Survival
E05	Survival	Mastery	Mastery
E07	Career	Resistance	Resistance
E09	Survival	Career	Career
E12	Survival	Career	Survival
E13	Career	Mastery	Mastery
E14	Survival	Career	Career
E19	Survival	Resistance	Resistance
E21	Career	Mastery	Mastery
E02, E04, E06, E08, E10, E11, E15, E16, E17, E18 and E20 experienced no change in their intentions in mathematics learning since pre-tertiary years.			

In summary, students' intentions in engineering mathematics appear to be either solitary or hierarchical. At the same time, students' intentions can be fluid during the first few months of their engineering courses but stabilise by the time they are in their second year of study. As dictated by the differences in their stabilised intentions in engineering mathematics learning, each learner's type may react differently in their actualising process as shown in the subsequent sections.

6.2 Intentions and Actualising Approach

This section focuses on the effect of the learners' intentions on their approach to the actualising process, consisting of the two main categories of understanding and practising. Different types of learners exhibit their own unique attitudes in understanding and practising engineering mathematics. In this study, the learners' attitudes displayed towards engineering mathematics learning comprise of four components: psychological attributes, social attributes, aims in understanding and characteristics of practising.

6.2.1 The Idealistic Learner

In terms of psychological attributes in the processes of understanding and practising, idealistic learners tend to be interested and motivated in their engineering mathematics learning. They believe that it is their personal responsibility to invest sufficient time in understanding and practising engineering mathematics. Their motivation is thus internally driven. They are also active and independent learners as they pursue extra mathematical knowledge not covered in the syllabus on their own. When idealistic learners fail to understand or solve certain mathematical problems, they usually persevere and exhaust all avenues of assistance until they manage to solve them. As idealistic learners generally do well in engineering mathematics examinations, they are likely to possess high levels of self assurance in mathematics learning.

In the processes of understanding and practising, the idealistic learners' relationships with their peers are unique as compared to the other types of learners. As idealistic learners perform better than their peers in engineering mathematics learning, they are often looked up to by their peers and are frequently expected to help them if required. Thus, academic modelling is predominant in the case of idealistic learners' relationships with their peers. Idealistic learners are also generally well liked by their lecturers and tutors. In the categories of actualising, idealistic learners have a tendency to aim to achieve conceptual, functional, procedural and associational understanding. They typically believe that understanding the conceptual roots of the mathematical formulae learnt can advance their understanding of engineering. In terms of practising, idealistic learners usually invest a substantial amount of time in procedural training. They finish all their tutorials required in the engineering mathematics modules consistently. They also tackle mathematics questions outside the stipulated tutorials. To prepare for the examinations, they finish all the past years' examination papers. Thus, idealistic learners are able to achieve both simple and complex procedural competence. Besides, they tend to have a wider repertoire of approach strategies in the understanding and practising processes as compared to pragmatic, fatalistic and dissonant learners. The table below summarises the predominant aspects of idealistic learners in the actualising process.

Table 6.9 Illustration of idealistic learners in the actualising process

TYPE OF LEARNERS	IDEALISTIC	ILLUSTRATION (E21)
Psychological attributes	Self driven, interested, optimistic, internally motivated, independent, self assured, consistent and persevering	*At study, when you find the thing is interesting, then it shouldn't be tough to study ....Just learn consistently…if I don't understand it, I would think until I understand it… I feel confident (in learning).*
Social attributes	Academic modelling Well liked by lecturers and peers	*My friends ask me to help them then I learn too.*
UNDERSTANDING Aims	To achieve conceptual, functional, procedural and associational understanding May not be able to achieve conceptual understanding	*I make sure I know all formula and their proofs and uses.*
PRACTISING Characteristics	❖ Invest substantial time in training and achieving simple and complex competence ❖ Complete all tutorials ❖ Do other questions outside tutorials ❖ Complete all past year papers ❖ Have a wider repertoire of approach strategies	*Do all tutorials. Finish all past year tests. Try questions not in tutorial. There are a lot of such questions in the library.*

6.2.2 The Competitive Learner

Competitive learners are mostly driven by their sense of pride in their mathematical ability. They aim to do better than their peers in engineering mathematics learning. They are also interested and highly confident in mathematics learning as they have always done well in it. Due to the fact that they hope to perform better than their peers, competitive learners tend to be egocentric in their learning. Consequentially, they seldom help their peers or cooperate with them in mathematics learning. Instead, they see beating their peers academically as a motivation for them to do well in mathematics learning. Thus, their relationship with their peers is mainly competitive in nature.

Competitive learners generally believe that achieving functional, procedural and associational understanding are sufficient for them to achieve good results in mathematics examinations. They are able to attain the above three types of understanding – some take more time over this than others. They tend to invest a significant amount of time in procedural training to reach both simple and complex procedural competence. They are also very persevering in learning due to their competitive nature. They generally finish all the required tutorial assignments stipulated. To prepare for the engineering mathematics examinations, they usually finish all the past years' examination papers. Like idealistic learners, competitive learners tend to use more approach strategies in their actualising process as compared to pragmatic, fatalistic and dissonant learners. Below is an illustration of competitive learners and their predominant attributes in the actualising process.

Table 6.10 Illustration of competitive learners in the actualising process

TYPE OF LEARNERS	COMPETITIVE	ILLUSTRATION (E02)
Psychological attributes	Competitive, interested, strong sense of pride, egocentric, highly confident, persevering	*I am always confident during mathematics examination. For peers, competition also motivates us in some way. Nobody likes to lose. I felt very happy and proud as I won a lot of people.*
Social attributes	Academic competition Not on close terms with peers	*I studied at home, friends are disruptive. They will keep pestering you if they don't know how to do.*
UNDERSTANDING Aims	To achieve functional, procedural and associational understanding Achieved all three	*The section C questions usually takes up more of my attention as I need more understanding to solve them. I also try to understand where the formula can be used so that I can better use it.*
PRACTISING Characteristics	❖ Invest substantial time in training and achieving simple and complex competence ❖ Complete all tutorials and all past year papers ❖ Use approach strategies frequently	*I started studying in week 10, 5 weeks before semestral test.* *I redo all the tutorial and test questions for all the topics.*

6.2.3 The Pragmatic Learner

There are two subgroups of pragmatic learners. In terms of psychological attributes, both groups are motivated by the materialistic pursuits impressed on them by societal norms. They are generally pragmatic in nature as they understand the importance of their current engineering mathematics learning in their future careers or education. Type I pragmatic learners who are more proficient in mathematics learning since their pre-tertiary years, tend to enjoy studying the subject. They are usually more confident and exhibit higher self efficacy in engineering mathematics learning. On the contrary, Type II pragmatic learners are resigned to the fact that they are not good enough to pursue their academic interests in the polytechnic. Through their own self rationalisation, they have decided to compromise by postponing the pursuit of their academic interests and taking this course as a stepping stone to pursue what they want to learn at the university level. As they have always been weaker in mathematics learning, they tend to be more realistic about their engineering mathematics ability. They do not expect to get excellent grades in mathematics examinations as they know they are not mathematically inclined. However, they still try to work hard in the subject, as they do not want the overall grade in their courses to be affected by their poor performance in engineering mathematics examinations. In terms of their social attributes, pragmatic learners are predominantly cooperative and empathic in their relationship with their peers. They engage in supportive group studies but at the same time, they may be influenced negatively by their peers in skipping lectures or tutorials. To achieve their intentions in engineering mathematics learning, pragmatic learners generally seek the assistance of lecturers or tutors when needed.

Pragmatic learners believe that engineering mathematics understanding is important functionally, associationally and procedurally. Although all of them are able to achieve procedural understanding, their levels of functional and associational understanding tend to vary due to their differences in the level of mathematical aptitude and the amount of tutorial or past years' examination questions they have completed.

Type I pragmatic learners are able to achieve functional and associational understanding - similar to the idealistic and competitive learners. They usually complete all their tutorial and past years' examination questions. Type I pragmatic learners are also able to achieve simple and complex procedural competence in engineering mathematics through their higher mathematical aptitude and persevering nature in learning. However, this is not so for Type II pragmatic learners who may not be as mathematically confident. Thus, these Type II pragmatic learners may not be able to attain complex procedural competence. Consequently, the grades they achieve in mathematics examinations may not meet their expectations. Another contributing reason is that Type II pragmatic learners may not finish their entire set of stipulated tutorial and past years' examination questions as compared to Type I pragmatic learners. This is due to their lower interest in, and liking for, engineering mathematics. They also have a lower level of perseverance in learning. Pragmatic learners generally utilise approach strategies in their learning. However, pragmatic Type II learners may use some evasive, compromising or procrastinating strategies in the actualising process too. The table below illustrates the predominant attributes and some examples of pragmatic learners.

Table 6.11 Illustration of pragmatic learners in the actualising process

TYPE OF LEARNERS	PRAGMATIC		ILLUSTRATION (E16 Type I, E09 Type II)
	Type I	Type II	
Psychological attributes	Pragmatic, externally motivated		*I thought I was important to study for every exam so that I can further my studies. I was quite confident before the paper as I used to do well in maths tests. (E16)* *So that I can achieve promotion in the course…At the start, I'm more to…., wanting to learn in business course. But, too bad, I failed my English… so Engineering is the substitute. (E09)*
	Confident, high self efficacy, persevering, interested	Realistic, resigned, compromising	
Social attributes	Academic cooperation Academic empathy Depends on peers and lecturers		*…first I would ask my friends, then my lecturers. (E16)* *Sometimes I would also ask friends if I don't understand. They are more patient with me. We help one another. Asks my lecturers for help. (E09)*
UNDERSTANDING Aims	Aim to achieve functional, procedural or associational understanding		*I make sure I can do all the section questions. (E16)* *Sometimes, I cannot link the formulae to engineering questions. (E09)*
	Achieved associational or functional understanding	Achieved procedural understanding	
PRACTISING Characteristics	❖ Time invested in training and achieving simple and complex competence varies ❖ May complete all tutorials and all past year papers ❖ May use evasive, compromising and procrastinating strategies		*I started studying for my examination during the 2 week break. I did tutorial and all the years' papers from the blackboard. (E16)* *I only started learning for my semestral test when we had our e-learning week I do past year papers. (E09)*

6.2.4 The Fatalistic Learner

Fatalistic learners have low self efficacy in mathematics learning due to their learned helplessness developed through their multiple failures in mathematics learning since their pre-tertiary learning years. Learning engineering mathematics is an emotionally draining chore to them and they are resigned to the fact that they will never do well in it. Their sense of resignation is further reinforced by the fact that they understand that they will not be good enough to advance into university studies due to their academic incompetence as shown by their poor overall academic records since their pre-tertiary learning years. Thus, fatalistic learners are generally pessimistic and resigned when it comes to mathematics endeavours. Due to their defeatist nature, fatalistic learners are generally very unmotivated and passive in their learning. They need to be "pushed" by their lecturers or family members. Specifically, their inertia to learn engineering mathematics is usually very strong during the early part of the semester. Thus, they are usually procrastinating in their learning as it allows them to avoid the unpleasant emotions that may otherwise surface. Even, at times, where they are engaged in learning, they give up easily once an obstacle appears in front of them. Although procrastinating in nature, fatalistic learners are usually gripped with a sense of urgency nearing the impending examinations as they need to fulfil their intention of obtaining a minimum pass in it. Therefore, they typically intensify their effort in self learning or seeking lecturers' and peers' assistance during the examination period. This contrasts with their inactivity in the earlier part of the semester.

Fatalistic learners tend to perceive engineering mathematics learning as memorising formulae. They fail to see the relationship between engineering mathematics and engineering concepts. Thus, they are only interested in achieving procedural understanding. In terms of practice, they engage in little procedural training as they seldom complete tutorial questions. This is due to their general inability and lack of determination in solving these mathematical problems. Coupled with their learned helplessness, they usually believe that procrastination is the best way to deal with the unpleasant emotions they always experience during mathematics learning. However, in view of the need to pass examination, fatalistic learners "drill" themselves in solving past years' examination questions during the examination period as they know – for them – it is the most efficient way to pass their examinations. This is usually achieved without any functional, conceptual or associational understanding. Thus, in short, fatalistic learners are only interested in achieving procedural understanding and simple procedural competence in engineering mathematics - enough to get a minimum pass in mathematics examinations. This also means that they do not have a wide repertoire of approach strategies in understanding and practising. At the same time, their strategies are mostly evasive, procrastinating or compromising in nature. An illustration of fatalistic learners in the actualising process is shown below.

