Factors Associated with Level of Interest in Engineering

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ABSTRACT

The purpose of this research was to investigate the relationship between a set of student characteristics (the reasons for choosing engineering, study approaches, motivational goals, self-efficacy and academic buoyancy) and the level of interest in engineering among polytechnic students in Singapore.

The research involved 309 students from the Engineering with Business Management, Engineering Science, and Electronic and Computer Engineering diploma programmes, from one polytechnic in Singapore. The research was a quantitative correlational study that involved the use of survey instruments to measure the student characteristics and students' level of interest in engineering at the start and end of a semester for the three diploma programmes.

The results of this research showed that (i) Engineering Science students scored highest in their level of interest in engineering which differed significantly as compared to other diploma groups. The same trend was observed at the start and end of the semester; (ii) there was a general trend of decreasing level of interest in engineering among all diploma groups from the start to the end of the semester but the drop was not significant; (iii) there were many strong positive correlations between different student characteristics and levels of interest in engineering at the start and end of the semester; and (iv) among the student characteristics, internal reasons for choosing engineering, task value as a motivational goal and deep approaches to studying were the best predictors of the level of interest in engineering. The level of interest in engineering at the start of the semester is also a predictor of the level of interest in engineering at the end of the semester.

The main findings were that students with higher academic ability tend to be more interested in engineering; that students' level of interest in engineering decreased

slightly over a semester of study; and that students' entry interest level in engineering has to be high and this will be dependent on the student characteristics of the reasons for choosing engineering, task value as a motivational goal and deep approaches to studying. An implication of the above findings is that researchers likely need to consider these three student characteristics when they measure students' level of interest in engineering.

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CHAPTER ONE

INTRODUCTION

1.1 Engineering Education

Engineering education is the activity of teaching knowledge and principles related to the professional practice of engineering – the branch of science and technology concerned with the design, building, and use of engines, machines, and structures ("Engineering," 2015).

Engineering instruction incorporates science, technology and mathematics concepts, which begin in the primary and secondary schools. The teaching of subjects such as science and mathematics at primary and secondary levels serves as foundation for engineering education at the tertiary level. The way engineering is taught varies from country to country. For example, engineering education in China differs much from that in the United States in two main ways - curriculum content and teaching methods (Bai & Zhang, 2009). China needs a great number of engineers for its fast growing economy while the United States needs a new type of engineer who can play roles in coordinating outsourcing and supplier chain management. The difference in the requirements of the economy has influenced the way engineering education is run in each country, in two main ways.

Firstly, the engineering curricula in China are government-dominated and competence standards are not widely used, while curriculums in the United States are ability-oriented and are based on international standards like the Accreditation Board for Engineering and Technology (ABET) and Conceiving — Designing — Implementing — Operating (CDIO). ABET is a non-governmental organization that accredits post-secondary education programmes in applied science, computing, engineering, and engineering technology. The accreditation of these programmes occurs mainly in the United States but also internationally. CDIO is a framework that provides students with an education stressing engineering fundamentals set in the context of Conceiving — Designing — Implementing — Operating real-world systems.

Secondly, engineering education in China focuses on the concepts, rules and theories of knowledge; on the other hand, in the United States, education emphasizes more hands-on experience, which provides more opportunities for students to develop their ability to practice and find their individual personality, allowing them to find their footing in the globalized market. This means in China, the task of teachers is delivery of facts to students while in the United States, teachers are more likely to be instructors to encourage students to take part in the learning/studying process. With respect to the current research, engineering education in Singapore is very much mid-way between these two countries. Faced with the new roles expected of engineers who are not only technically sound but well-equipped with interpersonal skills such as communication, Singapore's engineering education is moving towards a proportional allocation of engineering curriculum to humanities and social sciences, with the use of more student-led teaching methodologies. This trend in engineering education will be elaborated in Section 1.5.

Even though the way engineering is taught varies from country to country, engineering institutions typically build their curriculum on the 'big four' in engineering – civil, mechanical, electrical and chemical. Engineering is embarking on a transformation in order to address to the needs of the 21st century, but what remains unchanged is that it continues to be a profession that drives the economy and works for the betterment of society in the decades to come.

1.2 Singapore's Education System

In Singapore, the Ministry of Education aims to help students to discover their own talents, to make the best of these talents and realize their full potential, and to develop a passion for learning that lasts through life. Among the key strengths of the Singapore education system are its bilingual policy, emphasis on broad-based and holistic education, high teacher quality and integration of information technologies to aid learning (Ministry of Singapore, 2015).

The five stages in the Singapore education system are illustrated in Figure 1 below (Ministry of Singapore, 2015).

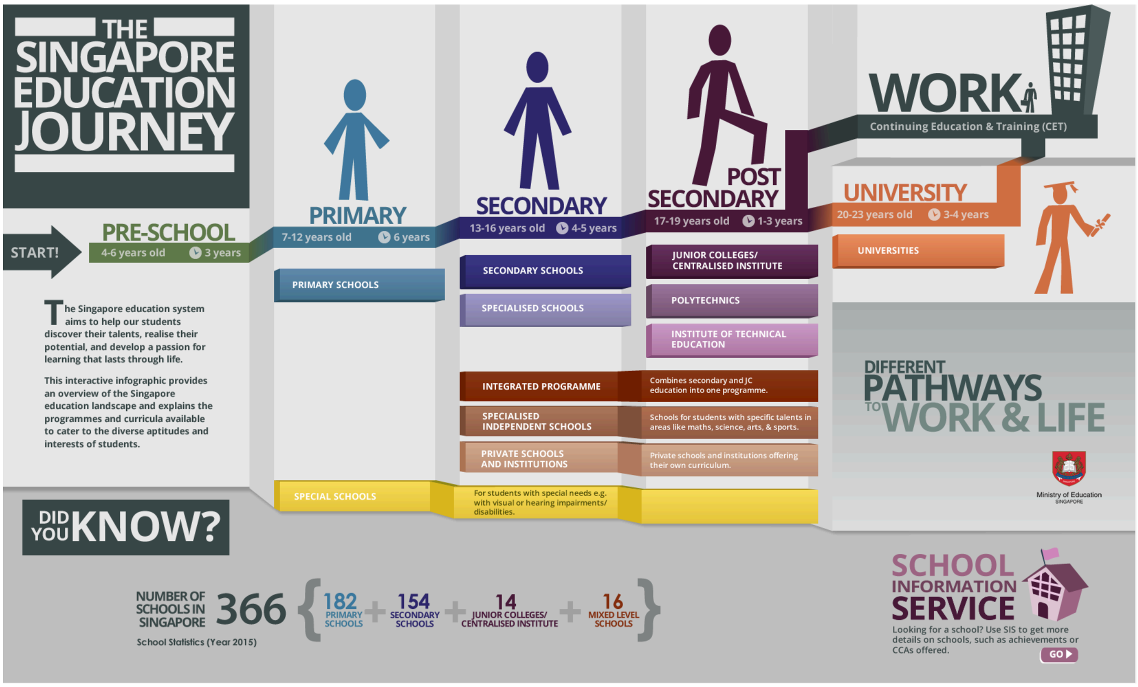

Figure 1. The education landscape in Singapore. From "Bringing out the best in every child" by Ministry of Education, 2015. Retrieved July 8, 2015, from http://www.moe.gov.sg/education/

The first stage is pre-school education (4 to 6 years) that provides children with opportunities to build self-confidence, learn social skills and develop learning dispositions.

The second stage is primary education (7 to 12 years) that helps to lay a strong foundation in students, with English language, mathematics and mother tongue language making up a significant part of the curriculum. Singapore embraces an English-based bilingual education system. Students are taught subject-matter curriculum with English as the medium of instruction, while the official mother tongue of each student - Mandarin Chinese for Chinese, Malay for Malays and Tamil for ethnically Tamil Indians – is taught as a second language

The third stage is secondary education (13 to 16 years), which places students in the Express, Normal (Academic) or Normal (Technical) course according to how they perform at the Primary School Leaving Examination. The different curricula are designed to match their learning abilities and interests, and to help in building up strengths of the students.

The education structure in Singapore provides many educational pathways for students. The fourth stage in post-secondary education is a good example. There are three pathways in the fourth stage, namely junior colleges, institutes of technical education and polytechnics. A pre-university course leading to the Singapore-Cambridge General Certificate of Education (Advanced Level) Examination prepares students in the first pathway of junior colleges for further education by equipping them with the essential skills and knowledge required for tertiary education. The institute of technical education in the second pathway aims to equip students with technical skills and knowledge to meet the workforce needs of the various industry sectors.

The third pathway is polytechnic education. The ages of polytechnic students range from 17 to 21 years and they typically take three years to complete their polytechnic education. The main role of polytechnic education is to provide quality practice-oriented training and produce suitably trained manpower to support the changes in

Singapore's industrial development. The polytechnics are instrumental in training the technologists and middle-level professionals needed for the emerging and growing industries.

The fifth stage in the Singapore education system is university education with programmes to equip students to achieve their full potential and contribute to the society. Universities in Singapore mainly admit students from the junior colleges and some from the polytechnics. Beyond university education, Singapore also encourages working adults to continue upgrading themselves by taking relevant courses during the course of their work.

1.3 Engineering Education in Singapore

In Singapore, engineering education is found in the institutes of technical education, polytechnics and universities. Singapore universities are autonomous and their engineering degrees are accredited by the Engineering Accreditation Board, which is set up by the Institution of Engineers Singapore. Engineering education in institutes of technical education and polytechnics is government-led to work closely with industries, economic planners and development agencies to keep abreast of changes and to respond readily to industries' requirements. Since 2014, a government-led initiative known as ASPIRE - Applied Study in Polytechnics and Institute of Technical Education Review - started with the aim of studying how applied education in the polytechnics and institutes of technical education could be enhanced by "better matching" students' strengths and interests to applied education pathways to enable them to maximize their potential (Indranee, 2014). Students' interests are of significance here, and are also a factor to be further investigated in the current research.

There are currently five polytechnics in Singapore and all offer engineering diploma programmes. The current research involves engineering students from one of these polytechnics. Each engineering cohort comprises approximately 1600 students. The polytechnic offers twelve engineering diploma programmes that include Engineering with Business Management, Engineering Science and Electronic and Computer Engineering.

1.4 Trends in Engineering Education

The idea that engineers have societal responsibility and are the heroic creators of the material structures of the society has been replaced by the mundane image of engineers as the technical workers of the industry. Crawley et al. (2007) have made this observation and illustrate how this has influenced the evolution of engineering education over time to the present day. This trend in engineering education will be further detailed in Chapter Two.

This observation points to a trend of declining interest in engineering (Dimopoulos et al., 2011), especially in developed countries. In the United States, enrollments in engineering programmes have seen 15 years of steady decline – the number of engineering graduates at the bachelor's level peaked at around 80,000 per year in the mid 1980's then declined to about 65,000 per year by the end of the century (Johnson & Jones, 2006). Though the level of interest has recovered recently, when measured against the overall increase in enrollments of the colleges, interest in engineering is still declining (Kemnitzer et al., 2005). The same trend is mirrored in Japan and Germany (Ng, 2008). In Japan, the young are increasingly choosing other fields like finance, arts and creative industry as they deem engineering to be "unglamourous". Germany's shortage of engineers has been so acute that some leading companies such as Siemens and Bosch have started to nurture interest at kindergarten level. By contrast, developing countries like Vietnam, India and China are still young and economically hungry, for example - China produces as many as 400,000 engineers per year (Ng, 2008).

The downward trend in the level of interest in engineering is faced by local polytechnics. This downward trend is witnessed by the declining number of students who choose engineering, and the increasing number of students who opt for non-science based disciplines (Davie, 2007; Tai, 2014). In Singapore, where the current research is conducted, 95 per cent of students who are admitted to the National University of Singapore's business school could have qualified for science and engineering courses. This is a concern as Singapore needs more engineers with the growing number of infrastructural developments (Tai, 2014).

1.5 Declining Interest in Engineering

There are global concerns over the declining interest in engineering that need to be investigated. The continuing trend will lead to a shortage of engineers (Marjoram, 2010) to meet the new demands of globalisation. This continuing trend in declining interest in engineering has a detrimental effect on the world's economy – which thrives on the scientific and technological advancements made possible by engineers. More needs to be done to understand what factors affect the level of interest in engineering – the central problem in the current research. It is important to attract the right pool of students with unique student characteristics to engineering and to enhance the level of interest in engineering in existing students. It will also be interesting to find out which student characteristics may be associated with the level of interest in engineering.

Other than the wide ranges of career choices students have these days and the misconceptions that engineering is "mundane" (Crawley et al., 2007), a "boring" profession and “a hard slog with little rewards” (Davie, 2007), these trends may also be due to two other reasons. Firstly, the changing education landscape is a transformation that is greatly influenced by the use of technology and the ease of access to information on the internet. Secondly, there are new roles expected of future engineers of the 21st century. These changes require a shift in the engineering education towards globalization (Duderstadt, 2008). It will not be surprising that a new generation of students, possessing unique student characteristics, may be needed to succeed in the new engineering education structure.

1.6 Purpose and Research Questions

So far, little attention has been paid to understand the characteristics of polytechnic engineering students and the association of these characteristics with the level of interest in engineering. Therefore, the purpose of the present research is to fill an important gap in the growing literature by investigating the relationship between a set of student characteristics and the level of interest in engineering over a semester of study. There may be many student characteristics that engineering students need to have in order to develop and maintain their interest in engineering and to learn engineering effectively. A full discussion of all these characteristics is beyond the scope of this study, which will focus on the five characteristics of reasons for choosing engineering, study approaches, motivational goals, self-efficacy and academic buoyancy. These characteristics are chosen mainly from the researcher’s own experience in teaching polytechnic engineering students, and because they are supported in other research that will be covered in the literature review chapter (Chapter Two).

From the review of the literature, the following research questions are generated:

1. What is the level of interest in engineering at the start of the semester amongst three groups of diploma students (Engineering with Business Management, Engineering Science, and Electronic and Computer Engineering)? Are there any differences between the groups in their level of interest in engineering?
2. What is the level of interest in engineering at the end of the same semester amongst the three groups of diploma students (Engineering with Business Management, Engineering Science, and Electronic and Computer Engineering)? Are there any differences between the groups in their level of interest in engineering?
3. What is the change in the level of interest in engineering between the start and end of semester? Are there any differences between the groups in their change in level of interest in engineering?
4. What is the bivariate relationship between each of the student characteristics (reasons for choosing engineering, study approaches, motivational goals, self-efficacy and academic buoyancy) and the level of interest in engineering?
5. What is the joint relationship between student characteristics (reasons for choosing engineering, study approaches, motivational goals, self-efficacy and academic buoyancy) as independent variables, and the level of interest in engineering as dependent variable?

1.7 Overview of Methods

This research is a quantitative correlational study that involves the use of survey instruments adapted from the literature to Singapore's context to measure the identified student characteristics and students' level of interest in engineering at the start (time 1) and end (time 2) of a semester. The final sample for the research involves 309 students from the Engineering with Business Management, Engineering Science, and Electronic and Computer Engineering diploma programmes, from one polytechnic in Singapore. The sample and other aspects of the methods are described in Chapter Three.

1.8 Rationale, Originality and Significance of Research

With the declining interest in engineering, a major concern is the shortage of engineers to meet the new demands of globalization. More needs to be done to learn what factors are associated with the level of interest in engineering – the central problem in the current research.

Due to the advancements in technology, the social context of teaching and learning is no longer the same as before and a new generation of students with different characteristics has emerged. It is therefore important to attract the right pool of students with unique student characteristics to engineering and to maintain or enhance the level of interest in engineering in existing students.

Very little research has been published that explicitly identifies student characteristics that may be associated with students' level of interest in engineering. It is therefore desirable to study the relationship between these variables, using quantitative methods.

The predictors are chosen so that they address the external characteristics that may influence students' decision to choose engineering and the internal characteristics that contribute to the way students approach engineering studies, the motivational goals and self-efficacy they have in the course and how they handle academic stresses.

The current research involves first-year students from Engineering with Business Management, Engineering Science, and Electronic and Computer Engineering diploma programmes. The researcher is currently teaching in the Engineering with Business Management and Engineering Science diploma programmes, which admit a diverse group of students. The Engineering with Business Management students have varying interest in the different fields of engineering and are undecided about which field to major in. The Engineering with Business Management diploma programme allows them to experience the different engineering majors and only choose which field to specialize in after a semester of study. They will choose to major in one of the nine engineering diploma programmes and the final allocation is based on merit - that is, it depends on how well they have scored in the semester. The diverse nature of the Engineering with Business Management students is likely to provide variation between students in the predictors, and changes in their level of interest in engineering.

The multidisciplinary nature of the Engineering Science diploma programme requires the Engineering Science students to be exposed to a wide range of engineering fields, which may develop varying levels of interest in them.

The third group of students will be recruited from the Electronic and Computer Engineering diploma programme, which unfortunately has the highest dropout rate and whose students are therefore likely to show substantial change in the level of interest in engineering over a semester.

By investigating the student characteristics of the polytechnic engineering students, this research can contribute to the literature, and to the practice of polytechnics in the following ways:

1. Deep approaches to studying have been associated with higher academic scores (Peters et al., 2007) and academically strong students are likely motivated and remain interested in engineering. Also intrinsically motivated students perform engineering-related tasks because they derive a sense of satisfaction and enjoyment in doing so (Arnason, 2006); this benefits students by enhancing long-term strategy development, self-direction and possibly their level of interest in engineering. Lecturers can therefore deploy particular strategies in the

teaching and assessment methods to encourage students to be intrinsically motivated and use deep approaches to studying.

2. Students who have low self-efficacy with respect to their studies often lose interest in the course itself over time (Niemivirta & Tapola, 2007). Academic gains that students make can be lost if they are not resilient to typical academic setbacks, challenges or chronic adversities. This ultimately affects their level of interest in engineering. Polytechnics can help to build self-efficacy and promote stress management techniques through facilitated workshops that can help students identify their sources of stress and fears, recognize them and change the beliefs that hold them back from succeeding in the course.

These internal student characteristics, being alterable by the learning environment, may contribute to higher level of interest in engineering if early interventions such as above are introduced.

3. Knowledge of students' reasons for choosing engineering (an external characteristic) is important so as to prepare potential students to make informed choices about engineering courses and facilitate the decision-making processes through appropriate publicity campaigns.

In general, knowledge of the student characteristics allows lecturers to have a better understanding of what characteristics are associated with the level of interest in engineering. This knowledge is useful in the recruitment process of potential students by attracting those who are more likely to have high level of interest in engineering studies. The knowledge is equally important for existing students as it allows lecturers to design pedagogical interventions by concentrating on the characteristics that are associated with students' level of interest in engineering.

1.9 Structure of Thesis

The next chapter (Chapter Two) provides a critical review of the literature. Changes in the role and image of engineers are discussed along with the historical origins and transformation of engineering education. Definitions of student characteristics are presented and discussed prior to reviewing the limited research literature pertaining to these characteristics of polytechnic engineering students and their association with the level of interest in engineering.

Chapter Three describes the methods used in the thesis to measure students' characteristics and their level of interest in engineering. It reports the use of survey instruments to measure the student characteristics (independent variables) and students' level of interest in engineering (dependent variable) at the start and end of a semester. It also presents an overview of the correlation and regression techniques that are used to study the bivariate and joint relationships between the variables.

Chapter Four presents the results of the data analysis in six sections. The first section reports the psychometric analysis of each survey instrument. This is followed by the second section on group scores in terms of the level of interest in engineering and student characteristics at the start of the semester. Section 3 reports the group scores in terms of the level of interest in engineering at the end of the semester. Section 4 studies the change in the level of interest in engineering over a semester. Section 5 examines the relationship between student characteristics and the level of interest in engineering. Finally in Section 6, the joint relationship between the student characteristics as independent variables and the level of interest as the dependent variable is reported.

Finally, Chapter Five presents a summary of the research and the results obtained, the conclusions that arise as well as a general discussion of the study in the light of the research questions and literature reviewed. Implications of the findings, limitations of the research and directions for future research are also suggested.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview of Chapter Two

This chapter is presented in two main sections. The first section focuses on the theoretical literature in engineering education, with a general discussion about its history, case studies in transforming engineering education and the theories and definitions used in the current research. The second section focuses on the research literature, with a review of the existing literature in tackling the declining interest in engineering. It also includes a critical discussion on the work done in the area of the level of interest in engineering as well as student characteristics.

2.2 Theoretical Literature

2.2.1 History of Engineering Education

Auyang (2006) has vividly described the history of engineering education from the past to the present day. This is summarized below.

The Past

The engineering profession emerged in the 19th century, with engineers focusing on the manual construction of armaments and infrastructure. During the first industrial revolution, the French and British pioneers in civil and mechanical engineering changed from practical artists to scientific professionals. The French emphasized mathematics and developed university engineering education. They were the first to establish the Polytechnique - a French public institution of higher education and research in science and engineering. This idea permeated both Europe and the United States where practical and intuitive thinking became scientific as engineers developed mathematical analysis and controlled experiments. Technical training then shifted from apprenticeship to university education. Although polytechnic education found its way to the United Kingdom, engineering was seen as a secondary trade – important but based on practical skills. This kept engineering education at a distance from universities for some time in the United Kingdom. During the industrial revolution, engineers' roles and responsibilities for progress were based on the idea of constructors of the material pillars of modern society.

The second industrial revolution in the latter half of the 19^{th} century marked the advent of electricity and mass production. This phase introduced many branches of engineering. Engineering education and curricula became more established, with engineering institutions building their curriculum on the "big four" in engineering – civil, mechanical, electrical and chemical. Engineers' roles expanded to become innovators and system builders as a result of their contribution to new systems, new knowledge and technical infrastructure. In these early years, engineering education played a critical role in transmitting knowledge to students to enable them to perform tasks which were mostly routine and repetitive calculations.

Science became the basis of engineering, as a result of the increased public and military funding of engineering research during World War II in the 20^{th} century. There was an explosion of engineering research, which was stimulated by the new technologies in the information age, most notably in the area of telecommunications from the internet to the cell phone. The number of disciplines and specializations in engineering expanded rapidly with the growth of technology in the latter half of the 20^{th} century.

