Enabling Success in Mathematics and Statistics: The Effects of Self-confidence and Other Factors in a University College

by

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ABSTRACT

This thesis reports empirical and theoretical research into learning of mathematics and statistics at university level, with particular regard to students' views of their self-confidence and experiences, and the effects of these on achievement. This study was conducted at a time of widespread national concern about difficulties in mathematics education in England, particularly at the transition from school to university Science, Technology, Engineering and Mathematics (STEM) courses.

Factors which affected non-specialist students' learning of mathematics and statistics were investigated using student surveys in 2004/5, 2005/6 and 2006/7 (701 questionnaires) in the a-typical setting of a University College specialising in rural and land-based higher education. 52 student interviews were also carried out, primarily in 2008 and 2009, and are referred to but are not the main focus of this thesis. Both deductive and inductive approaches were used. Self-confidence was defined using three Mathematics Self-confidence Domains: *Overall Confidence in Mathematics*, *Topic confidences* for specific tasks, and *Applications Confidence*. Self-confidence was considered a belief, whilst liking of the subjects was an attitude, both forming part of *'affect'*, where affect comprised beliefs, attitudes and emotions. Student motivation was also investigated.

The survey data, and examination and assignment marks, of engineering students learning mathematics and other non-specialist students learning statistics, were analysed both quantitatively (by descriptive statistics, ANOVA, Kruskal Wallis, Correlation, Multiple Regression, Factor and Cluster analyses) and qualitatively. Previous success in mathematics, primarily GCSE Mathematics grade, was found to be the greatest determinant of university students' success in mathematics and statistics, but self-confidence and other affective variables also had significantly measurable effects. Significant effects on student confidence were also found for gender and dyslexia despite good achievement.

Findings indicate that students' self-confidence in mathematics does matter, as evidenced by significant relationships between confidence and achievement, but it was also concluded that these inter-relations were complex. Educators are encouraged to adopt student-focussed teaching styles which improve students' self-confidence as a means to improving attainment.

KEY WORDS

Mathematics, Statistics, Self-confidence, Self-efficacy, Mathematics Support, Education, Engineering Mathematics, Learning

WORD COUNT

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GLOSSARY AND ABBREVIATIONS

AEMM	Agricultural Engineering with Marketing and Management
AgEng	Agricultural Engineering
ANOVA	ANalysis Of VAriance, a statistical test to compare sample means
APD	Academic and Professional Development module
BEng	Bachelor of Engineering degree
BSc	Bachelor of Science degree
CBI	Confederation of British Industry
DfE	Department for Education
EDD	Engineering Design and Development
GCE	General Certificate of Education
GCSE	General Certificate of Secondary Education
FdSc	Foundation Science degree
GenStat	General Statistical Package
HEI	Higher Education Institution
HND	Higher National Diploma
IP	Investigative Project
Mathcad	Mathematics software package
MEng	Master of Engineering degree
ORVD	Off Road Vehicle Design
QCA	Qualifications and Curriculum Authority
RDA	Research Design and Analysis module (pre-cursor to RMNat)
REALM	Rural Enterprise and Land Management
RMNat	Research Methods module for Natural Science students
RMSS	Research Methods module for Social Science students
SPSS	Statistical Package for the Social Sciences
STEM	Science, Technology, Engineering and Mathematics

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1 INTRODUCTION

This thesis describes research into undergraduate students' learning of mathematics and statistics at a University College. A longitudinal study was undertaken from 2004 to 2009 to investigate factors, including self-confidence, which affected student achievement within a particular higher education institution (HEI). This investigation consisted primarily of surveys of first and second year students who were learning mathematics or statistics (n=701). In addition, 52 student interviews were also conducted with final year students who reflected back over their whole course and talked about their future expectations. Whilst these interviews are not all fully reported in this thesis, they are referred to (for example, Parsons *et al.*, 2011) and further informed the study.

At the time of this research there were many individuals and organisations in England who were concerned about mathematics education, particularly at the transition from school to university. This had come to be known as '*The Mathematics Problem'* and is described in the following section, 1.1. Following that there is a description of the research setting and the author's motivation for this research in Section 1.2. The two main research questions and their sub-questions, which this thesis aimed to answer, are then described in Section 1.3. The final section in this chapter, Section 1.4, describes the contents of this thesis by chapter, providing the reader with more detail than was given in the Table of Contents.

1.1 National Difficulties with Mathematics: The Mathematics Problem

The principal motivation for this research arose as a response to the central issue, recognised nationally, that many students find mathematics and statistics difficult at school and university. This section describes the national concern over difficulties with mathematics known as *'The Mathematics Problem'*, with reference to various reports, and stresses the importance of mathematics to the UK economy and industry. One of the first occurrences of the name '*The Mathematics Problem'* was in the title of the 1995 report '*Tackling the Mathematics Problem'* (London Mathematical Society *et al*., 1995) which described unprecedented concern about the unpreparedness of new entrants to mathematics, science and engineering programmes. Sutherland and Pozzi's 1995 report was commissioned by the Engineering Council to investigate engineering students' difficulties with mathematics. They reported quantitative evidence that the mathematical capabilities of first year engineering students were weaker than they had been ten years earlier. Sutherland and Dewhurst (1999) investigated 36 university departments which covered a range of disciplines (mathematics, engineering, science, business, and computer science). Sutherland and Dewhurst concluded that students were not adequately prepared for higher education and recommended more substantial mathematics courses for 16-19 year olds. Lawson (1997) reported the declining performance of A Level mathematics students whose diagnostic test results revealed little difference between 1997 A-level grade C students and 1991 grade N students. This was further substantiated by Lawson (2003) who by then compared 1991 with the 2001 diagnostic test results. Hawkes and Savage's report for the Engineering Council (2000), titled *'Measuring the Mathematics Problem'* further documented this decline.

Richard Smith (of the National Training Organisation for Engineering Manufacture) captured the general lack of respect for mathematical skill, titling his article: *'It's cool to be poor at mathematics and we've got to change that'* (Smith, 2003, p.48). Kent and Noss (2003) further investigated the state of affairs in '*Mathematics in the university education of engineers*' and Challis and Gretton (2003, p.32) referred to *'a widely recognised problem with what can be assumed as pre-requisite knowledge and skills for engineering students newly arriving at university.'* This situation was further compounded by the government's widening participation strategy which encouraged students from more diverse backgrounds to go to university (Cox and Bidgood, 2003). At this time there were various projects investigating undergraduate mathematics learning in England and Australia and elsewhere (e.g. Brown *et al.,* 2003a and 2003b, and Cuthbert and MacGillivray, 2003) and these are described further in Chapter 2, see Table 2.1.

In the Roberts Report (2002), called 'SET for Success: the supply of people with science, engineering and mathematics skills', Roberts stated that these skills were presented as central to the UK government's strategy for innovation and productivity. Roberts provided evidence of skills shortages and concluded that these threatened the government strategy and the future strength of the UK economy. This was later backed up by the CBI whose 2006 Employment Trends Survey found that 44% of employers were unhappy with school leavers' numeracy skills (CBI, 2007). The CBI also reported their concern that *'poor literacy and numeracy skills damage people's lives and their employment prospects'*, and at that time 23% of adults were classified as having low basic skills (CBI, 2007, p.2-3).

So great was the level of widespread concern that a government inquiry was carried out; 'The Government Inquiry into Post-14 Mathematics Education: Making Mathematics Count' (Smith, 2004). This inquiry identified three key issues of major concern with school mathematics, one of which was *'the failure of the current curriculum, assessment and qualifications framework in England, Wales and Northern Ireland to meet the needs of many learners and to satisfy the requirements and expectations of employers and higher education institutions.'* (Smith, 2004, p.3). Recommendations by the inquiry included appointing a Government Advisor for Mathematics and establishment of the National Centre for Excellence in the Teaching of Mathematics (NCETM, 2006), which was established in 2006.

In 2000 there was a change to A levels whereby these became modular, with mathematics A level comprising six modules, and pupils generally studied four subjects in the sixth form rather than three. For A level mathematics it was a disaster and necessitated removal of one sixth of the content in 2003 due to major problems with students failing AS and A level mathematics, and being put off choosing mathematics A level. These changes were documented by Porkess (2003) and Stripp (2004), and were evaluated by the QCA (2006a and 2007). Lee *et al.* (2007) questioned whether these changes had caused a further decline in the availability and take-up of mechanics in A level mathematics. The availability and take-up of Further Mathematics A level has greatly increased over the past decade, particularly through the work of the Further Mathematics Network (Stripp, 2007) and the Further Mathematics Support Programme (Stripp, 2010). Ken Boston, the QCA Chief Executive, described the teaching, curriculum and assessment of mathematics as '*one of the most challenging areas in contemporary education.'* (Boston, 2006, p.1).

Various changes and studies regarding GCSE Mathematics also occurred during this period, including the QCA (2006b) report regarding the proposed change to a two tier GCSE (rather than three tiers) which later came into effect, the QCA-RSS Centre (2007) reviewed handling data and statistics in GCSE Mathematics, further GCSE changes were being considered and trialled (OCR, 2007) and GCSE mathematics coursework was discontinued. A brief description has been given of the developments in GCE A level and GCSE Mathematics, but there also existed a wide range of different UK pre-university Mathematics curricula and qualifications which Lee *et al.* (2010) documented as a guide for academic staff. In 2012 there was on-going debate about the continuation of mathematics learning post-16 for all young people (e.g. Vorderman *et al.*, 2011). This suggestion met with considerable resistance in some spheres, for example one 16-year-old's reason given for not continuing his study of mathematics was *"I would rather die."* Brown *et al.* (2008, p.3). However post-16 maths has been promoted by organisations such as the CBI (2011) who recognised that '*good numeracy skills are essential in today's labour market'* and reported that 35% of employers were concerned about the basic numeracy skills of school leavers (CBI,2011, p.1). At least this 35% statistic was about a one fifth reduction compared to the 44% published by the CBI in 2007, but was still worryingly high.

Bamforth *et al.* (2007) gave a later account of on-going issues and effective measures for the 'Retention and progression of engineering students with diverse mathematical backgrounds' demonstrating that almost a decade later students' mathematical skills on entry to university remained an area which required special attention and action. At this time The National Audit Office (2007) published their report highlighting issues with the retention of students in Higher Education. Included in their suggested actions was that institutions should promote learning support, not simply as remedial provision, but as a positive option for improving the prospect of a good degree.

Students' difficulties were, however, not confined to problems with lack of skills and knowledge. Referring to engineering students learning mathematics, Kent and Noss (2003) separated the problem into two distinct issues: the lack of skills, knowledge and techniques, and also the lack of confidence in using these. They pointed out that

> *'To develop students' mathematical confidence is a slow process, which cannot be achieved through quick remediation, unlike the problem of "filling in" some gaps in mathematical knowledge'.* (Kent and Noss, 2003, p.27).

The QCA (2006a, p.4) also referred to many problems in secondary schools *'with motivation and choice'* and difficulties in *'retaining students' interest and motivation.'* So in universities and schools alike there was a record of problems associated with low self-confidence, poor attitudes and motivation in mathematics.

As we entered the second decade of the millennium research into, and the reporting of, concerns and initiatives relating to university mathematics learning continued. The *'More maths grads'* project (Robinson *et al.*, 2010) sought to find good features of undergraduate mathematics courses as a means to generate more interest, enthusiasm and participation in mathematics at university. Data was gathered by student questionnaires, and student and teaching staff interviews. They discovered that most students were studying mathematics degrees as a passport to getting a good job, not necessarily as the pre-cursor to becoming mathematicians. Findings included good lecture features, for example the value of worked examples, and for students to see the mathematics developing real time in a lecture, not just the finished article as for example given in notes. Jaworski (2010) reported on the start of the project Engineering Students' Understanding of Mathematics, ESUM, which investigated the use of GeoGebra to promote students' engagement with learning mathematics. Jaworski (2010) found that whilst students understood that GeoGebra was intended to improve their understanding, its use did not contribute to success in the examination.