Table 6.12 Illustration of fatalistic learners in the actualising process

TYPE OF LEARNERS	FATALISTIC	ILLUSTRATION (E15)
Psychological attributes	Fatalistic, unmotivated, pessimistic, procrastinating, and passive and have low self efficacy, low sense of urgency towards examinations, low determination	*I started studying for the mid semestral test before the test of course, but it is only in the morning of the test I started studying in the train coming to the test because I am a very lazy person. I need someone to motivate me or pressure me to do something. If not, one work will be done hardly and lazily and mostly done just before the deadline or even exceed it… my maths is very lousy one…get more than a pass is enough.*
Social attributes	Academic reliance Depends heavily on peers and lecturers	*Have to ask my classmates and lecturers a lot towards the exams.*
UNDERSTANDING Aims	To achieve procedural understanding	*More formulas to memorise.*
PRACTISING Characteristics	❖ Invest minimum time in training and achieving simple competence ❖ Do little tutorials and complete some past year papers ❖ May use evasive, compromising and procrastinating strategies	*I never do tutorials… Exam comes just do the MST (mid semestral test) paper can already.*

6.2.5 The Dissonant Learner

Dissonant learners show no interest in their subjects, including engineering mathematics modules. This makes them unmotivated in their learning. They are also reproachful and distrustful towards mathematics learning as they believe that they are unfairly disadvantaged in their academic journey because of their weakness in mathematics. Their low mathematical ability also results in their lack of confidence in engineering mathematics learning. However, they usually do not acknowledge their self weaknesses in mathematics openly, but put blame instead on external factors. Anger dominates their whole engineering mathematics learning experience. As their aim in engineering mathematics learning is to avoid or resist it, they do not invest any time in both understanding and practising. This means that they skip lectures and tutorials and do not prepare for their examinations. Besides, they are mostly isolated in their learning as they do not know their peers and refuse to approach them for assistance. They also do not approach their lecturers or tutors for assistance as they see them as part of the discriminatory education system and are usually cynical about their ability to help them. Thus, their learning strategies are usually resistant and evasive in nature. The table below illustrates the characteristics of dissonant learners in the category of actualising.

Table 6.13 Illustration of dissonant learners in the actualising process

TYPE OF LEARNERS	**DISSONANT**	**ILLUSTRATION (E07)**
Psychological attributes	Reproachful, distrustful, resistant, unmotivated, uninterested, lack of perseverance and confidence	*Cos was too lazy to study for it. Why study mathematics? I don't care if I fail….*
Social attributes	Academic isolation Do not ask for lecturers' help	*I don't think I am on the same frequency as my peers so I avoid them after this. I don't need their help…. waste of time to ask them (the lecturers), they are not helpful.*
UNDERSTANDING **Aims**	Do not aim to achieve any forms of understanding	*I never study, how to understand?*
PRACTISING **Characteristics**	❖ did not invest any time in practising ❖ do not do tutorials or past year questions ❖ May use evasive or resistant strategies	*I also never do my tutorial.*

6.2.6 Conclusion

The learners' attitudes in their actualising process are shown by the above sections to be distinct across the proposed typology. A further analysis of the psychological attributes possessed by the learner types shows that there are three common students' psychological attributes present in all learners. These three common psychological attributes are grouped into the categories of "interest", "perseverance" and "self efficacy" although they have been generated as different unique concepts in open coding. This categorisation is also supported by similar categories generated in the students' assortment of affective strategies used in the understanding and practising processes. The table below shows the learners' psychological attributes categorised into the three main categories according to learner types.

Table 6.14 Conceptual labels under the categories of "interest", "perseverance" and "self efficacy" with respect to learners' types

Learner's Type	Interest	Perseverance	Self efficacy
IDEALISTIC	Self driven, love, very motivated	Highly persevering, consistent	Self assured, optimistic
COMPETITIVE	Very interested	Competitive, persevering	Strong sense of pride, highly confident
Type I PRAGMATIC	Interested	Persevering	Confident, high self efficacy
Type II PRAGMATIC	little interest, resigned	Compromising	Unconfident, realistic
FATALISTIC	Passive, unmotivated	Procrastinating, lack of determination	Fatalistic, pessimistic, low self efficacy
DISSONANT	Resistant, no motivation, uninterested	No perseverance	Lack of confidence

From the table, it can be observed that interest, perseverance and self efficacy in engineering mathematics learning vary in polarity and strength across the learner types. Although it is generally agreed that these personal qualities or psychological attributes seem to be important in the success of any form of learning, their definitions may differ from one discipline to another. This study does not attempt to differentiate the distinction in students' perceptions of these personal qualities in different disciplines. However, the definitions of these personal characteristics from the perspectives of the students in engineering mathematics learning will be depicted below.

Interest, in this study, does not necessarily refer to the students' interest in mathematics learning. It may also refer to their interest in engineering. This is because engineering mathematics and engineering in engineering courses are closely related. It is unlike secondary mathematics where it is learnt as a sole entity. **Perseverance,** as perceived by the participants, refers to the level of persistence of the students in understanding and solving mathematics problems. The participants believe that perseverance is important in doing well in engineering mathematics examination as engineering mathematics is a subject where all its concepts and procedures are inter-related. It is also closely related to the operationalisation of engineering concepts. Thus, giving up in a particular mathematics problem may lead to a chain of other unsolved ones. In this study, the students' **self efficacy** is defined as the belief of the students about their capability in completing the mathematics problems in tutorials and examinations correctly in engineering mathematics learning. The participants feel that self efficacy is important in their mathematics learning.

On the whole, in terms of interest, perseverance and self efficacy, Type II pragmatic, fatalistic and dissonant learners tend to be weaker than idealistic, competitive and Type I pragmatic learners.

In the practising process, it can be observed that the amount of tutorial and past years' examination questions completed correctly varies across the learner types. The amount of tutorial and past years' examination questions completed by the learners, termed as "effort", can possibly impact their grades in engineering mathematics examination. A simple presentation of such variation can be illustrated clearly across the learners' types on the continuum of effort as below.

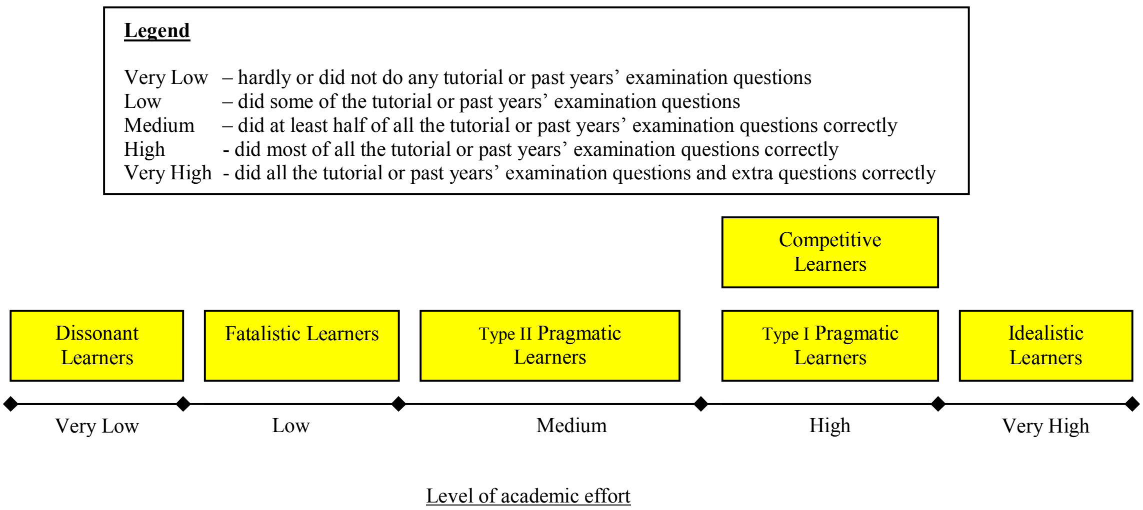


Figure 6.2 Level of effort in different learners' types

From these data, idealistic, competitive and Type I pragmatic students tend to put in more effort in procedural training in engineering mathematics learning as compared to Type II pragmatic, fatalistic and dissonant learners. As the data have shown, they have a tendency to finish all the tutorial questions allocated to them. In preparation for engineering mathematics examinations, idealistic, competitive and Type I pragmatic students are more likely to finish all the available past years' examination papers correctly. However, there is a need to note that this diagram is a rudimentary one as it does not specifically calculate the number of questions done by each student, but it sufficiently captures the approximate amount of effort as divulged by the participants in their interviews to highlight the distinction mentioned above.

Lastly, the process of actualising eventually leads to the success or failure of the learners' perceived intention-related consequences. In this regard, there appears to be some differences in the process of regulating for the different learner types. This will be presented in the next section.

6.3 Consequences of Actualising and Future Intentions

The different types of learners exhibit different attitudes and strategies in engineering mathematics learning as driven by their intentions. The success or failure in achieving the learners' perceived intention-related consequences plays an important part in the process of regulating. The process of regulating differs for each learner type, as explained below.

6.3.1 The Idealistic Learner

In the case of attaining their perceived intention-related consequences, the idealistic learners usually feel satisfied that they have achieved their aim of gaining understanding of the formulae used in engineering. This reinforces their belief in their ability to do well in engineering mathematics learning (assuring acceptance). They may attribute their success to their ability to understand the formulae taught or the amount of practice invested. At times when idealistic learners cannot achieve their targets, they will be more motivated to reach them. This is because they always attribute the cause to their own lack of understanding and see it as their responsibility to rectify the situation. They take any obstacle in engineering mathematics learning as a challenge for them to overcome (active acceptance). As they see a failure in achieving their aims as a chance for further learning experience, idealistic learners seldom encounter negative emotions in mathematics learning. From there, they strive to increase their level of understanding through improving their strategies in learning. An illustration of how the idealistic learners act in the regulating process is shown below.

Table 6.15 Illustration of idealistic learners in the regulating process

TYPE OF LEARNERS	IDEALISTIC	ILLUSTRATION (E06)
IDENTIFYING Dominant academic emotions	Satisfaction - Interest	*I felt satisfied as it is still the results I aimed for. But when I see I got that question wrong, I feel it is my lack of understanding so this make me more interested to know correct my mistake.*
ATTRIBUTING Success	Internal, controllable ❖ own effort in understanding	
Failure	Internal controllable ❖ own lack of understanding	*I feel it is my lack of understanding.*
RATIONALISING	Assuring Acceptance Active Acceptance	*I get more interested to learn more and to do better for my next paper.*

6.3.2 The Competitive Learner

When competitive learners achieve their targets in engineering mathematics learning, they tend to be proud of their achievement and gain more confidence in it (assuring acceptance). On the contrary, they generally feel angry if they fail to achieve their targets. This is because they cannot accept losing "face" in front of their peers. Their egoistic nature will see them attributing their failure to their lack of practice. They do not want others to see their lack of ability as the reason for their failure as this can greatly affect their self worth in mathematics learning. This anger translates into a form of motivation for them to seek better learning strategies so as not to suffer such embarrassment in future (active acceptance). The table below illustrates the competitive learners in the category of regulating.

Table 6.16 Illustration of competitive learners in the regulating process

TYPE OF LEARNERS	COMPETITIVE	ILLUSTRATION (E08)
IDENTIFYING **Dominant academic emotions**	Pride – Anger	*I am very proud of that (scoring better than others). The others are not interested to study. So when I lose to them, I am annoyed.*
ATTRIBUTING **Success**	Internal, controllable ❖ Superiority over peers	*I know I can do better than most of them.*
Failure	Internal, controllable ❖ Lack of practice	*I did not put in enough effort this time.*
RATIONALISING	Assuring Acceptance Active Acceptance	*...aims to work harder again.*

6.3.3 The Pragmatic Learner

Although there are two strains of pragmatic learners, their predominant experienced emotions are similar. If they are able to achieve their perceived intention-related consequences, they are usually happy (or other similar emotions) as they see such achievements as important steps to achieving their career or academic advancement goals (assuring acceptance). They may attribute such successes of their goals to factors such as their lecturers or their amount of practice put in. However, if they fail to achieve their aims, they usually experience sadness or other similar emotions. They also attribute similar reasons as those of their successes to their failures. However, the sadness experienced by them usually sees them actively seeking ways to improve their chances of achieving their intentions in engineering mathematics learning (active acceptance). The table below shows an example of pragmatic learners in the regulating process.

Table 6.17 Illustration of pragmatic learners in the regulating process

TYPE OF LEARNERS	PRAGMATIC	ILLUSTRATION (E17)
IDENTIFYING Dominant academic emotions	Joy – Sadness	*I feel happy when I saw I get an A. Then in the end you never do well, you lose a lot of hope.*
ATTRIBUTING Success	Internal, external, controllable, uncontrollable ❖ good teaching ❖ Amount of practise put in	*I appreciate that my teachers taught me well.* *I am happy with my hard work.*
Failure	Internal, external, controllable, uncontrollable ❖ Poor teaching ❖ Difficulty level of examination ❖ Lack of practice ❖ Peers	*….suddenly one killer question comes out.*
RATIONALISING	Assuring Acceptance Active Acceptance	*I will work harder next time.*

6.3.4 The Fatalistic Learner

The fatalistic learners are haunted by the constant fear that they may not be able to pass their engineering mathematics examinations. This may reach a stage for some where they become immune to such fear (such as E15 and E11). Their fear surfaces whenever they are not able to achieve their goals. They usually attribute their failure to their lack of aptitude in mathematics learning. Therefore, they tend not to take any remedial action (resigned acceptance). Even if they manage to achieve their targets, they see it as largely to do with luck, as they have low self efficacy of their mathematical ability. Nevertheless, they usually experience relief from achieving their intention-related consequences. An illustration of the fatalistic learners in the regulating process is provided below.