The Present

Changes in the role of technology and internet in society have influenced the way consumers use products and have resulted in complex production processes and infrastructures. These changes led to the integration of usability and design features, which created jobs in consulting, design and marketing. These jobs demand new personal and professional competencies and several engineering institutions introduced engineering design skills and social sciences into their curriculum. There is a need for engineers to demonstrate more than technical skills. The new roles expected of engineers include creativity, communication, business management, leadership skills and other generic skills, on top of the engineering knowledge required of them.

In the current 21st century, the new economy is driven by the information technology revolution and employers want to hire engineers who are knowledgeable in finance and global perspectives. Jobs in information technology, business and finance are now commanding higher salaries, way ahead of engineering careers (Giang, 2013). Innovations in the last decade are making the role of engineering less central – there is repositioning of engineers in a less influential and more subordinate role in their attempt to support business interests. The idea that engineers have societal responsibility and are the heroic creators of the material structures of the modern society has been replaced by the mundane image of engineers as the technical workers of the industry (Crawley et al., 2007). The new challenges faced in engineering point to the need to transform engineering education to meet the new roles and attributes expected of engineers and attract the right pool of students into engineering by enhancing the image of the course to make it more attractive and interesting.

2.2.2 Case Studies in Transforming Engineering Education

The purpose of engineering education is to provide the learning required by students to become successful engineers – in terms of technical expertise, social awareness and a keen interest towards innovation. It is seen from the earlier sections that in the last two decades, leaders in the academia, industry and government began to address the necessity for transformation by developing views of the desired attributes of engineers. To reiterate, the new roles expected of engineers include creativity, communication, business management, leadership skills and other generic skills, on top of the engineering knowledge required of them. These new roles mean engineering graduates are expected to apply theoretical knowledge to industrial problems as well as exhibit creativity, innovation, team-working, technical breadth and business skills. This combined set of knowledge, skills and attitudes is essential in strengthening productivity and entrepreneurship in an environment that is increasingly based on technologically complex and sustainable products and processes.

There has been a multitude of reports that demonstrate the urgent need to transform engineering education to ensure graduates are ready to take on the new and complex challenges of the 21st century (Graham, 2012; Crawley et. al., 2007). It is not the purpose of this research to cover all but to report on those pertinent to the level of interest in engineering.

Case Studies from universities in the United States and Hong Kong

Numerous case studies from universities have quoted recruitment and student engagement as the main drivers for transforming engineering education (Graham, 2012; Crawley et. al., 2007). The current research to investigate the factors associated with the level of interest in engineering is timely to provide more insights on these drivers. The following paragraphs will outline two of such case studies reported by Graham (2012) and focus on how the transformation of engineering education was achieved.

The first case study is located in the College of Engineering in the University of Illinois in the United States. The College of Engineering attracts high-caliber students and is seen to enjoy a strong reputation for rigor in engineering education. Like many other engineering institutes, opportunities for innovation or change to the core curriculum in the College of Engineering was described as "very tightly controlled" for fear of diluting the engineering science content in the curriculum. However it is recognized that a fundamental shift is necessary in the approach to engineering education in the United States, in particular to sustain the international leadership position.

With this in mind, the College of Engineering set up iFoundry (The Illinois Foundry for Innovation in Engineering Education) in 2007 as an initiative to nurture, develop and evaluate student-centered courses in pilot form before supporting their wider rollout into the curriculum. The driver behind this initiative is to improve student learning and the rates of retention in the first two years of engineering studies. Since 2007, there have been two educational changes implemented by iFoundry. Firstly, a school-wide freshmen experience known as the Illionis Engineering First-year Experience (iEFX) started in the academic year 2011/12, with the aim to build students' intrinsic motivation. This programme guides students through engineering projects and allows them to come together and choose significant topics in engineering and design their own instruction. Secondly, in the same academic year of 2011/12, a suite of liberal arts electives were introduced to students which include topics on design, innovation, business and entrepreneurship. The College has instituted formal mechanisms to capture students' experience, attitudes and expectations to evaluate the success of the iFoundry implementations.

The second case study is located in the School of Engineering in The Hong Kong University of Science and Technology. In the past, the educational approach in the university was seen to be broadly traditional and teacher-centered, with vast majority of contact time allocated to lecture-based instruction. In 2005, the Hong Kong government announced changes to the educational structure, which shifted from the British to the United States system where secondary education reduced by a year and tertiary education extended by a year. Changes to the educational approach was also announced which included broadening the curriculum and focusing on "whole person development" and "lifelong learning". The School of Engineering then took the opportunity to embark on an additional programme of transformation. This transformation was in response to the growing demand for engineering leaders with a global perspective as well as the concerns about student recruitment and the decline in popularity of engineering in Hong Kong in favor of subjects such as business.

During the academic year of 2012/13, the university saw its first intake of students under the new educational structure. Since 2012/13, there have been three changes affecting the School of Engineering. Firstly, curricular changes include the (i) reduction in the number of required technical courses; (ii) establishment of a context for engineering learning with engaging hands-on project experiences to increase students' interest in engineering concepts; (iii) increase in the focus on personal and professional skill development, especially in innovation and global awareness; and (iv) alignment of assessment procedures with the new educational approaches. Secondly, the School of Engineering has provided students with greater flexibility and opportunity within the curriculum to engage in non-curricular activities that involve opportunities within (such as industry internships) as well as outside engineering (such as community service projects). Thirdly, the School of Engineering has established a mechanism for continuous educational improvement and support. This includes the organization of cross-faculty dialogue and engagement sessions in education as well as the introduction of formal programmes in student support. As a result of these changes, engineering education in The Hong Kong University of Science and Technology has shifted from a "teacher-centered" to "learner-centered" paradigm. It is said that the university will be measuring the impact of the transformation and is currently developing a set of evaluation tools. Evidence will be captured from students and employees through surveys and interviews in the academic year of 2017/18.

One common fact between the two case studies is that formal mechanisms are in place to capture students' experiences and attitudes that arise from the transformation of engineering education. A possible extension and an important point of interest to educators is to study if the students' level of interest in engineering have enhanced as a result of the series of implementations both universities have put in place. The current research that measures students' level of interest in engineering may be useful in this sense.

Transforming Engineering Education in Singapore

In Singapore, there has not been large scale but incremental transformation efforts in engineering education. It is mentioned in Chapter One that Singapore's engineering education is moving towards a proportional allocation of engineering curriculum to humanities and social sciences, and with the use of more student-led teaching methodologies. This trend can be illustrated from the three universities in Singapore that offer engineering programmes.

The first example is from the Nanyang Technological University. The university injects flexibility and personalized learning experience by allowing students to choose their own minors and plan the pace of their studies. One of the new programmes developed by the university is known as the Renaissance Engineering Programme (REP), which provides a broad-based, inter-disciplinary engineering education, integrating engineering, science, business, technology management and humanities in the curriculum. This unique curriculum which started in 2011, is designed to nurture engineering leaders with an entrepreneurial spirit to serve society with integrity and excellence (Nanyang Technological University, 2016).

The National University of Singapore serves as a second example with the setup of the Technopreneurship and Incubation Programme (TIP). It is a hands-on, competitive, experiential learning module that is ideal for students to gain insight, confidence and basic capabilities about the theoretical and practical aspects of technopreneurship (National University of Singapore, 2016). Students who undertake this programme may gain credit exemptions from engineering modules as well.

The third and last example is from the Singapore University of Technology and Design. The university's academic structure is designed to support a curriculum that develops technically grounded leaders who will contribute to society through technology and design and make an impact on the world. The university is not structured via traditional disciplines (such as the “big four” in mechanical engineering or electrical engineering) but into four pillars (namely architecture and sustainable design, engineering product development, engineering systems and design, information systems technology and design), resulting in a multi-disciplinary engineering education that sets itself from others. There has also been deliberate inclusion of humanities, arts and social sciences subjects in the engineering curriculum to train critical thinkers among engineering students (Singapore University of Technology and Design, 2016).

So far, evidence in the transformation of engineering education is largely gathered in western countries at the university level and its efficacy on Asian cohorts is mostly untested. The current research on the factors associated with students’ level of interest in engineering may provide important insights on the impact of the transformation in engineering education, particularly for Asian cohorts at the polytechnic level.

The subsequent sections will cover in detail the concept of interest and the various student characteristics that are central to the current research.

2.2.3 The Concept of Interest

Being interested in something can mean that we care about it, that it is important to us and that we mostly have positive feelings towards it. Interest can also be more fleeting, such as when one watches an interesting show or an unexpected noise that arouses curiosity. Hidi and Renninger (2006) define interest as a psychological state of engaging both cognitively and affectively with “particular classes of objects, events or ideas”. Interest theorists (Hidi & Baird, 1988 and Renninger, 2000) have divided interest into two components: personal interest and situational interest. Personal interest is a stable interest in a specific topic, which endures over time (Schiefele, 1999) and tends to be long lasting. Personal interest is said to play a major role in the learner's preference to engage in a task or activity over time and in predicting future motivation (Xiang et al., 2005). Situational interest is more momentary and situationally bonding. It is activated by the environment rather than by the learner (Krapp et al., 1992).

A primary question in interest research is how situational interest, such as that prompted by watching a movie on fast cars, can develop into an enduring or personal interest in a topic or activity, such as automotive engineering. The current research will therefore focus on students' personal interest in engineering, which may ultimately predict their persistence in engineering. According to Hidi and Renninger (2006), three factors contribute to the development of interest: knowledge, positive emotion and personal value. As individuals learn more about a topic, they gain more knowledge and are skilled in the topic. An increase in knowledge can bring about positive emotions in individuals, as they feel more motivated and competent through task engagement. As they spend more time on the topic or activity that relates to the topic, they may find personal meaning and relevance in the activity. Schiefele et al. (1992) found that personal interest is correlated with academic and laboratory performance. In this sense, interest appears to play an important role in learning and academic achievement (Schiefele et al., 1992).

One way to enhance student interest is by creating an engaging and meaningful environment where students are able to discover the value in what they are learning (Brophy, 1999; Stipek, 2002 and Wigfield & Eccles, 2002). A recent book by Renninger and Hidi (2015) has compiled the work of researchers in the area of interest in mathematics and science learning. It has been found that the design of learning environments (both formal and informal) can spark and sustain people's interest-driven engagement with science (Flávio, 2015). It is also important to get students to become more highly identified with mathematics and science. To increase this domain identification and more enduring interest of students, lecturers should intentionally design instruction with a consideration of all five of the MUSIC (Jones et al., 2015) model principles which include e*m*powering students, demonstrating the *u*sefulness of the content, ensuring that all students perceive that they can *s*ucceed at challenging tasks, triggering students' *i*nterest, and *c*aring for students.

The research conducted by Harackiewicz and Hulleman (2010) found that both personal and situational interests play an important role in predicting future choices and career path. They conclude that interest in a topic or activity can have a powerful influence on people's lives, by impacting how they choose to spend their free time, and by influencing college course selections and majors, as well as the trajectory of students' careers after college. With the declining interest in engineering, a major concern is the shortage of engineers to meet the new demands of globalization. More needs to be done to learn about students' level of (personal) interest in engineering – the central problem in the current research.

2.2.4 Student Characteristics

The current research will focus on the following student characteristics: (i) external - reasons for choosing engineering; and (ii) internal - study approaches, motivational goals, self-efficacy and academic buoyancy. The definition of each student characteristic in this research is given below.

Reasons for Choosing Engineering

Ngambeki et al. (2008) state that it is logical to assume that students who choose a major which makes the best use of their skills will engage their interest and will more likely stay and thrive in engineering. On the other hand, those who make a poor choice because of incomplete information or misconceptions about engineering often find themselves frustrated and sometimes leave engineering.

There have been numerous studies on student persistence in engineering (Besterfield-Sacre et al. 1997; Hartman & Hartman, 2006; Ohland et al., 2008; Eris et al., 2010). Much of the work has focused on gaining better understanding about student decisions to leave engineering that may lead to higher retention. Litzler and Young (2012) conclude that the risk of attrition is sensitive to a combination of student characteristics, experiences and perceptions. Eris et al. (2010) suggest that parental and high school mentor influences may be a motivation for students to study engineering. Confidence in mathematics and science skills are also identified as correlates of persistence. These studies point to the suggestion that knowledge of the reasons behind students' choice of the engineering course is essential to properly prepare them to make their choices and facilitate the decision-making processes, ideally leading to a decision to choose a field that interests them most.

These reasons for choosing engineering may be associated with students' level of interest in engineering. But within the context of polytechnic engineering education, few studies have been conducted in this area. However in a recent piece of research, Mahani and Molki (2011) quote internal and external reasons as influencing students' decision to enter the engineering course. It will be interesting to know which of these "reasons for choosing engineering" will be related to students' level of interest in engineering. The possible reasons for students to choose engineering as defined in this research are: (i) engineering leads to higher social status (higher educational and income levels); (ii) interest in mathematics; (iii) parents, relatives or friends who are doing well in the engineering profession acting as role models; (iv) good recruitment measures provide correct information about engineering and the rewards of the profession; and (v) high employability of the engineering profession (Ngambeki et al., 2008).

Besides looking at the external characteristics that may be associated with students' level of interest in engineering, it is also important to investigate the internal characteristics of students that contribute to the way they approach engineering studies, the motivational goals and self-efficacy they have in the course and how they handle academic stresses.

Study Approaches

Research on the approach to studying has its origins in the work of Marton and Säljö (1976). Although the literature in this work is old, the two main types - surface and deep study approaches are still relevant in today's academic studies. Marton and Säljö (1976) made the distinction between the two types of study approaches. Surface approaches involve memorisation and acquisition of factual information where students aim to reproduce material in a test or examination rather than fully understanding it. On the other hand, deep approaches require students to seek meaning, an understanding of underlying principles and identification of relationships between ideas and concepts. This has paved the way for "student approaches to learning" theory by Biggs (1993) which describes a student's approach to learning as having two components, namely (i) how the student approaches the task (strategy); and (ii) why the student wants to approach it (motive).

Peters et al. (2007) explain that the students' approach to studying can be shaped by many factors, including prior experience, expectation of outcomes and perception of the learning context itself. Thus two learners may adopt different approaches to studying within the same context and a single learner may adopt differing approaches to studying in different contexts (Prosser & Trigwell, 1999).

While there is ample literature that studies the factors influencing study approaches, there is still a lack of research on the association between these approaches and the level of interest in engineering.

Motivational Goals

Motivation refers to the process whereby goal directed activity is instigated and sustained (Pintrich & Schunk, 2002). Researchers have developed a number of theories to explain motivation. It is not within the scope of the current research to cover all the theories but the more widely used theories, known as the expectancy-value theory of motivation and the self-determination theory of motivation, will be described in the following paragraphs. Although the literature in these theories is quite old, but they still have relevance to the motivational goals students have in today's engineering studies.

Expectancy-value theory (Eccles, 1983; Eccles et al., 1984; Eccles & Wigfield, 1995; Wigfield, 1994; Wigfield & Eccles, 1992, 2000) expands on the expectancy and value constructs initially developed by Tolman (1932), Lewin (1935) and Atkinson (1957, 1964). The theory that has been developed by Eccles and her colleagues was revised from the initial concept by making it more social-cognitive to reflect the current cognitive paradigm of motivation (Jones et al., 2010).

As defined by Pintrich and Schunk (2002), expectancies are people's beliefs and judgments about their capabilities to perform a task successfully; while values refer to beliefs students have about the reasons they might engage in a task. In other words, individuals will be motivated to engage in a task to the extent that they feel they can be successful at it (expectancy) and they perceive the task as being important to them in some way (task value). In the expectancy-value theory of motivation, both expectancies and values are important in predicting students' future choice behavior, engagement, persistence and actual achievement. The expectancy-value theory of motivation is gaining more attention in engineering studies; more recent works by Li et al. (2008) and Matusovich (2008) suggest that it holds promise for increasing our understanding of persistence (Hein, et al., 2012; Eris et al., 2010) as well as career choice in engineering students. It is interesting to note that researchers (Harackiewicz et al., 2005; Durik & Harackiewicz et al., 2005; Hulleman et al., 2008) have incorporated expectancy-value theory of motivation into research on interest. These researchers found that task values play an important role in the development of interest – where students' perceptions of task value are associated with subsequent interest. Task value is more closely aligned to situational interest (Hulleman et al., 2008), which is different from personal interest, the focus in the current research.

Other than conceptualizing motivation based on cognitive processes, another way to explain motivation is using the self-determination theory. Other studies on motivation have focused on the goals that students can set and how they can achieve those goals. Self-determination addresses the cause of this desire and identifies two causes of desire to study: the need for recognition, praise and/or money (extrinsic motivation) and the need to fulfill an interest (intrinsic motivation) (Deci et al., 1991).

Knowledge of students' preferred study approaches may be one of the first factors associated with students' level of interest in engineering. But this knowledge is insufficient without knowing the types of motivational goals they have that may subsequently help to direct and sustain their behavior (or interest) towards learning (Moreno, 2010).

Houghton (2004) concludes that attributes necessary for a student to learn engineering effectively include "intrinsic" and "extrinsic" motivation. In the current research, consistent with the definitions by Deci et al. (1991) as described above, intrinsic motivation refers to the motivation involved in a learning activity for its own sake and extrinsic motivation refers to the motivation involved in a learning activity as a means to an end, involving external rewards.

Most lecturers will want their students to be intrinsically motivated as they will be encouraged to work on engineering-related tasks and projects because they derive a sense of satisfaction and enjoyment in doing so (Arnason, 2006). This benefits students by enhancing long-term strategy development and self-direction. By contrast, extrinsic motivators encourage students to perform tasks or activities in order to receive some type of reward or to avoid some form of punishment. These motivators have short-term effects and need to be repeatedly reinforced by praise or rewards.

Savage and Birch (2008) state that the knowledge of students' motivation type may allow pedagogical interventions to be adjusted so as to enhance their learning experience, which may increase students' interest in the topic that they are studying. In line with this, the current research will include motivational goals as one of the student characteristics that may be associated with students' level of interest in engineering - a link yet to be fully explored in the current literature.

Self-efficacy

While motivational goals may help to direct and sustain students' behavior towards learning, there is also a need to determine the courses of action students choose in the face of obstacles and failures and how much effort and perseverance they put in – the notion of self-efficacy as defined by Bandura (1997). Self-efficacy mainly originates in the inferential process concerning one's prior performance, and influence performance by boosting persistence, resilience and sustained effort especially under challenging and changing circumstances (Multon et al., 1991).

The term self-efficacy is sometimes used interchangeably with "confidence". Understanding the differences between the two words is important in accurately interpreting the research literature. Bandura (1997) made a clear distinction between the two. Confidence refers to strength of belief but does not necessarily specify what the certainty is about. For example, a person can be confident of failure. Self-efficacy, on the other hand, refers to belief in one's capabilities that one can achieve particular levels of attainment. Although confidence is not the same as self-efficacy, it can be understood as a component of self-efficacy when expressed positively (Marra et al., 2009).

Academic Buoyancy

Other than reviewing the association of study approaches, motivational goals and self-efficacy with the level of interest in engineering, another internal characteristic of students that needs to be studied is their academic buoyancy – that is, their ability to handle academic stresses.

Although motivation and confidence are critical to student achievement (Shih & Gamon, 2001), academic gains that students make can be lost if they are not resilient to setbacks, study pressures and stresses (Martin, 2002), which can ultimately affect their level of interest in engineering. This is important to the present generation of students who are often faced with external stresses. Academic buoyancy is defined as students' ability to deal successfully with academic setbacks and challenges that are typical of the ordinary course of school life such as poor grades, completing deadlines, exam pressure and difficult schoolwork (Martin & Marsh, 2008). The dimensions of academic buoyancy include the effect of poor scores and study stress.

Academic buoyancy is developed as a construct reflecting everyday academic resilience within a positive psychology context. An extension of academic resilience is known as everyday resilience or academic buoyancy. Martin and Marsh (2008) make a clear distinction between academic buoyancy and academic resilience based on the type and degree of adversity one faces, as shown in Table 1.

Table 1: Difference in focus between academic resilience and academic buoyancy

Academic resilience	Academic buoyancy
Chronic underachievement	Isolated poor grades and patches of poor performance
Overwhelming feelings of anxiety	Typical stress levels and daily pressures
Debilitation in the face of chronic failure or anxiety	Threats to confidence as a result of a poor grade
Clinical types of effect such as anxiety and depression	Low level stress and confidence
Truancy and total disaffection from school	Dips in motivation and engagement
Comprehensive and consistent alienation or opposition to teachers	Minor conflicts with teachers such as negative feedback on schoolwork

Note: Adapted from "Academic buoyancy: towards an understanding of students' everyday academic resilience'" by Martin, A. J. and Marsh, H. W., 2008, *Journal of School Psychology, 46*(1), 53-83.

Though a relatively small amount of resilience research is focused on the academic domain, it has been studied widely in a more general sense (Pitzer, 2010). Within the academic domain, work on resilience tends to focus on a relatively small group of individuals who have experienced significant adversity such as extreme poverty and chronic underachievers. They do not address the many individuals who are faced with setbacks, challenges and pressures that are part of the ordinary course of life. Hence the current research will focus on academic buoyancy that is relevant to many students who must negotiate the ups and downs of everyday life.

2.3 Research Literature

This section reviews the empirical studies conducted by professional bodies of education in tackling the declining interest in engineering, work done in the area of the level of interest in engineering as well as student characteristics.

2.3.1 Professional bodies of education – their influence on engineering education

There are numerous professional bodies of education that have influenced and tackled the declining interest in engineering. The most well documented professional body is the Organisation for Economic Co-operation and Development (OECD), which provides a forum in which governments can work together to share experiences and seek solutions to common problems. With more than 34 countries, including the United States, South America, Europe and the Asia-Pacific region, OECD has explored the following solutions to increase interest in engineering related studies (Hemmo & Love, 2008):

1. Governments should actively promote equal opportunity for students, and should take steps to eliminate negative stereotypes - in particular to modify the learning context and approach, to make engineering more attractive to female students.
2. Enhancing the image of engineering profession through the provision of accurate and unbiased information about engineering and its career possibilities.
3. Engineering curricula need to be redesigned to make them more relevant and attractive. Teaching should focus on scientific concepts and methods rather than

retention of information. At the tertiary level, professional skills and cross-disciplinary studies should be promoted.