Concerns over nurses' numeracy skills were raised by Jukes and Gilchrist (2006) and by McMullan (2010) about the high numbers of nurses failing numeracy tests, which called into question their competency at drug calculations which are important for patient safety and clinical effectiveness. In 2010 '*Responding to the Mathematics Problem: The Implementation of Institutional Support Mechanisms'* (report edited by Marr and Grove, 2010) was published. This described a range of mathematics support provision in the UK which had by then been established in universities in response to *'The Mathematics Problem'*. This described how much had been done during two decades to help thousands of students by means of a diverse range of provision. More details on the evolution and types of such support provision will be given in Chapter 2, Section 2.6.

Two reports investigated a wider range of subjects at A level with regard to mathematical content and difficulty. Coe *et al.* (2008) reported the relative difficulty of A level examinations in different subjects finding that General Studies, Physics, Chemistry, Biology, Further Maths, French, German, Music and Maths were the most difficult subjects at A level. The actual mathematical content of A level science examinations was reported by SCORE, the Science Community Representing Education (2012). Only a minority of mathematics topics in the syllabi were examined and a striking similarity in the topics examined by different examining bodies was found, which was impossible to have occurred purely coincidentally.

The Institute of Physics (2011) published '*Mind the Gap'* which presented empirical evidence of the perceptions of students on Physics and Engineering degree courses of the Mathematics they encountered on their courses, and also their lecturers' perceptions of how well prepared the students were. It was concluded that a sizeable proportion of lecturers felt that students were not adequately prepared for the mathematics they learnt at university and that students' perceptions were not as negative (as their lecturers'), but also indicated some lack of preparedness.

2011 and 2012 saw the publication of further major reports into areas of mathematics learning: Vorderman *et al.* (2011), ACME (2011) and Norris (2012), as well as the House of Lords Select Committee on Science and Technology report (GB. Parliament, 2012) which included Mathematics as one of its areas of concern. Despite two decades of writing and action there were still high level concerns. In their report '*A world-class mathematics education for all our young people*' Vorderman *et al.* (2011) reported some shocking statistics: that an estimated 22% of 16-19 year olds were functionally innumerate; that nearly half of all students failed to achieve Mathematics GCSE grade A*-C; and only 15% continued to study mathematics post-16. Vorderman *et al.* were also concerned at the declining comparison of achievement in mathematics in the UK with that of other countries, for example China. Carol Vorderman explained her motivation for working on this report:

> *'Over the years, hundreds of thousands of adults and children have told me of their fear of numbers and I have always longed to be able to do something to change that.'* (Vorderman *et al.,* 2011, p.104).

ACME, the Advisory Committee on Mathematical Education produced their report '*Mathematical Needs: Mathematics in the workplace and in higher education'* (2011) in which almost all respondents wanted *'more young people to know more maths and be more confident in using it.'* (ACME, 2011, p.1). Many employers wanted employees to have studied mathematics to a higher level than they would use so that they would have the confidence to apply mathematics in new situations. The shift away from manual low-paid jobs meant that more people required mathematical problem-solving skills in the workplace. They estimated that 330,000 of those entering higher education in any year could benefit from having studied some maths beyond GCSE, but less than 125,000 had done so. They recommended study of mathematics post-16, a wider mathematics curriculum, teaching of essential techniques and applications of mathematics, familiarisation with mathematical models, and that pupils experience the power of computerised computation. (ACME, 2011).

Norris' report *'Solving the maths problem: international perspectives on mathematics education'* (2012) examined successful approaches and reforms in other countries (Scotland and Hong Kong) to inform debate on mathematics education. Concern was expressed at the declining, or plateaued, mathematical capability of English students at a time when mathematics skills, and STEM industries' reliance on them, were increasingly important for national economic success. Both Hong Kong and Scotland offered qualifications at different levels, and included applications to the real-world, and were both recommended as models for consideration in designing improvements to the UK system.

The House of Lords Select Committee on Science and Technology, in their report '*Higher Education in Science, Technology, Engineering and Mathematics (STEM)'* (GB. Parliament, 2012), stated their concern that insufficient numbers of pupils studied mathematics post-16 to satisfy the demands of modern society, and that students' mathematical background was insufficient for studying STEM subjects at university. They proposed that post-16 mathematics should be made compulsory, and that A2 mathematics should be made compulsory for all entrants to HE STEM courses.

An extensive alternative literature review of the historical background to '*The Mathematics Problem'* and a history of the introduction of mathematics support provision in universities are provided by Lawson *et al.* (2012).

The range of difficulties discussed in the variety of reports referred to in this section can be divided into several categories: difficulties in schools; students' lack of mathematical skill and knowledge on arrival at university; difficulties with progression and retention of students in higher education (and also with recruitment of students in the early years of this research); and problems with student self-confidence, attitudes, effort and motivation. The next section will describe the particular circumstances in the Higher Education Institution (HEI) researched, and how this provided the motivation for this study.

1.2 The Setting and Motivation for the Research

The University College which was the setting for this thesis was an a-typical higher education institution. Smaller in size than a typical university; the course cohorts ranged from approximately 15 to 90 students. The College ran a range of courses, which included Agricultural Engineering, Agriculture, Animal Behaviour and Welfare, Veterinary Nursing, Business, Food and Surveying courses. Only the engineering courses and the Access course included modules of mathematics, and only the MEng and BEng engineering courses had an entry requirement of A level mathematics. All of the courses included some calculations and some compulsory study of statistics; for most of the students the requirement to study statistics was a surprise and was often approached with some reluctance. The college also had relatively high proportions of dyslexic students, in 2005 approximately 14% of students were dyslexic, and up to 25% of students on 1st year engineering courses were dyslexic.

During the timeframe of this study the mathematics and statistics lectures were taught in classroom-sized groups (of approximately 15 to 30 students) and consisted of two hour sessions which were divided into periods of instruction from the lecturer and periods when the students worked on set exercises whilst the lecturer was still present and available to give assistance. Some of the modules, especially the statistics modules, included instruction in the use of computer packages including Microsoft Excel, Mathcad, GenStat and SPSS.

In common with other universities (although that was not known at the time) there were difficulties with mathematics and students' achievement on the mathematical and statistical modules in the late 1990's, which had a detrimental effect on student progression rates (as was documented by Cowap, 1998). As a result a mathematics support tutor was employed part-time from 2001/2, and all of the mathematics and statistics modules were redesigned around this time to the format described above. Other changes which were introduced were comprehensive student lecture handouts and the integration of the use of computer packages in lectures. These changes resulted in much improved retention and progression (Parsons, 2004; Parsons, 2005; and Parsons, 2008a). Such was the improvement that the new second year statistics module for natural science students (Research Design and Analysis) and the revised and supported first year engineering mathematics modules both received internal Teaching Fellowship Awards in 2003, thus demonstrating not only the dramatic improvement, but also that the improvement had received internal recognition. These improvements, however, had not removed the students' difficulties with these subjects, but had provided a more suitable learning environment and the opportunity for extra help and practice which some students needed in order to improve their performance.

Sarah Parsons, author of this thesis, was employed from 2001 as the part-time mathematics support tutor, and has also worked increasingly as an engineering mathematics and mechanics lecturer. From giving the mathematics support and doing the teaching role, it became clear that there were some students who arrived at university worried about the mathematics content who became positively transformed in their mathematical skills and also in their self-confidence, attitudes and enjoyment of the subject. By contrast, there were some other students who had had difficult experiences in the past, which had left them with a lasting negativity in their outlook, ability and low self-confidence. The motivation for this research developed from a desire to understand better what helped students to learn mathematics effectively and what gave students self-confidence. There was also an interest to find out 'the bigger picture': to look beyond those students who had taken up the mathematics support; and to find out what the wider student body's experiences of learning mathematics and statistics were; and what could be learned from these? An outcome from the early stages of the research work was also a desire to provide a record of the student viewpoint; to take the opportunity to document the students' views and experiences, albeit in a specialised setting. It was hoped that the results from the data that was collected and analysed would augment the body of current knowledge at a time when there was acknowledged to be widespread difficulties in the UK about learning mathematics.

1.3 Research Questions

In order to provide a structure and focus for the research, the following research questions were posed. Research question I is primarily about students' self-confidence in their ability to learn and do mathematics. Research Question II is a broader, more open enquiry with a more inductive approach, which explores what was always expected to be a range of different factors which affected students' learning of mathematics and statistics.

RQ.I What is the effect of students' self-confidence in mathematics on their learning of mathematics and statistics?

- RQ.I.a How can students' self-confidence in mathematics be defined and measured?

- RQ.I.b What effect does students' self-confidence in mathematics have upon their learning and performance?

- RQ.I.c What contributes to forming students' self-confidence, both before and at university?

RQ.I.d How does students' self-confidence in mathematics subsequently change from that on entry to university through university?

RQ.II What different factors can be identified which affect students' learning of mathematics and statistics?

RQ.II.a What are the attitudes and views of students towards learning mathematics and statistics?

RQ.II.b How do the students' attitudes and views affect their learning of mathematics and statistics?

RQ.II.c What, in the students' opinions, are the characteristics of mathematics and statistics teaching which promote effective learning and improve self-confidence when learning mathematics and statistics?

RQ.II.d What differences can be identified for students with dyslexia, dyscalculia and/or other special needs when learning mathematics and statistics?

RQ.II.e What evidence can be found for the effect of mathematics support on students' achievement and self-confidence in mathematics and statistics?

These research questions are referred to during the Methodology and results chapters (Chapters 3,4 and 5) and are responded to with answers, as far as was possible, in the Conclusions (Chapter 6).

1.4 Thesis Outline

Chapter 1, this chapter, has introduced this thesis and in Section 1.1 set the scene in terms of the national situation regarding mathematics education which has come to be known as '*The Mathematics Problem'*. Statistics education has been assumed to be an integral part of the Mathematics Problem, but in the empirical research in this thesis it is given due consideration separately. In Section 1.2 the particular features of the University College in which the research was conducted have been described, along with the researcher's own motivation to conduct the study, which was partly a result of experiences teaching and supporting mathematics, but also from an awareness of the wider concerns nationally. The Research Questions were listed in the previous section (1.3), and in this final section (1.4) of Chapter 1 a description is provided of each chapter to provide the reader with more detail than was given in the Table of Contents.

Chapter 2 contains a review of the literature relating to the fields of knowledge contained in this thesis. Before the reader reaches the chapters that describe the empirical research, it is necessary to appreciate the range of related studies and work conducted to date by other researchers, and the theoretical foundations upon which this study was built. The earlier studies which have looked at university students' achievement in mathematics and statistics are listed and described in Chapter 2. These were found to span several decades and to be from several countries around the world, especially from those which were once under British influence and may thus have had some similarities in their education system to education in the UK. In fact, there were only a very few related studies found initially, and much of the literature described in Chapter 2 was produced during the timeframe of this research. Thus it can be seen that this research was in an area which had not been explored fully already and was in an area of current interest at the time. A sub-section describes Mathematics attitudes scales, only one of which was used in the data collection for this thesis. Literature regarding statistics education and research is presented along with an overview of the development and range of mathematics support provision in existence in the UK.

The literature in Chapter 2 also describes the theoretical framework used in this research, particularly with respect to Affect (in this case beliefs and attitudes) and in particular self-confidence and related constructs of self-efficacy and self-concept, which are both used predominantly in the US. Epistemological and ontological assumptions at the start of the study are explained. The three Self-confidence Domains proposed in this thesis are defined and explained. Mathematics failure and success learning cycles (Ernest, 2000), and Fishbein and Ajzen's model (1975) of beliefs, attitudes, intention and behaviour are described. Bandura's (1997) Self-efficacy theory (or social Cognitive theory) of four self-efficacy sources and four mediating processes is set out and discussed. There are short sections on motivation, which is considered in this thesis, and mathematics anxiety, which is not considered in this thesis but the concept is explained for comparison with lack of confidence. Dyslexia and dyscalculia are discussed, and the effects of gender in earlier studies are summarised. This chapter then concludes with a reflection on gaps in the existing literature and areas which past papers have noted as worthy of future investigation, some of which it is hoped that this thesis will address.