Table 6.18 Illustration of fatalistic learners in the regulating process

TYPE OF LEARNERS	FATALISTIC	ILLUSTRATION (E20)
IDENTIFYING Dominant academic emotions	Relief – Fear – Emotionless	*A bit scared that I may fail. If fail have to repeat… Thank god …. I passed. A stone off my chest.*
ATTRIBUTING Success	External, uncontrollable ❖ Luck ❖ Difficulty of examinations	*Thank god, at least luck is on my side I passed.*
Failure	Internal, uncontrollable ❖ Level of prior mathematical aptitude	*Fated, never score well again. No choice this is my limit.*
RATIONALISING	Resigned Acceptance	*See one step at a time.*

6.3.5 The Dissonant Learner

The dissonant learners are so overwhelmed by their dislike for mathematics learning that they do not experience any other predominant emotions. The dissonant learners' aims involve obtaining poor results in engineering mathematics examinations to register their protest in regard to their perceptions of an unfair education system. This is in contrast to the other learner types who aim to get good results in engineering mathematics examinations. As their aim is usually resistant and avoidant in nature, its successful achievement means that they generally perform badly in mathematics learning. This only reinforces their dislike for mathematics and the educational system (blaming defiance). Thus, they will not take any remedial action to improve their learning. Dissonant learners will always tend to succeed in their intention to do badly in examinations. Consequently, they may eventually drop out of the course voluntarily or possibly be expelled from the course, due to poor results. In fact, E19 withdrew from her course two months after I interviewed her. An example of the dissonant learners in the regulating process is illustrated below.

Table 6.19 Illustration of dissonant learners in the regulating process

TYPE OF LEARNERS	DISSONANT	ILLUSTRATION (E19)
IDENTIFYING **Dominant academic emotions**	Hatred	*I hate this course. I do not care although I don't know how to do. I hate maths.*
ATTRIBUTING **Success**	External, uncontrollable ❖ Education policies	*Hope the system will be fairer to those weak in maths or other subjects in future.*
Failure	Nil	
RATIONALISING	Blaming Defiance	*So might as well don't study at all.*

6.3.6 Conclusion

As shown above, each learner type is portrayed differently as compared to others in the process of regulating. The types of attribution and rationalisation for the success or failure of the students' intention-related consequences vary for the learner types. These two processes of attributing and rationalising are very important in the regulation of the academic emotions that occur in the learners when studying engineering mathematics. The learners need to regulate both the positive and negative emotions that arise mainly because of the results of their engineering mathematics examination. If the students attain grades that meet their expectations, their experienced positive emotions can strengthen their intentions and strategies in future engineering mathematics learning (assuring acceptance). Even if they encounter negative emotions due to undesirable grades, they can actively seek new strategies to improve on their future learning (active acceptance). This will help to alleviate their negative emotions too. Active acceptance usually occurs in idealistic, competitive and pragmatic learners who attribute internal/external controllable factors to their failures. On the other hand, fatalistic learners, dissonant learners and a minority of Type II pragmatic learners subscribe to resigned acceptance or blaming defiance as the attributions made for their failures are usually uncontrollable. This means that such learners will not engage in any constructive actions in their future mathematics learning. In short, through the proper regulation of their academic emotions, the learners can influence their engineering mathematics examination grades. The two tables below summarise the relationships between the processes of attributing and rationalizing across the learner types in the typology.

Table 6.20 Attribution and rationalisation across typology in the case of intention-related consequences achieved

DIMENSIONS OF ATTRIBUTION in **ACHIEVING** intention-related consequences.	Internal	External	RATIONALISATION
Controllable	**IDEALISTIC, COMPETITIVE, PRAGMATIC**	**PRAGMATIC**	Assuring Acceptance Active Acceptance
Uncontrollable		**PRAGMATIC, FATALISTIC, DISSONANT**	Resigned Acceptance Blaming Defiance

Table 6.21 Attribution and rationalisation across typology in the case of intention-related consequences not achieved

DIMENSIONS OF ATTRIBUTION in **NOT ACHIEVING** intention-related consequences.	Internal	External	RATIONALISATION
Controllable	**IDEALISTIC, PRAGMATIC, COMPETITIVE**	**PRAGMATIC**	Assuring Acceptance Active Acceptance
Uncontrollable	**FATALISTIC PRAGMATIC**	**PRAGMATIC**	Resigned Acceptance

In summary, the distinctions between the five learner types in the proposed typology have been clearly illustrated in the processes of analysing, intending, actualising and regulating within the theory of Selective Intentionality in engineering mathematics learning. Through the analysis of these distinctions in the typology, two propositions are suggested in the study. These propositions are elaborated in the subsequent sections.

6.4 Propositions Arising from The Typology

As a result of the comparison of the characteristics of different learner types in the resultant typology, two propositions with regard to the learners of engineering mathematics, are raised. These propositions serve as useful information for both students and teachers. To maximise the usefulness of these propositions to them, they are made with regard to the assumptions below:

i) They are proposed with regard to the students' attitudes in engineering mathematics learning and possible external intervening factors such as teachers, peers, syllabi of their courses.

ii) They are made in relation to only one of the perceived intention-related consequences that is common across all learner types – grade in engineering mathematics examinations. This is because engineering mathematics examination grades are the most important yardstick for all the learners in gauging their levels of accomplishment in understanding and practising which are important in achieving their intentions.

As dictated by the above conditions, the two propositions with regard to the students' engineering mathematics learning in the typology are suggested as follows:

a) External factors such as the society, families, teachers and peers may have a significant impact on the learners' grades in engineering mathematics.

b) The degree of the learners' intention, interest, perseverance, self efficacy, effort, emotional regulation and prior mathematical ability may have a significant impact on their grades in engineering mathematics or vice versa.

6.4.1 Factors Influencing Academic Performance

Engineering mathematics grades are direct consequences of the process of actualising (understanding and practising) in the theory of Selective Intentionality. This is because the students' levels of understanding and practising determine how well they do in their examinations. The mediating factors of understanding and practising in the theory of Selective Intentionality may be influenced by the students' personal qualities, beliefs about engineering mathematics and pre-tertiary mathematics learning experiences. The types and levels of teachers', peers' and families' support they have also appear to influence their examination results. Both these external and personal factors are discovered in the main categories in the theory of Selective Intentionality. They seem to be inter-related too. At the same time, they may exist at both macro and micro levels.

At a macro level, it has been shown that societal beliefs about mathematics and government education policies play a part in influencing the engineering students, their families, peers and teachers in engineering mathematics learning (in the process of gathering). At a micro level, engineering students' families may provide academic, financial and affective support to them (in the processes of gathering, analysing and actualising). In the context of the case Polytechnic, teachers influence the students' learning through their pedagogical methods (in the processes of gathering and actualising). Peers can exert both positive and negative influences on the students' learning (in the processes of gathering, analysing and actualising). These external factors can affect the processes of understanding and practising, which in turn influence students' results in engineering mathematics examinations. Thus, the **first proposition states that external factors such as the society, families, teachers and peers may have a significant impact on the learners' grades in engineering mathematics.**

Personal factors, which also influence engineering mathematics learning, include the learners' personal qualities such as intention, academic interest, perseverance, self efficacy, effort, emotional regulation and prior mathematical ability (as discovered in the processes of intending, actualising and regulating). These personal factors are affected by external societal factors and the students' prior experiences in mathematics learning. They (other than prior mathematical ability) are perceived to be controllable such that the learners themselves can improve on them through different learning strategies. As shown in the data, these personal characteristics appear to affect the processes of understanding and practising. These personal qualities exist commonly across the learner types at different polarities and strengths. The students' engineering mathematics examination results, as retrieved from the polytechnic's student management system, also appear to vary noticeably across the typology in relation to the strengths of their personal qualities. While data shows that high levels of their personal qualities seem to lead to better performance in engineering mathematics examinations, the students' improved grades appear to be able to strengthen their personal qualities too. Thus, the relationship between these desirable personal qualities in engineering mathematics learning and examination grades may be bidirectional and iterative. From here, the **second proposition states that the degree of the learners' intention, interest, persistence, self efficacy, effort, prior mathematical ability and their emotional regulation may have a significant impact on their grades in engineering mathematics examinations or vice versa.**

The diagram below illustrates the relationships between both external and internal factors in relation to the different main categories in the theory of Selective Intentionality and the students' engineering examination grades.

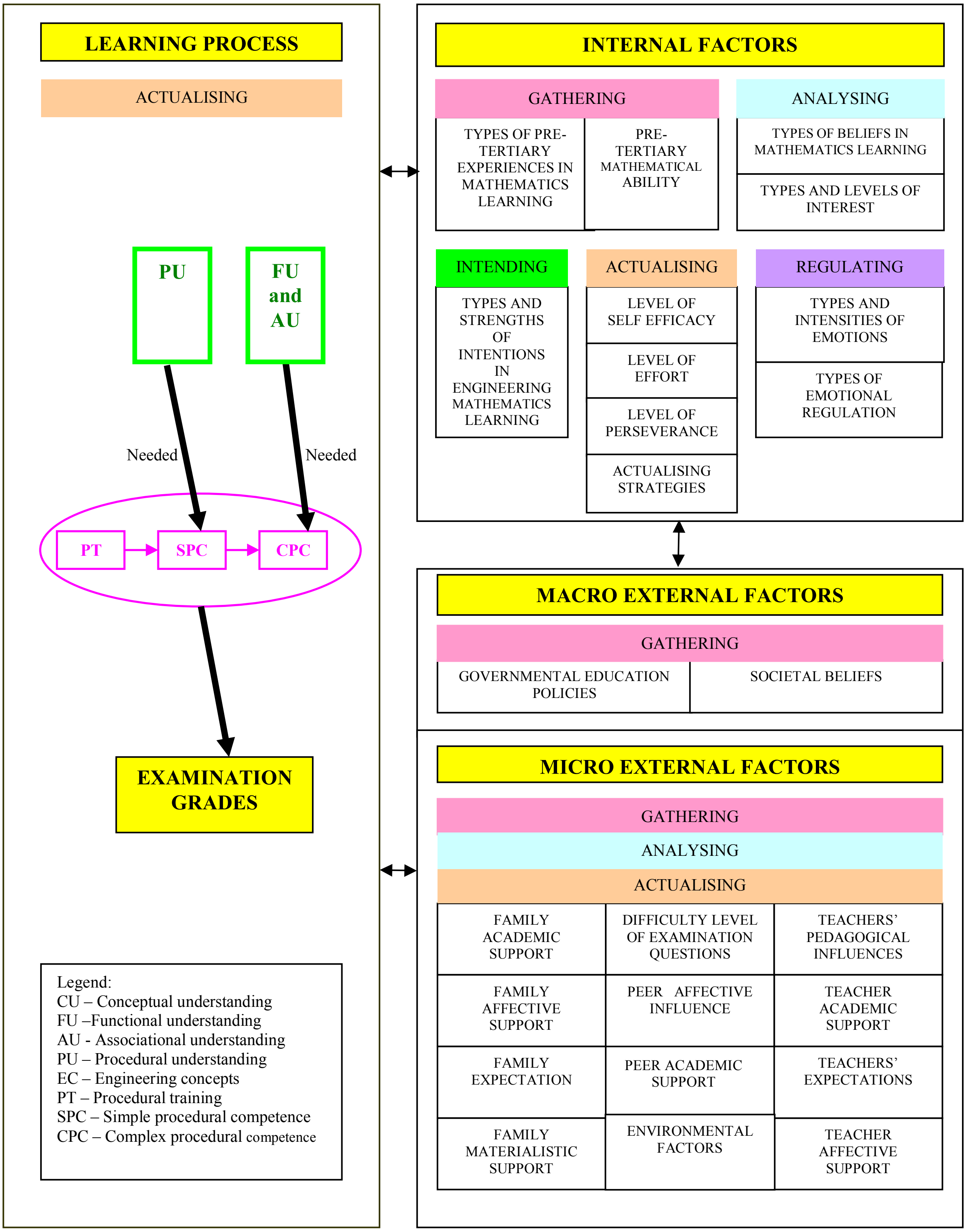


Figure 6.3 Relationships between internal and external factors and examination grades

Although, the data have confirmed that these external and internal factors can affect grades in engineering mathematics learning or vice versa, it does not explain the possible relationships between individual influencing factors. The relationship or correlation between individual factors seems to be either unidirectional or bidirectional. In order to verify such relationships or correlations between individual external and personal characteristics, statistical factor analysis is highly desirable. However, such analysis is not achieved in this study due to its qualitative nature.