4. Governments and relevant institutions should provide adequate resources for teacher training and classroom activities, and rewards should be provided to those who make the effort to upgrade their skills and knowledge or invest their time in communicating a positive image of engineering to students.

In Singapore, in order to increase interest in engineering related studies, the Public Service Division is reviewing the pay and career progression of its engineers and will inject more variety into the work they do, in order to attract and retain such talent (Tai, 2014). For example, engineers will have more opportunities to rotate to various job functions. A nation-wide poll will also be conducted on engineering undergraduates or graduates who did not pursue the profession with the aim of finding out how they view the engineering profession and to identify factors which attract potential recruits and retain existing ones. The current research to find out the student characteristics that may be associated with the level of interest in engineering is timely to support this national study on the engineering profession.

Another government-led initiative in Singapore known as ASPIRE - Applied Study in Polytechnics and Institute of Technical Education Review - has been started with the aim of studying how applied education in the polytechnics and institutes of technical education can be strengthened. A series of recommendations have been rolled out under ASPIRE (Indranee, 2014):

1. Help students make well-informed education and career choices through education and career guidance programmes.

2. Strengthen education and training in polytechnics and institutes of technical education by working more closely with the industry in the development of programmes so as to equip students with good skills foundation.
3. Help polytechnic and institutes of technical education students deepen skills post-graduation.
4. Help polytechnic and institutes of technical education graduates progress in their careers through continuing education and training opportunities.

In conjunction with the Applied Study in Polytechnics and Institute of Technical Education Review, the government also set up a SkillsFuture Council that develops an integrated system of education, training and career progression for all Singaporeans, promote industry support for individuals to advance based on skills, and foster a culture of lifelong learning. It is a national movement to provide Singaporeans with the opportunities to develop their fullest potential throughout life, regardless of their starting points. Four thrusts as identified by the SkillsFuture Council (SkillsFuture, 2016) are:

1. Help individuals make well-informed choices in education, training and careers.
2. Develop an integrated high-quality system of education and training that responds to constantly evolving needs.
3. Promote employer recognition and career development based on skills and mastery.
4. Foster a culture that supports and celebrates lifelong learning.

Both government-led initiatives (Applied Study in Polytechnics and Institute of education Review and SkillsFuture) have implemented a series of programmes. Example is the introduction of education and career counseling to students in primary and secondary schools to expose them to a wide range of education and career options, and given opportunities to make informed post-secondary education choices. Education and career counseling continue in the institutes of technical education, polytechnics, junior colleges and universities to help students make informed choices for their careers. Another programme is the enhanced internships that allow students to learn through meaningful work assignments and industry exposure to deepen and apply both technical and soft skills. These enhanced internship helps to bind the gap between the engineering industry and institutions. Such internships will also help students make better career choices through real-world exposure to the industries. These programmes aim to provide accurate information about engineering and expose students to the possibilities and rewards of engineering studies and its profession – giving the students good reasons for choosing engineering (one of the student characteristics in the current research).

2.3.2 Empirical Studies on Level of Interest in Engineering

Various aspects of what is said to be a declining interest in engineering among young people have been covered by a great deal of research studies, conferences and events throughout the last decade, as mentioned in Chapter One (Section 1.4). They have been well cited and developed countries have put or are in the process of putting national strategies in place to address the issues raised. These research studies describe the declining interest in engineering in terms of poor enrollment rates to engineering related studies and declining numbers of graduates in the field (Hemmo & Love, 2008; Jones et al., 2010). But few research studies have reported on the quantitative trends in the level of interest in engineering itself.

One such study on the level of interest in engineering is that of the Innovative Technology Experiences for Students and Teachers programme, which was established by the National Science Foundation (Tyler-Wood et al, 2010) in the United States. The programme's primary goal is to increase the nation's number of highly capable scientists in science, technology, engineering and mathematics areas to increase the United States' competitive edge as the country enters the 21st century. The programme has measured grade six to eight (11 to 14 years) students' (n = 60) level of interest in engineering to be at a mean of 4.94 on a seven point scale; levels of interest are summarized in Table 2. The Science, Technology, Engineering and Mathematics (STEM) Semantics Survey was used in this research to assess students' personal interest in science, technology, engineering, mathematics and engineering career. There are five items per variable and all items were rated on a seven point Likert-type scale. Higher scores indicate higher levels of interest in the variable. It will be interesting to find out Singapore's polytechnic students' level of interest in engineering using the same instrument, adapted to Singapore's context.

Table 2: Means and standard deviations of the levels of interest in science, mathematics, engineering, technology and career of grade six to eight students in the United States

Variable	M	SD
Science	5.48	1.17
Math	4.49	1.67
Engineering	4.94	1.68
Technology	5.69	1.33
Career	4.91	1.58
Overall level of interest	127.55	

Note: Adapted from "Instruments for assessing interest in STEM content and careers" by Tyler-Wood, T., Knezek, G. and Christensen, R., 2010, *Journal of Technology and Teacher Education*, *18*(2), 345-368.

1. All items were rated on a seven point Likert-type scale. Averaging the 5 items in each variable (Science, Mathematics, Engineering, Technology and Career) in the Science, Technology, Engineering and Mathematics Semantics Survey gave a mean scale score that ranged from 1 to 7.
2. Overall level of interest was computed based on the sum of the 25 items in the survey, which gave a scale score that ranged from 25 to 175.

Past studies have conducted research on the declining interest in engineering; however few have documented quantitative trends in the level of interest, or changes in the level of interest, especially in polytechnic students (17 – 19 years). This is a possible gap in the literature that the current research will attempt to address.

2.3.3 Empirical Studies on Student Characteristics

Reasons for Choosing Engineering

A recent piece of research by Mahani and Molki (2011) on female Emirati undergraduate engineering students (n = 75) in the United Arab Emirates reveals that (i) a student's parents' field of education is not an influential factor in his/her decision to study engineering; (ii) parental support and perceived strong mathematical abilities are noticeable reasons in their decision; (iii) having a role model (female engineering professor) is not a significant factor; and (iv) recruitment measures are important in attracting female students.

Factors that influence students to choose engineering have been studied and covered in other empirical reports as well. The section below provides a brief summary of the reports that discuss the internal and external reasons that influence students to choose engineering.

Internal reasons:

1. Students with higher social status (higher educational and income levels) are more likely to choose engineering (Kvande, 1986; Felder et al., 1995; Jagacinski, 1987). With a good family background and family support, it is likely that these students are more engaged in their studies and have high levels of interest in engineering.

2. Studies also show that interest in mathematics is a strong factor linking students to their decision to study engineering (Kvande, 1986). These studies reveal that students who are good in mathematics are likely to choose engineering as they perceive themselves as being able to do well. The same applies for science. It is logical to assume that students who choose a course which makes the best use of their skills and engages their interest, are more likely to stay and thrive in the field of engineering which they choose (Ngambeki et al., 2008).
3. Parents, relatives or friends who are doing well in the engineering profession often act as role models to students who want to be as successful as them. They help to provide correct information, clear the misconceptions students have about engineering and are able to set realistic expectations of the course at the start.

External reasons:

4. Good recruitment measures will attract students to choose engineering as they provide the correct information about engineering and the rewards of the profession. Ngambeki et al. (2008) comment that those who make a poor choice because of incomplete information or misconceptions about engineering often find themselves frustrated.
5. High employability of the engineering profession is likely another reason that leads students to choose engineering as they need not worry about employment upon graduation. This can be a motivational factor to get students more involved and engaged in engineering activities, and in turn increase their level of interest in engineering.

The existing literature has covered the various reasons for choosing engineering, with little or no mention of students' ultimate interest in the various engineering fields. The current research will attempt to build on the existing body of literature by investigating the association of these reasons with students' level of interest in engineering.

Study Approaches

Deep approaches to studying have consistently been identified as being associated with higher academic scores (Peters et al., 2007). This is because deep-level learning - notably motivation to seek meaning, an understanding of underlying principles and identification of relationships between ideas and concepts - has been shown to be the pre-requisite of self-directed learning (Kreber, 2003).

Approaches to studying in the fields of health sciences (Biggs et al., 2001), higher education sports (Peters et al., 2007) and the engineering context (Case & Marshall, 2004) have been reported but they have not correlated these approaches with the level of interest in any field.

Research by Biggs et al. (2001) was done on 229 undergraduate students in the health sciences faculty of a university in Hong Kong. The study helped to validate a revised instrument, reducing it from 32 items in the original Study Process Questionnaire (Biggs, 1987), to the current 20 items known as the Revised Two-Factor Study Process Questionnaire (R-SPQ-2F). All items in the questionnaire are coded A (this item is never or rarely true of me), B (this item is sometimes true of me), C (this item is true of me about half the time), D (this item is frequently true of me) and E (this item is always or almost always true of me). There are five items in each category of deep motive, deep strategy, surface motive and surface strategy.

The research conducted by Peters at al. (2007) made comparisons between male and female undergraduate students (n = 338) in the fields of higher education sports in the United Kingdom. The Revised Two-Factor Study Process Questionnaire (R-SPQ-2F) was used where all items are coded 0 (strongly disagree) to 4 (strongly agree). Deep orientation comprises eight items while surface orientation comprises 12 items. They conclude that there are no gender differences for deep orientation but females are significantly higher in surface orientation. Some results of the research reflected in Table 3 may serve as a guide for the current research on engineering students.

Table 3: Group differences for study approaches between female and male undergraduate students in higher sports education in the United Kingdom

	Overall			Female		Male		
Study approaches	M	SD	Alpha	M	SD	M	SD	t
Deep orientation	19.31	3.51	0.62	No gender differences for deep orientation				
Surface orientation	28.30	5.72	0.68	30.28	5.94	27.36	5.37	4.46*

Note: Adapted from "Approaches to studying, academic achievement and autonomy" by Peters, D., Jones, G. and Peters, J., 2007, *Journal of Hospitality, Leisure, Sport and Tourism Education 6*(2), 16-28. *p < 0.01.

In the engineering context, the most relevant study has been made by Case and Marshall (2004), who followed 13 students who were doing a first-year engineering foundation course in the United Kingdom over a period of one year. They conclude that the choice of study approach is generally made in response to students' perception of the course context - that is, a course that focuses on deep objectives will unlikely elicit from students a surface approach. This means given the strong focus of engineering courses on the ability to solve problems, deep approaches are expected of engineering students

(Case & Marshall, 2004). Whether this approach to studying will elicit or increase interest in engineering among students remains unknown. But once students are enrolled into the engineering course, it is important to understand how they approach engineering studies, which may predict their ability to study well in the course (since deep approaches to studying have been associated with higher academic scores as reported by Peters et al., 2007) and in turn may affect their level of interest in engineering.

Motivational Goals

There has been a great deal of empirical research done on the concept of motivation; this review will not attempt to report all studies but will focus on the recent reports done in the context of engineering studies, based on the expectancy-value theory and the self-determination theory of motivation as explained in Section 2.2.4.

One such piece of research by Jones et al. (2010) studied the persistence in engineering using motivation theories from the fields of education and psychology as a framework. The relationship among the following constructs, based on the expectancy-value theory, was examined for first-year undergraduate engineering students in the United States: engineering self-efficacy, expectancy for success in engineering, engineering intrinsic value, engineering attainment value, engineering extrinsic value, identification with engineering, engineering achievement and engineering career plans. The students were asked to complete a questionnaire that measures the above constructs at the start and end of a term that spans over eight weeks. All items were rated on a seven point Likert-type scale except for self-efficacy, which was rated on a ten point Likert-type scale. The key findings of the study relevant to the current research are that the students' expectancy-related beliefs (expectations for success in engineering and engineering self-efficacy) and value-related beliefs (identification with engineering and engineering intrinsic interest value, attainment value and extrinsic utility value) decreased over eight weeks of the first year among 363 engineering students. A summary of results is shown in Table 4 below. A possible addition to this research is to expand the current instrument used to cover more aspects of motivation in engineering students.

Table 4: Motivational goal differences between time 1 and time 2 of first-year undergraduate engineering students in the United States

	Time 1		Time 2		df	t
Variable	M	SD	M	SD		
Expectancy	5.31	0.92	5.08	1.09	356	4.42*
Interest	5.34	1.03	4.89	1.19	359	7.26*
Attainment	6.17	0.72	5.71	1.00	353	9.21*
Utility	6.31	1.09	5.84	1.42	360	5.86*
Identificat-ion	5.89	0.80	5.51	1.04	345	7.32*
Self-efficacy	8.04	1.39	7.40	1.93	340	7.01*
Career	6.01	1.19	5.79	1.58	350	2.62

Note: Adapted from “An analysis of motivation constructs with first-year engineering students: relationships among expectancies, values, achievement, and career plans” by Jones, B. D., Paretti, M. C., Hein, S. F. and Knott, T. W., 2010, *Journal of Engineering Education*, *99*(4), 319–336.
*$p < 0.001$

Another notable research study based on the expectancy-value theory of motivation is the one by Pintrich et al. (1991), using a comprehensive instrument – Motivated Strategies for Learning Questionnaire. All items in the questionnaire were rated on a seven point Likert-type scale. Pintrich et al. (1991) study the motivational orientation and self-efficacy of college students (n = 380) from five disciplines of natural sciences, humanities, social science, computer science and foreign language. A summary of results is shown in Table 5. As these results were obtained from non-engineering students, it will be interesting to extend this instrument to measure the motivational goals and self-efficacy of engineering students in Singapore's context.

Table 5: Means and standard deviations of motivational goals of college students (across five disciplines) in the United States

Variable	M	SD
Intrinsic goal orientation	5.03	1.09
Extrinsic goal orientation	5.03	1.23
Task value	5.54	1.25
Control of learning beliefs	5.74	0.98
Self-efficacy for learning and performance	5.47	1.14
Test anxiety	3.63	1.45

Note: Adapted from "A Manual for the Use of the Motivated Strategies for Learning Questionnaire (MSLQ)" by Pintrich, P. R., Smith, D. A. F., Garcia, T., and McKeachie, W. J., 1991, Washington, DC: Office of Educational Research and Improvement.

Other than empirical studies based on the expectancy-value theory of motivation, there have also been studies based on the self-determination theory of motivation. Savage and Birch (2008) evaluate motivation in engineering students using qualitative data-gathering methods, including questionnaires and semi-structured interviews. The study concludes that electronic and computer engineering students operate more intrinsically.

There is no one overriding theory of motivation, but the expectancy-value theory of motivation is deemed to be the most comprehensive and widely used method in the context of engineering studies (Matusovich, 2008; Panchal et al., 2012; McGrath et al., 2013 and Mariafé et al., 2015). It is then logical to build on the current literature to investigate the link between motivation goals and the level of interest in engineering, using the expectancy-value theory of motivation.

Self-efficacy

Self-efficacy is an extensively researched psychological construct grounded in social cognitive theory. In the context of engineering, there is a substantial amount of empirical research on self-efficacy beliefs in relation to academic achievement and career choice. The old literature quoted by Lent et al. (1986), Betz and Hackett (1981) had provided much insight into this relationship and is still relevant to today's context. These studies point to the case that a strong sense of self-efficacy is integral to students' entry and persistence in engineering and this is most relevant to women in engineering.

Past researchers have identified self-efficacy as an important factor in students' persistence, achievement and interest (Hackett et al., 1992; Lent et al., 2003; Schaefers et al., 1997). A study by Niemivirta and Tapola (2007) was done on 100 ninth-graders (mean age of 15.4 years) who were asked to complete a task that required complex problem solving during mathematics, information and communication technology classes. The students were asked to rate their self-efficacay (measured by two items) and interest (measured by one item) three times during the task, once after each exploration. This research found that "increase/decrease in self-efficacy during the task was related to increase/decrease in interest and vice versa".

One longitudinal study that was done in the context of engineering is that reported by Marra et al. (2009). They researched 164 undergraduate women studying engineering in the United States. The students were asked to complete the longitudinal assessment of engineering self-efficay that measures their self-efficacy in engineering at the start and end of a year of their study. All items in the questionnaire were rated on four point Likert-type scale. A summary of the results is shown in Table 6.

Table 6: Means and standard deviations of self-efficacy between time 1 and time 2 of undergraduate female engineering students in the United States

	Time 1		Time 2	
Variable	Mean	SD	M	SD
Engineering self-efficacy	2.91	0.83	2.87	1.03
Engineering career expectations	6.31	1.45	6.34	2.01
Engineering self-efficacy II	6.39	1.34	6.92	1.03
Feelings of inclusion	2.65	0.61	2.49	0.96
Coping self-efficacy	6.28	1.34	6.67	0.94
Math outcomes efficacy	6.23	1.95	6.66	1.71

Note: Adapted from "Women engineering students and self-efficacy: a multi-year, multi-institution study of women engineering student self-efficacy" by Marra, R. M., Rodgers K. A., Shen, D. and Bogue B., 2009, *Journal of Engineering Education 98*(1), 27–38.

The study concludes that in general female students do not show growth in self-efficacy as they move from one year to the next in their engineering degree programmes. This result is consistent with that reported by Brainard and Carlin (1998) and Felder et al. (1995).

Given the number of research studies done in the area of self-efficacy among female engineering students, it seems timely to extend the research to include male students. Therefore this study will investigate the link between self-efficacy and the level of interest in engineering explicitly.

Academic Buoyancy

Given that academic buoyancy is a new concept, there has been limited empirical research on academic buoyancy especially in the engineering domain. The most relevant research may be that reported by Martin and Marsh (2008), who developed a model of academic buoyancy based on the results obtained from mathematics students. Among other things, they found that predictors of academic buoyancy comprise self-efficacy, control, academic engagement, anxiety and the teacher-student relationship. They also identified anxiety as playing the salient role in academic buoyancy. It is also reported that female students have lower academic buoyancy than male students. Mathematics is known to elicit higher levels of anxiety among students and this in turn lowers their academic buoyancy.

It may be postulated that being able to overcome occasional poor grades, daily school pressure, low confidence, occasional dips in motivation and engagement and minor conflicts with teachers and classmates can lead to academic buoyancy in students. Knowledge of students' level of academic buoyancy can help lecturers know if the students are resilient to daily stresses and pressures faced in school. At this point, therefore it should be useful to identify the role of academic buoyancy in the level of interest in engineering – a link previously unexplored.

2.4 Summary

This chapter has reviewed the literature that drives the purpose and research questions in the current research. The chapter is presented in two sections – theoretical research in engineering education and research literature in the area of the level of interest in engineering and student characteristics.

The first section covers the history in engineering education that illustrates the idea of engineers as the heroic creators of the material structures of the society, being replaced by the more mundane image of engineers as the technical workers of the industry. The new challenges faced in engineering point to the need to transform engineering education to meet the new roles expected of engineers and to attract the right pool of students, with unique student characteristics, into engineering.

The second section covers the empirical studies conducted by professional bodies of education in tackling the declining interest in engineering. These studies point to the lack of literature that associates the level of interest in engineering with student characteristics.

Despite the vast research on student characteristics, there has not been a strong focus placed on the characteristics of polytechnic engineering students and their association with the level of interest in engineering. Therefore, the purpose of the present research is to fill a gap in the growing literature by investigating the relationship between the student characteristics and the level of interest in engineering. The methods used in this research will be described in Chapter Three.

CHAPTER THREE

METHODS

3.1 Overview of Design

This research is a quantitative correlational study that uses survey questionnaires to measure the independent variables - students' reasons for choosing engineering, study approaches, motivational goals, self-efficacy and academic buoyancy. In addition, students' level of interest in engineering, the dependent variable, is measured at the start (time 1) and end (time 2) of their first semester. The instruments used in these survey questionnaires are adapted from past research. Correlation and regression techniques are then used to study the bivariate and joint relationships between the variables.

3.2 Participants

A total of 689 first-year students ranging in ages from 17 to 18 years, from the School of Engineering of one polytechnic in Singapore were invited to participate in the research. Of these students, 209 students were recruited from the Engineering with Business Management diploma programme, which the researcher teaches. The diverse nature of the Engineering with Business Management students, as described in Chapter One, is likely to provide variation in the independent variables, and changes in students' level of interest in engineering. Another 47 students were recruited from the Engineering Science diploma programme, also taught by the researcher. The multidisciplinary nature of the Engineering Science diploma programme requires the Engineering Science students to be exposed to a wide range of engineering fields, which may develop varying levels of interest in them.

The remaining 433 students were recruited from the Electronic and Computer Engineering diploma programme, which has the highest dropout rate and whose students are therefore likely to show substantial change in the level of interest in engineering over a semester. The researcher, with the help of colleagues, was able to achieve a high response rate to the survey questionnaires with these Electronic and Computer Engineering students.

Every effort was made to get the highest possible response rate. Instrument 1 and Instrument 2 were administered at time 1 (start of the semester in April 2014) and time 2 (end of the semester in September 2014) respectively. Of the 689 students who were invited to participate in the research, 335 students completed Instrument 1; 316 students completed Instrument 2 and a total of 309 students completed both instruments. Table 7 summarizes the response rate data. Data analysis in the subsequent chapters was based on the 309 students (44.8% of the total population) who completed Instruments 1 and 2.

Table 7: Overall response rate

Activity	Number	Percentage
(1) Total population	689	100%
(2) Completed Instrument 1 at time 1	335	48.6%
(3) Completed Instrument 2 at time 2	316	45.9% of (1)
		94.3% of (2)
(4) Completed instrument 1 and 2	309	44.8% of (1)

Note: time difference between time 1 and time 2 is six months.

Linder et al. (2001) indicated that steps should be taken to account for possible non-response error whenever a response rate is less than 85%. To do this, a missing values analysis was conducted using SPSS. An expectation maximization technique based on

Little's chi-square statistic (Little & Rubin, 1987) was used for testing whether values were missing completely at random (MCAR). For this test, the null hypothesis is that the data is missing completely at random and the p value is significant at the 0.05 level. If the value is less than 0.05, the data is not missing completely at random. The Little's MCAR test (Little & Rubin, 1987) obtained for this study's data resulted in a chi-square = 80.084 (df = 65, p = 0.099), which indicates that the data is indeed missing completely at random. That is, no identifiable pattern exists to the missing data. This means the complete cases are a random subset of all cases and only those cases with no missing values are analyzed. In this case, data analysis in the subsequent chapters was based on the 309 students (44.8% of the total population) who completed Instruments 1 and 2.