Chapter 3 outlines the methodology adopted with justification of the approach and tasks undertaken as a third element of the literature review. A mixed methodology was adopted with quantitative and qualitative data collected and analysed, primarily from questionnaire and interview methods, but also secondary data relating to achievement was obtained and utilised. The data collection timing and quantity of questionnaires and interviews conducted are summarised and explained; in general the questionnaire surveys were conducted with first and second year students who were taking mathematics or statistics modules (in 2005, 2006 and 2007). The questionnaire content and question wording are described. Brief mention is made of the student interviews which were also carried out, but the results of which are outside the scope of this thesis. There is also an explanation of research paradigms, especially those relating to educational and sociological research, with their application to the study undertaken, and the ethical considerations which were taken into account are described.

The results of the engineering students' questionnaires are presented in Chapter 4. Results are presented for the 1st year engineering students who were on BSc and FdSc/HND courses for the three years surveyed (2005, 2006 and 2007), and separately, but similarly, for the 1st year BEng and MEng engineering students. All these 1st year students had studied Engineering mathematics by hand (with calculators, but without the use of software), but the BSc and FdSc/HND students were also given some additional non-assessed introductions to Excel and Mathcad. All the first year engineering students had also studied statistics using Mathcad. 2nd year BEng and MEng students had studied mathematics by hand for the first half of their 2nd year, and had then learnt Analytical Techniques using Mathcad for the second half of the year.

Statistical analysis was conducted on the data for descriptive and summary statistics, to test whether any differences or trends found were significant, to produce models, reduce the data (Factor Analysis) and classify the data (Cluster Analysis) as appropriate. Closed questions were analysed using quantitative methods and open questions were analysed using qualitative methods. The results are presented in text, tables and graphs, with cross-comparisons of the different student groups and different years of their courses.

The questionnaire results for students who were studying statistics modules (who were non-engineering students) are presented in Chapter 5. Similar analysis and reporting of results was carried out on this data as for the engineering students' data in Chapter 4. However more data had been collected for these students (than for engineering students) and additional consideration was given to other factors, for example the type of student: natural science or social science, and gender.

Chapter 6 is the Conclusions Chapter, and is introduced in Section 6.1. The contribution to knowledge made by this study is summarised in Section 6.2, and a summary of statistical analysis results with other findings of interest are detailed in Section 6.3. The findings in relation to the Research Questions are listed in Section 6.4 and Section 6.5 contains suggestions for future work. The chapter ends with closing remarks in Section 6.6.

Details of literature referred to throughout this thesis are listed in the References section. Samples of the student questionnaires are provided in the Appendices, along with the list of interview questions used in June 2009. Results of ANOVA and Kruskal Wallis tests to justify combining data from different survey years are also included in the Appendices.

2 BACKGROUND LITERATURE REVIEW

2.1 Introduction to the Background Literature Review

This section will present the literature relevant to this thesis that is related to university students' learning of mathematics and statistics. This includes self-confidence, the three Mathematics Self-confidence Domains proposed in this thesis, other beliefs and attitudes towards mathematics and statistics, and issues regarding the transition from school to university and during their university experience. There is a range of background literature in order to cover the various facets of the research questions for this thesis and the findings of the empirical investigation. Self-confidence was a factor which was always intended to be investigated, but as useful results were obtained it gained greater importance in relation to the other areas of enquiry and this is reflected in the range and quantity of literature for self-confidence and related constructs. The effects of dyslexia were also intended to be investigated, however, the initial results, whilst useful, did not lead to broader enquiry in this area, so dyslexia diminished in terms of importance to this study and hence only a small section on dyslexia literature is included. The effect of gender was not an initial area of interest, however because some gender effects were found, literature regarding gender effects on mathematics learning are included in this literature review. Engineering students were learning mathematics and some statistics, whereas other student groups were not learning mathematics but were learning statistics (as will be explained in the Methodology in Chapter 3), so literature regarding learning of statistics is included in this chapter. Most of the background literature is in this chapter, but there are also references to the literature describing the *'Mathematics Problem'* in the Introduction (Chapter 1), and literature regarding Methodology and Ethics in the Methodology (Chapter 3)

In Section 2.2 the main studies, which were known of during the active data collection stages of this research, are summarised and then described individually. More recent or less closely related mathematics education research is described in Section 2.3. Mathematics attitude scales are discussed in Section 2.4; followed by literature specific to learning statistics in Section 2.5; and literature regarding mathematics support in Section 2.6.

The theoretical framework and definitions of the concepts and constructs being researched are presented in Section 2.7; these include: Ontological and epistemological assumptions (Sub-section 2.7.1); Learning cycles (Sub-section 2.7.2);

Belief, attitude, intention and behaviour (Sub-section 2.7.3); Bandura's self-efficacy (Sub-section 2.7.4); Pajares' self-efficacy and self-concept (Sub-section 2.7.5); this author's Mathematics Self-confidence Domains (Sub-section 2.7.6); Motivation (Sub-section 2.7.7); Mathematics anxiety (Sub-section 2.7.8). This section concludes with a Summary of affect in mathematics which draws together self-confidence, self-efficacy and self-concept, attitudes and emotions in learning mathematics (Sub-section 2.7.9).

Definitions and literature relating to dyslexia and dyscalculia are described in Section 2.8, followed by a selection of the research into the effects of gender on learning mathematics and statistics (in Section 2.9). A discussion of the gaps in the literature and the motivation for this study are presented in the concluding Section, 2.10.

In the following sections it will be shown that at the start of this study there was only a small collection of eleven related studies (ten at the end of 2004, and one in 2005) which were taken into account in the design of the instruments used (these eleven studies are described in the next sub-section). During the timeframe of this research there have been many other studies conducted into students' learning of mathematics and statistics at university in the areas of interest related to students' self-confidence and their transition to university. This growth in the number of studies demonstrates that during the timeframe of this research this was an area of widespread interest and concern, both nationally and internationally.

2.2 Main Studies

Of primary relevance are eleven studies which investigated students' attitudes and confidence in learning mathematics and statistics, and which were known about during the data collection stages of this research. These are summarised in chronological order in Table 2.1 below and then described in detail individually.

Table 2.1 Main Studies of Students' Learning of Mathematics and Statistics in Chronological Order

Author(s) and Year Published	Town or University, Country	Description
Frid *et al.,* 1997	Perth, Australia	Research into engineering and science students' confidence in their mathematics background and current mathematics

		curriculum by mathematics topic, and staff perceptions.
Shaw and Shaw, 1997 and 1999 [2 separate studies]	Warwick University and three other universities, UK	Investigation of engineering students' performance and attitudes to mathematics, initially at the University of Warwick (1997) and subsequently at three other different UK universities (1999). The results grouped students into five categories (clusters), and also identified the main factors which influenced attitudes and performance.
Armstrong and Croft, 1999	Loughborough University, UK	Surveys of student confidence by mathematics topic, of new entrants to engineering, science, technology and mathematics courses, in 1995, 1996 and 1997.
Fogarty *et al.,* 2001	University of Southern Queensland, Australia	Investigation of students' attitudes towards mathematics, computers and the use of computers for learning mathematics. This paper was the source of eleven questions used in student questionnaires, called the 'Scale questions'.
Brown *et al.,* 2003a and 2003b and many other papers	Two traditional universities, UK	Investigation of single subject honours mathematics undergraduates' experiences, attitudes and university achievement.
Cuthbert and MacGillivray, 2003	Queensland University of Technology, Australia	Investigation of initial and longer term effects of different student mathematical backgrounds in first year engineering programmes.
Gordon, 2004	Sydney, Australia	Study of psychology students' attitudes to learning statistics and conceptions of statistics.
Tapia and Marsh, 2004a	Georgia and Alabama, USA	Attitude Toward Mathematics Inventory (ATMI) instrument, with factor analysis, which investigated the underlying dimensions of attitudes toward

		mathematics.
Liljedahl, 2005	Simon Fraser University, Canada	Effect of 'AHA!' experiences on pre-service elementary school teachers.
Carmichael and Taylor, 2005	University of Southern Queensland, Australia	Study which investigated Preparatory Mathematics Course students' confidence in mathematics at three levels: course, topic and question, and the relationships with achievement.

Only four of the studies in Table 2.1 were conducted in the UK. Seven (so most) of these studies were conducted abroad, in Australia, Canada, US and South Africa, all of which had strong links with the UK in the past and might have elements in common in their education system. These studies are now described in detail below.

Frid *et al.* (1997) surveyed 350 science and engineering undergraduate students towards the end of their first year regarding their confidence in their mathematics background, their confidence with current mathematics topics and the reasons for any lack of confidence in the current mathematics topics. Students also took a diagnostic test before the start of the academic year that determined which mathematics course they followed. Many of the findings from the survey related to the curriculum delivery, particularly the (large) amount of content in the courses. Reasons given by students for lack of confidence in the current course material included:

- Lack of time
- The (high) number of formulae to remember
- Could not see the relevance
- The text was hard to understand
- Speed of delivery
- The amount of material to copy
- The difficulty of simultaneously listening and copying
- It was hard to catch up any missed lectures.

The main issues identified by the Frid *et al.* (1997) study were:

- The need to identify the appropriate amount of content in undergraduate mathematics courses
- The need to incorporate relevant, practical, real-world applications

- The need for better communication between departments to avoid student work overload, and to know the nature of mathematics used by other disciplines
- The need to better prepare students for a technological world, for example, by greater use of computer packages.

Some gender differences were identified; females became generally more confident than males whilst learning university mathematics (which was an unusual finding and in contrast to Brown *et al.,* 2003b). Frid *et al.* (1997) recommended further research into general trends in confidence areas and into why some student groups were more confident than others.

Shaw and Shaw (1997) studied first year engineering students at the University of Warwick. Two surveys were administered: in February 1994 and 1995. 58 questionnaires were completed (from 206 students, a 28% response rate), and 139 questionnaires were completed (from 238 students, a 58% response rate), respectively. The questionnaires gathered information in four key categories:

- Personal background: gender, age, mathematics qualifications, etc.
- Mathematics before university
- First year mathematics at university
- General questions regarding the difficulty of various mathematics topics on a 5-point scale, student motivation and their desire to improve in mathematics ability.

Shaw and Shaw (1997) performed Cluster Analysis on their Warwick data producing five student categories (clusters) which they named: High Flyers, Downhillers, Haters, Ambivalents and Realistics. Each category had different characteristics of attitudes, effort and success. Of particular concern were: the increase in the number of students who did not enjoy mathematics at university, 51%, approximately treble the number who had not enjoyed mathematics before university; and the number of students who found mathematics difficult at university, 62%, approximately double the number who had found mathematics difficult before university.

Similar surveys were subsequently conducted in three other UK universities to explore whether a similarly high proportion of students experienced difficulty and lack of enjoyment in mathematics at other types of universities (Shaw and Shaw, 1999). The three universities comprised a traditional university, a former polytechnic and a small university college, all with different student intakes. A positive finding was that the proportions of students with difficulties and lack of enjoyment of mathematics were not as high as at the University of Warwick. This was considered due to a more sympathetic approach to teaching mathematics at these universities and a different curriculum, whereby some of the more difficult parts of the syllabus taught at Warwick were left out.

Cluster Analysis of the three university study results produced five categories of students which were named as: High Flyers, Downhillers, Haters, Ambivalents with good pre-university teaching, and Ambivalents with poor pre-university teaching (Shaw and Shaw, 1999). The first three clusters were similar to those previously found at Warwick (Shaw and Shaw, 1997). These student groups were suggested for use in targeting support and monitoring students with difficulties.

Factor analysis of the three university study found that three independent factors were important in determining students' attitudes towards learning mathematics: pre-university experience, university experience; and perceived workload and difficulty (Shaw and Shaw, 1999). The conclusions of the three university study included a clear link between entry qualifications and performance in mathematics, and a clear link between performance and attitudes towards mathematics. The study of attitudes was considered important in order to inform the design of courses which would improve attitudes as well as performance (Shaw and Shaw, 1999). In this thesis similar links were investigated and found (see results chapters) between entry qualifications, attitudes to mathematics and performance.