6.5 Conclusion

This chapter has depicted the distinctions among the five learner types that arise from the theory of Selective Intentionality in engineering mathematics learning in a Singapore polytechnic. These distinctions are based in the categories of analysing, intending, actualising and regulating in the theory of Selective Intentionality. At the same time, two propositions arise from the typology. The propositions provide potentially useful information for practitioners in engineering mathematics education. In the next chapter, the whole study will be summarised and its implications for the teaching and learning community will be discussed.

CHAPTER SEVEN

DISCUSSION, IMPLICATIONS AND RECOMMENDATIONS

Introduction

This chapter comprises of three main sections. First, it provides a summary of the main conclusions in regard to the phenomenon of engineering mathematics learning in a Singapore polytechnic. At the same time, these conclusions are discussed in relation to the literature review done in Chapter Two. Further literature and research in view of the results of the study are incorporated for a more comprehensive discussion. Second, it discusses the implications for the practitioners of engineering mathematics learning (engineering students, teachers, researchers and policy makers). Lastly, in view of the implications of the whole study for the practitioners, recommendations are made to improve the teaching and learning of engineering mathematics. In short, this chapter is structured as below:

7.1 Discussion;
7.2 Implications;
7.3 Recommendations.

7.1 Discussion

This section provides a summary of the main conceptions of this research and its investigative process. More importantly, the resultant outcomes are discussed with regard to the literature review and the specific research questions. The section is subdivided into:

7.1.1 Conceptions of the Study;
7.1.2 Investigative Processes of the Study;
7.1.3 Outcomes of the Study.

7.1.1 Conceptions of The Study

This study first arises from my experiences as a lecturer teaching engineering mathematics in a Singapore polytechnic. I have observed that engineering mathematics learning constitutes a host of concerns for both lecturers (in terms of teaching) and students (in terms of learning). My concerns were increased by the lack of research and general understanding of mathematics learning in engineering courses in polytechnics in Singapore. This study was conceived in order to address these concerns. Its aim is to develop a substantive theory of how engineering students experience mathematics learning in a polytechnic setting. This has been achieved by addressing the main research question:

> **What are the students' experiences of studying mathematics as part of their electrical and/or electronic engineering diploma courses in a polytechnic in Singapore?**

7.1.2 Investigative Processes of The Study

Guided by the main research question presented above, the study seeks to understand and interpret the students' perspectives of studying engineering mathematics. It does not attempt to seek the causal relationships between influencing variables in engineering mathematics learning. Since it is based on perspectives, the study utilises the interpretive research paradigm as the philosophical basis of its investigative process.

To understand the experiences of students studying engineering mathematics entails understanding their thoughts, emotions and behaviours in their learning processes. Therefore, a symbolic interactionist perspective was adopted, recognising that the engineering students' perspectives towards mathematics learning is a result of their social experiences gained, and the meanings extracted from, years in family, school and society. A grounded theory approach was adopted on the grounds that it is most suitable for the exploratory nature of a study such as this, due to its inductive ability whereby a theory is built from emerging data (Glaser & Strauss, 1967; Glaser, 1978, 1992; Strauss & Corbin, 1998; Charmaz, 2006). Grounded theory also aims to generate a theory and propositions, as well as a typology – all of which are considered appropriate for a doctoral study of this kind.

Data were collected from a number of sources. The main source of data came from interviews with 21 engineering students, sampled on the basis of achieving theoretical saturation of the data (Glaser & Strauss, 1967; Glaser, 1978, 1992; Strauss & Corbin, 1998; Charmaz, 2006). The 21 participants were selected through the process of theoretical sampling, that is, sampling choices were dictated by the categories of the emerging theory (Glaser & Strauss, 1967; Strauss & Corbin, 1998) as the study evolved. Each student was also requested to write a one-off online reflection of their thoughts, emotions and behaviours before, during and after an engineering mathematics examination. Other sources of data included their bio-data, course materials and grades retrieved from the Polytechnic's student management system, and informal conversations with the 21 students' tutors regarding their attitudes during engineering mathematics lessons. The literature review conducted for the study was also an important source of data (Strauss & Corbin, 1998). In summary, the collection of data from multiple sources ensured triangulation of the data collected and analysed.

The analysis process is based on the constant comparative method (Glaser & Strauss, 1967; Glaser, 1978, 1992; Strauss & Corbin, 1998; Charmaz, 2006). This method employs analytical procedures of asking questions and making comparisons with respect to the data (Glaser 1978). The study adopted all stages of the grounded theory process, namely, open, axial and selective coding; these stages are inter-related and cyclical (Strauss & Corbin, 1998). Open coding involves the labelling and categorisation of the phenomena as indicated by the data. Axial coding aims to assemble and then reconstruct the data in new ways by making associations between a category and its subcategories. Finally, selective coding involves the integration of the categories to structure the initial theoretical framework so as to analytically generate the grounded theory from the data. They are supported by diagrams, code memos, operational memos and theoretical memos (Strauss & Corbin, 1998).

7.1.3 Outcomes of The Study

The outcomes of the study address each of the four specific research questions below:

a. **What are the societal factors that influence the students' experiences in studying engineering mathematics?**
b. **How are the students' intentions in engineering mathematics learning formed?**
c. **What strategies will the students use in realising their intentions and why are they used?**
d. **What are the expected consequences of the strategies on the students in engineering mathematics learning?**

Data analysis through grounded theory generated the so-called Theory of Selective Intentionality. This theory explains how the group of engineering mathematics students perceive and make sense of their mathematics learning (depicted in detail in Chapter Five). The core category and main categories in the theory of Selective Intentionality each address the four specific research questions above. At the same time, other important outcomes that arise from the theory of Selective Intentionality will be discussed in this chapter.

7.1.3.1 Specific Research Question 1

The first specific research question is **"What are the societal factors that influence the students' experiences in studying engineering mathematics?"** This is addressed by the categories of **gathering** and **analysing** in the theory of Selective Intentionality. In the process of **gathering** information about engineering mathematics as a subject area, engineering students are influenced by societal beliefs and norms about mathematics and its learning at the macro level. They recognise that such societal beliefs are related to the social, economic and education policies advocated by the Singapore Government. At the micro level, engineering students gain information about engineering mathematics through interactions with their families, teachers and peers in the different contexts of home, lecture, tutorial and examination.

The strong influence of the Singapore Government on engineering mathematics learning is acknowledged by the students. The economic, social and education policies advocated the government create a unique set of beliefs that are eventually embedded into the culture of the Singaporean society. In this regard, the students perceive that mathematics education is highly valued in the Singaporean society and their level of mathematical ability plays an important part in their future education and work careers. Most of them also feel that the Singapore Government places a strong emphasis on the cultivation of technology and sciences related expertise to support its economy. Thus, these create different levels of stress for the students in mathematics learning. Among the participants, there are those who excel in their academic endeavours in this socially engineered environment and support such government policies. There are also others who think that they are disadvantaged by the government policies as they are academically weak in mathematics learning. Such social injustice of mathematics education will be further elaborated in Section 7.2.3. All these beliefs espoused by the students are in congruence with the hypotheses proposed in the earlier literature review about the role of the Singapore Government in influencing their perceptions of mathematics learning. In short, the influences by the Singapore Government on education also extend to tertiary level engineering mathematics learning as shown by this study.

The significance of family influences on the students in engineering mathematics learning usually diminishes as their courses get underway. This is because data has shown that engineering mathematics - being a more specialised and difficult form of mathematics as compared to secondary mathematics - is usually foreign to the students' family members if they are not trained in this discipline. This is likely to be less so with pre-tertiary mathematics learning, where families can still wield a certain substantial amount of influence on the students as shown by Cain-Cason (1986) and Cai et al. (1997). However, family can still influence the students' engineering learning indirectly in terms of financial and affective support for them.

On the other hand, peers still exert significant influence on engineering students similar to that of their pre-tertiary years (as reported in studies such as Ballantine, 1997, Perret-Clermont & Schubauer-Leoni, 1988, Sternberg & Wagner, 1994, Zimmer & Toma, 2000). In this study, it is specifically shown that such peer influences arise from social comparison among the students, and are significant in the areas of competition, cooperation, reliance, modelling, empathy and isolation in engineering mathematics learning.

The earlier literature reviewed showed that teachers' influence on mathematics learners is undoubtedly significant in terms of pedagogies, affective support and expectation. This study concurs with the above conclusion and agrees with Jaworski (2002) that teachers' influences in engineering mathematics learning may come from the areas of *management of learning*, *sensitivity to students* and *mathematical challenge* in tertiary mathematics teaching.

In conclusion, the main social influences on engineering mathematics learning come from the government, teachers and peers. More importantly, this study discovers that these social influences work together to mould the students' beliefs and emotions towards engineering and engineering mathematics education through the process of **analysing**.

Within the context of societal influences, engineering students form their own perceptions about engineering mathematics learning. As shown in the earlier literature review, students tend to hold a wide variety of perceptions of mathematics learning that often change as they advance from lower levels to more advanced levels of mathematics (Kloosterman, 2002). This study agrees with Kloosterman (2002) as data show that engineering students' beliefs about mathematics tend to be more focused on its relation to the discipline of engineering and its effect on the completion of the diploma courses they are currently in, as compared to perceptions of pre-tertiary mathematics. These conclusions also concur with those of Graves (2005), Steen (1988) and Peterson (1996) on engineering students.

Although the students may share some common attitudes towards engineering mathematics learning, their other beliefs and emotions towards it may differ. Beliefs and emotions, as influenced by the above social factors, eventually serve as a significant foundation on which they form their individual intentions in, and aspirations towards, engineering mathematics learning. Together, the students' attitudes towards engineering mathematics learning are formed through their beliefs, emotions and intentions towards it (Leder, 1992).

7.1.3.2 Specific Research Question 2

The second specific research question is **"How are the students' intentions in engineering mathematics learning formed?"** These intentions can be related to the amount of mathematical knowledge gained (mastery-oriented intention), the level of social status attained (ego-oriented intention), the level of assurance of a good diploma and academic future (career-oriented intention), the level of assurance of passing examinations (survival-oriented intention) and the level of resistance or avoidance towards education policies (resistance-oriented intention) as perceived by the students. The conceptualisation of different types of intentions in engineering mathematics appears to arise from Maslow's Hierarchy of Needs and Murray's Taxonomy of Needs (Maslow, 1954; Murray, 1938). Mastery-oriented intention seems to arise from students' need for self actualisation (Maslow, 1954) and understanding (Murray, 1938). On the other hand, ego-oriented and pragmatic-oriented intentions appear to develop from Murray's achievement, affiliation and dominance needs and Maslow's esteem needs. Resistance-oriented intention may be related to Murray's infavoidance needs, while survival-oriented intention seems to evolve from Maslow's needs for security and social acceptance. Thus, students' individual needs in engineering mathematics learning appear to lead to the formation of their intentions in it. However, this study shows that the formation of such intentions in engineering mathematics learning may entail more processes and may thus be more complex.

The formation of students' intentions in engineering mathematics learning in this study can further draw parallels from the studies of Kloosterman (1996), Pintrich & De Groot (1990), Gibbs (2001) and Malle & Knobe (2001). Kloosterman (1996) proposed that there is a relationship between a learner's beliefs about mathematics and his/her motivational decisions in mathematics learning. This is supported by Malle & Knobe (2001) who stated that learners have to undergo some amount of reasoning that takes into account their prior beliefs, in the formation of their learning intentions. This reasoning process aims to justify the basis underlying the intention and arises from social interactions between individuals (Gibbs, 2001). Pintrich & De Groot (1990) further defined three important components in academic motivation (that can be seen as synonymous with intentions in engineering mathematics): the expectation component (the student's beliefs about his/her capability in finishing a task), the value component (the student's beliefs about the importance of the task and aims in achieving it) and the affective component (the tangible results and emotional consequences of achieving or not achieving the task). These conclusions are somehow similar to students' intentions in engineering mathematics learning where they take into account their beliefs about their prior experiences and abilities in mathematics learning, their perceived importance of engineering mathematics and the possible consequences of achieving it as affected by the social factors around them (in the process of **analysing**). However, one of the important components of engineering students' intentions in mathematics as discovered in this study – the critical trigger, is not mentioned in the above studies.

Another finding in this thesis agrees with Hannula (2006) who stated that different types of intentions may not be mutually exclusive, but instead appear to be complementary or hierarchical. The hierarchical nature of intentions is demonstrated by the relationships between mastery-oriented, ego-oriented, career-oriented and survival-oriented intentions. At the same time, this study proposes that intentions can also be mutually exclusive as shown by the solitary nature of resistance-oriented intention as related to the other forms of intentions in engineering mathematics learning.

This study also shows that students' intentions can be fluid in the earlier months of their engineering courses and would stabilise and become permanent by the time they are in their second year of study. The permanency of their intentions in engineering mathematics learning depends substantially on the level of success in the achievement of their intention-related consequences.