Another important consideration in the conduct of the survey is the practice or memory effect of students participating in the two surveys over the period of six months. Practice or memory effect is the influence the past-experience of taking a test has on taking that same test (on the level of interest in engineering) again. It can result in higher than normal scores, and is most pronounced when the interval between the two tests is short. In the current research, this effect is thought to be minimal as the time interval between the two tests is six months – a period that allows the students time to immerse themselves in the new learning environment and is likely to produce variability in their responses.

3.3 Instruments

Data were collected using a variety of instruments which are described below. As the instruments have been developed and used by previous researchers, care was taken to preserve the integrity of the original instruments as much as possible, while adapting to the Singapore context.

3.3.1 Level of Interest in Engineering – Science, Technology, Engineering and Mathematics Semantics Survey

The Science, Technology, Engineering and Mathematics Semantics Survey (Tyler-Wood et al., 2010) is a 25-item self-report scale with five major dimensions measuring interest in science, technology, engineering, mathematics (STEM) and engineering career. Each of the five dimensions has five semantic perception adjective pairs as shown in Appendix 1. The instrument is created to assess the general perceptions of STEM disciplines and careers using semantic differential adjective pairs from Osgood's (1962, 1957) evaluation dimension. These general perceptions help to indicate students' personal interest in engineering. This instrument was created by adapting Knezek and Christensen's (1998) Teachers' Attitudes Towards Information Technology Questionnaire (TAT), which was itself derived from the earlier semantic differential research by Zaichknowsky (1985). Although this is a relatively new instrument, it is gaining popularity (cited more than 30 times in google scholar as of August 2015) with its capability of measuring changes in attitudes towards science, technology, engineering, mathematics (Tyler-Wood et al., 2010).

The instrument has been found to demonstrate Cronbach's coefficient alpha between 0.84 to 0.93 – in the range of "very good" to "excellent" according to guidelines provided by DeVellis (1991).

3.3.2 Reasons for Choosing Engineering Questionnaire

The instrument to measure students' reasons for choosing engineering as their course of study is adapted from Mahani and Molki (2011). It is a 16-item questionnaire (Appendix 2) where respondents rate themselves on a scale from 1 (agree not at all) to 5 (totally agree). It has two dimensions – internal and external. The internal dimension consists of four items on their role models (example, advice from parents influences the student to join engineering), and three items on students' self-perception in mathematics and science ability (example, the student feels that he or she is good in mathematics and will therefore do well in engineering). The external dimension consists of five items on recruitment into the engineering course (example, the student has participated in Open House and received accurate information about engineering before joining the course) and four items on the employment opportunities in the engineering field (example, the student sees engineering as a high paying profession and decides to join).

3.3.3 Approaches to Studying – the Revised Two Factor Study Process Questionnaire

Approach to studying research has its origins in the work of Marton and Säljö (1976). The two main types of approaches identified are surface and deep study approaches. Marton and Säljö made the distinction between them. Surface approaches involve memorisation and acquisition of factual information where students aim to reproduce material in a test or exam rather than fully understanding it. On the other hand, deep approaches require students to seek meaning, an understanding of underlying principles and identification of relationships between ideas and concepts. This has paved the way for the "student approaches to learning" theory by Biggs (1993) which describes a student's approach to learning as having two components, namely (i) how the student approaches the task (stratgegy); and (ii) why the student wants to approach it (motive).

The instrument to measure this variable follows the framework of the Revised Two Factor Study Process Questionnaire developed by Biggs et al. (2001). It is a 20-item questionnaire (Appendix 3) that contains ten items on deep approaches (with subscales of deep motive and deep strategy) and ten items on surface approaches (with subscales of surface motive and surface strategy). Respondents rate themselves on a scale from 1 (agree not at all) to 5 (totally agree). The instrument has been found to demonstrate Cronbach's coefficient alpha between 0.57 to 0.72. These values are said to have reached "acceptable levels", indicating that the subscales can be interpreted as reasonably internally consistent (Biggs et al., 2001). This instrument has frequently been used to examine the study approaches of students in higher education in different countries including Asia (such as Hong Kong and Japan) and various subject areas (such as health sciences) (Stes et al., 2013).

3.3.4 Motivational Goals and Self-efficacy – Motivated Strategies for Learning Questionnaire

Motivation refers to the process whereby goal directed activity is instigated and sustained (Pintrich & Schunk, 2002). Researchers have developed a number of theories to explain motivation. It is not within the scope of the current research to cover all the theories but the more widely used theories are noted here – the expectancy-value theory of motivation and the self-determination theory of motivation as explained in Section 2.2.4.

The Motivated Strategies for Learning Questionnaire – motivation and self-efficacy sections (Pintrich et al., 1991) is a 31-item self-report scale that assess students' goals and value beliefs for a course, their beliefs about their skill to succeed in their course and their anxiety about tests in that course, which will be elaborated below. The other remaining section on learning strategies is not included as it is not relevant in the current research. This instrument is chosen due to its vast usage in literature (cited more than 2000 times in google scholar as of May 2015) and the combination of motivation and self-efficacy in one instrument. Pintrich et al. (1991) define the six dimensions and subscales of the motivation and self-efficacy sections as follows.

The first dimension is the intrinsic goal orientation which refers to students' general goals or orientation to the courses as a whole. Intrinsic goal orientation concerns the degree to which the student perceives himself/herself to be participating in a task for reasons such as challenge, curiosity and mastery. The second dimension is the extrinsic goal orientation that concerns the degree to which the student perceives himself/herself to be participating in a task for reasons such as grades, rewards, performance, and evaluation by others and in competition.

The third dimension is the task value that refers to the students' perception of the course material in terms of interest (subjective interest in the topic itself), importance (of doing the task well - attainment value) and utility (how well the task relates to current or future goals such as career goals) (Eccles & Wigfield, 2002). As mentioned in section 2.2.4, task value is closely aligned to situational interest and should not be confused with the personal interest measured by the Science, Technology, Engineering and Mathematics Semantics Survey (Tyler-Wood et al., 2010).

The fourth dimension is the control of learning that refers to students' beliefs that their efforts to learn will result in positive outcomes. The fifth dimension is the self-efficacy for learning and performance which is self-appraisal of one's ability to master a task.

The sixth dimension is test anxiety which is thought to have two components: a worry or cognitive component, and an emotionality component. The worry component refers to students' negative thoughts that disrupt performance, while the emotionality component refers to affective and physiological arousal of anxiety.

Appendix 4 shows a sample of the questions. All items were measured using a five point Likert-type scale ranging from "agree not at all" to "totally agree". The instrument is reported to have robust Cronbach's coefficient alpha ranging from 0.62 to 0.93 (Pintrich et al., 1991).

3.3.5 Academic Buoyancy – the Academic Buoyancy Scale

The Academic Buoyancy Scale (Appendix 5) developed by Martin and Marsh (2008) was used to measure the academic buoyancy of students. There are a total of four items accounting for one dimension that measures students' confidence in dealing with setbacks, the effect of study stress, how well they deal with homework pressures and the effect of a bad mark on their confidence level. All items are measured using a five point Likert-type scale with responses ranging from "agree not at all" to "totally agree". Even though academic buoyancy is a relatively new construct, the instrument has been cited 127 times in google scholar as of August 2015. Researchers have documented that this scale is reliable from both internal consistency and test-retest perspectives (Time 1 Cronbach's coefficient alpha = 0.80; Time 2: Cronbach's coefficient alpha = 0.82; test-retest r = 0.67) (Martin & Marsh, 2008).

3.4 Procedure

Prior to the research being initiated, permission to conduct the research was sought from the Human Research Ethics Committee of the University of Western Australia as well as the Polytechnic. Before the conduct of the full survey, a small pool of randomly selected students was requested to participate in the draft survey questionnaires to gather suggestions and feedback that could be incorporated into the final design of the questionnaire. At the same time, class advisors of Engineering with Business Management, Engineering Science, and Electronic and Computer Engineering students were briefed on the intent and purpose of the research as well as the assistance required of them in the conduct of the survey.

At the start of the new semester in April 2014, through the researcher, class advisors distributed the information sheet to all Engineering with Business Management, Engineering Science, and Electronic and Computer Engineering students inviting them to participate in the research by completing an online survey instrument during the following week (time 1) and near the end of the same semester in September 2014 (time 2). Students were informed that their participation was voluntary, all personal information would be kept completely confidential and they would be eligible to win one of the twenty $10 gift vouchers (redeemable from a local movie company or cafe) if they participated in the research, on top of the co-curriculum points given to each of them. Only participant codes (not names) were used to label the data collected and a third party held a separate list of codes-to-names matchups. Information about this was included in the students' information sheet mentioned earlier.

In the following week in April 2014 (time 1), an email that included a link to the first online survey Instrument 1 was sent to all Engineering with Business Management, Engineering Science, and Electronic and Computer Engineering students. Reminders to complete the questionnaire were then sent one and two weeks later. Instrument 1 measured students' level of interest in engineering at time 1 as well as the students' characteristics, namely students' reasons for choosing engineering, study approaches, motivational goals, self-efficacy and academic buoyancy.

Near the end of the same semester in September 2014 (after a span of six months), another email that included a link to the online survey Instrument 2 was sent to the students who completed the first online survey instrument. Instrument 2 measured only students' level of interest in engineering at time 2.

The email was resent one and two weeks later after the initial email as a reminder. Data analysis in the subsequent chapters was based on the 309 students (44.8% of the total population) who completed Instruments 1 and 2, as indicated in Table 7 in Section 3.2.

3.5 Data Analysis

After the survey questionnaires were completed, the data were coded and entered into computers for analysis using the Statistical Package for the Social Sciences (SPSS). Prior to any analysis being performed, all data were checked both for errors in entry and conformity to assumptions of the tests conducted (e.g. normality, outliers). The analysis of the large database was conducted in six parts and is reported in Chapter Four.

3.5.1 Psychometric Analysis

In this research, even though the measurement instruments were based on existing tools, it is still important, as the first part of the data analysis, to assess their factor structure and reliability in the Singaporean context. Firstly, factor analysis was performed to confirm the factor structure of the different variables. Secondly, checks of internal consistency were done using Cronbach's coefficient alpha.

3.5.2 Analysis of Variance (ANOVA)

The second part of the data analysis involved the use of the analysis of variance (ANOVA) to investigate the differences between the three groups of students in the three diploma programmes - Engineering with Business Management, Engineering Science, and Electronic and Computer Engineering diploma programmes - in terms of their level of interest in engineering at time 1 (research question one). For this analysis, the dependent variable was the level of interest in engineering at time 1 and the independent variable was the diploma programme students come from.

The ANOVA results indicated if the difference in the level of interest in engineering between the groups at time 1 was statistically significant. The same procedure was done to address research question two in the third part of the analysis, where the dependent variable was the level of interest in engineering at time 2 and the independent variable was the diploma programme students come from.

3.5.3 Analysis of Covariance (ANCOVA)

The fourth part of the data analysis involved the use of the analysis of covariance (ANCOVA) to remove the effects of the influences of the level of interest in engineering at time 1, especially when the ANOVA results revealed statistical differences between any two groups of students. Change scores were calculated (time 1 – time 2) and ANCOVA was conducted on the change scores as the dependent variable with the level of interest at time 1 score as the covariate. The ANCOVA results generated adjusted scores for the change in the level of interest in engineering between time 1 and time 2, with the effects of the influences at time 1 removed. The adjusted change scores were then fedback into ANOVA to check for any statistical differences in the change in the level of interest in engineering among the diploma groups. This test is to address research question three where the dependent variable was the change in the level of interest in engineering and the independent variable was the diploma programme students come from.

3.5.4 Pearson product-moment correlation

Research question four studied the bivariate relationships between all variables in the research. To do this, Pearson product-moment correlation coefficients were calculated in the fifth part of the data analysis.

3.5.5 Multiple linear regression analysis

To study the joint relationship between the independent variables and dependent variable in research question five, multiple linear regression analysis was used in the sixth part of the data analysis. In this analysis, the dependent variable was the change in the level of interest in engineering and the independent variables were the student characteristics (i.e. reasons for choosing engineering, study approaches, motivational goals, self-efficacy and academic buoyancy). This analysis shows to what extent student characteristics account for the variance in the level of interest in engineering, and the relative importance of each characteristic in accounting for this variance.

3.6 Summary

Chapter Three has outlined the methods that were used in this research. The design of the research together with the sampling, instruments, procedure and data analysis were described to measure the level of interest in engineering and student characteristics in terms of the reasons for choosing engineering, study approaches, motivational goals, self-efficacy and academic buoyancy. Instruments of measurement for these characteristics follow the frameworks suggested by Mahani and Molki (2011), Biggs et al. (2001), Pintrich et al. (1991) and Martin and Marsh (2009) respectively. The instrument for measuring the level of interest in engineering is based on that reported by Tyler-Wood et al. (2010).

Data analysis of the large database was conducted in six parts using psychometric analysis, analysis of variance, analysis of covariance, Pearson product-moment correlation and multiple linear regression. The next chapter, Chapter Four, reports the results obtained from these analyses.

CHAPTER FOUR

RESULTS

4.1 Introduction

This chapter presents the results of the six analyses of the data. They are as follows:

- analysis one: psychometric analysis of the instruments
- analysis two: the level of interest in engineering at time 1 and the differences between the diploma groups
- analysis three: the level of interest in engineering at time 2 and the differences between diploma groups
- analysis four: the change in the level of interest in engineering and the differences between diploma groups
- analysis five: the bivariate relationship between all variables
- analysis six: the joint relationship between student characteristics and the level of interest in engineering.

4.2 Analysis One – Psychometric Analysis

Before conducting the central analyses of interest, it was important to first test the psychometric properties of the entire set of measures. To do this, checks of internal consistency and exploratory factor analysis were conducted for each instrument.

The internal consistency reliability of the instruments was estimated by computing the Cronbach's coefficient alpha. The following criteria was used to judge the values according to the guidelines provided by DeVellis (1991): less than 0.6 was unacceptable, between 0.6 and 0.64 was undesirable, between 0.65 to 0.70 was minimally acceptable, between 0.70 and 0.80 was respectable and between 0.80 and 0.90 was very good.

Prior to performing principal components analysis, the suitability of data for factor analysis was assessed by computing the Kaiser-Meyer-Oklin values and Bartlett's Test of Sphericity. The following criteria was used to judge the values according to the guidelines provided by Kaiser (1970) and Bartlett (1954) respectively: the data is suitable for factor analysis for Kaiser-Meyer-Oklin values that have exceeded 0.6 and Bartlett's Test of Sphericity that have reached statistical significance ($p < 0.01$).

The results of the psychometric analysis using Cronbach's coefficient alpha, Kaiser-Meyer-Oklin values and Bartlett's Test of Sphericity for each instrument are presented in the sections that follow. The results were based on a combined group of 309 students from the Engineering with Business Management, Engineering Science and Electronic and Computer Engineering diploma programmes.

4.2.1 Level of Interest in Engineering – Science, Technology, Engineering and Mathematics Semantics Survey

The Science, Technology, Engineering and Mathematics Semantics Survey (Tyler-Wood et al., 2010) is a 25-item self-report scale with five major dimensions (five items per dimension) measuring personal interest in science, technology, engineering, mathematics (STEM) and engineering career. In this study, students' level of interest in engineering is measured at the start (time 1) and end (time 2) of their first semester.

The internal consistency reliabilities for the Science, Technology, Engineering and Mathematics Semantics Surveys were very good, with Cronbach's coefficient alpha ranging from 0.86 to 0.92 at time 1 and 0.89 to 0.93 at time 2. The results are as shown in Table 8.

Table 8: Cronbach's coefficient alpha for the Science, Technology, Engineering and Mathematics Semantics Survey

Dimension	Time 1	Time 2
Level of interest in science	0.89	0.90
Level of interest in technology	0.89	0.89
Level of interest in engineering	0.86	0.89
Level of interest in engineering career	0.92	0.93
Level of interest in mathematics	0.90	0.89

Based on the high Cronbach's coefficient alpha (above 0.89) for each dimension as shown in Table 8, it can be inferred that the dimensions had high internal consistencies where the items were highly correlated with one another in each dimension. Therefore, instead of using item scores, the five dimension scores of the Science, Technology, Engineering and Mathematics Semantics Survey were used for next analysis. For the remaining instruments, the Cronbach's coefficient alpha values were not as high and item scores were used instead.

The dimension scores of the Science, Technology, Engineering and Mathematics Semantics Survey were then subjected to principal components analysis using SPSS version 22. Prior to performing principal components analysis, the suitability of data for factor analysis was confirmed using the Kaiser-Meyer-Oklin values (0.78 and 0.80 at time 1 and time 2 respectively) and Bartlett's Test of Sphericity.

A principal components analysis with varimax rotation of the five dimensions from the Science, Technology, Engineering and Mathematics Semantics Survey was conducted on the data gathered from the combined group of students. The initial eigenvalues at time 1 and time 2 for the level of interest in engineering are shown in Table 9. Both analyses yielded a one-factor solution which accounted for 58.86% and 58.52% of the variance at time 1 and time 2 respectively. The results of the varimax rotation of the one-factor solution as shown in Table 10 indicate that the factor analysis results at time 1 and time 2 were very similar, including the pattern of factor loadings. The dimensions that loaded on the main factor indicated that this factor represented the overall level of interest in engineering. Therefore one summed scale score for the overall level of interest in engineering at time 1 was used for time 1 analyses while one summed scale score for the overall level of interest in engineering at time 2 was used for time 2 analyses.

Table 9: Eigenvalues, percentages of variance and cumulative percentages for factors of the Science, Technology, Engineering and Mathematics Semantics Survey at time 1 and time 2

	Time 1			Time 2		
Factor	Eigenvalue	% of variance	Cumulative % of variance	Eigenvalue	% of variance	Cumulative % of variance
1	2.84	56.86	56.80	2.93	58.52	58.52
2	0.75	15.06	71.92	0.71	14.14	72.66
3	0.63	12.65	84.57	0.64	12.72	85.38
4	0.51	10.20	94.77	0.44	8.76	94.13
5	0.26	5.23	100.00	0.29	5.87	100.00

Table 10: Factor loadings and communalities for the Science, Technology, Engineering and Mathematics Semantics Survey based on varimax rotated one-factor solution at time 1 and time 2

	Time 1		Time 2	
	Factor loading	Communality	Factor loading	Communality
Dimension	1		1	
Level of interest in engineering	0.88	0.78	0.87	0.75
Level of interest in engineering career	0.76	0.57	0.76	0.58
Level of interest in technology	0.74	0.55	0.76	0.58
Level of interest in science	0.72	0.51	0.73	0.54
Level of interest in mathematics	0.65	0.43	0.69	0.48

4.2.2 Reasons for Choosing Engineering Questionnaire

The instrument to measure students' reasons for choosing engineering as their course of study at time 1 is adapted from Mahani and Molki (2011). The reasons for choosing engineering in this 16-item questionnaire comprises four dimensions which include the influence of role models (especially from parents and teachers), recruitment measures that influence students to take up engineering, the lure of good employment opportunities in engineering and self-perceived capability in mathematics and science that influence students to think that engineering is right for them.

The internal consistency reliability for the reasons for choosing engineering questionnaire ranged from 0.47 to 0.80, using the Cronbach's coefficient alpha. The results are shown in Table 11. A low Cronbach's coefficient alpha for self-perceived capability in mathematics and science could be due to the low number of questions in that subscale (three for this case).

Table 11: Cronbach's coefficient alpha for the reasons for choosing engineering survey

Dimension	Alpha
Influence of role models	0.77
Recruitment measures that influence students to take up engineering	0.80
Lure of good employment benefits in engineering	0.66
Self-perceived capability in mathematics and science	0.47

The 16 item scores of the reasons for choosing engineering survey were then subjected to principal components analysis using SPSS version 22. Prior to performing principal components analysis, the suitability of data for factor analysis was confirmed using the Kaiser-Meyer-Oklin value (0.87) and Bartlett's Test of Sphericity.

A principal components analysis with varimax rotation of the 16 items on the Reasons for Choosing Engineering Questionnaire was conducted on the data gathered from the combined group of students. The analysis revealed the presence of three components with eigenvalues exceeding 1, explaining 33.81%, 11.20% and 8.31% of the variance respectively. As components 1 and 2 captured more of the variance than the remaining components and were easier to interpret, it was decided to retain two components for further investigation. The two-factor solution therefore accounted for a total of 45.00% of the variance. The results of the varimax rotation of the two-factor solution are shown in Table 12.

Table 12: Factor loadings, communalities, eigenvalues and percentages of variance for the Reasons for Choosing Engineering Questionnaire based on varimax rotated two-factor solution

Items that influence students to choose engineering	Factor loading 1	2	Communality
Guidance counsellor	0.79	-0.03	0.62
Previous employment in engineering	0.75	-0.05	0.57
Open House experience	0.73	0.14	0.55
Career exhibitions experience	0.72	0.08	0.53
Advice from teachers	0.72	0.04	0.52
Advice from friends	0.71	-0.02	0.50
Engineering headstart, Red Camp experience	0.69	0.10	0.48
Advice from parents	0.60	0.81	0.40
General media	0.58	0.30	0.43
Status of engineering profession	0.55	0.44	0.49
High starting pay in engineering	0.51	0.31	0.35
Confidence of finding a job in engineering upon graduation	0.10	0.75	0.57
Wide range of career opportunities in engineering	0.04	0.69	0.48
Found engineering to be interesting all along	0.22	0.60	0.41
Self-perceived capability in mathematics	0.02	0.43	0.18
Self-perceived capability in science	-0.00	0.37	0.14

Factor	Eigenvalue	% of variance	Cumulative %
1	5.41	33.81	33.81
2	1.79	11.20	45.00

There were 11 items that loaded on the first factor. The highest item loadings on this factor were the influence of role models (guidance counsellors, employers in previous engineering employment, teachers, parents and friends), recruitment measures (open house, career exhibition, engineering headstart, red camp and media) that influence students to take up engineering and the lure of good employment benefits (high employability upon graduation, high status of engineering profession and high starting pay for engineering). This factor was therefore labelled as the external reasons for choosing engineering.