Armstrong and Croft (1999) surveyed 1750 students over three years 1995-1997 at Loughborough University. New entrants to engineering, science, technology and mathematics courses were surveyed for their confidence in approximately 40 mathematics topics, and diagnostic tests of students' competency in a range of mathematics tasks were also administered to the engineering students in 1996 and 1997. Analysis revealed that considerable numbers of new students needed help with the whole range of basic mathematics. The topics most frequently indicated by students as needing help with included: partial fractions; logarithms; and integration by parts, which were recommended as priorities for the mathematics support provision.

Fogarty *et al.* (2001) developed an instrument, called the Attitudes to Technology in Mathematics Learning Questionnaire to investigate, what they called, student attitudes towards the use of technology for learning university level mathematics (linear algebra and calculus). The questionnaire comprised three scales: Mathematics Confidence, Computer Confidence, and Attitudes towards use of technology in learning mathematics, in 34 items with further items collecting biographical data. 289 students participated in an initial survey, of which 184 also participated in a follow-up survey. The scales were found to have good internal consistency reliability, and were recommended for standalone use or for inclusion in larger questionnaires. The eleven Mathematics Confidence questions were also used in the empirical research for this thesis.

The desire to understand the reasons for success or failure of single honours mathematics students led to the project *'Students' Experiences of Undergraduate Mathematics (SEUM)'* conducted in two traditional UK universities (Brown *et al*., 2003b). Four student surveys were conducted over three years: 2000/1, 2001/2 and 2002/3, with an overall return rate of 50%. Students were also interviewed in small groups and individually. The findings of the Brown *et al*. study (2003b) included the following:

- Students' attitudes to their academic work were impacted on, and influenced by, their attitudes to their social and emotional lives, and these were not easily separated.
- Many students reported reduced enjoyment and relevance of the course over time, especially that the pure maths had so little possible use.
- Some students were very enthusiastic, often the very successful ones.
- Success at the subject was one of the main factors found to affect their attitudes regarding mathematics. This will be shown to be consistent with Bandura's Enactive mastery experiences, which is one of his sources of self-efficacy beliefs (Bandura, 1997).
- Correlations were found between students' knowledge and A level results. However, having studied Further Mathematics A level did not influence whether students became successful.
- Other conclusions related to lecturer style (e.g. enthusiasm), students' family backgrounds and general student participation in university life.

Rodd (2002) (from the Brown *et al.*, 2003b, study) reported the following desirable and undesirable characteristics of the mathematics lectures and lecturers from student interviews. Students wanted lecturers to be enthusiastic and interested, not appear bored with what they were doing. Students wanted their imaginations stimulated by inspiring lecturers. When the mathematics was hard, the energy surge required to work at it was sought from the lecturer. One student wanted explanations he could understand and for the lecturer to help him (like *'real teachers'*). Not for the lecturer *'to* *be so busy doing their lecture and writing on the board that they don't even look at you'* (Rodd, 2002, p.7). This student did not like lecturers to just come in and start without even speaking to the students, and if the students had not already got their pen out they were already behind.

Brown *et al.* (2003b) make the following conclusions:

- Entry qualifications and diagnostic tests cannot be used alone to identify failing students, for example there were equal numbers of students with Further Mathematics A level in both the most and least successful groups.
- Most females prefer to remain invisible in lectures.
- Enthusiastic lecturers helped learning. Rodd (2003) quotes a first year female mathematics student *'It makes it all worth learning if the lecturer sounds as if he's enjoying it and he likes it.'* (Rodd, 2003, p.1).
- Too fast lectures were frequently identified as a hindrance.
- Tutorial group size did not have great effect.
- Struggling students blamed themselves, not staff nor the course being too difficult.
- Many students became mildly depressed in the second year when they lost confidence that they were coping.
- Success did not equate with enjoyment, as some successful students did not enjoy the course.
- Students who had problems with coping tended to withdraw, blame themselves and find it difficult to talk about their problems.
- The transition to university was a big step for some, especially those who were the first in their family to go to university.

Cuthbert and MacGillivray (2003) at Queensland University of Technology, Australia, investigated the initial and longer term effects of different student mathematical backgrounds in first year engineering programmes. A mathematics diagnostic test was given to identify general and individual mathematics weaknesses. The results demonstrated how difficult engineering programmes were for students who had not studied extension mathematics, and consequently also for the teaching staff. In response various forms of student mathematics support programmes were introduced and the effectiveness of these was analysed.

Over 250 psychology students at the University of Sydney completed questionnaires on their attitudes to learning statistics and their conceptions of statistics (Gordon, 2004). Gordon aimed to give the students a *'voice'* on how they felt about learning statistics (giving the students a *'voice',* in the sense of enabling their opinions to be aired, was also an aim of the research in this thesis). Most students were reluctant to study statistics; as was demonstrated by their responses to the question *'Would you study statistics if it were not a requirement of your psychology course?'* (Gordon, 2004, p.46), to which 73% of the students responded that they would not have studied statistics had they been given a choice.

The three most common reasons given for willingness or reluctance to study statistics were as follows. Of the students who would have chosen to study statistics 46 (16%) stated statistics as '*necessary for psychology*' (Gordon, 2004, p.47). The most frequently occurring negative responses were in the categories of statistics not being interesting (80 responses, 29%), for example *'I generally find it dull, boring and tedious'* (Gordon, 2004, p.47), or that statistics was not liked as a subject (37 responses, 13%). The main conclusions from the Gordon (2004) study are listed below:

- The majority of psychology students were unwilling to study statistics at university.
- Students reported learning mechanical procedures.
- Students would benefit from learning experiences which enable them to reinterpret statistics as personally meaningful knowledge, for example, by problem based learning and reflection (Gordon, 2004).

Tapia and Marsh (2004a) developed a new instrument to measure students' attitudes towards mathematics, called the 'Attitudes Toward Mathematics Inventory' (ATMI) containing 49 items (later reduced to 40) which took 10 to 20 minutes to complete. The ATMI was based on 6 underlying factors: confidence; anxiety; value; enjoyment; motivation; and parent/teacher expectations. The responses of 545 US students, from all grade levels of secondary education, were analysed and four factors were identified: self-confidence, value of mathematics, enjoyment of mathematics and motivation. The psychometric properties of the scale were valid and it was recommended for use. The ATMI was considered innovative because it was the first to incorporate confidence (Chamberlin, 2010).

Liljedahl (2005) studied the effect of 'AHA!' experiences on reluctant mathematics students' affective domain, i.e. whether these could alter students' emotions, attitudes or beliefs towards mathematics. By 'AHA! experience' he was referring to a sudden inspiration or leap in understanding. The students were pre-service elementary school teachers in Canada who deemed themselves incapable of and/or phobic towards mathematics and learning mathematics. Attitudes and beliefs were considered slow to change, however emotions were viewed as relatively unstable and more easily changed. The investigation focussed on whether AHA! experiences could produce a more rapid improvement in attitudes and beliefs, and it was found that they did. In the responses of 76 students were examples of emotions, changes in beliefs and some changes in attitudes. The results indicated that

> '*an AHA! experience has a transformative effect on 'resistant' students' affective domains, creating positive beliefs and attitudes about mathematics as well as their abilities to do mathematics.'* (Liljedahl, 2005, p.219).

Carmichael and Taylor (2005) investigated motivational effects, primarily student confidence in their ability to succeed in mathematics, on student performance in a tertiary preparatory mathematics course at the University of Southern Queensland, Australia. The study investigated two areas:

- Relationships between performance, confidence towards mathematics and beliefs on intelligence, i.e. whether intelligence is *a 'fixed entity (you either have 'it' or you don't)'* or '*incremental* (*you can improve your intelligence by learning new things*).' (Carmichael and Taylor, 2005, p.714, and Dweck, 2000)
- Students' confidence (or self-efficacy) at three levels of specificity: confidence for success on their course, confidence for success in a mathematical topic and confidence for a particular mathematics question, and determined the relative predictive strengths of these confidences.

The characterisation of intelligence not as innate, but as something that can be acquired by effort and perseverance is considered very important and helpful in this thesis. This differentiation was also made in Stipek *et al.* (2001) describing intelligence as *'fixed versus malleable'* (Stipek *et al.,* 2001, p.213), and similarly differentiated in Bandura (1997), Dweck (2000) and Warwick (2008a).

Carmichael and Taylor (2005) did not differentiate between mathematics self-efficacy and mathematics self-concept, and considered this distinction '*academic'*, focussing solely on students' self-confidence towards the mathematical content. They also combined confidence and motivation, believing that confidence would *'provide significant motivation for the students to adopt positive learning behaviours and to ultimately achieve.'* (Carmichael and Taylor, 2005, p.715). The author of this thesis would, however, disagree and does differentiate between the three constructs of self-efficacy, self-concept and motivation in mathematics, as will be explained in sub-sections 2.7.4 – 2.7.9.

Carmichael & Taylor (2005) found that confidences were based in part on previously acquired knowledge and skills, and influenced performance. Females and mature students were found to have lower confidence, but not significantly different performance. Contrary to their initial assumptions, empirical evidence was found for the distinction between confidence and motivation, and they questioned the clear causal link between confidence and motivation commenting on mature students who with '*low confidence and inadequate prior knowledge and skills'* … '*may have gained through life's experiences a determination (as opposed to confidence) to overcome these and succeed.'* (Carmichael and Taylor, 2005, p.718). This study was published after the data collection phase had started for this thesis.

All of the above eleven studies influenced, to varying degrees, the design of the research in this thesis. More recent or less closely related studies are now described in Section 2.3 below.

2.3 Other Mathematics Education Research and Reports

As early as 1992, McLeod found that student beliefs about mathematics affected their performance, that males tended to have more positive views than females, and that mathematical self-belief gradually became less positive during primary school years. They also found that attitudes were related to performance, but that neither depended on each other, rather they were related in ways that were often complicated and unpredictable. Casey *et al.* (2001) found that girls had lower scores in mathematics by 8th grade, and that this was more due to their poorer spatial mechanical reasoning skills than due to differences in self-confidence. There have been many other studies investigating gender differences in the learning of mathematics (e.g. Ferla *et al.*, 2009) which are described in section 2.9.

Some studies sought to investigate student levels of mathematical understanding (e.g. Wilson, 1992) whilst others investigated links between confidence and achievement. For example, Muijs' (1997) study of Flemish children found that academic self-concept and academic achievement were strong predictors of each other, but that prior achievement more strongly predicted self-concept than self-concept predicted achievement. Yusof and Tall (1999) found evidence that students' attitudes to mathematics could be changed by a supportive problem-solving environment.

Several studies have investigated the use of computers for learning mathematics, and some of these are described here because the use of computers was an integral part of most of the mathematics and statistics modules surveyed in this thesis. Galbraith and Haines (1998) investigated attitudes to mathematics and technology in a computer learning environment and found that undergraduate students learning mathematics were fairly confident, motivated and engaged with mathematics, and were also fairly positive in their use of computers. However, concern was raised by students' agreement with the statement: '*When I read a computer screen, I tend to gloss over the details of the mathematics.'* Galbraith and Haines (1998, p.283). Heid *et al.* (2002) described fifteen years of research into the use of Computer Algebra Systems (CAS) and whether CAS restricted development of by-hand symbolic-manipulation skills. It was found that students of all levels could use CAS without impeding their by-hand symbolic-manipulation skills, and a range of studies showed that the conceptual understanding of students who used CAS was better than that of students who did not. Galbraith and Haines (2000a) surveyed 423 students to determine their skills in parameterisation and linking graphical with algebraic representations to identify students' conceptual misunderstanding, and Challis and Gretton (2003) wrote of their success in introducing technology into the teaching of mathematics. O'Callaghan (undated) found that students who took graphing calculator sections of a college algebra course showed significant improvements in attitudes towards mathematics, mathematics self-concept and enjoyment of mathematics. These students were found to be more successful than those taking the traditional sections of the course, and rated the calculators and teachers very highly. Overall it could be concluded that students liked the use of technology and it benefitted their learning.