A further important finding of this study contrasts with Klein (2002) and Buzeika (1996) who claimed that students may have to hide learning intentions which are not congruent with the cultural norms in the society or classroom. In the Singaporean society that emphasises excellence in mathematics learning, this study shows that such students with intentions that are incongruent with the common societal beliefs often fall into the resistance-oriented category. However, these students generally do not hide their intention and would actively and openly avoid or oppose mathematics learning in actualising it.

From the earlier literature review, studies such as Elliot & Harackiewicz (1996), Diener & Dweck (1978), Hoyenga & Hoyenga (1984), Maehr & Braskamp (1986), Middleton & Midgley (1997) and Kloosterman (2002) proposed that intentions in mathematics learning can be categorised into three types: mastery-oriented, ego/performance-oriented or work avoidance-oriented. All five types of intentions in engineering mathematics learning are similar to the above proposed categories. This study agrees with the presence of mastery-oriented intentions in all types of learning. In engineering mathematics learning, ego-oriented and career-oriented intentions can possibly fit into the ego/performance-oriented category. Although survival-oriented and resistance-oriented intentions that have evolved from this study may be placed in the avoidance-oriented category as proposed by the authors above, it would be more appropriate to differentiate them. This is because survival-oriented intentions skew towards passive and covert avoidance (evasive, compromising and procrastinating strategies) while resistance-oriented intentions stress on more on open and defying avoidance (resistant strategies).

7.1.3.3 Specific Research Question 3

This section addresses the third specific research question, **"What strategies will the students use in realising their intentions and why are they used?"** With their intentions in engineering mathematics in place, the students form strategies to learn engineering mathematics through the category of **actualising,** a category that is made up of the **understanding** and **practising** processes.

Although most studies on mathematical understanding have focused on Skemp's (1971) conceptual/relational and procedural/instrumental understanding, this study shows that the understanding of engineering mathematics may entail more forms. This is because engineering mathematics focuses specifically on the learning of applied mathematical skills in the context of solving engineering problems. Thus, it involves the combination of the two separate disciplines of mathematics and engineering. This may then demand more distinctions in the understanding process of engineering mathematics as this study has shown.

From a pure mathematics viewpoint, students perceive understanding of engineering mathematics in terms of their procedures, functions and concepts. In this study, conceptual understanding and procedural understanding can draw parallels from those of conceptual/relational and procedural/instrumental understanding in Skemp (1971) respectively. Skemp (1971) categorised understanding in mathematics learning into two main types: conceptual/relational and procedural/instrumental. Conceptual understanding means comprehending the various mathematical concepts, their interrelationships and the basis they operate, while procedural understanding refers to recognising and utilising the rules of the mathematical concepts in solving mathematics problems.

In this study, functional understanding refers to the ability of the students to understand the functions of the formulae in general mathematical terms. To some extent, functional understanding can be subsumed under Skemp's (1971) conceptual understanding that also encompasses the process of understanding the uses of the concepts. In this study, both conceptual and functional understanding are detached into separate entities as it is revealed that only functional understanding is needed in the important associational understanding process. In order to utilise mathematics in engineering scenarios, students have to master the relevant engineering concepts and theories that give meanings to the functions of the mathematical concepts they have learnt. This ability to convert mathematical formulae into its engineering forms to solve engineering problems is termed as associational understanding in this study. It is different from that of Skemp (1971) as it is relating mathematical concepts and formulae to solving engineering problems while the one proposed by Skemp (1971) refers to the relationships between mathematical concepts.

The findings of the study reveal that the students generally focus on achieving procedural, functional and associational understanding of engineering mathematics. The possible omission of the learning of conceptual knowledge of engineering mathematics may well be related to the nature of mathematics as discussed by Schneider & Stern (2005). In general mathematics learning, the abstract nature of mathematics requires the learners to constantly reflect on, and make inferences from, a mathematical formula if they are to understand it conceptually (Schneider & Stern, 2005). Thus, conceptual understanding may not be easily taught or learnt and it is exacerbated by the higher level of difficulty in engineering mathematics concepts (as compared to pre-tertiary mathematics) learnt in the case Polytechnic. In contrast, procedural understanding of mathematics demands rather less attention and cognitive input from the learners (Schneider & Stern, 2005). Thus, it may be perceived to be easier to teach and learn. This explanation is shown to collaborate with the students' perspectives as they (other than idealistic students) generally find conceptual understanding to be too difficult for them to grasp, regardless of their mathematics abilities. On the other hand, procedural understanding is achieved by all students in the study, while students' levels of achievement of functional or associational understanding, vary across the typologies.

However, in the context of this research, the reasons why conceptual understanding is not pursued by most of the students may be influenced by the wider social and educational context. First, the students recognize that attaining procedural, functional and associational understanding is sufficient for them to perform well in their tests and examinations. This is because the format of their examinations is based on the students' ability to understand functionally, associationally and procedurally. Thus, conceptual understanding is of no academic value to all but the idealistic students. In addition, all but the idealistic students generally feel that conceptual understanding is irrelevant to them as they are not required to prove or justify the formulae they are expected to learn in their future engineering careers. Even if some lecturers emphasise conceptual understanding, it may be perceived by the students as too cognitively demanding. Third, the students report that the lecturers usually adopt pedagogical approaches that stress procedural, functional and associational understanding. The lecturers generally engage a teacher-centred approach where mathematics knowledge is transmitted directly to students who then behave as passive receivers. They normally emphasise step-by-step mathematics and engineering related mathematics computations to prepare the students for assessments. When some teachers adopt the student-centred and constructivist approach, all but the idealistic students find it to be time wasting. In short, the abstract nature and the wider social and educational context of engineering mathematics learning may have contributed to the students' 'limited' notion of the process of understanding. These experiences also seem to be contrary to the Singapore Mathematics

Curriculum Framework that stresses conceptual understanding, procedural understanding and active learning.

Nonetheless, there are some limitations to the research approach adopted in this study regarding the conceptualisation of understanding in engineering mathematics. First, although the research reported on why the various types of understanding were pursued in the students' learning, it did not explain how these were formed. This was because the investigation of the category of understanding did not centre on a micro, cognitive, process-based approach, which would have focused on how students perceived the actual ordered step-by-step process of mathematics problem solving. Thus, the research results could not clearly reveal the forms of understanding the students might potentially have achieved in the different engineering mathematics topics. It also could not explain why conceptual understanding in particular, and functional and/or associational understanding to a lesser extent, were not attained by some of the students. Neither did this study sufficiently clarify how the social contexts of the school (such as the lecturers' beliefs, pedagogies and affective support and peers' academic and affective support) as influenced by the curriculum, pedagogical or time constraints, might influence the development of the various kinds of understanding. Lastly, it is uncertain whether the four subcategories of understanding would be found in other domains of learning such as arts, humanities, business or languages. The confines of this study meant that the above issues fell outside its boundaries. However, these issues might well serve as possible topics to research in future.

This study also shows that the concepts of understanding and practising may be different in tertiary and pre-tertiary learning contexts although both tertiary and pre-tertiary students may agree on the importance of understanding and practising in mathematics learning. While tertiary students perceive and understand engineering mathematics learning at procedural, functional, associational and conceptual levels, many pre-tertiary students may simply perceive and understand mechanistically in relation to the mathematics problems presented to them (Kloosterman, 2002; Cotton, 1993; Cooney, 1992).

Practising at the tertiary level is seen as multifaceted in terms of simple and complex procedural competence and its relationship to procedural, functional, associational and conceptual understanding. This contrasts with many pre-tertiary students' perceptions of practising in mathematics learning as monotonous rote or routine repetitive training (Cotton, 1993; Cooney, 1992). More importantly, it is shown that the types and levels of understanding can influence the success of students' practising processes that in turn, affect their engineering mathematics grades in examinations.

These understanding and practising strategies in engineering mathematics learning can be cognitive, affective or behavioural. This conclusion is similar to the one proposed by Anthony (2005) and Gonzalez Lopez (2005) which stated that mathematics learning strategies may be cognitive, meta-cognitive, affective and external resources management oriented. At the same time, they can be either approach or avoidant, as similar to the ones proposed by Covington (1992) and Newman & Goldin (1990). This study also shows that approach strategies may be control, attitudinal or social while avoidant strategies can be evasive, procrastinating, compromising or resistant, in engineering mathematics learning.

7.1.3.4 Specific Research Question 4

The category of **regulating** in the theory of Selective Intentionality addresses the fourth specific research question, **"What are the expected consequences of the strategies on the students in engineering mathematics learning?"** As shown in the study, after the processes of **gathering**, **analysing**, **intending** and **actualising,** the consequences experienced in engineering mathematics learning can be tangible or intangible and direct or indirect. One of such consequences has a significant effect on the students' future learning process. It is their experienced academic emotions that may be psychologically positive or negative. It is shown in this study, through the process of **regulating**, that students reframe their thoughts so as to leverage their experienced academic emotions to their perceived advantage. From this, the strengthening or modification of the strategies in the **actualising** process and intentions in the **intending** process, occurs. This concurs with the studies by McLeod (1992) and Pekrun et al. (2002) which stated that emotions are the consequences or expressions of the students' beliefs, motivations and learning strategies, and their relationship is cyclical. Through the process of **regulating**, students' negative emotions can be alleviated or removed. At the same time, their intentions and strategies can be modified and/or reinforced.

In the earlier review of the studies done by Elliot & Harackiewicz (1996), Diener & Dweck (1978), Hoyenga & Hoyenga (1984), Maehr & Braskamp (1986), Middleton & Midgley (1997) and Kloosterman (2002), it is shown that regulating in learning can be task-oriented, emotion-oriented or avoidance-oriented, and adaptive or maladaptive. This study supports the above conclusion as regulation in engineering mathematics learning can be categorised into assuring acceptance (emotion-oriented, adaptive), active acceptance (task-oriented, adaptive), resigned acceptance (emotion-oriented, maladaptive), and blaming defiance (emotion-oriented, avoidance-oriented, maladaptive).

Besides addressing the four specific research questions in this study, the theory of Selective Intentionality also generates a typology of engineering mathematics learners. At the same time, it also proposes some external factors and desirable internal qualities in the students that may impact on their engineering mathematics examination grades.

7.1.3.5 A Typology of Engineering Mathematics Learners

A major outcome arising from this study is the development of a typology of students with regards to how they experience and manage mathematics learning in their engineering courses (depicted in Chapter Six). The main intervening characteristic in distinguishing students in this typology is the differences between their intentions in mathematics learning. These differences result in other predominant distinctions being made in the analysing, actualising and regulating processes in the theory of Selective Intentionality. Accordingly, based on theory grounded in data, the participants may be broadly classified into five types of learners: **idealistic learners**, **competitive learners**, **pragmatic learners**, **fatalistic learners** and **dissonant learners**.

In terms of engineering mathematics learning, *idealistic learners'* main preoccupation is the acquisition of mathematical knowledge, while *competitive learners* are driven by their aim to be academically better than their peers. *Pragmatic learners*, on the other hand, perceive a successful education as simply an important component of the pursuit of their future materialistic needs. *Fatalistic learners*, due to their poor ability in mathematics learning, aim only for a minimum pass in engineering mathematics examinations, while *dissonant learners* tend to resist or avoid mathematics learning completely.

A comparison of this typology to the one suggested by Shaw & Shaw (1999) of engineering students' attitudes towards mathematics learning in universities, is noteworthy. The typology of Shaw & Shaw (1999) classifies engineering students into five categories. The first cluster is termed - *Ambivalent with Poor Pre-University Teaching* where the students are interested in mathematics learning but they believe they are disadvantaged by their pre-tertiary teachers' poor teaching. The next cluster is the *Downhillers* who used to like mathematics and have had helpful pre-tertiary teachers, but who are currently performing at an average level in their engineering mathematics modules. The third group is the *Haters* who have never enjoyed or done well in pre-tertiary mathematics learning and they find no motivation in learning engineering mathematics in their current courses. *Ambivalent with Good Pre-University Teaching* is the fourth group where the students like mathematics learning and have benefited from their pre-tertiary teachers' good teaching. The last group is the *High Flyers* who have always liked mathematics learning and have done well in mathematics learning.

Due to the survey research form of data collection used, Shaw & Shaw (1999) focused on eight limited and pre-determined variables in their classification of engineering students in engineering mathematics learning. The resultant typology in this present study is based on more differentiating variables as it is qualitative in nature. Thus, there may be some differences in the criteria by which students are differentiated in both typologies. However, there may be some parallels to be drawn from both studies. From both typologies, it can be seen that the characteristics of the *dissonant learners* and *idealistic learners* in this study are similar to the *Haters* and *High Flyers* respectively proposed by Shaw & Shaw (1999). Both studies also show that students' interests and abilities in mathematics learning do play a part in their motivations in it. At the same time, both studies agree on the significance of teachers' quality playing a part in determining engineering students' attitudes toward mathematics learning.