There were five items that loaded on the second factor. The highest item loadings on this factor were the students' interest in engineering prior to entering the polytechnic, perception about their ability in engineering related subjects (mathematics, science and engineering), the ease of finding a job and the exposure to a wide range of career opportunities upon graduation. This factor was therefore labelled as the internal reasons for choosing engineering. Hence in this study, summed scale scores for the external reasons for choosing engineering as well as the summed scale scores for internal reasons for choosing engineering were used in the subsequent analyses.

4.2.3 Approaches to Studying – the Revised Two Factor Study Process Questionnaire

The instrument to measure approaches to studying at time 1 follows the framework of the Revised Two Factor Study Process Questionnaire developed by Biggs et al. (2001). It is a 20-item questionnaire (Appendix 3) that contains ten items on deep approaches (with subscales of deep motive and deep strategy) and ten items on surface approaches (with subscales of surface motive and surface strategy).

The internal consistency reliability for Revised Two Factor Study Process Questionnaire was acceptable, with Cronbach's coefficient alpha ranging from 0.61 to 0.68. The results are shown in Table 13

Table 13: Cronbach's coefficient alpha for the Revised Two Factor Study Process Questionnaire

Dimension	Alpha
Deep motive	0.68
Deep strategy	0.61
Surface motive	0.64
Surface strategy	0.63

The 20 item scores of the Revised Two Factor Study Process Questionnaire were subjected to principal components analysis using SPSS version 22. Prior to performing principal components analysis, the suitability of data for factor analysis was confirmed using the Kaiser-Meyer-Oklin value (0.79) and Bartlett's Test of Sphericity.

A principal components analysis with varimax rotation of the 20 items from the Revised Two Factor Study Process Questionnaire was conducted on the 309 student responses. The analysis revealed the presence of five components with eigenvalues exceeding 1, explaining 20.26%, 17.45%, 7.19%, 6.23% and 5.34% of the variance respectively. As components 1 and 2 captured more of the variance than the remaining components and were easier to interpret, it was decided to retain two components for further investigation. The two-factor solution was also consistent with the previous research by Biggs et al. (2001). The two-factor solution accounted for a total of 37.71% of the variance. The results of the varimax rotation of the two-factor solution are shown in Table 14.

There were 10 items that loaded on the first factor. The highest item loadings on this factor were students who seek meaning, an understanding of underlying principles and the identification of relationships between ideas and concepts. This factor was therefore labelled as the deep approaches to studying.

There were 10 items that loaded on the second factor. The highest item loadings on this factor were students who tend to memorise factual information and reproduce material in a test or exam rather than fully understanding it. This factor was therefore labelled as the surface approaches to studying. Hence in this study, summed scale scores for the deep approaches to studying as well as the summed scale scores for the surface approaches to studying were used in the subsequent analyses.

Table 14: Factor loadings, communalities, eigenvalues and percentages of variance for the Revised Two Factor Study Process Questionnaire based on varimax rotated two-factor solution

Items	Factor loading 1	Factor loading 2	Communality
I find that at times studying gives me a feeling of deep personal satisfaction	0.70	-0.12	0.51
I find most new topics interesting and often spend extra time trying to obtain more information about them	0.67	-0.17	0.48
I find that studying academic topics to be as exciting as a good novel or movie	0.67	-0.04	0.45
I work hard at studies because I finds the material interesting	0.66	-0.21	0.48
I test myself on important topics until he/she understands them completely	0.58	0.03	0.34
I spend a lot of free time finding out more about interesting topics which have been discussed in different classes	0.55	-0.09	0.31
I feel that virtually any topic can be highly interesting once I get into it	0.54	-0.03	0.29
I make it a point of looking at most of the suggested readings that go with the lectures	0.53	0.09	0.29
I come to most classes with questions in mind that I want answering	0.51	0.24	0.31
I find that I have to do enough work on a topic so that I can form own conclusions before I am satisfied	0.50	-0.05	0.26
I generally restrict my study to what is specifically set as I think it is unnecessary to do extra	-0.02	0.74	0.54
I see no point in learning material which is not likely to be in the examination	-0.11	0.68	0.47

(Table 14 continued)

Items	Factor loading 1	2	Communality
I find it is not helpful to study topics in depth as it confuses and wastes time, when all you need is a passing acquaintance with topics	-0.04	0.63	0.40
I find the best way to pass examination is to try to remember answers to likely questions	0.18	0.62	0.42
I believe lecturers shouldn't expect students to spend significant amounts of time studying materials everyone knows won't be examined	-0.14	0.58	0.35
I find I can get by in most assessments by memorising key sections rather than trying to understand them	0.29	0.57	0.41
My aim is to pass the course while doing as little work as possible	-0.13	0.57	0.34
I only study seriously what's given out in class or in the course outlines	-0.12	0.56	0.33
I do not find my course very interesting so I keep my work to the minimum	-0.16	0.52	0.29
I learn most things by rote, going over and over them until I know them by heart even if I do not understand them	0.33	0.42	0.28

Factor	Eigenvalue	% of variance	Cumulative %
1	4.05	20.26	20.26
2	3.49	17.45	37.71

4.2.4 Motivational Goals – Motivated Strategies for Learning Questionnaire

The Motivated Strategies for Learning Questionnaire – motivation and self-efficacy sections (Pintrich et al., 1991) is a 31-item self-report scale with six dimensions that assess students' goals and value beliefs for a course, their beliefs about their skill to succeed in their course and their anxiety about tests in that course. The six dimensions are intrinsic goal orientation (four items), extrinsic goal orientation (four items), task value (six items), control beliefs (four items), test anxiety (five items) and self-efficacy for learning and performance (eight items). The last dimension on self-efficacy will be covered in the next section.

The internal consistency reliability for the Motivated Strategies for Learning Questionnaire – motivation and self-efficacy sections ranged from 0.68 (acceptable) to 0.93 (very good), using the Cronbach's coefficient alpha. The results are shown in Table 15.

Table 15: Cronbach's coefficient alpha for the Motivated Strategies for Learning Questionnaire – motivation and self-efficacy sections

Dimension	Alpha
Intrinsic goal orientation	0.68
Extrinsic goal orientation	0.75
Task value	0.82
Control beliefs	0.71
Self-efficacy	0.93
Test anxiety	0.74

The 31 item scores of the Motivated Strategies for Learning Questionnaire were subjected to principal components analysis using SPSS version 22. Prior to performing principal components analysis, the suitability of the data for factor analysis was confirmed using the Kaiser-Meyer-Oklin value (0.92) and Bartlett's Test of Sphericity.

A principal components analysis with varimax rotation of the 31 items from the Motivated Strategies for Learning Questionnaire was conducted on the 309 responses. The analysis yielded a six-factor solution with eigenvalues greater than 1.0, which together accounted for 61.26% of the variance. As the number of factors were also consistent with the previous research by Pintrich et al. (1991), the six-factor solution was retained for further investigation. Because of the large number of items involved here, the results of the varimax rotation of the six-factor solution are shown in Appendix 6.

As shown in Appendix 6, most of the items in each factor loaded as anticipated except for one in each case. To clarify, items such as tskv_4 and intr_24 have substantial loadings on two factors which as a result, comprised of a mix of items that appeared to measure different aspects of motivational goals. In addition, the sixth factor has only two items.

Previous research by Pintrich et al. (1991) had pointed out the suitability of a six-factor solution to measure students' motivational goals and self-efficacy. In addition, the current research had shown the six dimensions to be internally consistent where the items in each dimension are highly correlated with one another. Therefore for the Motivated Strategies for Learning Questionnaire, it was decided to retain the original six dimensions where the summed scores for the subscales in motivation (intrinsic motivation, control beliefs, task value, extrinsic motivation and test anxiety) and self-efficacy were used in the subsequent analysis. The dimension on self-efficacy will be elaborated further in the next section.

4.2.5 Self-efficacy - Motivated Strategies for Learning Questionnaire

As mentioned in Chapter Three on methods, the Motivated Strategies for Learning Questionnaire is chosen due to its vast usage in literature (cited more than 2000 times in google scholar as of May 2015) and the combination of motivation and self-efficacy in one instrument. For the dimension on self-efficacy for learning and performance, there are a total of eight items. From the earlier section, it was found that the internal consistency reliability for Motivated Strategies for Learning Questionnaire – self-efficacy section was very good, with a Cronbach's coefficient alpha of 0.93. Hence the eight items were grouped as a single component where the summed scale score of self-efficacy was used in the subsequent analysis.

4.2.6 Academic Buoyancy – the Academic Buoyancy Scale

The Academic Buoyancy Scale (Appendix 5) developed by Martin and Marsh (2008) was used to measure the academic buoyancy of students. There are a total of four items accounting for one dimension that measures students' confidence in dealing with setbacks, the effect of study stress, how well they deal with homework pressures and the effect of a bad mark on their confidence level.

The internal consistency reliability for the Academic Buoyancy Scale was very good, with a Cronbach's coefficient alpha of 0.84. As the Academic Buoyancy Scale only consisted of four items, factor analysis was not needed and these items were grouped as a single component where the summed scale score of academic buoyancy was used in the subsequent analysis.

In summary, the checks of internal consistency and exploratory factor analysis indicated a generally clear structure underpinning the set of instruments with each component internally consistent, although less so for motivational goals, self-efficacy and academic buoyancy. On the basis of this psychometric analysis, scale scores were calculated and the subsequent analysis used:

1. One scale score for the level of interest in engineering
2. Two scale scores for reasons that influence students to choose engineering, namely the external and internal reasons
3. Two scale scores for study approaches, namely the deep and surface approaches
4. Five scale scores for motivational goals, namely intrinsic, control beliefs, task value, extrinsic and test anxiety
5. One scale score for self-efficacy
6. One scale score for academic buoyancy

4.3 Analysis Two: level of interest in engineering and differences between groups at time 1 (Research Question One)

Research question one was: what is the level of interest in engineering at time 1 amongst three groups of diploma students (Engineering with Business Management, Engineering Science, and Electronic and Computer Engineering) and are there differences between the groups? To answer this research question, one overall level of interest in engineering scale score was created for each student, based on the sum of the 25 items for the Science, Technology, Engineering and Mathematics Semantics Survey. This yielded a score range of 25 to 175. Higher scores indicated higher levels of interest in engineering.

The levels of interest in engineering at time 1 among Engineering with Business Management, Engineering Science, and Electronic and Computer Engineering diploma groups were 127.68, 148.23 and 131.14 respectively (Figure 2). All scale scores were in the upper third of the scale values, indicating that students generally had a high level of interest in engineering. The level of interest in engineering at time 1 was highest for Engineering Science, followed by Electronic and Computer Engineering and Engineering with Business Management recorded the lowest level.

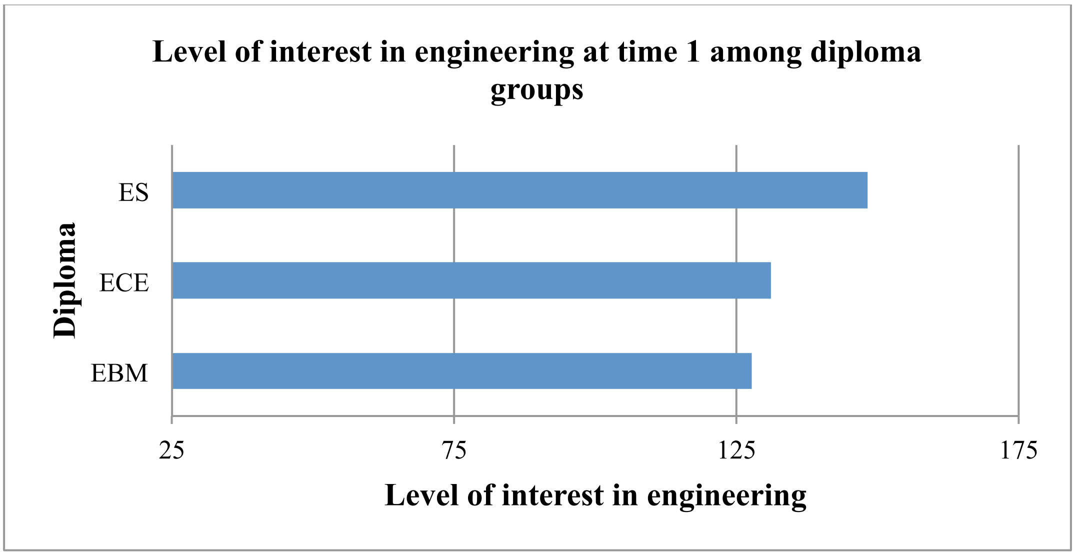

Figure 2. Graphical representation of the level of interest in engineering between Engineering with Business Management (EBM), Electronic and Computer Engineering (ECE), and Engineering Science (ES) diploma groups at time 1.

Analysis of variance (ANOVA) was used to investigate the statistical significance of differences in the level of interest in engineering at time 1 between the three diploma groups: Engineering with Business Management, Electronic and Computer Engineering, and Engineering Science. There was a statistically significant difference in the level of interest in engineering scale scores for the three diploma groups: $F (2, 306) = 14.27$, $p < 0.01$. The actual difference in scale scores between the groups was moderate since the effect size, calculated using eta squared, was 0.09. Using Cohen's (1985) guidelines, an effect size of 0.01 is small, 0.06 is moderate and 0.14 is large. Post-hoc comparisons using the Tukey HSD test indicated that at time 1, the scale score for Engineering with Business Management ($M = 127.68$, $SD = 21.41$) was significantly lower than

Engineering Science (M = 148.23, SD = 18.98); and Electronic and Computer Engineering (M = 131.14, SD = 20.02) was also significantly lower than Engineering Science (M = 148.23, SD = 18.98). However Engineering with Business Management did not differ significantly from Electronic and Computer Engineering. Table 16 summarizes these results for the level of interest in engineering at time 1.

Table 16: Means, standard deviations and one-way analysis of variance for the level of interest in engineering at time 1

	EBM (n = 165)		ECE (n = 109)		ES (n = 35)		ANOVA	
Variable	M	SD	M	SD	M	SD	F (2, 306)	η^2
Level of interest in engineering	127.68	21.41	131.14	20.02	148.23	18.98	14.27*	0.09

Note:
1. All items were rated on a seven point Likert-type scale. Summing the 25 items in the Science, Technology, Engineering and Mathematics Semantics Survey gave a scale score that ranged from 25 to 175.
2. EBM = Engineering with Business Management; ECE = Electronic and Computer Engineering; ES = Engineering Science; η^2 = effect size.

* $p < 0.05$.

4.4 Analysis Three: level of interest in engineering and differences between groups at time 2 (Research Question Two)

Research question two was: what is the level of interest in engineering at time 2 amongst three groups of diploma students (Engineering with Business Management, Engineering Science, and Electronic and Computer Engineering) and are there differences between the groups? Once again, one overall level of interest in engineering scale score was created, based on the sum of the 25 items for the Science, Technology, Engineering and Mathematics Semantics Survey administered at time 2. As before, this yielded a score range of 25 to 175, and higher scores indicated higher levels of interest in engineering.

The levels of interest in engineering at time 2 among Engineering with Business Management, Engineering Science, and Electronic and Computer Engineering diploma groups were 127.09, 147.83 and 129.05 respectively (Figure 3). All scale scores were again in the upper third of the scale values, indicating that students again generally had a high level of interest in engineering. The level of interest in engineering at time 2 was highest for Engineering Science, followed by Electronic and Computer Engineering and Engineering with Business Management recorded the lowest level. This was similar to time 1.

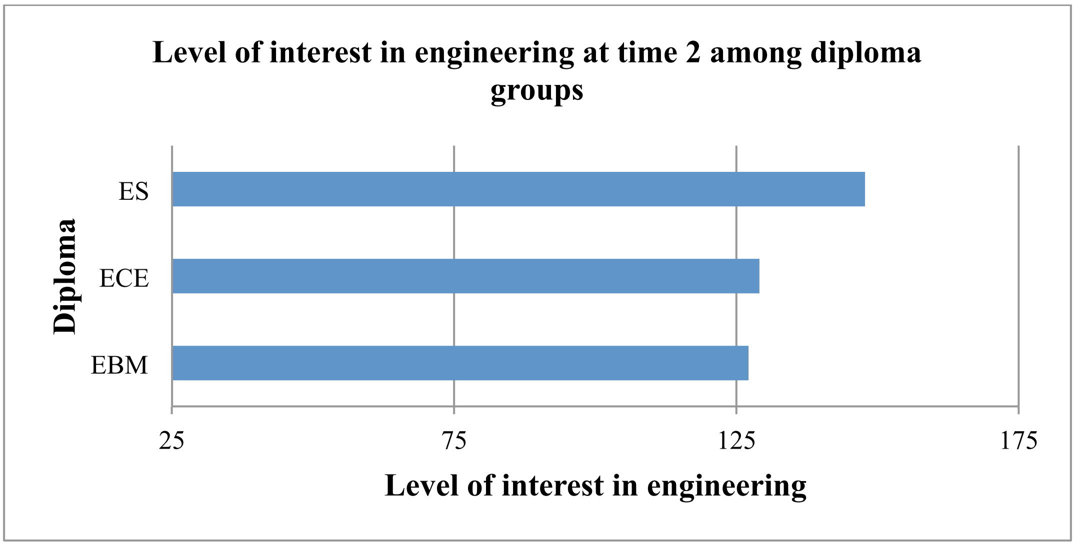

Figure 3. Graphical representation of the level of interest in engineering between Engineering with Business Management (EBM), Electronic and Computer Engineering (ECE), and Engineering Science (ES) diploma groups at time 2.

Once again, there was a statistically significant difference in the level of interest in engineering scale scores for the three diploma groups: $F (2, 306) = 13.34$, $p < 0.01$. The actual difference in the scale scores between the groups was again moderate since the effect size, calculated using eta squared, was 0.08. Post-hoc comparisons using the

Tukey HSD test indicated that at time 2, the scale score for Engineering with Business Management (M = 127.09, SD = 24.00) was significantly lower than Engineering Science (M = 147.83, SD = 17.47); and Electronic and Computer Engineering (M = 129.05, SD = 19.21) was significantly lower than Engineering Science (M = 147.83, SD = 17.47). However Engineering with Business Management did not differ significantly from Electronic and Computer Engineering. These results are similar to those at time 1. Table 17 summarizes these results for the level of interest in engineering at time 2. It is clear that there is an overall drop in the level of interest in engineering for each diploma group from time 1 to time 2, but it is not a large drop. A more detailed treatment on the change in the level of interest in engineering will be covered in section 4.5.

Table 17: Means, standard deviations and one-way analysis of variance for the level of interest in engineering at time 2

	EBM (n = 165)		ECE (n = 109)		ES (n = 35)		ANOVA	
Variable	M	SD	M	SD	M	SD	F (2, 306)	η^2
Level of interest in engineering	127.09	24.00	129.05	19.21	147.83	17.47	13.34*	0.08

Note:
1. All items were rated on a seven point Likert-type scale. Summing of the 25 items in the Science, Technology, Engineering and Mathematics Semantics Survey gave a scale score that ranged from 25 to 175.
2. EBM = Engineering with Business Management; ECE = Electronic and Computer Engineering; ES = Engineering Science; η^2 = effect size.
   - $p < 0.05$.

4.5 Analysis Four: change in level of interest in engineering and differences between groups (Research Question Three)

Based on the results obtained from research questions one and two, there was a general trend of decreasing level of interest in engineering among all diploma groups from time 1 to time 2, as indicated in Figure 4. The change in the level of interest in engineering from time 1 to time 2 was highest for Electronic and Computer Engineering, followed by Engineering with Business Management and Engineering Science recorded the lowest change.

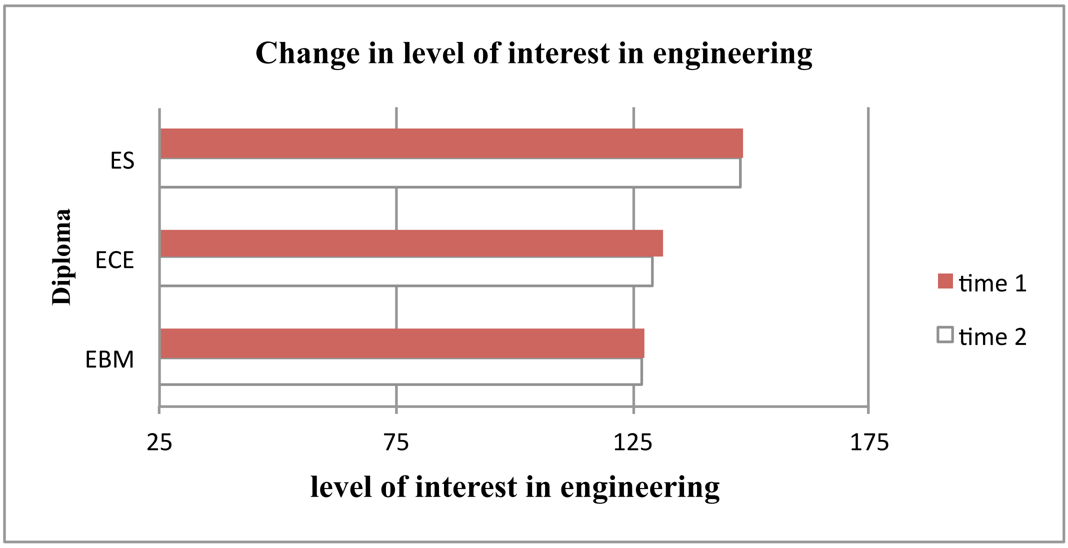

Figure 4. Graphical representation of the change in the level of interest in engineering between Engineering with Business Management (EBM), Electronic and Computer Engineering (ECE), and Engineering Science (ES) diploma groups.