There have been several studies on teacher confidence in schools: Graven (2004) investigated the confidence of in-service mathematics teachers and viewed confidence as essential for on-going learning in the mathematics teaching profession. Stipek *et al.* (2001) assessed 21 school teachers and found substantial coherence between the teachers' beliefs and practices, where the beliefs were of six types, two of which were the teachers' self-confidence and enjoyment of mathematics, and the nature of mathematical ability e.g. *fixed versus malleable* (Stipek *et al.,* 2001, p.213). Significant associations were found between the teacher's self-confidence as mathematics teachers and the students' self-confidence as mathematics learners. Burton (2004) investigated how English pupils studying A level Mathematics and their teachers viewed confidence. In Burton's findings (2004), teachers defined confidence in terms of pupil behaviour observed (e.g. putting hands up, willingness and getting on with the work), whereas the pupils had very different definitions; they defined confidence in terms which were more consistent with the definitions used in this thesis. Pupils defined confidence by '*how they felt'*, and '*I can do it'* thoughts or feelings (Burton, 2004, p.367), which were reinforced by success (i.e. a 'mastery experience', Bandura, 1997), and that confidence came more from understanding than from memory. They also spoke of situations when they were able to do something that others could not and how that raised their confidence ('vicarious experiences', Bandura, 1997). Males were more competitive than females, who wanted to work with their friends. The most-enjoyed lesson was a problem solving class, which was conducted in a more collaborative style. Whilst pupils considered confidence important, there was a clear understanding, in all four participating schools, that work (or effort) was required in addition to confidence. The pupils listed positive classroom characteristics which they considered would boost confidence, as follows: a discursive environment; teamwork; a light-hearted approach; and a relaxed classroom where you are not afraid to make errors. Overall this described a collaborative environment rather than a competitive one.

Pupils also listed desirable teacher characteristics, who in their views should: explain well, not rush, know what they are talking about, and be sensitive to students who are struggling. Whilst Burton (2004) found that pupils' and teachers definitions of confidence were different, the *'link between confidence and success in mathematics appears to be robust for teachers and students.'* (Burton, 2004, p.374). For teachers, deciding which pupils were confident was much easier than creating classroom conditions which helped confidence to flourish.

Other studies which have investigated confidence include Kyriacou and Goulding (2006) and Hardy (2006 and 2008). Kyriacou and Goulding's 'Systematic review of strategies to raise pupils' motivational effort in Key Stage 4 Mathematics' found:

> *'the most effective strategies appeared to be those which enhanced pupils' self-confidence by enabling them to see themselves as pupils who can understand and can do mathematics.'* (Kyriacou and Goulding, 2006, p.1)

In the literature there are examples of teaching approaches and innovations which have been adopted to help students learn mathematics. Carter (2004) reported on the successful use of problem-based learning in engineering mathematics which had enabled students to think more broadly, but that it had still been found to be necessary to keep providing some traditional lectures in basic mathematics techniques. Problem-based learning is particularly recommended in the literature which will be presented for learning statistics. The HELM (Helping Engineers Learn Mathematics) project produced lecture booklets as handouts for engineering students learning mathematics (Green *et al.,* 2003), and handouts were also appreciated by the students surveyed in this thesis. Engelbrecht *et al.* (2005) compared life science students' conceptual and procedural abilities and found that these students were not more confident in procedural than in conceptual problems as a result of the teaching approach which focussed on conceptual understanding. This demonstrates that with appropriate teaching students can be helped not to take a mechanical approach to doing mathematics, but can be helped in their understanding.

Concerns in the UK prompted a report into participation in A Level Mathematics, which found that mathematics was viewed as *'more difficult and higher risk than other A level subjects'* (QCA, 2006a, p.6) and suitable only for a '*clever core'* (QCA, 2006a, p.6). This report proposed that as well as a higher uptake in A level mathematics, an improved perception and reputation of mathematics A level among students should also be aimed for (QCA, 2006a).

Research into students' transition from school to university mathematics includes Solomon (2006 and 2007) who interviewed twelve mathematics students to understand their epistemologies for learning proof in mathematics and functional student learning identities. Solomon found that students needed to move away from *'rule-following'* (Solomon, 2006, p.19) towards the *'creativity and ownership associated with proof'* (Solomon, 2006, p.20). She also found that some students (particularly males) were undisturbed by their lack of participation in mathematics, whereas others (predominantly female) aimed for more dual goals, such as '*speed and understanding'* (Solomon, 2007, p.14), who were consequently more at risk of feeling they did not belong to the mathematics learning community.

Wilson and MacGillivray (2007) investigated 566 science students' results in a basic mathematics multiple choice test completed over two years. A model was derived of 6 main performance predictors, which were: past mathematics qualification, whether a mathematics student at university, gender, whether the student had taken Higher Level Mathematics pre-university, self-efficacy, and which year (of the 2 years tested). This model explained 30.5% of the variation in the test score obtained. An overall pass rate of 75% indicated that some students would need help with basic mathematics. It was concluded that school students should be encouraged to continue their mathematics education as far as they were able to and take Higher Level Mathematics if possible (which is consistent with ACME, 2011). This is similar to the findings of Cuthbert and MacGillivray (2003). Also in Australia, Klinger (2004, 2006, 2008a and 2008b) investigated students' study skills, anxiety, negative attitudes, and low self-efficacy beliefs.

Warwick (2008a) surveyed Computing and IT students to investigate means to enhance students' self-efficacy and their engagement with mathematics. He successfully applied Bandura's four main sources of self-efficacy beliefs (Bandura, 1997) to interpret his findings, but he did not differentiate between self-efficacy and self-concept beliefs.

Liu and Koirala (2009) investigated the effects of mathematics self-efficacy on mathematics achievement of 11,726 high school students in USA. The results indicated a positive correlation between mathematics self-efficacy and mathematics achievement. Mathematics self-efficacy was a significant positive predictor of mathematics achievement. It was recommended that mathematics self-efficacy should be promoted for high school students in order to increase their achievement. Strategies suggested to achieve this were: for students to set learning goals, to provide timely and explicit feedback, encourage hard work, and use high achieving students as role models. The large scale of this American study demonstrates the importance of self-efficacy in current mathematics education research worldwide.

Liston and O'Donoghue (2009a) report a 2006/7 study of Irish students on service mathematics courses which investigated students' Attitude to mathematics, Beliefs about mathematics, Mathematics self-concept, Conceptions of mathematics and Approaches to learning, using questions from existing scales. Positive correlations were found between the first semester mathematics examination results and students' Enjoyment of mathematics (R=0.24) and also with Mathematics self-concept (R=0.22). The more students enjoyed mathematics the higher their achievement, and the more positive mathematics self-concept beliefs a student held the better his achievement in mathematics. No other significant correlations were found between affective variables and achievement. All of the affective and scale variables correlated with one another. A multiple regression model was produced which explained 23.3% of the variation in first semester marks using students' leaving certificate points and their 'Cohesive Conception' of mathematics (i.e. whether or not students expected connections between different parts of mathematics). A positive correlation was also found between diagnostic test scores and the first semester mathematics results (R=0.31, n=559, P<0.01), and diagnostic test results accounted for 9.6% of the variation in first semester mathematics examination results. The findings confirmed existing concerns about students' lack of preparedness for studying mathematics on university courses for non-specialist mathematics students.

The above study was followed up by Liston and O'Donoghue (2010) with 15 semi-structured student interviews, which included 5 mature students. Findings highlighted key insights which included: the role of the teacher on enjoyment of mathematics at school, mathematics was not viewed as valuable in everyday life and in careers, mathematics solutions were expected to only require minimal time, students were not confident in unfamiliar areas of mathematics, and that achieving good grades helped to boost their mathematics self-concept, amongst other findings. Liston and O'Donoghue suggested that teaching strategies should be adjusted in many Irish secondary schools, and in higher education, although they do not specify how. They do, however, conclude that the effect of affective variables should be made known to in-service and pre-service teachers in order to be aware of affective variables' influence on their own mathematics learning and that of their students.

The Liston and O'Donoghue papers (2009a and 2010) are of particular interest because they have similarities to the research into engineering mathematics for this thesis. There are however some differences in that Liston and O'Donoghue included approaches to learning and conceptions of mathematics, and their scale instrument used was based on pre-existing instruments. More recently Loo and Choy (2013) reported on sources of self-efficacy for 178 third-year engineering students in Singapore and concluded that mastery experiences were the main predictor of achievement in mathematics.

There have also been some large studies conducted In the UK looking into school mathematics and the transition to university. A selection of these are listed here with the intention of conveying to the reader an awareness of the recent high level of interest and investment in the areas of mathematics education research in the general field of knowledge in which this thesis sits. These studies are investigating the later years at senior school and the transition to university. Brown *et al.* (2008) investigated school pupils' reasons for not continuing their study of mathematics post-16, titling their report '*I would rather die*'. Perceived difficulty and lack of confidence were found to be important reasons for students not continuing post-16, and perceived dislike, boredom and lack of relevance were also factors. Another such study 'Opening doors to mathematically demanding programmes in further and higher education (FHE) project' is reported by Davis *et al.* (2010) and Williams (2008). Nunes *et al.* (2009a and 2009b) reported on the development of maths capabilities and confidence in Primary school. The GMAP Project investigated participation in mathematics (Noyes, 2009), and Noyes *et al.* (2011) reported on the final outcomes of a Department for Education project called *Evaluating Mathematics Pathways,* which gave an independent evaluation of the larger project which was established in 2005 by the QCA which produced new proposals for GCSE Mathematics and pilot testing of these in over 600 schools. The TransMaths project based at Manchester University looked into two problematic transitions: from GCSE to A level (Hernandez-Martinez *et al.,* 2009, and Hernandez-Martinez and Williams, 2010) and from A Level to university mathematics (Williams, 2010). Reiss *et al.* (2011) explain the UPMAP project, 'Understanding Participation rates in post-16 Mathematics and Physics', which had three strands: Stand 1 aimed to obtain 20,000 questionnaires from Year 8 school children and to obtain follow up questionnaires two years later; Strand 2 worked in more depth with 12 schools; and Strand 3 documented the reasons for HE students course choices (for example Rodd *et al.,* 2010). UPMAP was part of the Targeted Initiative for Science and Mathematics Education (TISME, 2013), in which the *Aspires* project also found issues with pupils not believing they were clever enough to study science, despite liking science and finding it interesting, and believing it led to worthwhile careers. Pampaka *et al.*, (2011) investigated the self-efficacy of English pupils studying A Level mathematics.

It has been shown that whilst only ten relevant studies were identified at the start of the data collection for this thesis (and one during data collection), there has been on-going activity researching Mathematics education worldwide into the areas of self-confidence and the transitions from school to university. This has included some large research projects: 8,796 Belgian school children in Ferla *et al.* (2009); 11,726 US High school pupils in Liu and Koirala (2009); 20,000 UK school pupils in Reiss *et al.* (2011); 15 year olds in 33 countries in Williams and Williams (2010); and 15 year olds in 65 countries in OECD (2013), thus demonstrating significant worldwide interest and concern regarding these areas of mathematics learning.

2.4 Mathematics Attitude Scales

Various scales have been created to measure attitudes towards mathematics and learning of mathematics; lists and discussion of these instruments have been produced by Chamberlin (2010), Cretchley (2008), Cretchley and Galbraith (2002) and Pajares and Miller (1994). In the 1960's and 1970's the focus of such scales was on anxiety and attitudes towards mathematics (Zan *et al.*, 2006).

Higgins (1970) describes a study of school pupils' attitude changes after learning mathematics through science, which Chamberlin (2010) claims was the first study of affect in mathematics, and that it was innovative and with high reliability. This national study in the US, with more than 850 participants, did not create an instrument, but was based on 18 scales developed by the National Longitudinal Study of Mathematics Abilities. According to Chamberlin (2010) the most significant impact of which is more likely to have been that it brought attention to the relationship between affect and mathematics achievement, than the actual results which were that attitude groups were not a major factor for consideration in the curriculum design.