7.1.3.6 Intervening Individual Qualities in Engineering Mathematics Learning

An important outcome from the creation of the typology of engineering mathematics learners in the theory of Selective Intentionality is the discovery of individual qualities that may impact on their grades in engineering mathematics examinations. Students' grades in engineering mathematics are generally accepted by the teachers and students as the most realistic gauge of the effectiveness of the teaching and learning of engineering mathematics. These internal factors include the **students' intentions**, **prior abilities**, **interest**, **perseverance**, **effort**, **self efficacy** and **emotional regulation** (depicted in Chapter Six) in engineering mathematics learning. As shown in Chapter Six, the relationship between these students' internal factors and their examination grades may be bidirectional. At the same time, there exists possible unique bidirectional or unidirectional relationships between individual internal factors in engineering mathematics learning. However, these relationships are not verified through statistical tools due to the qualitative nature of this study.

This section has summarised and discussed the conception, investigative process and outcomes of the study. The following section details the important implications of this study for students, teachers, researchers and policy makers.

7.2 Implications

This study aims not only to generate a theory about students' mathematics learning, but also to provide useful insights for practitioners, including students, teachers, researchers and policy makers in engineering mathematics learning. It is hoped that the implications – micro and macro - for these stakeholders are important and useful to them.

7.2.1 Implications of The Study for Students

As shown in this study, engineering students approach mathematics learning in different ways, for the most part according to their different intentions. Through the theory of Selective Intentionality, other students may be able to relate their own engineering mathematics learning experiences to those of the participants in this study (transferability). This may enable them to develop a better understanding of how they approach the learning of engineering mathematics. From the findings of this study, students may also develop a broader understanding of the repertoire of useful strategies for learning engineering mathematics. More importantly, engineering students may also become aware of the unique relationship between their personal qualities (**effort, interest, perseverance, emotional regulation** and **self efficacy**) and their performance in engineering mathematics learning.

The amount of **effort** invested in engineering mathematics learning appears to be related to grades in examinations as shown by the data in this study. This conclusion is supported by Zhang et al. (1990), Fan et al. (2005) and Chen (1995). The participants generally agree on the importance of effort in engineering mathematics learning. However, a substantial number of them (especially those in the Type II pragmatic, fatalistic and dissonant learners) still do not work to expend the required effort to do well in it. Moreover, tertiary teachers usually do not monitor the amount of effort students put into their studies as compared to pre-tertiary teachers.

This may be because tertiary students are deemed mature enough to be responsible for their own learning. However, this may be a misconception by tertiary teachers. Many students in polytechnics (especially Type II pragmatic, fatalistic and dissonant learners) are still teenagers who may not have yet acquired the perceived maturity and responsibility to learn successfully, as shown in this study.

In concurrence with D'Ailly (2004) and Abrantes et al. (2007), the present study states that students who exhibit higher levels of **interest** in either engineering or mathematics learning (especially those in the idealistic, Type I pragmatic and competitive learner types) tend to do better in engineering mathematics examinations. Some students, especially Type II pragmatic, fatalistic and dissonant learners, generally do not do well in engineering mathematics examinations. These students have also divulged that they have no interest in mathematics and engineering. Such students are likely to attribute their lack of interest in engineering mathematics to the fact that they are placed in their current courses against their will. They have also pointed out that their teachers teach engineering mathematics as a solitary disciplinary entity with hardly any reference to engineering concepts. Therefore, they cannot relate the concepts and procedures of engineering mathematics learnt to real life engineering scenarios. However, their lack of interest in mathematics learning may be also related to their continual poor examination grades. The study also shows that the absence of close academic support from the teachers can greatly decrease the students' levels of interest in engineering mathematics learning.

As revealed in this study, the students' **perseverance** (defined as the level of persistence exhibited by the students in solving mathematical problems) in engineering mathematics learning appears to be related to examination grades. Oyedeji (1991) and Van Blerkom (1996) also agreed that there is a positive correlation between secondary school students' perseverance and performance in learning. In this study, Type II pragmatic, fatalistic and dissonant learners generally exhibit low levels of perseverance in solving mathematics learning and perform badly in engineering mathematics examinations. In addition, they do not take steps to address their poor performance in examinations, even though they have acknowledged that it is important to persevere when solving mathematical problems. On the contrary, they have divulged that they give up easily in engineering mathematics as they are not interested in learning it or they cannot get adequate academic support from their teachers. Their lack of perseverance may also be related to their continual poor performance in mathematics examinations.

Although the students are aware of other desirable internal qualities (effort, interest and perseverance) mentioned earlier, they generally do not recognize the role of **emotional regulation** in their mathematics learning, even though they may practise it instinctively. Without awareness of the role of emotional regulation, students may unconsciously engage in its unconstructive forms (resigned acceptance and blaming defiance as defined in this study) in coping with psychologically unpleasant emotions (Zan et al., 2006; Malmivuori, 2006). Their engineering mathematics learning may well suffer as a result. To make matters worse, mathematics teachers usually do not attempt to alleviate the negative emotions the students have when learning mathematics. Turner et al. (2002) believed that this may be due to the teachers' belief that such negative emotions are normal in mathematics learning and will fade away as the students get more proficient in their learning. Although there may possibly exist other reasons for this situation, the win-win situation is such that teachers' role in students' emotional regulation can be more prominent. If students do not cope well with these negative emotions in mathematics learning, such repeated negative emotional experiences may culminate eventually in the students' negative attitudes towards mathematics learning.

This study also shows that the students' **self efficacy** (defined as the belief of the students about their capability in completing the mathematics problems in tutorials and examinations correctly) in engineering mathematics learning appears to be positively related to their examination grades and vice versa. This concurs with Pajares & Kranzler (1995) and Skaalvik & Skaalvik (2006) who reported that self efficacy has strong direct effects on students' mathematics problem solving ability at tertiary level. However, the concern here is that the development of students' self efficacy in mathematics learning may not be widely enhanced and developed by teachers, as it seems to be a largely ignored phenomenon in Singapore.

A further conclusion from this study may serve as a motivation to students with poor **prior mathematical ability** (as shown by their poor results in "O" level mathematics) before they enrol in their current engineering courses. This study suggests that students are likely to minimise the disadvantage of their poor prior secondary mathematics ability in engineering mathematics learning by practising the desirable internal qualities proposed above.

7.2.2 Implications of The Study for Teachers

This study has major implications for teachers in terms of pedagogical approaches and interventions. Currently, data from the interviewed tutors have shown that tertiary teachers rely on their personal teaching experiences in understanding how students learn in engineering mathematics. The creation of the theory of Selective Intentionality and its typology of engineering mathematics learners in this study may assist teachers in adopting more effective teaching strategies – especially with lower achieving students.

This study reveals that students believe that closer academic support from their teachers in mathematics learning can greatly improve their performance. However, students' beliefs may be contrary to many tertiary teachers' assumptions that tertiary students are mature enough to take full ownership of their own learning.

At the same time, the identification of a typology of engineering mathematics learners in this study may assist teachers in identifying and compartmentalising their students into the different learner types. This may be useful to teachers as each learner type may respond to specific pedagogic and counselling approaches. Thus, teachers may then develop appropriately honed instructional or motivational responses to support their students' learning.

This study is also useful to the teachers in providing important information about the desirable internal qualities that need to be nurtured in students - such as **interest, perseverance, effort, self efficacy** and **emotional regulation**. If they can incorporate the nurturing of these qualities into their pedagogical practices, then student learning should improve.

7.2.3 Implications of The Study for Future Policy Making

The first issue that arises for future policy makers from this study pertains to the social justice of education in Singapore. Education is faithfully pursued and closely regulated by the Singaporean government in ways that promote mathematics and science in the Singaporean society - largely because of their perceived economic value. However, such education regulation poses a form of social injustice for the group of students who are not academically competent in mathematics and science. In the context of the present study, groups of disadvantaged students have been identified, consisting of the Type II pragmatic, fatalistic and dissonant learners.

Such students have protested that the current application criteria set for diploma courses in publicly funded polytechnics seems unfair to those who have performed badly in "O" level mathematics. This is because students' "O" level mathematics grades are currently one of two compulsory requirements for application (besides the English language) for most of the courses (such as science related, architecture related, business related, technology related, social sciences related, apart from language courses) in polytechnics. The inclusion of the English language as a compulsory pre-requisite is logical as these courses are taught in English. However, not all these courses (especially some business, architecture or social sciences related courses) de facto require a significant amount of mathematical knowledge. Therefore, the compulsory requirement of "O" level mathematics grades in the application for most of the diploma courses may pose an unnecessary obstacle, in the form of a social injustice, to those students who are weak in mathematics learning, but good in other non-mathematics subjects. Therefore, this group of students could not get into the polytechnics' non-engineering courses they preferred due to the perceived unfair admission criteria. Although these students can choose to enrol in their preferred courses in private institutions, most of them cannot afford their high fees (as compared to the fees of publicly funded polytechnics that are heavily subsidised by the government). Coincidentally, there is always a surplus of vacant learning places in engineering courses every year. The surplus of learning places in engineering courses can be attributed to the large number of such learning places created by the government and the existing trend of engineering courses being unpopular among many student applicants. Consequently, most of them have no other choices but to reluctantly enrol in their current engineering courses although they have little or no interest in engineering or mathematics.
In summary, in the context of Singapore, students who are academically weaker in mathematics perceive themselves as socially disadvantaged due to such education policies that favour high competence in mathematics learning. These students see this as unjust as they are unable to exercise their personal choice to learn what they prefer in tertiary education.

Besides disadvantaging these students, this form of social engineering and education regulation by the Singapore Government may also have a wider implication on the proper functioning of the society, as more poorly trained engineers may be created. The creation of poorly trained engineers is due to the irony that many students with poor records of achievement in mathematics learning are placed in their current engineering courses where mathematics is extremely important. In a nutshell, the present education system does not present the freedom of choice to students in their selection of polytechnic courses, especially for those who are not mathematically inclined or whose parents are not well-off.

Another issue for policy makers arising from this study concerns the lack of students' interest in engineering and mathematics learning. The Singapore Government may find it tough to fill up the learning places in engineering courses with interested and competent students if the above issue is not addressed appropriately. This concern appears to be related to the content of the secondary and engineering mathematics curricula as disclosed by the participants in this study.

With regard to the content of the secondary and engineering mathematics curricula, all students in this study (except idealistic learners) generally agree with the conclusions below. First, most of the time, secondary students are not formally introduced to the field of engineering and its importance in a technologically-reliant society. At the same time, the secondary mathematics curriculum fails to communicate the elements of engineering to the students even if some mathematical procedures are closely linked to engineering concepts or scenarios. Thus, secondary students may not know anything about engineering and its important relationship to mathematics. Secondly, as perceived by the participants, secondary mathematics learning involves monotonous procedures that do not relate to real life scenarios most of the time. Even if some mathematics problems may be crafted in real life scenarios, they do not relate to the students' daily lives. For example, calculating how a rower moves from one bank to another across a flowing river utilising the concepts of vectors may be a real life example. But, this example may not relate to the students' daily lives at present and thus may not interest them. Even at the tertiary level, the engineering mathematics curriculum is more procedure- and concept-based than engineering scenario related. Thus, students usually find engineering mathematics modules uninteresting and monotonous. This also results in engineering mathematics being unpopular among many students. In summation, the above reasons result in students' lack of interest in engineering and mathematics.

The implications of this study for policy makers are essentially related to the social injustice of mathematics education and the negative effects of the current secondary and engineering curricula on the students' interest in learning engineering and engineering mathematics. In summary, these implications are very important as they concern the educational rights of the students and the economic interests and political future of the society. Therefore, they should not be conveniently ignored.

7.2.4 Implications of The Study for the Research Community

There has been little research investigating tertiary mathematics learning in the Singaporean community. The theory of Selective Intentionality in engineering mathematics learning and its resultant typology of engineering mathematics learners add significantly to the current shortage of relevant research literature in Singapore. Thus, it is hoped that this study can lay the groundwork for other educational researchers to study engineering mathematics learning in Singapore. This study also breaks new ground in adopting a grounded theory research approach to investigate the topic in Singapore. It is hoped that this work may inspire more such studies in Singapore.

7.3 Recommendations

This study proposes a number of recommendations to address the implications for practitioners of engineering mathematics learning stated in the earlier sections. They are made in relation to the categories of understanding, practising and personal qualities generated in the theory of Selective Intentionality and the different learner types in the typology. These recommendations are supported by further critical literature review on proven pedagogical and motivational intervention measures that can possibly improve the teaching and learning of each learner type. The first set of recommendations, made in relation to each learner type, concerns the improvement of the teaching and learning of engineering mathematics at classroom level. They are as follows:

1) Idealistic learners – Such learners are highly competent and motivated in engineering mathematics learning as compared to the other learner types in the typology. They have generally acquired conceptual understanding of engineering mathematics. They are also hardworking and persevering in learning. However, a concern that arises here is that idealistic learners' intellect may not be sufficiently challenged due to the less demanding curriculum that is designed in relation to students of moderate ability. At the same time, idealistic students do not get enough instructional time from teachers who usually pay more attention to the weaker students in tutorial or lecture sessions. Therefore, the above

constraints may hinder the development and attainment of idealistic learners' high academic potential. The measures below are recommended to address the above concern:

i) To further challenge idealistic learners intellectually, it is proposed that specific activities to promote students' higher order mathematical thinking are formulated for them to work on. These tasks may include more challenging mathematical concepts and problems outside the curriculum.

ii) At the same time, it would be beneficial to organise special sessions for idealistic learners to actively discuss and critically reflect upon the tasks in i) above. Teachers can serve as facilitators in such sessions. In these sessions, teachers can give undivided attention to them.