This is formalized in research question three: what is the change in the level of interest in engineering amongst three groups of diploma (Engineering with Business Management, Engineering Science, and Electronic and Computer Engineering) and are there differences between the groups in this change? To answer this research question, one overall change in the level of interest in engineering scale score was created for each student, based on the difference in the sum of the 25 items for the Science, Technology, Engineering and Mathematics Semantics Survey at time 1 and time 2. This meant the change score from time 1 to time 2 was computed for each student by subtracting each person's time 1 score from his or her time 2 score (that is, change score = time 2 scale score – time 1 scale score). This yielded a change score possible range of -150 to 150. A positive change score indicated an increase in the level of interest in engineering from time 1 to time 2. Conversely, a negative change score indicated a drop in the level of interest in engineering from time 1 to time 2. The numbers of students who reported a decrease, increase and no change in their level of interest in engineering are summarized in Table 18. For each diploma group, the number of students who reported decrease in the level of interest in engineering is almost equal to those who reported increase in the level of interest in engineering. This supports the small changes in the overall level of interest in engineering, which will be seen later in Table 19.

Table 18: Number of students who reported decrease, increase and no change in their level of interest in engineering over a semester of study

Diploma group	Number of students who reported decrease in level of interest	Number of students who reported increase in level of interest	Number of students who reported no change in level of interest
EBM	78	80	7
ECE	55	48	6
ES	20	15	0

Note:
EBM = Engineering with Business Management; ECE = Electronic and Computer Engineering; ES = Engineering Science.

Using ANOVA, there was no statistically significant difference in the change in the level of interest in engineering scale scores for the three diploma groups: $F(2, 306) = 0.26$, $p = 0.77$. The actual difference in the change scores between the groups was very small since the effect size, calculated using eta squared, was 0.002. Table 19 summarizes these results for the change in the level of interest in engineering from time 1 to time 2.

Table 19: Means, standard deviations and one-way analysis of variance for the change in the level of interest in engineering

	EBM (n = 165)		ECE (n = 109)		ES (n = 35)		ANOVA	
Variable	M	SD	M	SD	M	SD	F (2, 306)	η^2
Change in level of interest in engineering	-0.59	19.76	-2.09	15.53	0.40	-14.77	0.26	0.002

Note:

1. All items were rated on a seven point Likert-type scale. Change score from time 1 to time 2 was computed for each student by subtracting each person's time 1 score from his or her time 2 score (that is, change score = time 2 scale score – time 1 scale score). This yielded a change score possible range of -150 to 150.
2. EBM = Engineering with Business Management; ECE = Electronic and Computer Engineering; ES = Engineering Science; η^2 = effect size.

In section 4.3, there was a statistically significant difference beyond the $p < 0.05$ in the level of interest in engineering scale scores at time 1 for the three diploma groups. As noted, the change scores were calculated based on the difference between time 1 and time 2 scale scores for the level of interest in engineering. But there can be psychometric problems with the change scores calculated this way. In particular, such change scores can be a function of the level of interest in engineering scale scores at time 1. One way to deal with this is to control for the pre-existing differences between the diploma groups (Harris, 1967; Gottman & Rushe, 1993). An analysis of covariance (ANCOVA) was conducted to remove the effects of time 1 scale scores from the change scale scores in the level of interest in engineering. After adjusting for the level of interest in engineering scale score at time 1, once again, there was no statistically significant difference in the change in the level of interest in engineering scale scores for the three diploma groups: F (2, 306) = 3.03, p = 0.051. The actual difference in the change scores between the groups was small since the effect size, calculated using eta squared, was 0.02. Table 20 summarizes the results of the ANCOVA for the change scores in the level of interest in engineering, after adjusting for the level of interest in engineering scale score at time 1.

Table 20: Means, standard deviations and one-way analysis of covariance for the change in the level of interest in engineering, after adjusting for the level of interest in engineering scale score at time 1

	EBM (n = 165)		ECE (n = 109)		ES (n = 35)		ANCOVA	
Variable	M	SD	M	SD	M	SD	F (2, 306)	η^2
Change in level of interest in engineering	-0.20	8.27	-1.71	7.58	-3.46	6.60	3.00	0.02

Note:
1. All items were rated on a seven point Likert-type scale. Change score from time 1 to time 2 was computed for each student by subtracting each person's time 1 score from his or her time 2 score (that is, change score = time 2 scale score – time 1 scale score). This yielded a change score possible range of -150 to 150.
2. EBM = Engineering with Business Management; ECE = Electronic and Computer Engineering; ES = Engineering Science; η^2 = effect size.

4.6 Analysis Five – bivariate relationship between the variables (Research Question Four)

Research question four was: what is the bivariate relationship between each of the student characteristics (reasons that influence students to choose, study approaches, motivational goals, self-efficacy and academic buoyancy) and the level of interest in engineering (at time 1 and time 2)? In this section, the bivariate relationship between 13 scale scores (level of interest in engineering at time 1 – one scale score, level of interest in engineering at time 2 – 1 scale score, reasons that influence students to choose engineering – two scale scores, study approaches – two scale scores, motivational goals – five scale scores, self-efficacy – one scale score and academic buoyancy – one scale score) was investigated using the Pearson product-moment correlation. Based on earlier psychometric analysis, the 13 scale scores for each student were created as follows:

1. An overall level of interest in engineering scale score at time 1 was based on the sum of the 25 items for the Science, Technology, Engineering and Mathematics Semantics Survey at the start of the semester.
2. An overall level of interest in engineering scale score at time 2 was based on the sum of the 25 items in the same survey as above at the end of the semester.
3. An external reasons scale score was based on the sum of 11 relevant items of the Reasons for Choosing Engineering Questionnaire. The items included the influence of role models (guidance counsellors, employers in previous engineering employment, teachers, parents and friends), recruitment measures (open house, career exhibition, engineering headstart, red camp and media) that influence students to take up engineering and the lure of good employment benefits (high employability upon graduation, high status of engineering profession and high starting pay for engineering).
4. An internal reasons scale score was based on the sum of five relevant items of the Reasons for Choosing Engineering Questionnaire. The items included students' interest in engineering, perception about their ability in engineering related subjects (mathematics, science and engineering), the ease of finding a job and the exposure to a wide range of career opportunities upon graduation.
5. A deep approaches scale score was based on the sum of ten relevant items of the Revised Two Factor Study Process Questionnaire. The items included students

who take an understanding approach to learning by engaging in an active search for the meaning behind what they learn.

6. A surface approaches scale score was based on the sum of ten relevant items of the Revised Two Factor Study Process Questionnaire. The items included students who take a reproduction approach to learning with the focus on memorizing part of the learning materials which they think will be tested on.
7. An intrinsic motivation scale score was based on the sum of four relevant items of the Motivated Strategies for Learning Questionnaire – motivation section. The items included the degree to which the student perceives himself/herself to be participating in a task for reasons such as challenge, curiosity and mastery.
8. A control beliefs scale score was based on the sum of four relevant items of the same motivated strategies questionnaire. The items included students' beliefs that their efforts to learn will result in positive outcomes.
9. A task value scale score was based on the sum of six relevant items of the same motivated strategies questionnaire. The items included students' perception of the course material in terms of interest (subjective interest in the topic itself), importance (of doing the task well - attainment value) and utility (how well the task relates to current or future goals such as career goals).
10. An extrinsic motivation scale score was based on the sum of four relvant items of the same motivated strategies questionnaire. The items included degree to which the student perceives himself/herself to be participating in a task for reasons such as grades, rewards, performance, and evaluation by others and in competition.
11. A test anxiety scale score was based on the sum of five relevant items of the same motivated strategies questionnaire. The items included students' feelings of worry and self-doubt that can interfere with test-taking performance.

12. A self-efficacy scale score was based on the sum of eight relevant items of the Motivated Strategies for Learning Questionnaire – self-efficacy section. The items included self-appraisal of one's ability to master a task.
13. An academic buoyancy scale score was based on the sum of all four items of the Academic Buoyancy Scale.

The correlations are shown in Table 21. The highest correlations (above 0.65) were between the level of interest in engineering at time 1 and that at time 2 ($r = 0.68$); between deep approaches to studying and intrinsic motivation (0.65); and between intrinsic motivation and task value (0.67). Task value had high positive correlations with other scores. These high correlations indicate strong relationships between task value and other variables. On the other hand, test anxiety had low positive correlations with other scores.

The relationships between the levels of interest in engineering and most student characteristic scores were generally significant. At time 1, there were significant positive correlations between the level of interest in engineering and other scores except test anxiety. At time 2, there were significant positive correlations between the level of interest in engineering and other scores except test anxiety and external reasons for choosing engineering.

The differences in the magnitude of correlations between the level of interest in engineering and each of the student characteristics with more than one dimension were also examined. Among the reasons for choosing engineering, the correlation between the level of interest in engineering at time 1 and internal reasons for choosing engineering was significantly higher than that between the level of interest in engineering at time 1 and external reasons for choosing engineering. For approaches to studying, the correlation between the level of interest in engineering at time 1 and deep approaches to studying was significantly higher than that between the level of interest in engineering at time 1 and surface approaches to studying. For motivational goals, the correlation between the level of interest in engineering at time 1 and task value was significantly higher than that between the level of interest in engineering at time 1 and other motivation goals. Similar pattern of correlations were found for the level of interest in engineering at time 2.

In summary, the study of the bivariate relationships between the variables indicated the following:

1. There were strong relationships between the level of interest in engineering at time 1 and time 2; between deep approaches to studying and intrinsic motivation; between intrinsic motivation and task value; and between task value and other variables, as shown by the high correlation coefficient values.
2. There was a low correlation between test anxiety and other variables.
3. There were strong relationships between the levels of interest in engineering and most student characteristics.
4. There were strong relationships between the level of interest in engineering and internal reasons for choosing engineering; between the level of interest in engineering and deep approaches to studying; and between the level of interest in engineering and task value as a motivational goal.

Table 21: Correlations for scores on student characteristics and levels of interest in engineering

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Time 1 interest	--													
2. Time 2 interest	0.68*	--												
3. External reasons	0.12*	0.10	--											
4. Internal reasons	0.51*	0.47*	0.48*	--										
5. Deep approach	0.45*	0.41*	0.42*	0.47*	--									
6. Surface approach	-0.19*	-0.21*	0.24*	-0.04	-0.04	--								
7. Intrinsic motivation	0.44*	0.38*	0.19*	0.42*	0.65*	-0.13*	--							
8. Control beliefs	0.34*	0.27*	0.09	0.27*	0.47*	-0.12*	0.60*	--						
9. Task value	0.56*	0.49*	0.19*	0.52*	0.59*	-0.24*	0.67*	0.64*	--					
10. Extrinsic motivation	0.17*	0.14*	0.08	0.18*	0.20*	0.15*	0.35*	0.51*	0.37*	--				
11. Test anxiety	0.02	0.03	0.10	-0.11	0.10	0.24*	0.15*	0.21*	0.14*	0.32*	--			
12. Self-efficacy	0.41*	0.36*	0.22*	0.54*	0.51*	-0.05	0.58*	0.46*	0.63*	0.36*	-0.15*	--		
13. Buoyancy	0.15*	0.13*	0.17*	0.27*	0.34*	-0.01	0.34*	0.29*	0.33*	0.08	-0.29*	0.56*	--	

* For $N = 309$, $r \geq 0.10$, $p < 0.05$

4.7 Analysis Six: joint relationships between student characteristics and the level of interest in engineering (Research Question Five)

Research question five was: what is the relationship between student characteristics (reasons for choosing engineering, study approaches, motivational goals, self-efficacy and academic buoyancy) as the independent variables, and the level of interest in engineering as the dependent variable? Multiple linear regression was used to analyze the joint relationships between the variables in these steps. The first two steps investigate to what extent student characteristics account for the variance in the level of interest in engineering at time 1 and the level of interest in engineering at time 2 respectively. The third and last step investigates to what extent both student characteristics and the level of interest in engineering at time 1 account for the variance in the level of interest in engineering at time 2.

In the first step, the regression model used student characteristics as the independent variables, and the level of interest in engineering at time 1 as the dependent variable. The student characteristics together accounted for 42.0% of the variance in the level of interest in engineering at time 1 ($R_1^2 = 0.42$, $F_1 = 19.58$, $p < 0.05$). Of these student characteristics, internal reasons for choosing engineering ($\beta_1 = 0.35$, $p < 0.05$) were the most important predictor of the level of interest in engineering at time 1. Other student characteristics such as task value as a motivational goal ($\beta_1 = 0.29$, $p < 0.05$), deep approaches to studying ($\beta_1 = 0.19$, $p < 0.05$) and external reasons for choosing engineering ($\beta_1 = -0.17$, $p < 0.05$) also reached statistical significance.

In the second step, the regression model used student characteristics as the independent variables, and the level of interest in engineering at time 2 as the dependent variable. Here, the student characteristics together accounted for 35.1% of the variance in the level of interest in engineering at time 2 ($R_2^2 = 0.35$, $F_2 = 14.61$, $p < 0.05$). Of these student characteristics, internal reasons for choosing engineering ($\beta_2 = 0.35$, $p < 0.05$) were again the most important predictor of the level of interest in engineering at time 2. Other student characteristics such as task value as a motivational goal ($\beta_2 = 0.23$, $p < 0.05$), deep approaches to studying ($\beta_2 = 0.20$, $p < 0.05$) and external reasons for choosing engineering ($\beta_2 = -0.16$, $p < 0.05$) also made statistical significance. These results were similar to the first step as described earlier. The full results in first and second steps are shown in Table 22.

Table 22: Regression analysis summary for student characteristics accounting for the variance in the level of interest in engineering at time 1 and time 2

Independent variable	β_1	R_1^2	β_2	R_2^2
		0.42*		0.35*
External reasons	-0.17*		-0.16*	
Internal reasons	0.35*		0.35*	
Deep approach	0.19*		0.20*	
Surface approach	-0.05		-0.12	
Intrinsic motivation	0.02		0.00	
Control beliefs	0.00		-0.07	
Task value	0.29*		0.23*	
Extrinsic motivation	-0.03		-0.01	
Test anxiety	0.01		0.06	
Self-efficacy	0.04		0.03	
Buoyancy	-0.10		-0.06	

* $p < 0.05$.
For time 1: $R_1^2 = 0.42$, F_1 (11, 297) = 19.58, $p < 0.05$
For time 2: $R_2^2 = 0.35$, F_2 (11, 297) = 14.61, $p < 0.05$

In the third and last step, the regression model used both student characteristics and the level of interest in engineering at time 1 as the independent variables, and the level of interest in engineering at time 2 as the dependent variable. This time, the student characteristics together with the level of interest in engineering at time 1 accounted for 50.1% of the variance in the level of interest in engineering at time 2 ($R_3^2 = 0.50$, $F_3 = 24.80$, $p < 0.05$). The level of interest in engineering at time 1 ($\beta_3 = 0.51$, $p < 0.05$) was the most important predictor of the level of interest in engineering at time 2. One other student characteristic - internal reasons for choosing engineering ($\beta_2 = 0.17$, $p < 0.05$) - also reached statistical significance. The full results in the third step are shown in Table 23.

Table 23: Regression analysis summary for student characteristics and the level of interest in engineering at time 1 accounting for the variance in the level of interest in engineering at time 2

Independent variables	β_3	R_3^2
		0.501*
External reasons	-0.08	
Internal reasons	0.17*	
Deep approach	0.10	
Surface approach	-0.09	
Intrinsic motivation	-0.01	
Control beliefs	-0.07	
Task value	0.09	
Extrinsic motivation	0.01	
Test anxiety	0.06	
Self-efficacy	0.01	
Buoyancy	-0.01	
Time 1 interest	0.51*	

* $p < 0.05$

In summary, the results in the three steps of the multiple linear regression analysis indicated the following:

1. Student characteristics had a large effect on the level of interest in engineering at both time 1 and 2, as shown by the R^2 values of 0.420 and 0.351 in steps one and two respectively. Internal reasons for choosing engineering were the most important predictor of the level of interest in engineering at time 1 and time 2. To a lesser degree, task value as a motivational goal, deep approaches to studying and external reasons for choosing engineering were also predictors of the level of interest in engineering at time 1 and time 2.
2. Student characteristics together with the level of interest in engineering at time 1 had a large effect on the level of interest in engineering at time 2 as shown by the R^2 value of 0.510 in step three. The level of interest in engineering at time 1 was the most important predictor for the level of interest in engineering at time 2. Among the student characteristics, internal reasons for choosing engineering were also another significant predictor of the level of interest in engineering at time 2.

4.8 Summary

Chapter Four has reported the results obtained from the data analysis. Results of the six analyses are summarized below.

Analysis one focusing on the psychometric properties has indicated a generally clear structure underpinning the set of instruments with each component internally consistent. The analysis has generated: one overall scale score for the level of interest in engineering; two scale scores for reasons that influence students to choose engineering (the external and internal reasons); two scale scores for study approaches (the deep and surface approaches); five scale scores of motivational goals (intrinsic, control beliefs, task value, extrinsic and test anxiety); one scale score of self-efficacy; and one scale score of academic buoyancy.

Analysis two reported the level of interest in engineering at time 1 and the differences between the diploma groups, in response to research question one. It was found that students generally had a high level of interest in engineering. The level of interest in engineering at time 1 was highest for Engineering Science, followed by Electronic and Computer Engineering and Engineering with Business Management recorded the lowest level. The level of interest in engineering at time 1 for Engineering with Business Management was significantly different from Engineering Science; and Electronic and Computer Engineering was significantly different from Engineering Science. Engineering with Business Management did not differ significantly from Electronic and Computer Engineering.

Analysis three reported the level of interest in engineering at time 2 and the differences between the diploma groups, in response to research question two. Again, it was found that students generally had a high level of interest in engineering. The level of interest in engineering at time 2 was again highest for Engineering Science, followed by Electronic and Computer Engineering and Engineering with Business Management recorded the lowest level. The level of interest in engineering at time 2 for Engineering with Business Management was significantly different from Engineering Science; and Electronic and Computer Engineering was significantly different from Engineering Science. Engineering with Business Management did not differ significantly from Electronic and Computer Engineering. These trends were similar to those observed at time 1.

Analysis four reported the change in the level of interest in engineering and differences between the diploma groups, in response to research question three. There was a decreasing trend in the level of interest in engineering for all diploma groups from time 1 to time 2, although the drop was not large. Even after controlling for the level of interest in engineering at time 1, there was no significant difference in the change in the level of interest in engineering between the diploma groups.

Analysis five, in response to research question four on the bivariate relationships between variables, provided correlations between the 13 scale scores and reported many strong positive correlations between them. Firstly, the highest correlation was between the level of interest in engineering at time 1 and that at time 2. Task value had high positive correlations with other scores while test anxiety had low positive correlations with other scores. Secondly, the levels of interest in engineering at time 1 and time 2 correlated strongly with other scores. Thirdly, the differences in the magnitude of correlations between the level of interest in engineering and each of the student characteristics with more than one dimension were also examined. Among the reasons for choosing engineering, the correlation between the level of interest in engineering at time 1 and internal reasons for choosing engineering was significantly higher than that between the level of interest in engineering at time 1 and external reasons for choosing engineering. For approaches to studying, the correlation between the level of interest in engineering at time 1 and deep approaches to studying was significantly higher than that between the level of interest in engineering at time 1 and surface approaches to studying. For motivational goals, the correlation between the level of interest in engineering at time 1 and task value was significantly higher than that between the level of interest in engineering at time 1 and other motivation goals. A similar pattern of correlation was found for the level of interest in engineering at time 2.

Analysis six reported the joint relationships between student characteristics and the level of interest in engineering, in response to research question five. It was found that student characteristics had a large effect on the level of interest in engineering at both time 1 and 2. Internal reasons for choosing engineering were the most important predictor of the level of interest in engineering. To a lesser degree, task value as a motivational goal, deep approaches to studying and external reasons for choosing engineering were also predictors of the level of interest in engineering. It was also found that student characteristics together with the level of interest in engineering at time 1 had a large effect on the level of interest in engineering at time 2. The level of interest in engineering at time 1 was the most important predictor. Among the student characteristics, internal reasons for choosing engineering were also another significant predictor of the level of interest in engineering at time 2.

The next chapter will provide a summary of the research and the results obtained, the conclusions that arise as well as a general discussion of the study in the light of the research questions and literature reviewed. Implications of the findings, limitations of the research and directions for future research are also suggested.

CHAPTER FIVE

SUMMARY, CONCLUSION, DISCUSSION AND IMPLICATIONS

5.1 Introduction

Chapter Five presents a summary of the research and the results obtained, the conclusions that arise as well as a general discussion of this study in the light of the research questions and literature reviewed. Implications of the findings, limitations of the research as well as directions for future research are also suggested.

5.2 Summary of Research

There are global concerns over the declining interest in engineering that need to be investigated. The continuing trend will lead to a shortage of engineers to meet the new demands of globalisation. More needs to be done to learn about the declining trend in the level of interest in engineering – the central problem in the current research.

Due to the advancements in technology, the social context of teaching and learning is no longer the same as before and a new generation of students with different characteristics has emerged. It is therefore important to attract the right pool of students with unique student characteristics to engineering and to maintain or enhance the level of interest in engineering in existing students.

Very little research has been published that explicitly identifies student characteristics that may be associated with students' level of interest in engineering. It is therefore important to study the relationship between these variables.

Thus the purpose of the present research is to fill an important gap in the growing literature by investigating the relationship between a set of student characteristics and the level of interest in engineering over a semester of study. There may be many student characteristics that engineering students need to have in order to develop and maintain their interest in engineering and to learn engineering effectively. A full discussion of all these characteristics is beyond the scope of this study, which has instead focused on the five characteristics of the reasons for choosing engineering, study approaches, motivational goals, self-efficacy and academic buoyancy. These characteristics are chosen mainly from the researcher's own experience in teaching polytechnic engineering students, and because they are supported in other research that has been covered in the literature review chapter (Chapter Two).