Aiken (1974) created two scales of attitudes towards mathematics: Enjoyment of Mathematics and Value of Mathematics; the Enjoyment Scale correlated highly with mathematical ability and interest, whereas the Value Scale correlated more with verbal and general scholastic ability. This scale has since been shortened (Aiken, undated). Fennema and Sherman's Mathematics Attitude Scale (1976) contained 9 mathematics scales (Galbraith and Haines, 2000b), and has been used extensively by feminists to research female participation in mathematics (Zan *et al.*, 2006). Sachs and Leung (2007) produced shortened versions of the Fennema-Sherman Mathematics Attitudes Scales. Sandman's Mathematics Attitude Inventory (1980) comprised six scales relating to: Perception of mathematics teacher; Mathematics anxiety; Value of mathematics in society; Mathematics self-concept; Enjoyment and Motivation (Sandman, 1980).

Betz and Hackett (1983) developed the Mathematics Self-Efficacy Scale (MSES) which investigated self-efficacy, gender and course selection, and found a significant relationship between mathematics self-efficacy and selection of science based courses, and that males had significantly stronger maths-related self-efficacy than females. Kay (1989) describes the Computer Attitude Measure (CAM), initially administered to 383 student teachers producing positive correlations between attitudes and computer literacy. Langenfeld and Pajares (1993) investigated the modified Mathematics Self-Efficacy Scale, comprising three sub-scales: mathematics problems self-efficacy, mathematics tasks self-efficacy and college courses self-efficacy.

Galbraith and Haines (1998 and 2000b) produced Mathematics-Computing Attitude Scales by focussing on confidence and motivation, because these both appeared extensively in the literature for mathematics and computing. They produced six scales: Mathematics Confidence, Mathematics Motivation, Computer Confidence, Computer Motivation, Computer-Mathematics Interaction and Mathematics Engagement. Results from 156 mathematics students revealed the questions with the strongest contributions to Mathematics Confidence were:

- *'Mathematics is a subject in which I get value for effort.'* (Galbraith and Haines 1998, p.281)
- *'No matter how much I study, maths is always difficult for me.'* (Galbraith and Haines, 1998, p.281)

All the scales revealed highly or reasonably positive student attitudes and beliefs, except for the Computer-Mathematics Interaction Scale; unfortunately students generally agreed with *'When I read a computer screen, I tend to gloss over the details of the mathematics'* (Galbraith and Haines, 1998, p.283). A similar study was also reported by Cretchley and Galbraith (2002).

Fogarty *et al.*'s (2001) questionnaire on student confidence in mathematics, student confidence in using technology, and student attitudes toward use of technology in learning mathematics has been described in the Main Studies (section 2.2). Eleven questions based on Fogarty *et al.* (2001) were used in the questionnaires for the empirical research for this thesis. The other scales described above were not, either because they were lengthy and time consuming or because they were not known of at the start of the research for this thesis, so these other scales are described here for information and historical background purposes.

The Attitude Toward Mathematics Inventory, ATMI (Tapia and Marsh, 2004a), is also described in the Main Studies (section 2.2). According to Chamberlin (2010) the ATMI was innovative to include confidence, although Fogarty *et al.*, 2001 had already researched Confidence. The Mathematics and Science Attitudes Inventory (Project EDGE, undated) was a 62 item questionnaire (2 sets of 31 questions), aimed at US high school and college students.

Pierce *et al.* (2007) and Barkatsas (2004) described a new scale for secondary school pupils called the '*Mathematics and Technology Attitudes Scale'* (MTAS) for student attitudes to learning mathematics with technology in Australia, which consisted of 20 short items taking under 10 minutes to complete. It contained four questions for each of five areas: Mathematics Confidence, Confidence with technology, Attitude to learning mathematics with Technology, Affective Engagement and Behavioural engagement. This scale is relatively short and quick to administer and it would have been interesting to try some of the questions for this thesis had they been known about. The results from 350 students in 6 schools revealed some gender differences. Boys had significantly higher scores for each subscale except Behavioural engagement. The results for Mathematics confidence (t=6.13, df=155, p=0.000) indicated a very clear difference between genders, but not all of the pupils with negative attitudes to learning mathematics with technology were girls. This research is referred to again in the sub-section on Gender.

It has been shown in this sub-section that there is a range of scale instruments available for measurement of attitudes and self-confidence in learning mathematics and other related areas, such as attitudes towards science or the use of technology.

2.5 Statistics Education

This section presents a description of literature related to students' learning of statistics. In the setting for this thesis all first year students and most second year students were required to study statistics as a compulsory part of their course. These were not statistics specialist students and there were many issues surrounding such students' learning of statistics for which the literature outlined below describes the field of relevant knowledge.

Unfortunately the learning of statistics is often viewed negatively by many students, for example Morris (2012) who described statistics lectures as confusing students. In 2005 the Higher Education Academy student essay prize winner Hanson (2005) described statistics as dull and difficult, and to improve this suggests active participation in data collection, clear distinct summaries, flow charts and diagrams. Early reports such as Zeidner (1991) detailed the anxiety some students experienced whilst learning statistics and compared this with the more widely recognised mathematics anxiety.

Garfield (1995) investigated students' learning of statistics from the available literature based on constructivist principles and produced a list of ten general principles of learning statistics:

- *Students learn by constructing knowledge;*

- *Students learn by active involvement in learning activities;*
- *Students learn to do well only what they practise doing;*
- *Teachers should not underestimate the difficulty students have in understanding basic concepts of probability and statistics;*
- *Teachers often overestimate how well their students understand the basic concepts;*
- *Learning is enhanced by having students confront their misconceptions;*
- *Calculators and computers should be used to help students visualise and explore data;*
- *Students learn better if they receive consistent and helpful feedback on their performance.*
- *Students learn to value what they know will be assessed.*
- *Use of the suggested methods of teaching will not ensure that all students will learn the material.* (Garfield, 1995, pp.30-32)

These were reduced to eight principles by Garfield and Ben-Zvi (2007) who excluded the final two principles. This thesis' author concurs with the eight principles, and probably also the ninth, as these all offer useful insights into approaches which are helpful to students.

Wild and Pfannkuch (1999) discuss the process of empirical investigation and the thought processes which require the synthesis of statistical understanding. The reasoning processes of students and practising statisticians were investigated using in-depth interviews. A four-dimensional framework was produced for what they title *'Statistical Thinking in Empirical Enquiry'*, including an investigative cycle, an interrogative cycle, types of thinking and dispositions. Wild and Pfannkuch include some excellent diagrams, for example one diagram which shows '*ideas and information'* being poured into a funnel and through successive '*distil and discard'* cycles until a small droplet is produced coming out of the funnel titled *'encapsulate*.'

Holmes (2000) reported on the MeaNs project (Matching Education and Assessment with employment Needs in Statistics) which found that employers were generally more interested in attitudes and personal skills than the ability to perform specific statistical calculations. One middle manager's reflection on his university experience was: *'They tried to teach me how to do statistics – what I find I really needed was a course teaching me what statistics could do.'* (Holmes, 2000, p.12). Motivating students to learn was a major problem in the service teaching of statistics and to improve this Holmes considered that the approach should be adapted for different disciplines, for example, a different approach for engineering students from that for business students. A constructivist approach of learning by doing was viewed as helpful, which required more student involvement, for example through student projects and practical classes. Holmes also reflected on the increasingly useful role that technology could play in statistics teaching.

Zetterqvist (1997) described how to make a statistics course useful by focusing on applications for chemistry students to increase their motivation and understanding. MacGillivray (2002) described the success achieved by using project work to help students own their data and improve learning, and provided guidance for staff on the implementation of such projects in their teaching. Other literature on the benefits of project work include: Biajone (2006) who successfully promoted positive attitudes towards statistics through project work, and Cesar (2008) who investigated collaborative work for learning statistics in schools in Portugal. Cesar found that this not only increased respect for diversity but it also increased the desire to learn, and recommended projects and problem-solving as effective methods for teaching statistics.

Gordon's study of psychology students (2004) who were generally reluctant to study statistics was described in the Main Studies, section 2.2. Akram *et al.* (2004) described a paper cutting experiment used to generate real data to help students to learn and understand statistical concepts. Baxter *et al.* (2004) sought to understand why teaching statistics to service departments was so difficult and made suggestions for improvement. Features of statistics which made it hard included: the concept of uncertainty, the use of specialist terminology, different symbolic notations and sometimes different methods of calculation with irreconcilable answers. Students' previous experiences or preconceptions of statistics, for example as difficult or boring, also contributed to a lack of motivation. For service teaching 'interpretation' was viewed as more important, which is considered analogous (by Baxter *et al.*) to a person driving a car and changing gear perfectly well, without necessarily understanding the clutch mechanism.

Petocz and Reid (2005) were motivated by an engineering student who had described statistics as '*something strange and useless … I didn't know why I had to study statistics'* (Petocz and Reid, 2005, p.789) to investigate service students' views about statistics. Petocz and Reid recommended approaches such as: projects based on areas of interest to the student, problem-based learning, use of computers, analysis of research papers, and case study videos, thereby promoting a broader view of statistics.

This contrasted with a traditional approach which focussed on mastering statistical techniques, based on purely numerical or artificial settings, which contributed to a narrower view of statistics. Holding the broader view was found to lead to a better appreciation of the value of statistics and a better approach to learning.

Christou and Dinov (2010) studied student learning, learning styles and attitudes towards probability and statistics education using technology. It was found that difficult statistical concepts could be explained using simulations and virtual experiments to complement classical approaches, and that students generally appreciated the IT-based instruments, being more used to technology than their lecturers.

A range of literature regarding teaching and learning statistics has been presented in this sub-section. These are relevant to this thesis because three of the five students groups surveyed were learning statistics rather than mathematics, as will be explained in the Methodology (Chapter 3). Problem-solving, project work and the use of computers have all consistently emerged as positive approaches for learning statistics.

2.6 Mathematics Support

In response to the Mathematics Problem, as described in the Introduction chapter, universities started to provide mathematics support. Coventry University was one of the institutions which established a mathematics support centre in the 1990's to help address the mathematical issues of their incoming students (Mac an Bhaird and Lawson, 2012). The earliest example of a guide for mathematics support was written about the Mathematics Learning Support Centre at Loughborough University which was intended as a guide for others to follow (Croft, 2000). Lawson *et al.* (2001b) described the range of measures being adopted by universities which included: curriculum changes; bridging units; staff availability and mathematics support centres. They also presented the results of a survey of mathematics support provision in the UK in 2001; 46 out of the 95 universities responding were providing some form of mathematics support, including several long established 'old' universities. A Good Practice Guide was subsequently produced (Lawson *et al.,* 2001a), including guidance for support of dyslexic students and details of the web-site *mathcentre* (mathcentre, 2003). By 2004 the number of UK HEIs providing mathematics support had risen to 66 out of the 106 surveyed (62.3%) (Perkin and Croft, 2004).

At Harper Adams University College the need for mathematics support had been recognised independently from other universities in 1999-2000, and the improvements in student achievement after the introduction of support and curriculum changes in 2001 were documented in Parsons (2003 and 2005).

Croft and Robinson (2003) described the effective follow-up of engineering students after mathematics diagnostic testing, through student action plans and extra support, however, low uptake of the support was identified as an issue. Trott (2003a and 2003b) described the work undertaken to date to support dyslexic and dyscalculic students at Loughborough University. Action research into mathematics support was proposed by Challis *et al.* (2004).

Lawson *et al.* (2007) described additional support targeting *'at risk'* students at two universities, mainly through additional classes in small groups which were sufficiently helpful to be continued, but once again a lack of engagement with mathematics support was a problem (Symonds, 2008); those students not engaging with their courses were found to be less likely to engage in the support (Symonds *et al.,* 2006, 2007a, 2007b, 2007c, 2008a, 2008b and 2009).