2) Competitive learners – Such learners are usually able to perform well in engineering mathematics learning as they are able to master both functional and associational understanding of engineering mathematics and achieve a high level of complex procedural competence. Competitive learners also possess the desirable internal qualities in successful engineering mathematics learning. Their learning is driven by the motivation of performing better than their peers in mathematics activities and assessments. Competitive learners also aim to gain academic recognition from their peers. The recommendations below may assist in the teaching and learning of competitive learners:

i) Teachers can set mathematical tasks such as marked assignments that promote competition among students to keep competitive learners motivated in their learning.

ii) To sustain competitive learners' good performance in mathematics learning, teachers can maintain their needs for self-efficacy by praising them whenever they do well in engineering mathematics learning, either individually or in front of their peers.

iii) Brophy (2004) stated that peer competition can be a powerful but problematic extrinsic incentive in learning. While it is useful to learners as a form of self motivation in learning, it may affect their personality and social development (Brophy, 2004). In this study, competitive learners tend to be competitive and self centred in nature. Thus, they are usually not on close terms with their peers. Since social skills and personality development have always been an integral part of education, teachers should assist them in improving their social relationships with their peers through providing appropriate advice or counselling.

3) Type I Pragmatic learners - Such learners are able to do well in engineering mathematics examinations as they have achieved complex procedural competence in engineering mathematics. They are motivated extrinsically in engineering mathematics learning. However, Brophy (2004) stated that extrinsic motivation is not as reinforcing as intrinsic motivation in sustaining students' learning. This is supported by this study that shows that Type I pragmatic learners tend to be less persevering and focused as compared to idealistic and competitive learners. Besides, due to their pragmatic nature, they may not be keen on acquiring relevant knowledge outside the syllabus that is not examinable. This is in contrary to both idealistic and competitive learners. Thus, their true academic potential may not be attained. These two problematic issues in the learning of Type I pragmatic learners, may be tackled through the recommendations below:

i) Teachers need to understand the types of extrinsic motivation that drive Type I pragmatic learners and constantly remind them to keep on track in their pursuit of such tangible benefits.

ii) Teachers can help to support Type I pragmatic learners' pursuit of their external goal by providing them with sustained short term tangible targets such as achieving good test or assignment results that will lead to their final long term aim.

iii) Teachers can consciously encourage Type I pragmatic learners to actively explore knowledge outside the syllabus. This can be done by emphasising the practicality of pursuing extra knowledge as it is useful to them in closing the knowledge gap as they enrol in future university engineering mathematics modules.

4) Type II Pragmatic learners – Such students lack the interest, do not put in as much as effort as needed and are average, in mathematics learning. Since these students perceive their current courses as a stepping stone to future non-engineering university courses they would like to enrol in, it is important for them to acquire an acceptable grade in engineering mathematics examinations. This will ensure the overall grades in their courses not being affected. However, Type II pragmatic learners usually perform average or below average in engineering mathematics examination due to their poor grasp of functional and associational understanding of engineering mathematics that contributes to their low level of complex procedural competence in it. Therefore, the main concern here is to raise their level of complex procedural competence so as to improve their engineering mathematics examination grades. To help Type II pragmatic learners achieve a higher level of complex procedural competence in engineering mathematics, raising their level of effort in its learning is perceived to be the most effective way. It is because it would be difficult to raise their interest or perseverance in engineering mathematics as they generally have never been interested in mathematics learning or a future engineering career. The students' level of effort in engineering mathematics is proposed to be achieved as below:

    i) It is also suggested that teachers place greater emphasis on ensuring increased student effort (for learning to be effective) through constantly motivating, rewarding and monitoring their work, especially in tutorial assignments.

    ii) Teachers can also attempt to provide a more caring and supportive learning environment for Type II pragmatic students to raise their level of effort and address their difficulties in engineering mathematics learning.

    iii) Since Type II pragmatic learners are generally collaborative and reliant in learning, they can be assigned idealistic or pragmatic Type I learners as their tutors to guide them in their learning.

5) Fatalistic learners – Such learners are crippled by their constant failure in mathematics learning since their pre-tertiary years. They usually cope badly in engineering mathematics learning. Presently, these learners have fallen into a state of learned helplessness and are resigned to performing badly in mathematics learning. They exhibit no interest, have no perseverance, put little effort in, and experience negative emotions in engineering mathematics learning. Therefore, the most pressing educational concern here is to improve their self efficacy in engineering mathematics learning so that they can regain their belief in their ability to perform in the subject. It is hoped that their gain in confidence or self efficacy will further catalyse positive changes in their examination results, interest, perseverance and emotional experiences in engineering mathematics learning. It is recommended that their self efficacy in engineering mathematics learning be developed through ways suggested by Bandura (1997).

i) Teachers can build up fatalistic learners' self efficacy through sustained successful student experiences by assigning them mathematics problems that are systematically achievable and of gradually increasing difficulty in keeping with individual student progress.

ii) Teachers should know their students and be sensitive to their individual needs and provide an assuring, encouraging and supportive learning environment for them.

iii) Teachers can provide social models (other students with similar academic standards to them) who are successful in engineering mathematics learning, for fatalistic learners. Seeing other students of similar standard succeed academically through sustained effort may allow them to believe that they can also be successful. And by observing and understanding how others succeed in engineering mathematics learning, fatalistic learners can build up their self efficacy by modelling others' successful strategies.

iv) Teachers can constantly assure fatalistic learners that they are able to perform well in engineering mathematics if they put in the required hard work. Teachers may also set reasonable individual learning targets for them. This usually motivates them to be interested in engineering mathematics learning and makes them work harder and longer. This may greatly strengthen their self efficacy in engineering mathematics learning.

v) Fatalistic learners' self efficacy in engineering mathematics learning may be improved through the maintenance of positive emotions and low stress. Therefore, teachers should constantly monitor their emotional well-being during their interactions. They may be taught proper emotional regulation in learning by professional counsellors.

6) Dissonant learners – Such learners are highly resistant to engineering mathematics learning. Psychological intervention instead of pedagogical interventions may be more applicable and feasible in such cases. Teachers can attempt to counsel dissonant students if they are trained in counselling. However, if the teachers are not counselling-trained or the students are not receptive to their counselling, it would be advisable to refer them to professional counsellors for intervention. Ensuring fatalistic learners receive early and effective intervention is very important. This is because they may lose their chance of education if they are removed from the education system eventually due to either insufficient or no help being rendered to them.

The second set of recommendations can be viewed at a macro level as they are related to the improvement of education policies at societal or institutional levels. They are as below.

7) The current national secondary mathematics curriculum is in need of review, as it does not adequately stimulate students' interest in engineering and mathematics. It needs to relate more to the daily lives of students to arouse their interest in mathematics learning. It can also be consciously injected with the elements of engineering so that students can recognise engineering and its importance in the technological and scientific society. This may well help to generate more familiarity and interest among the secondary students in the discipline of engineering or mathematics. By raising students' interest in engineering and mathematics, the social unfairness of mathematics education can be greatly reduced as lesser students will take up engineering courses reluctantly by default.

8) The current Polytechnic course admission policy also needs to be reviewed as it is perceived to disadvantage students who are weak or uninterested in mathematics learning. The recommendations are as below:

   i) More weight can be given to relevant pre-requisite subjects depending on the nature of the courses, instead of adopting the current practice of making the "O" level mathematics grade point as compulsory in the total grade point calculation in the application for all diploma courses.

   ii) Some courses may not require mathematics and thus the compulsory requirement of "O" level mathematics should be removed.

   iii) For other courses that still need some basic mathematical knowledge, their admission criteria may require a pass in "O" level mathematics. However, this "O" level mathematics grade point should not be used in the total grade point calculation that determines the success or failure of the students' applications.

   iv) For courses that need extensive knowledge of mathematics in their learning, the current application criteria and grade point calculation should remain.

9) The current engineering mathematics curricula in polytechnics needs to be reviewed as it does not sufficiently ensure acceptable levels of conceptual, functional and associational understanding to be achieved in students' effective learning in engineering mathematics. On the contrary, they have emphasised substantially on procedural understanding. As shown in the data, only idealistic learners may understand engineering mathematics conceptually while the others could not. The suggestions below that aim to enhance the students' levels of conceptual, functional and associational understanding are based on the guiding principles of *purpose* and *utility* as advocated by Ainley & Pratt (2002).

   i) A *purposeful* task is "one which has a meaningful outcome for the learner, in terms of an actual or virtual product, the solution of an engaging problem, or an argument or justification for a point of view." (Ainley & Pratt, 2002:20). In the case of engineering mathematics, it is proposed that the curricula should engage engineering problems as the basis where the concepts and formulae are taught. This will allow these prospective engineers to engage *purposeful* engineering tasks as part of their learning. This will thus enable them to build up their associational understanding of engineering mathematics.

ii) The *utility* of a mathematical idea is defined as "knowing how, when and why that idea is useful, by applying it in a purposeful context." (Ainley & Pratt, 2002:20). It is desirable for the students to experience the *utility* of any engineering mathematics formula or concept related to the above *purposeful* engineering tasks through their own discovery learning. At the same time, students can be enlightened on the origins of the concepts and formulae in engineering mathematics so as to raise their curiosity and awareness. These will allow the student to better appreciate the origins and functions of engineering mathematics and thus improve their conceptual and functional understanding.

iii) Lastly, the affordances of tools such as technology can also be incorporated effectively in the engineering mathematics curricula to improve students' learning. This can help in improving engineering students' conceptual, functional and associational understanding through effective visualisation and modelling of mathematical concepts.

10) A structured institutional programme should be designed to educate on and inculcate the desirable internal qualities (**effort, interest, perseverance, emotional regulation** and **self efficacy**) in engineering mathematics learning for the students.

The third set of recommendations concerns the research community in engineering mathematics education. They are:

11) Researchers can enhance the generalizability of this study through expanding and varying the sample size in the same polytechnic or conducting similar studies in other polytechnics. Through such studies, the theory of Selective Intentionality can be further refined, tested and the typology confirmed or modified.

12) Students' internal qualities (**effort, interest, perseverance, emotional regulation** and **self efficacy**) and external influencing factors (**society, government, teachers, families and peers**) in engineering mathematics learning can be further explored and investigated in depth for the benefit of the teachers and students. At the same time, the inter-relationships between these influencing factors can be examined.

13) Researchers may be able to make use of the results of this study to relate to other areas of learning outside engineering mathematics learning (transferability).

In reality, some stakeholders may not agree with some of the recommendations stated above. Even if some of these recommendations are not agreed to by all stakeholders or constrained by social factors, they may serve to heighten awareness that there is much about engineering mathematics learning in Singapore that needs to be improved. In the true spirit of education, it is hoped that these problematic issues in engineering mathematics learning can be resolved sooner than later for all concerned.

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Appendix A

Profiles of Participants in Study

Subject	Course	Race	Sex	Type of Sec Edn*	"O" level ELR2B2**	"O" level Maths Grade	Eng Maths Overall Results*** (/4)	Poly current course Average GPA**** (/4)	
E01	BE	C	M	Normal	17	A2	C+, C+, C 2.35	2.135	
E02	EE	C	M	Express	10	A1	AD, AD, AD 4.00	3.929	
E03	CE	I	M	Normal	19	C6	D+, D-, D- 0.67	1.635	
E04	CE	C	F	Express	23	B4	B, B, B 3.00	2.814	
E05	CE	C	M	Express	25	C6	A, A, A 4.00	3.907	
E06	AE	C	M	Express	6	A1	AD, AD, AD 4.00	3.906	
E07	CE	M	M	Normal	20	C5	F, D, D-, D- 0.50	1.001	
E08	EE	C	M	Express	10	A1	A, AD, AD 4.00	3.939	
E09	CE	M	F	Normal	25	C6	B, B, B 3.00	2.535	
E10	CE	C	M	Normal	19	A2	B,B+,A 3.50	3.041	
E11	BE	C	M	ITE	Nil	D7	C, B, C+ 2.50	2.848	
E12	CE	C	M	Normal	20	C5	C, D+,D- 1.50	1.931	
E13	EE	M	M	Express	14	B3	A, A, A 4.00	3.842	
E14	EE	C	M	Express	19	B3	A, B+, A 3.83	3.480	
E15	CE	C	M	Express	25	C6	C, C, C 2.00	1.826	
E16	AE	I	M	Express	14	A2	AD, A, A 4.00	3.455	
E17	EE	C	M	Express	13	A2	B+, B, A 3.50	3.125	
E18	AE	M	M	ITE	Nil	D7	B+, A, B 3.50	3.787	
E19	BE	C	F	Express	20 (dropped out halfway, (computed for 1 ½ year)	C5	F, F 0.00	0.501	
E20	CE	C	M	Normal	17	C5	C, D+, C 1.83	2.605	
E21	BE	C	M	Express	16	A2	A, AD, AD 4.00	3.800	

* Students may be either enrolled in the four years' secondary education (Express stream) or the five years' secondary education (Normal stream) in their "O" level examination preparation. If a student in either stream fails to get into polytechnic courses, he/she can be enrolled in a course in Institute of Technical Education (for at least 2 years) and then apply for a course in the polytechnic again.