From the review of the literature, the following research questions were generated:

1. What is the level of interest in engineering at the start of the semester amongst three groups of diploma students (Engineering with Business Management, Engineering Science, and Electronic and Computer Engineering)? Are there any differences between the groups in their level of interest in engineering?
2. What is the level of interest in engineering at the end of the same semester amongst the three groups of diploma students (Engineering with Business Management, Engineering Science, and Electronic and Computer Engineering)? Are there any differences between the groups in their level of interest in engineering?
3. What is the change in the level of interest in engineering between the start and end of semester? Are there any differences between the groups in their change in level of interest in engineering?
4. What is the bivariate relationship between each of the student characteristics (reasons for choosing engineering, study approaches, motivational goals, self-efficacy and academic buoyancy) and the level of interest in engineering?

5. What is the joint relationship between student characteristics (reasons for choosing engineering, study approaches, motivational goals, self-efficacy and academic buoyancy) as independent variables, and the level of interest in engineering as dependent variable?

Based on the above research questions, the following variables were measured: the level of interest in engineering at the start and end of the semester and the five student characteristics of the reasons for choosing engineering, study approaches, motivational goals, self-efficacy and academic buoyancy. Measuring instruments for these characteristics followed the frameworks suggested by Mahani and Molki (2011), Biggs et al. (2001), Pintrich et al. (1991) and Martin and Marsh (2009) respectively. The instrument for measuring the level of interest in engineering was based on that reported by Tyler-Wood et al. (2010).

At the start of the semester in April 2014, students' level of interest in engineering as well as the student characteristics were measured using an online survey Instrument 1. At the end of the semester in September 2014, only students' level of interest in engineering was measured using an online survey Instrument 2. Of the 689 first-year students who were invited to participate in the research, 335 students completed Instrument 1; 316 students completed Instrument 2 and a total of 309 students completed both instruments. The final sample for the research thus involved 309 first-year students from the Engineering with Business Management, Engineering Science, and Electronic and Computer Engineering diploma programmes, from one polytechnic in Singapore.

Data analysis of the large database was conducted in six parts using psychometric analysis, analysis of variance, analysis of covariance, Pearson product-moment correlation and multiple linear regression in response to the research questions. The next section provides a summary of the results obtained from these analyses.

5.3 Summary of results

The variables in the research included the level of interest in engineering and the student characteristics of the reasons for choosing engineering, study approaches, motivational goals, self-efficacy and academic buoyancy. The results of the six analyses of the data are summarized in this section.

Firstly, the checks of internal consistency and exploratory factor analysis reported in analysis one indicated a generally clear structure underpinning the set of instruments with each component internally consistent, although less so far for motivational goals, self-efficacy and academic buoyancy. On the basis of this psychometric analysis, scale scores were calculated and used in subsequent analysis as follows:

- One scale score each for the level of interest in engineering at time 1 and time 2
- Two scale scores for reasons that influence students to choose engineering, namely the external and internal reasons
- Two scale scores for study approaches, namely the deep and surface approaches
- Five scale scores for motivational goals, namely intrinsic, control beliefs, task value, extrinsic and test anxiety
- One scale score for self-efficacy
- One scale score for academic buoyancy

The following sections summarize the results obtained from the data analysis in response to the research questions.

5.3.1 Research Question One: finding levels of interest in engineering and investigating differences between diploma groups at time 1

Analysis two reported the level of interest in engineering at time 1 and the differences between the diploma groups, in response to research question one. It was found that students generally had a high level of interest in engineering. On a score range of 25 to 175, the level of interest in engineering at time 1 was highest for Engineering Science (148.23), followed by Electronic and Computer Engineering (131.14) and Engineering with Business Management (127.68) recorded the lowest level. The level of interest in engineering at time 1 for Engineering with Business Management was significantly different from Engineering Science; and Electronic and Computer Engineering was significantly different from Engineering Science. Engineering with Business Management did not differ significantly from Electronic and Computer Engineering.

5.3.2 Research Question Two: finding levels of interest in engineering and investigating differences between diploma groups at time 2

Analysis three reported the level of interest in engineering at time 2 and the differences between the diploma groups, in response to research question two. Again, students generally had a high level of interest in engineering. On a score range of 25 to 175, the level of interest in engineering at time 2 was again highest for Engineering Science (147.83), followed by Electronic and Computer Engineering (129.05) and Engineering with Business Management (127.09) again recorded the lowest level. The level of interest in engineering at time 2 for Engineering with Business Management was significantly different from Engineering Science; and Electronic and Computer Engineering was significantly different from Engineering Science. Engineering with Business Management did not differ significantly from Electronic and Computer Engineering. These are very similar findings to those reported in analysis two at time 1.

5.3.3 Research Question Three: examining changes in levels of interest in engineering and investigating differences between diploma groups

Analysis four reported the change in the level of interest in engineering and differences between the diploma groups, in response to research question three. Based on the results obtained from research questions one and two, there was a general trend of decreasing level of interest in engineering among all diploma groups from time 1 to time 2, but the drop was not large. For each diploma group, the number of students who reported decrease in the level of interest in engineering is almost equal to those who reported increase in the level of interest in engineering.

These change scores were calculated based on the differences between time 1 and time 2 scale scores for the level of interest in engineering. There was no statistically significant difference in the change scores between the diploma groups. Even after controlling for the level of interest in engineering at time 1, there was no significant difference in the change in the level of interest in engineering between the diploma groups.

5.3.4 Research Question Four: examining relationships between variables

Analysis five, in response to research question four on the bivariate relationship between the variables, reported correlations between the 13 scale scores and revealed many strong positive correlations between them. Firstly, the highest correlation was between the level of interest in engineering at time 1 and that at time 2. Task value had high positive correlations with other scores while test anxiety had low positive correlations with other scores. Secondly, the levels of interest in engineering at time 1 and time 2 correlated strongly with other scores. Thirdly, the differences in the magnitude of correlations between the level of interest in engineering and each of the student characteristics with more than one dimension were also investigated. Among the reasons for choosing engineering, the correlation between the level of interest in engineering at time 1 and internal reasons for choosing engineering was higher than that between the level of interest in engineering at time 1 and external reasons for choosing engineering. For approaches to studying, the correlation between the level of interest in engineering at time 1 and deep approaches to studying was higher than that between the level of interest in engineering at time 1 and surface approaches to studying. For motivational goals, the correlation between the level of interest in engineering at time 1 and task value was higher than that between the level of interest in engineering at time 1 and other motivation goals. Similar patterns of correlations were found for the level of interest in engineering at time 2.

5.3.5 Research Question Five: predicting level of interest in engineering

Analysis six reported the joint relationships between student characteristics and the level of interest in engineering, in response to research question five. Student characteristics together accounted for 42.0% and 35.0% of the variance in the level of interest in time 1 and time 2 respectively. Internal reasons for choosing engineering were the most important predictor of the level of interest in engineering. To a lesser degree, task value as a motivational goal, deep approaches to studying and external reasons for choosing engineering were also predictors of the level of interest in engineering.

Finally, student characteristics together with the level of interest in engineering at time 1 accounted for 50.1% of the variance in the level of interest in engineering at time 2. The level of interest in engineering at time 1 was the most important predictor of the level of interest in engineering at time 2. Among the student characteristics, internal reasons for choosing engineering were also another significant predictor of the level of interest in engineering at time 2.

5.4 Conclusion

This section presents the conclusions that arise from the research in the light of the research questions and literature reviewed in Chapter Two.

5.4.1 Research Questions One and Two: levels of interest in engineering and differences between diploma groups

Incoming first-year polytechnic engineering students generally had a high level of interest in engineering, as indicated by their scale scores, which were in the upper third of the scale values. It was noted that in general for polytechnic students (17 to 21 years), their level of interest in engineering was higher than that of the younger students (11 to 14 years) as reported by Tyler-Wood et al. (2010). This was expected, as the polytechnic students would have been more exposed to the benefits of engineering over time as compared to the younger students, to develop their interest in that field. A comparison of the levels of interest in engineering for the current research and those reported by Tyler-Wood et al. (2010) is summarized in Table 24.

Table 24: Summary and comparison of the level of interest in engineering with past literature

Diploma/ source	Level of interest in engineering at time 1	Level of interest in engineering at time 2
EBM	127.68	127.09
ECE	131.14	129.05
ES	148.23	147.83
Tyler-Wood et al., 2010	127.55*	

Note:

1. All items were rated on a seven point Likert-type scale. Summing of the 25 items in the Science, Technology, Engineering and Mathematics Semantics Survey gave a scale score that ranged from 25 to 175.
2. EBM = Engineering with Business Management; ECE = Electronic and Computer Engineering; ES = Engineering Science; η^2 = effect size.

*Adapted from "Instruments for assessing interest in STEM content and careers" by Tyler-Wood, T., Knezek, G. and Christensen, R., 2010, *Journal of Technology and Teacher Education*, *18*(2), 345-368.

Amongst the three groups of diploma students, Engineering Science students recorded the highest level of interest in engineering. This was a consistent finding at the start (time 1) and end (time 2) of the semester. The levels of interest in engineering for Engineering Science students were significantly higher as compared to other diploma groups. This is a logical finding as these students are academically stronger than the other groups with a better foundation in mathematics and science (as can be seen from their better entry points to the polytechnic). Research conducted by Schiefele et al., (1992) found that interest and academic performance were positively correlated. This may suggest that students with higher academic ability in mathematics and science tend to have higher levels of interest in engineering too.

5.4.2 Research Question Three: changes in levels of interest in engineering and differences between diploma groups

As mentioned, incoming first-year polytechnic engineering students generally had a high level of interest in engineering. Near the end of the first semester, students' level of interest in engineering decreased slightly for all the three diploma groups but the drop was not significant. Nonetheless, the levels of interest in engineering were still relatively high in that they remained in the upper third of the scale values as shown in Table 24. No one diploma group differed significantly from any other in their change in the level of interest in engineering, suggesting that, whatever the reasons for the small decline, they affect all diploma groups similarly.

The finding that at the end of the first semester of study, all diploma students were slightly less interested in engineering, was expected. One explanation for the slight decrease in the level of interest in engineering over a semester could be the transition from secondary school to polytechnic. In the polytechnic, the assignments and examinations students complete are likely harder than those in their secondary school courses. This increased level of difficulty could result in a greater academic challenge that could lower their performance or require them to put forth more effort. These outcomes could have a negative effect on their interest in engineering, further emphasizing that engineering is “a hard slog with little rewards” (Davie, 2007).

A second explanation is that some aspect of the first semester curriculum is leading students to think that engineering is a “mundane” and “boring” subject as documented by Crawley et al. (2007), thus negatively affecting students’ interest in engineering. There could be other reasons such as less effective or even outdated teaching pedagogies and learning environments to impart the necessary knowledge, skills and values to engineers in the current society that is driven by information technology. The negative effect may be more apparent if first-year engineering students are idealistic and had high expectations about engineering education at the start of the semester.

The level of interest in engineering is characterized by the interest in science, mathematics, engineering, technology and an engineering career. Hence a third explanation for the slight drop in the level of interest in engineering could point to the lack of the following factors: (i) connection between the fundamental subjects (science, mathematics) to engineering and their relevance in real life applications; (ii) awareness of the technological advancements made possible by engineers; and (iii) exposure and knowledge these first-year engineering students have about the prospects of the engineering profession.

5.4.3 Research Question Four: relationships between variables

This research found the highest correlation to be between the level of interest in engineering at time 1 and time 2. This finding provides some evidence that students who are interested in engineering at the start of the semester remain so at the end of the same semester. The higher correlation between task value and other scores shows that it is theoretically important to the level of interest in engineering as well as the other student characteristics. For example, as a student's task value increases where he/she perceives the course to be interesting, important and useful, his/her level of interest in engineering also increases. Conversely, test anxiety has low correlations with other scores, showing that it is not theoretically important to the level of interest in engineering as well as the other student characteristics. For example, as a student's test anxiety increases where he/she experiences stress and a fear of failure before or during test situations, his/her level of interest in engineering is expected to decrease.

The finding that the levels of interest in engineering at time 1 and time 2 correlated strongly with other scores demonstrates the need to pay more attention to the student characteristics, which could influence students' level of interest in engineering at the start (time 1) and end (time 2) of the semester.

Lastly, the research documented the differences in the magnitude of correlations between the level of interest in engineering and each of the student characteristics with more than one dimension. Among the reasons for choosing engineering, the correlation between the level of interest in engineering and internal reasons for choosing engineering was higher than that between the level of interest in engineering and external reasons for choosing engineering. For approaches to studying, the correlation between the level of interest in engineering and deep approaches to studying was higher than that between the level of interest in engineering and surface approaches to studying. For motivational goals, the correlation between the level of interest in engineering and task value was higher than that between the level of interest in engineering and other motivational goals. These results suggest that a student's level of interest in engineering increases if he/she is more influenced by his/her internal reasons for choosing engineering; if he/she uses more of deep approaches to studying; and if his/her task value is more pronounced as a motivational goal as compared to others.

5.4.4 Research Question Five: predictors of level of interest in engineering

Of the student characteristics measured in this research, the most important predictor of the level of interest in engineering (at the start and end of the semester) was the internal reasons for choosing engineering. One conclusion from this finding is that in order to develop high levels of interest in engineering, there is a need to know and pay particular attention to the students' internal reasons for choosing engineering - such as the belief in their good mathematics and science capability. The research also found that task value as a motivational goal, deep approaches to studying and external reasons for choosing engineering were also predictors of the level of interest in engineering, although these are less important than internal reasons for choosing engineering. This suggests that as well as knowing students' reasons for choosing engineering, which is useful to properly prepare them to make their choices and facilitate the decision-making processes, it may be desirable to admit those students, whose motivational goal is task value, and those who use deep approaches to studying.

It is to be hoped that students' levels of interest in engineering can be increased over time. This research found that student characteristics together with the level of interest in engineering at the start of the semester had a large effect on the level of interest in engineering at the end of the semester. The level of interest in engineering at the start of the semester is the most important predictor for the level of interest in engineering at the end of the semester, followed by internal reasons for choosing engineering. This suggests that in order to have students more interested in engineering at the end of the semester, their entry interest level has to be high and, as mentioned above, this will be dependent on the student characteristics of the reasons for choosing engineering, task value as a motivational goal and deep approaches to studying.

5.5 Discussion and Implications

In summary, the key findings of this research are as follows:

1. Students with higher academic ability in mathematics and science tend to be more interested in engineering.
2. Students' level of interest in engineering decreased slightly over a semester of study, although the drop was not significant. Possible explanations for this slight decrease in level of interest in engineering include the effect of students transiting from secondary school to polytechnic, the negative experiences in the first semester curriculum, the inability of students to connect mathematics and science to engineering and their daily lives, the lack of awareness of the technological advancements made possible by engineers and the lack of exposure and knowledge about the prospects of the engineering profession.
3. In order to have students be more interested in engineering at the end of the semester, their entry interest level has to be high and this will be dependent on the student characteristics of the reasons for choosing engineering, task value as a motivational goal and deep approaches to studying.

An implication of the above findings is that researchers likely need to consider reasons for choosing engineering, task value as a motivational goal and deep approaches to studying as a measure of the level of interest in engineering. There is a need to integrate the knowledge of these student characteristics to better understand students' level of interest in engineering. As engineering education seeks to increase the number of engineering graduates, researchers need to continue to examine student characteristics and the way they interact as students move through the curriculum.

The next section notes five main areas where policy and practical implications of this study may be applied: (i) policies or practice to enhance mathematics and science fundamentals; (ii) policies or practice to attract students to engineering, giving them good reasons to choose engineering (iii) helping students make a smooth transition from secondary school to polytechnic; (iv) enhancing the delivery of engineering education in polytechnics to connect learning and engage students' interest; and (v) placing emphasis on student characteristics in the design of the engineering curriculum.

5.5.1 Policies or practice to enhance mathematics and science fundamentals

Research conducted by Schiefele et al., (1992) found that interest and academic performance were positively correlated. This may suggest that students with higher academic ability in mathematics and science tend to have higher level of interest in engineering too. The correlation between higher academic performance and interest (Schiefele et al., 1992) points to the need for a dedicated publicity campaign that should be targeted at students who are good in mathematics and sciences. Policies need to be developed to expand opportunities for high quality programmes that focus on the learning of mathematics and science fundamentals.

There may be many ways to improve mathematics and science teaching and learning at primary and secondary level. At the teachers' level, more needs to be done to improve the skills, knowledge and retention of mathematics and science teachers. There needs to be better professional development and better support structure. This can include mentorship for new teachers and internship opportunities in the related fields to allow teachers to learn more about the application of the content that they teach. More aids to improve the education system in mathematics and science can be implemented. For example, the government can provide grants to schools to improve their mathematics and science instruction and innovation. The grants can also be used to increase the material, equipment and technology in schools to allow them to integrate technology to support the teaching of mathematics and science. At the polytechnic, initiatives similar to iFoundry (The Illinois Foundry for Innovation in Engineering Education) in the College of Engineering, University of Illinois, can be set up to develop and evaluate student-centered teaching pedagogies before rollout into the curriculum. With the focus on mathematics and science education, it is to be hoped that students' level of interest in engineering can be nurtured from an early age and that with increased ability in these two subjects, students will feel more confident and competent to take up engineering courses at tertiary level.

5.5.2 Policies or practice to attract students to engineering, giving them good reasons to choose engineering

In Singapore, in order to increase interest in engineering related studies, the Public Service Division is reviewing the pay and career progression of its engineers and will inject more variety into the work they do, in order to attract and retain such talent (Tai, 2014). Another government-led initiative in Singapore known as - Applied Study in Polytechnics and Institute of Technical Education Review - has been started with the aim of studying how applied education in the polytechnics and institutes of technical education can be strengthened. The current research to find out the student characteristics that are associated with the level of interest in engineering is timely to support this national study on the engineering profession.

This research has highlighted the importance of the reasons for choosing engineering in connection with the level of interest in engineering. The reasons for choosing engineering are studied here in two dimensions – internal and external. The internal reasons for choosing engineering include the influence of (i) students' social background (example, the student's parent studied engineering and for this reason decides to pursue the same career), (ii) their role models (example, advice from parents influences the student to join engineering), and (iii) their self-perception in mathematics and science ability (example, the student feels that he or she is good in mathematics and will therefore do well in engineering). The external reasons for choosing engineering include the influence of the publicity campaign in the engineering course and the employment opportunities in the engineering field. A well-rounded publicity campaign targeting potential students, parents and those with good academic potential, that give them good reasons to choose engineering, is outlined below.

In order to attract potential students to engineering studies, polytechnics should organize a comprehensive publicity campaign to engage secondary school leavers, letting them know what engineering is all about and providing them with an external environment that gives them good reasons to choose engineering. Such publicity efforts could utilize traditional advertising methods (through newspapers, magazines, radio programmes, television and social media), school visits with interactive mobile laboratory to showcase what engineering is all about, exciting hands-on competitions to highlight the practice-oriented aspect of engineering and engineering career-oriented talks. The publicity content should focus on creating the awareness of the technological advancements made possible by engineers to impress the potential students, providing them with accurate information. It can also show that engineering courses are not at all boring and hard work, and expose them to the prospects of the engineering profession including good employability upon graduation. Publicity efforts should not be limited to secondary schools, but extended to primary schools, allowing young students to be aware of the engineering profession and of what good it brings to the society, so as to nurture their interest in engineering from young. Over time, it is to be hoped that students will grow to find engineering interesting and exciting.

The publicity campaign can also be one that targets parents and teachers of the potential students. It is important for parents and teachers to have a clear understanding of what engineering is about, so that they can impart the correct information and knowledge to their children and students, hence exerting a positive influence on them to take up engineering as a course of study. The engagement with potential parents and teachers could come in the form of talks and exhibitions that highlight and compare the different engineering courses and prospects, both in terms of academic pursuits as well as engineering careers.

The last group of students to attract to engineering is the group with good academic potential. While the same publicity effort to attract secondary school leavers will apply here, the publicity content to lure students with good academic potential should focus more on the use of intellectual stimulation provided by engineering concepts. Examples include the use of robotic competitions to engage students and guide them through the use of computer programming and engineering concepts that require higher order thinking in applying them.

5.5.3 Providing a smooth transition from secondary school to polytechnic

To help students' better transition from secondary schools to polytechnics, a new first-year experience programme can be introduced to build students' intrinsic motivation in engineering studies. The programme should not rush into imparting core engineering knowledge to students, but should aim to (i) build a sense of engineering identity among the freshmen; (ii) develop their confidence and motivation in engineering studies; and (iii) provide tips on how they can excel and do well in their course. The programme can roll out a series of activities to provide a "soft" introduction to engineering to first-year engineering students. These activities can include team bonding sessions that allow students to get to know one another and the new learning environment; and hands-on competitions that utilize simple engineering concepts to excite students about engineering. Invited guest speakers from the engineering industry can be insightful and inspirational to students as they share the recent inventions and projects made possible by engineering. The first-year students will also benefit from the industry visits to places familiar to them, such as the airport, where they can connect and relate engineering to their everyday lives. Chapter Two covered an excellent example of how a school-wide freshmen experience known as the Illionis Engineering First-year Experience (iEFX) can help to build first-year students' intrinsic motivation by providing hands-on experiences in engineering.

Polytechnics can do more to provide a support structure that is open to help students better cope with their studies. Student mentorship programmes and course counseling may be able to help students identify their weak areas and improve on them under proper guidance.

5.5.4 Enhancing delivery of engineering education to connect learning and engage students' interest

The use of technology has greatly transformed the education landscape. Engineering education needs to keep up with the latest trends and move in pace with the students who are "tech savvy" and can readily obtain information on the internet. Polytechnic lecturers need to equip themselves with the latest instructional methods to engage students in classrooms, which will create a more positive learning experience for the students. The focus should shift away from the simple presentation of knowledge, and towards the integration of knowledge and the development of critical new skills such as creativity, communication, business management and leadership skills. On top of imparting technical knowledge, the exposure of these critical new skills is important to train future engineering leaders to have a global perspective of their work.

Lecturers should also try to use more industrial and practical examples to reinforce the theory delivered in the classroom. The use of practical examples can help students connect engineering theory with practical applications and see how relevant they are in real life applications. This use of practical examples during classroom delivery can help to bind the gap between the industry and what they learn in classrooms. Even as new concepts are being introduced, lecturers can explain how to apply their understanding of the basic principles to real engineering problems. This can be done through organized trips to engineering companies or exposing students to the latest technological advancements in engineering via talks and exhibitions.