In 2005 *sigma* was established as a Centre for Excellence in Teaching and Learning (CETL) for university-wide mathematics support at Loughborough and Coventry Universities (*sigma* CETL, 2006). Croft *et al.* (2009) and Lawson *et al.* (2008b) described the range of provision of the *sigma* CETL, and Lawson *et al.*(2008a) described the investment in new technologies. Croft *et al.* (2009) described the evolution of the *sigma* mathematics support centres with increasing attendance year on year, and other initiatives including: staff training; educational research; outreach into schools; and service teaching of mathematics for other departments, concluding that these initiatives led to an improved student learning experience. Solomon *et al.* (2010) described the use of the *sigma* mathematics learning support centres by mathematics students as an essential safe space in which they formed a learning community.

Research into students' study skills in the Mathematics Learning Support Centre was carried out at Sheffield University (Patel and Little, 2006, and Samuels and Patel, 2010), concluding that mathematics support resulted in '*tangible student benefits'* and that the centre offered a *'real solution to the problem of retaining students who struggle with the maths content of their degrees.'* (Patel and Little, 2006, p.131).

Marr and Grove (2010) edited '*Responding to the Mathematics Problem'* in which the varied means of mathematics support provision across the UK was documented. As the name suggests this volume was produced to follow-on from the earlier reports: Measuring the Mathematics Problem (Hawkes and Savage, 2000) and Tackling the Mathematics Problem (London Mathematical Society, 1995) cited in the Introduction (Chapter 1).

In 2011 an e-mail survey of the mathematics support centres in forty UK universities was conducted (Gillard *et al.*, 2011) to find out how these centres measured their effectiveness. The survey found that much work had been done to record the student perspectives of the support. They strongly recommended that, at least, minimum student details, the number of visits and their mathematics problems should be recorded.

Whilst this sub-section has described the evolving problem and response to students' lack of mathematical knowledge in the UK, a similar situation has unfolded in Ireland. Irish students were also found to be under-prepared for their university courses (Hourigan and O'Donoghue, 2007) and similarly, in response, a network of mathematics support centres has evolved and a National Centre for Excellence in Mathematics and Science Teaching and Learning has been established (NCE-MSTL, 2011). The mathematics support centres have become well established for student support and also conduct mathematics education research, outreach to local schools and collaboration between centres. The need for the mathematics support in Ireland is explained in Gill and O'Donoghue (2007), Hourigan and O'Donoghue (2007), Faulkener, *et al.* (2009), Faulkener *et al.* (2010), Ni Fhloinn (2009), and Grehan *et al*. (2011). The wide range of provision across different institutions was also documented in the Audit of Mathematics Support Provision (Gill *et al.,* 2008). Attention has also been given to mathematics teacher training courses, for example Liston and O'Donoghue (2009b) studied pre-service teachers' conceptions of mathematics. An illustration of the depth and volume of research into Irish mathematics education and mathematics support is demonstrated by the range of recent publications by the Mathematics Education Research Group at the National University of Ireland. (Mac an Bhaird *et al*., 2011).

The provision of Mathematics support has also developed in other countries around the world, for example in Australia (Cuthbert and MacGillivray, 2003) and the Netherlands (Heck and Van Gastel, 2006).

This subsection has contained a description of the evolution of mathematics support provision from small beginnings to what is currently a prevalent and well recognised form of student support in higher education. Research into the effectiveness of the mathematics support at Harper Adams was one of the research sub-questions in this thesis. It has not however been the main focus in this research due to ethical issues arising from this author also being the provider of the mathematics support. Mathematics support was however of interest in this thesis because it was the subject of various questions in the surveys and interviews as will be explained in the Methodology (Chapter 3), and it was one of the features which the students very much perceived had helped them to learn mathematics and statistics, as will be explained in the results (Chapters 4 and 5).

2.7 Theoretical Concepts and Underlying Assumptions

The section presents the theoretical framework which has not already been presented in the research studies in this chapter. This includes ontological and epistemological assumptions about the nature of mathematics as a subject and the process of learning it, learning cycles, background theory regarding attitudes and beliefs, definitions of self-confidence, self-efficacy and self-concept by other authors, this author's own three Mathematics Self-confidence Domains, motivation and mathematics anxiety. The final sub-section in this chapter summarises the position which has been adopted regarding the definition of Affect in Mathematics.

2.7.1 Ontological and Epistemological Assumptions

Grix (2004) defines Ontology as the *'way in which we view the world'* and ontological claims are

> '*claims and assumptions that are made about the nature of social reality, claims about what exists, what it looks like, what units make it up and how these units interact with each other'.* (Grix, 2004, p.171).

It was considered important to identify and be aware of the initial pre-conceptions and assumptions on which this research was based. The ontological position of the author and adopted for this research could be summarised by the following statements (many of which are expanded on in this thesis and are evidenced in this literature review chapter):

- Mathematical skill and knowledge is important in a modern technological society, and there is concern over the future supply of such skills (Roberts, 2002 and O'Donoghue, 2000a).
- Statistics, mathematics and general numeracy are important in academic research to quantify effects and observations, and to verify and support research claims.
- Many students encounter difficulties in higher education due to their poor mathematical skills, attitudes and beliefs (Marr and Grove, 2010).
- Schools and further education colleges pre-university are the main determinants of students' skills (or lack of skills) on arrival at university (Shaw and Shaw 1999).
- Negative student attitudes and beliefs about numeracy, mathematics and statistics are prevalent in the literature (Shaw and Shaw, 1997, Evans, 2000, O'Donoghue, 2000a, O'Donoghue, 2000b, Brown *et al.,* 2003b and QCA 2006a) and in this author's own experience.
- Students' experiences of learning mathematics at university has the potential to improve (or worsen) students' skills, attitudes and beliefs in and towards mathematics (Shaw and Shaw, 1999).

Epistemology is the '*theory of knowledge'* (in Greek episteme means knowledge and logos means reason) and '*epistemological considerations depend on beliefs about the nature of knowledge'* (Grix, 2004, p.166). Epistemological issues are *'assumptions about forms of knowledge, access to knowledge and ways of acquiring and gathering knowledge'* (Holloway, 1997, in Grix, 2004, p.166).

There are different types of epistemological assumptions relevant to this research:

i) assumptions which relate to the processes for the acquisition of knowledge for the study, i.e. to explore and answer the research questions (the outworking of which underlies the choice of methodology, which is described in Chapter 3); and

ii) assumptions which relate to how students learn mathematics and statistics, which can be
   a. generic to any learning processes and thereby would apply equally to learning any other subject, or
   b. particular to learning mathematics and statistics, i.e. considerations or assumptions which are unique or have particular or exaggerated effects when learning these subjects.

Epistemological assumptions which have been made regarding students' learning of mathematics and statistics include the following:

- A person's past experiences will affect their knowledge, skills, beliefs and attitudes (Frid *et al*., 1997, Brown *et al.,* 2003b, and Shaw and Shaw, 1997 and 1999).
- Learning mathematics requires sequential learning and scaffolding, i.e. building on previously learnt concepts and skills (Brown *et al.,* 2003b). Thus learning mathematics and statistics at university requires students to have some prior mathematical knowledge and skills. Lack of necessary pre-requisite knowledge and skill can prevent effective learning of new things.
- Failure in mathematics is more obvious, e.g. only one correct answer is usually accepted, and it is often difficult to learn new mathematics once a gap in knowledge or a misunderstanding exists. (Brown *et al.,* 2003b, and Frid *et al*., 1997).
- Beliefs and attitudes towards the subject(s) can affect a person's learning (e.g. Duffin and Simpson, 2000).
- A person's capability is the result of a combination of their past experiences (nurture), intrinsic abilities (nature) and current learning.
- Their current learning is a combination of external factors (for example, lecturer style and clarity, subject content, time of day, physical environment, etc.) and their own contribution (effort, attitude, belief, motivation, interest, etc.). It is the current learning which is sought to be maximised.
- Mathematics and statistics are best learnt by doing and understanding, not just by listening, watching and reading (Garfield, 1995). Learning requires active participation on the part of the student to practise and learn for themselves (Garfield, 1995, Garfield and Ben-Zvi, 2007 and Burton, 2004).
- Students with specific learning difficulties, such as dyslexia and dyscalculia, may have different needs or characteristics when learning mathematics and statistics (e.g. Chinn, 2001, Butterworth, 2005, Perkin and Croft, 2007, and Clayton, 2007)

The above list described many of the initial views and pre-conceptions of the researcher which influenced the areas investigated.

2.7.2 Mathematics Failure and Success Learning Cycles

Ernest (1991) referred to growing evidence that student achievement was affected by their attitudes and beliefs about mathematics. Belief in one's own ability, or confidence, was considered particularly important in mathematics and self-reinforcing cycles were observed to form where the achievement attitude link is observed, as shown in Figure 2.1 below (Ernest, 2000). Note: Figure 2.1 has been adapted by adding *'and Beliefs'* into the Attitudes box because in this thesis self-confidence is treated as a belief and not an attitude. The distinction between a belief and an attitude will be explained in Sub-section 2.7.3.

A negative vicious cycle can form when low achievement or persistent failure produces negative attitudes and reduced confidence, which discourages effort and can even create mathematics avoidance. Fortunately a positive cycle can also arise where success promotes good attitudes and confidence, which then encourages effort, which leads to further success (Ernest, 2000).

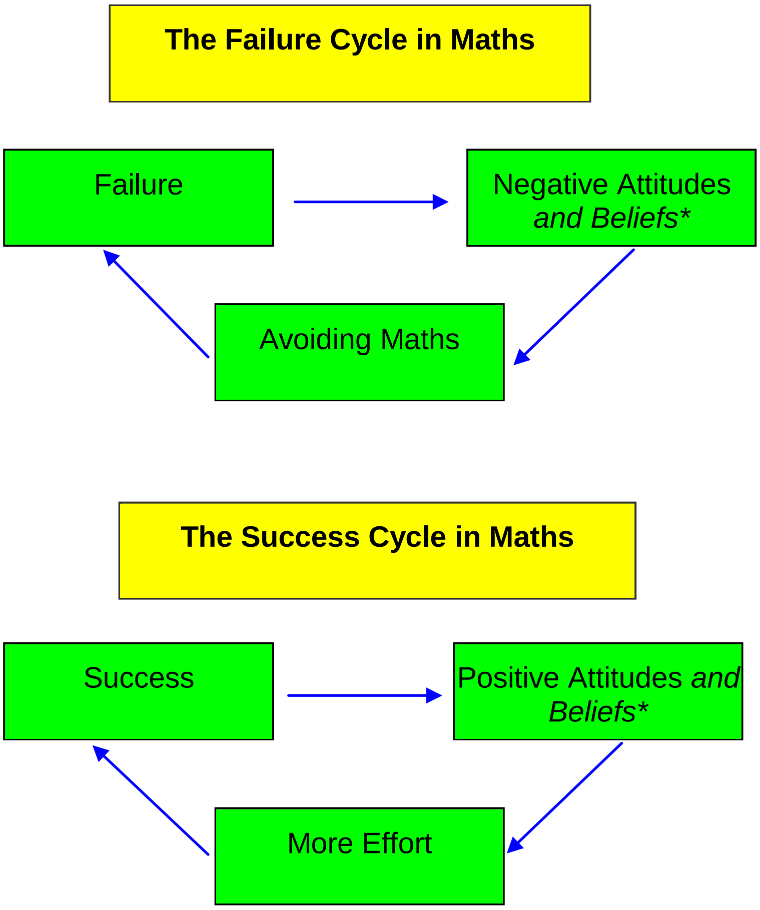

Figure 2.1 Failure and Success Cycles in Maths (Ernest, 2000)
* Adapted by adding '*and Beliefs'*

2.7.3 Belief, Attitude, Intention and Behaviour

In this section beliefs, attitudes, intentions and behaviours will be defined and differentiated, primarily by referring to the work of Fishbein and Ajzen (1975). They suggest that beliefs, attitudes, intentions and behaviours should be considered as four distinct variables, linked in a causal chain, and that this distinction serves to clarify the diverse definitions regarding attitudes. Beliefs are based on the information available (these may be known facts, for example a student's previous test result), which feed into attitudes, from which an intention may form which may result in a behaviour, as shown diagrammatically in Figure 2.2 below (which has been adapted by simplification and addition of the dotted Consequence box).