** Selection Criteria for GCE 'O' Level Holders - Aggregate Computation, based on EL- English Language, R2- Mathematics and another relevant subject and B2- any 2 other subjects.

*** The overall GPA (Grade Point Average) of their Engineering mathematics modules is based on the 3 compulsory mathematics modules (grades shown) they have to undertake during their three years in their engineering courses. AD – Distinction.

**** The average GPA for all their modules in their engineering courses for the 3 years' duration.

Electrical Engineering	EE
Aerospace Engineering	AE
Bioelectronics Engineering	BE
Communication Engineering	CE

Module Grade	Grade Point*	Module Grade	Grade Point*	Module Grade	Grade Point*	Module Grade	Grade Point*	Module Grade	Grade Point*
AD/A	4.0	B	3.0	D+	1.5	D	1.0	P	0.5
B+	3.5	C+	2.5	C	2.0	D-	0.5	F	0.0

Appendix B

Initial and Final Interview Guides

Initial Interview Guide

1. Share about your experience with learning mathematics in primary school. Share about your experience with learning mathematics in secondary school or ITE.
2. Talk about how your parents, teachers, peers and school affect your mathematics learning.
3. How is the study of engineering mathematics related to you?
4. What do you think are your intentions in studying engineering mathematics?
5. Why, how, when do you have these intentions?
6. Are these intentions important to you?
7. Why, how, when are these intentions important to you?
8. What strategies do you use to achieve these intentions?
9. Why, how, when are these strategies used?
10. What are the expected consequences of these strategies?
11. Why do you think are the reasons behind these consequences?

Last version of Interview Guide

Causal and Intervening Conditions influencing learning engineering mathematics

1. What do you think of mathematics and its uses in this society? Why?
2. What do you think is the society, government's, parents', peers' stand on mathematics and engineering? Why?
3. Why people learn engineering and engineering mathematics?
4. How do you think engineering mathematics is linked to engineering and secondary maths?
5. Talk about how your physical environment, parents, lecturers, peers, school, government and society influence your engineering mathematics/mathematics learning.

Contextual Conditions of learning engineering mathematics

6. Why do you choose this engineering course of study? Do you like it? Why?
7. What do you think of engineering mathematics? Why?
8. How is the study of engineering mathematics related to you?
9. What do you believe about engineering mathematics? Why? Is engineering mathematics important in your study? Why?
10. What do you feel about engineering mathematics? Why?
11. What is your intention in studying engineering mathematics as a whole?
12. Why do you have such intentions? Are these intentions important to you? Why, how, when?

Process (Action/Interaction) of learning engineering mathematics

In lecture/tutorial/self learning/examination:

13. What are your intentions in attending a mathematics lecture/tutorial/self learning/examination? Why?
14. What strategies do you take to achieve your intentions? Why?
15. How do you feel or think when you can or cannot achieve your intentions? Why?
16. How long will these feelings or thoughts last? How intense are they?
17. Do you attempt to remove or change such negative feelings? How?
18. What do you do to such positive feelings or thoughts?
19. What other strategies do you take when you cannot achieve your intentions?

Consequences of the process of learning engineering mathematics

20. What do you think are the consequences of studying engineering/engineering mathematics? Why?
21. What do you think are the consequences of studying engineering mathematics to you personally, society, parents? Why?
22. What are the expected consequences of your intentions in engineering mathematics learning?
23. What are the expected consequences of these strategies in terms of tangible results, beliefs, emotions and motivations?
24. Why do you think are the reasons behind these consequences? (success reasons, failure reasons)

Appendix C

Guiding Questions for Online Self Reflection

Please answer the questions below. Write as much as possible about your thoughts and feelings.
1) When did I start studying for this Mid Semestral Test? Why?
2) How did I study for this Mid Semestral Test?
3) What did I think and feel before I take the test?
4) What did I think and feel when I saw the questions in the paper?
5) What strategies did I use in doing the questions in the paper?
6) How long did I take to finish the paper?
7) What did I think and feel when I finished the questions?
8) What did I think and feel when I got back the result of my paper?
9) How long did these thoughts and feelings last?
10) What future plans did I made with regards to the result of my paper?

An Example of a Retrospective Report

According to his tutor, he (E02) is a very self motivated student who work hard during tutorials. He finishes all his tutorial questions beforehand. He also listens attentively during lectures. He has high academic ability as he is very good in mathematics since his secondary years. He even does extra questions not in the textbook. He told the tutor that he wants to go university in future and this is supported by his parents who encourage him. He has strong belief in his ability to do well too. However, he seems not very helpful when his friends need his help although he still helps.

Appendix D

An Interview Transcript and its Coding

	Codes
Interviewer: Why do you choose this engineering course of study?	
Respondent: Basically to obtain an engineering course, engineering maths is one of the reasons. Since secondary school, maths has been one of my favourite subjects, then engineering is quite a wide thing so can branch out to different types. That is why I did engineering.	*Paper qualification motivation; favourite subject* *career stepping stone*
Interviewer: So do you like this course?	
Respondent: And also to say this course is quite tough in some modules. But maths is not really that tough because of the first, training in secondary school has already taught us some of things that we are supposed to learn in engineering maths.	*relation of EM to secondary school maths*
Interviewer: How is the study of engineering mathematics related to you?	
Respondent: Engineering maths when we use it, most of the time, maths we use it in theory, very few practical aspect. So perhaps next time when we further our job, we can use this theory to help us construct or build something so that will be accurate.	*Theoretical nature of engineering mathematics* *Mathematical applications in engineering*

A Student's Online Reflection and its Coding

	Codes
1) When did I start studying for this Mid Semestral Test? Why?	
I start studying for my Mid Semestral Test when the first lesson starts. We have to constantly revise and practice in order for ourselves to become better. This is our responsibility. The reason for the early start because we need time for us to be better and time will allow us to do that. This way, we have plenty of time for us to practice without hurrying what we want to accomplish within a short period of time. I also tell myself that I need to do well to confirm I have understood the lessons.	*Consistent learning* *Taking responsibility* *Time management*
2) How did I study for this Mid Semestral Test?	
I study for this Mid Semestral Test by doing all tutorials and also the booklet that has been given to me for our own usage. I do them with my friends, I teach them if needed. Seeing that there are some exercises that look rather interesting and fun to do, therefore I decided that it is best for me to complete some of which I found it rather difficult to solve that are not in the book. If I cannot do any questions there, I am more interested to find out the answer. It is shiok(feel good in dialect) if I can solve it. I also try to understand how they come up with the concepts and formula. Important for me to score for section C too.	*Tutorials* *Taking initiative* *persevering* *conceptual understanding* *complex procedural competency*
3) What did I think and feel before I take the test?	
I feel rather confident that I am able to do the test without any difficulty because I have done all my exercises and was sure that there was no problem that I cannot solve. I think that I would finish the paper rather fast because maybe it is probably easy.	*High self efficacy* *Perception of exams*

A Retrospective Report of a Tutor's Comments on a Participant and its Coding

	Codes
She is a very hardworking girl, though slow in learning. She works harder than the others as she knows that she is not good in mathematics. But she is doing well in other modules. She harbours the hope of going university in future and having a good job. She pays attention during classes. She attempts the tutorial questions in class and seeks the tutor's and friends' help a lot. She also makes an effort to approach the tutor after study hours. However, she does not show much confidence in her ability to do well in engineering mathematics, although she is quite persevering when comes to doing mathematics.	*Low academic ability; hardworking,* *Intentions of going university* *Finish tutorials; ask for peer assistance* *Lack of confidence* *High perseverance*

Appendix E

An Example of Coding and Operational Memo

Interview No: E10 **Location: Library** **Date: 23/07/07** **Time: 1730hrs** **Coding and operational Memo:**
Self reflexivity: The subject makes me think about the concept of understanding. First of all, I have to tell myself not to be biased by what I know about understanding. To me, understanding is being able to apply the formulae. I seen students who cannot do the question even when they can understand the steps. I should conceptualise purely from the perspectives of the students. What is actually understanding to them? Do all participants see the same meaning of understanding? From the subject, I question the presence of understanding regarding how the participant relate the mathematics they have learnt to their engineering modules. Is this important? Important in exam results? Important in understanding the concepts of mathematics? Understanding through relating is another form of understanding? Are there other kinds of understanding besides understanding conceptually, associationally? Again, practice comes out as one of the concepts in the above interview as the other earlier interviews. I think there is a need to probe more into the domain of practice. What is practice to the students? How does practice impact the intentions of the students? How does practice impact exam results? Does practice differs in meaning from person to person?

An Example of Theoretical Memo

THEORETICAL MEMO **CATEGORY:** Tutorial	**REF: GA_EX_TU_0607_0907**
Causal Conditions Students already learning in the course	**Phenomenon** Gathering information about engineering mathematics
Properties First hand problem solving	**Dimensions** ○ Types of engineering mathematical calculations ○ Level of proficiency in computing engineering mathematics ○ Type of learning ○ Level of persistence ○ Affection level
Context Students taking part in tutorials.	**Intervening conditions** Types of pedagogies encountered Types of peers Environmental factors, such as lecture theatre, classrooms, air con etc
Action / interaction strategies During tutorials, participants have first hand experiences in solving engineering mathematics problems.	**Consequences** This is where they see the different types of mathematics questions. From here, they may form relations between engineering mathematics and engineering. From their problem solving process, they are able to understand their level of proficiency in computing engineering mathematics problems. At the same time, they may encounter the less intervening styles of tutors as compared to pre-tertiary teachers. Participants can too uncover their level of persistence of solving mathematical problems. Tutorial is also an avenue where students start to form liking for engineering mathematics.

Appendix F

Audit Trail

Reference	**Description of folder/file**	**Soft copy Name in Main Folder "Audit"**
E-Interviewee Number E01 --- E21	Each folder consists of the below for each participant. (Total: 21 folders) 1) Interview audio file 2) Interview, self reflection Transcript 3) Teacher's observation on participants 4) Open and Axial Coding 5) Coding and Operational Memo 6) Reflexive thoughts	Subfolders: E01 --- E21
Interview Qn (Version Number) 1 --- 4	Interview Questions used	Subfolder: Interview Questions
CCC	▪ Compilation of all codes ▪ All the open codes sorted according to participants	File: CCC
SP	Participants' profiles	File: SP
Category name_1st level subcategory_2nd level subcategory_ formed date_ last amended date.	Theoretical Memo: Categories Any subcategories of the described category below are explained in the concerned memo.	File: Categories
GA_0607_0907	Gathering	File: Categories
GA_EX_0607_0907	Experiencing	
GA_EX_LE_0607_0907	Lecture	
GA_EX_TU_0607_0907	Tutorial	
GA_EX_SL_0607_0907	Self learning	
GA_EX_AS_0607_1007	Assessment	
GA_RE_0607_1007	Receiving	
GA_RE_SO_0607_1007	Society	
GA_RE_FA_0607_0907	Family	
GA_RE_TE_0607_1007	Teachers	
GA_RE_PE_0607_1107	Peers	
GA_RE_PYE_0607_0907	Physical Environment	
GA_REC_0607_0907	Recalling	
AN_0607_1007	Analysing	
AN_OR_0607_1007	Organising	
AN_OR_PER_0607_0807	Perceiving	
AN_OR_REL_0707_1007	Relating	
AN_OR_COM_0907_1107	Comparing	
AN_REC_0907_1107	Recognising	
AN_FILT_1007_1207	Filtering	
INTE_1007_1207	Intending	
INTE_MAS_1007_1207	Mastery	
INTE_EGO_1007_1207	Ego	
INTE_PRAG_0707_1207	Pragmatic	
INTE_SUR_0707_1207	Survival	
INTE_RESIS_0707_0108	Resistant	
ACT_0907_0108	Actualising	
ACT_UND_0907_0108	Understanding	
ACT_PRAC_0807_0108	Practising	
REG_1207_0208	Regulating	
REG_IDEF_1207_0208	Identifying	
REG_ATT_1107_0208	Attributing	
REG_RAT_1007_0108	Rationalising	
SI_0108_0208	Selective Intentionality	
Ill-01-21	Illustrations of the various categories from data	File: Ill-01-21
All – Diag -3	All conceptual diagrams in analysis	File: All – Diag -3