5.5.5 Placing emphasis on student characteristics in the design of engineering curriculum

This research has shown the association of student characteristics with the level of interest in engineering. Therefore as well as enhancing teaching pedagogies in engineering and connecting students' learning to real life applications during classroom delivery, lecturers will need to be aware of the student characteristics that can aid in improving the level of interest in engineering. While the reasons for choosing engineering have been taken into consideration as the main driver for the publicity campaign explained previously, this section focuses on the remaining two student characteristics – task value as a motivational goal and deep approaches to studying.

Firstly, there is a need to emphasize the task value of studying engineering through exposing students to projects with large-scale implications (such as creating a new invention that helps vast majority of mankind). Such a showcase will suggest the importance of the engineering course the students need to study as well as enabling them to see its relation to what they may do in future as engineers. This allows students to get interested, to see the value of engineering and the prospects in the profession.

Secondly, to encourage students to use deep approaches to studying, lecturers can design the engineering curriculum for deep learning such as deploying particular strategies and assessment methods that move away from memorization. Possible ways for lecturers to encourage deep approaches to studying include showing personal interest in engineering itself, using assessment that requires thought and ideas to be put together, and concentrating on and ensuring plenty of time for key concepts to be learnt. One example of how this can be done is problem-based learning (Barrows & Tamblyn, 1980; Finkle & Torp, 1995). It allows students to link multiple ideas and concepts together, thereby putting theory into practice. Deep approaches to studying have been associated with higher academic scores (Peters et al., 2007) and academically strong students are likely to be motivated and to remain interested in engineering. Also intrinsically motivated students perform engineering-related tasks because they derive a sense of satisfaction and enjoyment in doing so (Arnason, 2006); this benefits students by enhancing long-term strategy development, self-direction and their level of interest in engineering.

5.6 Directions for Future Research

The findings of this research should be interpreted within the context of two limitations. Firstly, the sample consisted of only one cohort of first-year engineering students from three diploma programmes at one polytechnic, which may limit the generalizability of the results. Caution should therefore be taken in generalizing the results to the whole population of engineering students in local polytechnics. Secondly, the research was not intended to account for all factors that may be associated with the level of interest in engineering. In this research, only student characteristics were investigated and the assumption was made that these characteristics themselves did not change over time.

Further research can build on the present study in a number of ways. Firstly, a larger sample of engineering students should be recruited so that a more comprehensive evaluation of factors associated with students' level of interest in engineering can be attained. It could involve students from varying engineering diploma programmes across different polytechnics. Research could follow the students longitudinally and collect data on their level of interest in engineering and student characteristics across the full period of their engineering diploma study in the polytechnic, which is typically over three years. This research should also be extended to university level students and make comparisons on the possible changes in students' level of interest in engineering.

Secondly, future research should study the correlation between students' interest in engineering and their achievement scores in terms of grade point average. It is interesting to know if students' interest could influence their achievement. Students who have high levels of interest in engineering try to pursue knowledge and are more attentive in class in learning engineering concepts. These students will remain motivated to pursue their career in engineering. Monitoring the level of interest in engineering and achievement can be important in ensuring engineering career readiness for polytechnic students.

Thirdly, the general trends and emphasis from the data collected suggest that future research should look into the redesign of the engineering curriculum. Future work could benefit from a more comprehensive review of the engineering curriculum, on top of considering the effects of task value as a motivational goal and deep approaches to studying that seem to increase students' level of interest in engineering. The review of the engineering curriculum could include a systematic review of the engineering content to concentrate on imparting a core set of engineering fundamentals and helping students integrate knowledge and apply it in real life applications. The impact technology has on students' acquisition of knowledge will also play an important role in the review of the engineering curriculum. It is also important to integrate non-technical skills in the engineering syllabus to prepare students for the new roles expected of future engineers of the 21st century. The infusion of non-technical skills and technologies in the engineering curriculum, will help to bind the gap between the industry and institutions. These changes will eventually require a shift in the engineering curriculum towards globalization, developing students to be world-ready for the engineering challenges in today's context.

Fourthly, future work could benefit from looking at the learning environment in the engineering diploma programmes, which could go hand-in-hand with the revised engineering curriculum. Technology has enabled students to have ready access to the internet, so it is important to design learning spaces and computing policies to allow lecturers to have greater social control during classroom teaching. But it is also undeniable that when students can access the networked tools simultaneously, many collaborative teaching and learning opportunities emerge. To support this, the learning environment needs to be upgraded with the infrastructure and tools to facilitate these collaborative activities. For example, movable tables, chairs, whiteboard with engineering tools and mockups will be useful for students' discussion purposes.

Lastly, with the increasing amount of time students spend in front of their computer screens, virtual learning environments may possibly be the next direction in engineering education. With physical characteristics that are just as real as those of the actual engineering environment, virtual learning environments can simulate what engineering students will face in real life engineering challenges. More research and development needs to be done in this area in order to enrich engineering education and provide students with an authentic learning opportunity.

In conclusion, there are global concerns over the declining interest in engineering that need to be investigated. The continuing trend will lead to a shortage of engineers to meet the new demands of globalisation. More needs to be done to learn about the declining trend in the level of interest in engineering. Due to the advancements in technology, the social context of teaching and learning is no longer the same as before and a new generation of students with different characteristics has emerged. It is therefore important to attract the right pool of students with student characteristics appropriate to engineering and to maintain or enhance the level of interest in engineering in existing students.

Although there is a great deal of literature that examines the declining interest in engineering, very little research has been published that explicitly identifies student characteristics that may be associated with students' level of interest in engineering. The primary purpose of this research has therefore been to investigate the relationship between a set of student characteristics (the reasons for choosing engineering, study approaches, motivational goals, self-efficacy and academic buoyancy) and the level of interest in engineering. The research has found that among the student characteristics, internal reasons for choosing engineering, task value as a motivational goal and deep approaches to studying are important predictors of the level of interest in engineering. The implication of the findings is that researchers may need to consider these student characteristics as a measure of the level of interest in engineering. Changes in the policy and practical implications to engineering education would be expected at the polytechnic level and future research should look into correlation between students' level of interest in engineering and their achievement scores as well as the redesign of the engineering curriculum and the learning environment.

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APPENDICES

Appendix 1: Science, Technology, Engineering and Mathematics Semantics Survey

We would like to know your level of interest in science, mathematics, engineering and careers related to these areas. For the next 5 sets of questions, please choose one number between the adjective pair to indicate how you feel about the subject.

*Negatively worded items are reverse scored so that higher scores for all items indicate higher level of interest.

To me, SCIENCE is:

1	fascinating	1	2	3	4	5	6	7	mundane
2	appealing	1	2	3	4	5	6	7	unappealing
3	exciting	1	2	3	4	5	6	7	unexciting
4	means nothing*	1	2	3	4	5	6	7	means a lot
5	boring*	1	2	3	4	5	6	7	interesting

To me, MATHEMATICS is:

6	boring*	1	2	3	4	5	6	7	interesting
7	appealing	1	2	3	4	5	6	7	unappealing
8	fascinating	1	2	3	4	5	6	7	mundane
9	exciting	1	2	3	4	5	6	7	unexciting
10	means nothing*	1	2	3	4	5	6	7	means a lot

To me, ENGINEERING is:

11	appealing	1	2	3	4	5	6	7	unappealing
12	fascinating	1	2	3	4	5	6	7	mundane
13	means nothing*	1	2	3	4	5	6	7	means a lot
14	exciting	1	2	3	4	5	6	7	unexciting
15	boring*	1	2	3	4	5	6	7	interesting

To me, TECHNOLOGY is:

16	appealing	1	2	3	4	5	6	7	unappealing
17	means nothing*	1	2	3	4	5	6	7	means a lot
18	boring*	1	2	3	4	5	6	7	interesting
19	exciting	1	2	3	4	5	6	7	unexciting
20	fascinating	1	2	3	4	5	6	7	mundane

To me, CAREER IN ENGINEERING is:

21	means nothing*	1	2	3	4	5	6	7	means a lot
22	boring*	1	2	3	4	5	6	7	interesting
23	exciting	1	2	3	4	5	6	7	unexciting
24	fascinating	1	2	3	4	5	6	7	mundane
25	appealing	1	2	3	4	5	6	7	unappealing

Appendix 2: Reasons for Choosing Engineering Questionnaire

The following questions relate to your reasons for choosing engineering.

1. When you decided to study engineering, were your parents supportive of your decisions?
    a. Yes
    b. No

2. What is your parent's highest level of education?
    a. Primary
    b. Secondary
    c. A level
    d. Polytechnic
    e. University

3. Which one of your parents work as an engineer?
    a. Mother
    b. Father
    c. Both
    d. None

4. Did either of your parents study engineering?
    a. Mother
    b. Father
    c. Both
    d. None

To what extent do you agree with the following statements?

		Totally 100%	Mostly 75%	Some-what 50%	Only a little 25%	Not at all 0%
5	There is a wide range of career opportunities in engineering.	5	4	3	2	1
6	I feel confident that I can find a job in engineering, when I graduate.	5	4	3	2	1
7	Mathematics was one of my strongest subjects in secondary school	5	4	3	2	1
8	Science was one of my strongest subjects in secondary school.	5	4	3	2	1
9	I have always found engineering interesting.	5	4	3	2	1

How did the following influence your decision to choose engineering?

		Totally 100%	Mostly 75%	Some-what 50%	Only a little 25%	Not at all 0%
10	Advice from teachers	5	4	3	2	1
11	Career exhibitions	5	4	3	2	1
12	Advice from friends	5	4	3	2	1
13	Open House	5	4	3	2	1
14	Previous vacation employment in engineering	5	4	3	2	1
15	Guidance counsellor	5	4	3	2	1
16	Advice from parents	5	4	3	2	1
17	General media	5	4	3	2	1
18	Experience from one of the engineering programmes eg Engineering Headstart	5	4	3	2	1
19	Status of the profession (engineering)	5	4	3	2	1
20	High starting pay in engineering	5	4	3	2	1

21. If you are filling the application form again, will you choose engineering?
    a. Yes
    b. No

22. What is your immediate intention on completing your diploma course?
    a. Employment in engineering
    b. Time out/travel
    c. Further studies in engineering
    d. Further studies in another profession
    e. Others pls state

Appendix 3: The Revised Two Factor Study Process Questionnaire

This questionnaire has a number of questions about your attitudes towards your studies and your usual way of studying. It is important that you answer each question as honestly as you can. If you think your answer to a question would depend on the subject being studied, give the answer that woulld apply to the subject(s) most important to you.

		Totally 100%	Mostly 75%	Some-what 50%	Only a little 25%	Not at all 0%
1	I find that at times studying gives me a feeling of deep personal satisfaction.	5	4	3	2	1
2	I find that I have to do enough work on a topic so that I can form my own conclusions before I am satisfied.	5	4	3	2	1
3	My aim is to pass the course while doing as little work as possible.	5	4	3	2	1
4	I only study seriously what's given out in class or in the course outlines.	5	4	3	2	1
5	I feel that virtually any topic can be highly interesting once I get into it.	5	4	3	2	1
6	I find most new topics interesting and often spend extra time trying to obtain more information about them.	5	4	3	2	1
7	I do not find my course very interesting so I keep my work to the minimum.	5	4	3	2	1
8	I learn some things by rote, going over and over them until I know them by heart even if I do not understand them.	5	4	3	2	1
9	I find that studying academic topics can at times be as exciting as a good novel or movie.	5	4	3	2	1
10	I test myself on important topics until I understand them completely.	5	4	3	2	1

		Totally 100%	Mostly 75%	Some-what 50%	Only a little 25%	Not at all 0%
11	I find I can get by in most assessments by memorising key sections rather than trying to understand them.	5	4	3	2	1
12	I generally restrict my study to what is specifically set as I think it is unnecessary to do anything extra.	5	4	3	2	1
13	I work hard at my studies because I find the material interesting.	5	4	3	2	1
14	I spend a lot of my free time finding out more about interesting topics which have been discussed in different classes.	5	4	3	2	1
15	I find it is not helpful to study topics in depth. It confuses and wastes time, when all you need is a passing acquaintance with topics.	5	4	3	2	1
16	I believe that lecturers shouldn't expect students to spend significant amounts of time studying material everyone knows won't be examined.	5	4	3	2	1
17	I come to most classes with questions in mind that I want answering.	5	4	3	2	1
18	I make a point of looking at most of the suggested readings that go with the lectures.	5	4	3	2	1
19	I see no point in learning material which is not likely to be in the examination.	5	4	3	2	1
20	I find the best way to pass examinations is to try to remember answers to likely questions.	5	4	3	2	1

Appendix 4: Motivated Strategies for Learning Questionnaire

The following questions ask about your motivation for and attitudes about your course. They also look at your self-efficacy i.e. confidence level in the course. If you think your answer to a question would depend on the subject being studied, give the answer that would apply to the subject(s) most important to you.

To what extent do you agree with the following statements?

		Totally 100%	Mostly 75%	Some-what 50%	Only a little 25%	Not at all 0%
1	In a class like this, I prefer course material that really challenges me so I can learn new things.	5	4	3	2	1
2	If I study in appropriate ways, then I will be able to learn the material in this course.	5	4	3	2	1
3	When I take a test I think about how poorly I am doing compared with other students.	5	4	3	2	1
4	I think I will be able to use what I learn in this course in other courses.	5	4	3	2	1
5	I believe I will receive an excellent grade in this class.	5	4	3	2	1
6	I'm certain I can understand the most difficult material presented in the readings for this course.	5	4	3	2	1
7	Getting a good grade in this class is the most satisfying thing for me right now.	5	4	3	2	1
8	When I take a test I think about items on other parts of the test I can't answer.	5	4	3	2	1
9	It is my own fault if I don't learn the material in this course.	5	4	3	2	1
10	It is important for me to learn the course material in this class.	5	4	3	2	1

		Totally 100%	Mostly 75%	Some-what 50%	Only a little 25%	Not at all 0%
11	The most important thing for me right now is improving my overall grade point average, so my main concern in this class is getting a good grade.	5	4	3	2	1
12	I'm confident I can learn the basic concepts taught in this course.	5	4	3	2	1
13	If I can, I want to get better grades in this class than most of the other students.	5	4	3	2	1
14	When I take tests I think of the consequences of failing.	5	4	3	2	1
15	I'm confident I can understand the most complex material presented by the instructor in this course.	5	4	3	2	1
16	In a class like this, I prefer course material that arouses my curiosity, even if it is difficult to learn.	5	4	3	2	1
17	I am very interested in the content area of this course.	5	4	3	2	1
18	If I try hard enough, then I will understand the course material.	5	4	3	2	1
19	I have an uneasy, upset feeling when I take an exam.	5	4	3	2	1
20	I'm confident I can do an excellent job on the assignments and tests in this course.	5	4	3	2	1
21	I expect to do well in this class.	5	4	3	2	1
22	The most satisfying thing for me in this course is trying to understand the content as thoroughly as possible.	5	4	3	2	1
23	I think the course material in this class is useful for me to learn.	5	4	3	2	1

		Totally 100%	Mostly 75%	Some-what 50%	Only a little 25%	Not at all 0%
24	When I have the opportunity in this class, I choose course assignments that I can learn from even if they don't guarantee a good grade.	5	4	3	2	1
25	If I don't understand the course material, it is because I didn't try hard enough.	5	4	3	2	1
26	I like the subject matter of this course.	5	4	3	2	1
27	Understanding the subject matter of this course is very important to me.	5	4	3	2	1
28	I feel my heart beating fast when I take an exam.	5	4	3	2	1
29	I'm certain I can master the skills being taught in this class.	5	4	3	2	1
30	I want to do well in this class because it is important to show my ability to my family, friends, employer, or others.	5	4	3	2	1
31	Considering the difficulty of this course, the teacher, and my skills, I think I will do well in this clas	5	4	3	2	1

Appendix 5: Academic Buoyancy Scale

This survey looks at how you handle everyday stresses in your school life.

To what extent do you agree with the following statements?

		Totally 100%	Mostly 75%	Some-what 50%	Only a little 25%	Not at all 0%
1	I don't let study stress get on top of me.	5	4	3	2	1
2	I think I'm good at dealing with schoolwork pressures.	5	4	3	2	1
3	I don't let a bad mark affect my confidence.	5	4	3	2	1
4	I'm good at dealing with setbacks (eg bad marks, negative feedback on my work).	5	4	3	2	1

Appendix 6: Factor loadings, communalities, eigenvalues and percentages of variance for the Motivated Strategies for Learning Questionnaire based on varimax rotated six-factor solution

	Factor loading						Communality
Items	1	2	3	4	5	6	
I'm confident I can do an excellent job on the assignments and tests in this course (slfef_20)	0.80	0.20	0.21	-0.12	0.05	-0.02	0.75
I believe I will receive an excellent grade in this class (slfef_5)	0.80	0.18	0.21	-0.17	-0.01	0.01	0.75
I'm certain I can understand the most difficult material presented in the readings for this course (slfef_6)	0.79	0.08	-0.06	-0.13	0.18	0.10	0.69
Considering the difficulty of this course, the teacher, and my skills, I think I will do well in this class (slfef_31)	0.78	0.15	0.20	-0.06	0.18	0.03	0.71
I'm confident I can understand the most complex material presented by the instructor in this course (slfef_15)	0.78	-0.04	0.06	-0.08	0.25	0.13	0.69
I'm certain I can master the skills being taught in this class (slfef_29)	0.77	0.25	0.15	-0.07	0.16	0.11	0.72
I expect to do well in this class (slfef_21)	0.71	0.29	0.27	0.03	0.05	-0.05	0.66
I'm confident I can learn the basic concepts taught in this course (slfef_12)	0.59	0.33	0.31	-0.09	0.16	0.08	0.59
I think I will be able to use what I learn in this course in other courses (tskv_4)	0.40	0.30	0.01	0.20	0.15	0.27	0.38
I like the subject matter of this course (tskv_26)	0.47	0.66	-0.07	0.02	0.12	0.16	0.70
Understanding the subject matter of this course is very important to me (tskv_27)	0.14	0.65	0.31	0.03	0.18	0.05	0.57

Note: intr = intrinsic goal orientation, extr_ = xtrinsic goal orientation, tskv = task value, cont = control beliefs, slfef = self efficacy, tanx = test anxiety

(Appendix 6 continued)

Items	Factor loading 1	2	3	4	5	6	Communality
I think the course material in this class is useful for me to learn (tskv_23)	0.44	0.65	0.01	0.15	-0.00	0.13	0.66
It is important for me to learn the course material in this class (tskv_10)	0.05	0.59	0.42	-0.03	0.16	0.24	0.61
I am very interested in the content area of this course (tskv_17)	0.47	0.58	-0.03	0.09	0.19	0.04	0.60
The most satisfying thing for me in this course is trying to understand the content as thoroughly as possible (intr_22)	0.14	0.48	0.34	-0.01	0.29	0.22	0.50
When I have the opportunity in this class, I choose course assignments that I can learn from even if they don't guarantee a good grade (intr_24)	0.33	0.39	-0.10	0.14	0.26	0.18	0.39
The most important thing for me right now is improving my overall grade point average, so my main concern in this class is getting a good grade (extr_11)	0.09	0.00	0.76	0.14	-0.01	0.12	0.62
If I can, I want to get better grades in this class than most of the other students (extr_13)	0.20	0.24	0.70	0.19	0.13	-0.03	0.64
Getting a good grade in this class is the most satisfying thing for me right now (extr_7)	0.13	0.07	0.64	0.15	-0.12	0.34	0.58
I want to do well in this class because it is important to show my ability to my family, friends, employer, or others (extr_30)	0.23	-0.05	0.61	0.22	0.25	-0.08	0.5

Note: intr = intrinsic goal orientation, extr_ = xtrinsic goal orientation, tskv = task value, cont = control beliefs, slfef = self efficacy, tanx = test anxiety

(Appendix 6 continued)

Items	Factor loading 1	2	3	4	5	6	Communality
If I try hard enough, then I will understand the course material (cont_18)	0.29	0.28	0.50	-0.08	0.25	0.23	0.54
I have an uneasy, upset feeling when I take an exam (tanx_19)	-0.28	0.18	0.00	0.77	0.04	-0.13	0.72
I feel my heart beating fast when I take an exam (tanx_28)	-0.12	0.20	0.19	0.71	0.10	-0.14	0.63
When I take tests I think of the consequences of failing (tanx_14)	-0.02	-0.03	0.21	0.66	0.00	0.15	0.51
When I take a test I think about how poorly I am doing compared with other students (tanx_3)	-0.11	-0.16	0.10	0.61	0.01	0.39	0.56
When I take a test I think about items on other parts of the test I can't answer (tanx_8)	0.07	0.00	0.06	0.52	0.04	0.46	0.49
In a class like this, I prefer course material that arouses my curiosity, even if it is difficult to learn (intr_16)	0.25	0.15	0.10	0.11	0.74	0.05	0.65
In a class like this, I prefer course material that really challenges me so I can learn new things (intr_1)	0.41	0.24	0.03	0.05	0.63	0.15	0.66
If I study in appropriate ways, then I will be able to learn the material in this course (cont_2)	0.16	0.33	0.34	-0.01	0.56	0.12	0.57
If I don't understand the course material, it is because I didn't try hard enough (cont_25)	0.18	0.25	0.11	0.08	0.13	0.72	0.65

Note: intr = intrinsic goal orientation, extr_ = xtrinsic goal orientation, tskv = task value, cont = control beliefs, slfef = self efficacy, tanx = test anxiety

(Appendix 6 continued)

Items	Factor loading						Communality
	1	2	3	4	5	6	
It is my own fault if I don't learn the material in this course (cont_9)	0.01	0.35	0.32	0.00	0.13	0.66	0.67

Note: intr = intrinsic goal orientation, extr_ = xtrinsic goal orientation, tskv = task value, cont = control beliefs, slfef = self efficacy, tanx = test anxiety

Factor	Eigenvalue	% of variance	Cumulative %
1	9.87	31.85	31.85
2	3.62	11.68	43.53
3	1.80	5.80	49.33
4	1.48	4.79	54.12
5	1.21	3.92	58.03
6	1.00	3.23	61.26