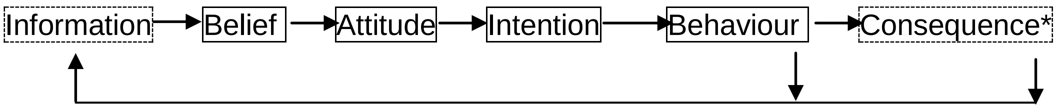

Figure 2.2 Causal Chain of Beliefs Attitude Intention and Behaviour
Source: Fishbein and Ajzen, 1975 (*adapted).

A person's confidence in mathematics can be considered a belief, in particular his belief as to whether he can reliably perform a mathematical task. A belief is understood to link an object with an attribute, or characteristic (Fishbein & Ajzen, 1975). In this case the object is the person himself and the attribute is his ability (or lack of) to do the mathematics successfully. The information on which the belief has been formed is primarily the person's past experiences of doing mathematics and also other general beliefs about mathematics, for example that mathematics is logical or difficult, etc. (as was also found in QCA, 2006a).

A definition of attitude which has widespread agreement is '*a learned pre-disposition to respond in a consistently favourable or unfavourable manner with respect to a given object*.' (Fishbein and Ajzen, 1975, p.6). The object(s) in this instance being the subjects of mathematics and statistics, and the processes of learning these subjects. A person's liking of mathematics, or liking of statistics would be classified by Fishbein and Ajzen (1975) as attitudes.

Intention is viewed as being related to a corresponding behaviour, where behaviour is an '*overt behaviour studied in its own right*.' Fishbein and Ajzen (1975). Intention is also classed as a type of belief, namely the belief as to whether the person will do the behaviour in question. Fishbein and Ajzen consider that intentions are generally carried out as the corresponding behaviour. This separation of intention and actual behaviour is helpful in this thesis, because an intention may not result in behaviour, e.g.

a student may intend to practise mathematics, but is prevented by other pressures, such as: other academic work; paid work; family pressures; or illness, etc.

Consequence has been inserted into the Fishbein and Ajzen model to denote that a behaviour can produce an important result, such as student marks.

Fishbein and Ajzen (1975) considered that a person's attitude towards mathematics is the total affect associated with his beliefs about mathematics. In this thesis, however, a person's beliefs, attitudes and emotions are all considered to collectively constitute a person's affect in mathematics, as explained in sub-section 2.7.8.

2.7.4 Bandura's Self-Efficacy Theory (or Social Cognitive Theory)

Professor Albert Bandura, an American psychologist (Pajares, 2004) defined perceived *self-efficacy* as

> '*not a measure of the skills one has, but a belief about what one can do under different sets of conditions with whatever skills one possesses.'*
> (Bandura, 1997, p.37).

Bandura considered each person to have sets of different *self-efficacy* beliefs which each relate to different skills, distinguishing between *sub-skills* and overall skills which he termed *operative capability.* For example, he deemed driving competently in varied conditions to be a non-trivial *operative capability* (Bandura, 1997, p.38). He considered that self-efficacy beliefs were especially important in the lives of young people, because it affected their psychological well-being, what they would go on to achieve and the future directions their lives took (Bandura, 1995). Self-efficacy beliefs are a strong predictor of academic attainment, and that knowledge, skills and prior attainments are often poor predictors because of beliefs which influence the way that individuals behave (Bandura, 1997).

Bandura proposed four principal sources of self-efficacy beliefs: *Enactive mastery experiences*, *Vicarious experiences*, *Verbal persuasion* and *Physiological and affective states* (1997, p.79). *Enactive mastery experiences* are past experiences of endeavours, both successful and unsuccessful. Past successes enhance self-efficacy, whilst failures undermine it, especially in early experiences of the activity. Persevering to complete difficult problems contributes towards producing a strong self-efficacy, because success in these make a person reappraise their level of self-efficacy; such reappraisal is not necessary with tasks that they consider they can already do. *Vicarious experiences* are comparisons with peers or similar persons and circumstances; perceived superiority enhances self-efficacy whereas perceived inferiority lowers self-efficacy. *Verbal persuasion* occurs when others say that they consider that we can succeed. Other people expressing faith in one's capabilities helps to sustain self-efficacy, but this must be realistic and has the greatest effect when people already have reasons to believe they can succeed. It is harder to raise someone's self-efficacy by persuasory means alone than it is to reduce it. *Physiological and affective states* provide further information about people's capabilities. '*Physiological'* means '*concerning the way a living organism or bodily part functions*' and *'affective'* means *'relating to moods, feelings and attitudes'* (Oxford, 2007, p.772 and p.18). For example, an accelerated heart rate may be interpreted as a sign of distress and not coping well. Mood states (affective states) can affect memory; a negative mood tends to activate thoughts of past failings thus diminishing self-efficacy and the reverse for positive moods (Bandura, 1997, p.107-113).

Bandura specified four types of mediating processes through which a person's perceived self-efficacy can take effect: *Cognitive, Motivational, Affective* and *Selective* processes (1997, p.116). In *Cognitive* processes a persons' self-efficacy affects whether he will view a task or situation as being achievable or not. *Motivational* processes are those which influence a person's reasons for and willingness to do certain actions (see 2.7.7). *Affective* processes can be affected by efficacy beliefs worked out in the person's thoughts, actions and emotions. For example, a person may feel anxiety if they lack self-efficacy for a task. *'Selective'* processes choose (or reject) particular endeavours. '*People of high efficacy not only prefer normative difficult activities, but also display high staying power in those pursuits'* (Bandura, 1997, p.160). This not only affects endeavours and areas of study chosen and pursued, but also those which are avoided or ruled out, and if these choices are made at a formative stage it could impact the rest of the person's life.

Bandura's self-efficacy theory (1997) has been widely recognised and referenced by other authors (examples include: Pajares and Miller, 1994 and 1995, and Warwick, 2008a). Both Bandura and Warwick emphasise the helpfulness of considering *ability* to be an acquirable skill rather than an inherent quality; which encourages positive cycles of effort, achievement and confidence (Warwick, 2008a; Ernest, 2000; Bandura, 1997, p.161). One aspect which Bandura however does not consider is the distinction between being able to do mathematics and really understanding the mathematics, a distinction which learners often find important, for example in Solomon 2006 and 2007, and as will be shown in the results in Chapters 4 and 5, and Conclusions in Chapter 6.

2.7.5 Pajares' Self-Concept and Self-Efficacy

Frank Pajares, an American educational psychologist, applied Bandura's self-efficacy (1997) to specific subject areas (domains). Pajares and Miller researched self-efficacy in mathematics performance (1994 and 1995) and constructs related to confidence and motivation, their meaning and inter-relations. The distinction between self-efficacy and self-concept was explained as follows.

> *'self-efficacy is a context-specific assessment of competence to perform a specific task'… 'Self-concept is not measured at that level of specificity and includes beliefs of self-worth associated with one's perceived competence.'* (Pajares and Miller, 1994, p.194).

Other self-efficacy beliefs investigated by Pajares include science self-efficacy beliefs (Britner and Pajares, 2006) and sources of writing self-efficacy beliefs of school pupils (Pajares *et al.* 2006). Pajares (1994) and Bandura (1997) argued the need for specificity, i.e. that there must be a good match between the self-efficacy task and performance tasks. Pajares (1996) and Bandura (1997) also described *'Collective efficacy'* which is a social construct of a shared belief pertaining to, for example, a class, team or school, regarding their combined capabilities to achieve.

Pajares and Miller (1994) investigated mathematics self-efficacy, perceived usefulness of mathematics, mathematics anxiety, mathematics self-concept and prior experience of 350 undergraduates. Self-efficacy was found to be a stronger predictor of attainment than the other variables, and self-efficacy mediated the effect of gender and prior experience. Interestingly the term confidence was used interchangeably with self-efficacy, which supports the use of the term confidence in the instruments used in this thesis (although confidence was described as the forerunner to self-efficacy), and confidence was found to predict maths-related performance. Pajares and Miller (1995) investigated 291 students' self-efficacy judgements and found evidence of the need for specificity in the measure of self-efficacy and the task being assessed.

In Pajares (2000) 30% of graduands said they had never received any emotional support and encouragement from their tutors; Pajares encouraged educators to ensure that classroom practices not only developed students' intellect and scholarship, but also helped students to develop good self-beliefs, to equip them to educate themselves throughout adulthood.

2.7.6 Mathematics Self-Confidence Domains Proposed in this Thesis

Three Mathematics Self-confidence Domains are proposed in this thesis: an *Overall Confidence in Mathematics*; *Topic Confidences;* and *Applications Confidence.* These three Mathematics Self-confidence Domains are described in detail below and shown in Figure 2.3 below (and also in Figure 6.1). Survey questions based on these three domains were used both to verify the Mathematics Self-confidence Domains and to explore how confident the students were.

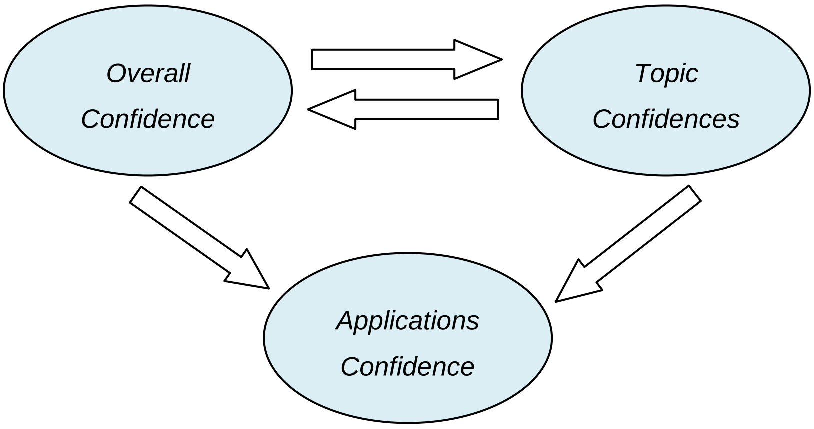

Figure 2.3 Mathematics Self-confidence Domains (Author's own, 2014)

Overall Confidence in Mathematics is a single measure which represents a persons' belief as to whether they can do 'any' or 'all' mathematics. '*I don't have a mathematical mind'* and *'I have never felt myself able to learn mathematics'* (Fogarty *et al.*, 2001, p.159) are phrases used by people who have a low *Overall Confidence in Mathematics*. Low *Overall Confidence in Mathematics* can result in reduced effort in mathematics, and even mathematics avoidance (both unhelpful behaviours), because students do not consider that they can succeed and therefore avoid expending what they perceive would be wasted effort. Low *Overall Confidence in Mathematics* can also be associated with mathematics anxiety, and sometimes even panic (both unhelpful emotions). It was considered that high *Overall Confidence in Mathematics* was beneficial, not simply as providing or engendering a positive outlook, but also because it motivated students to work at mathematics. This is then self-fulfilling because their efforts improve their ability and performance, and make the effort worthwhile (Ernest 2000). Low *Overall Confidence* was considered a barrier to learning mathematics, whereas high *Overall Confidence* was considered an enabler and a pre-requisite for independent learning in mathematics. *Overall Confidence in Mathematics* had been investigated in the US (as *'math self-concept')*, but when this study commenced in 2004 it was not known to have been investigated in a UK university before.

Topic Confidence is the student's *belief* as to whether he *can do* a particular task in mathematics, for example 'rearrange an equation' or 'differentiate a product'. Each student would have any number of *Topic Confidences* depending on the list of topics being considered, he would have a *Topic Confidence* for each topic. Confidence at any one topic will vary greatly depending on a range of criteria, including: whether the student has studied this topic, understood it, remembers it, and the perceived level of difficulty, etc. Students' *Topic Confidences* were assessed by Armstrong and Croft (1999), Croft (2005), Frid *et al.* (1997), Shaw and Shaw (1997) and Carmichael and Taylor (2005), as described in Section 2.2, and the results of these studies were used mostly to determine student needs for additional support.

Applications Confidence is the confidence to apply mathematics, and was of interest because students should be prepared for their future studies and future lives, and not only for short-term success at university. Many jobs in engineering require competency in mathematics, as do the latter parts of many courses, for example for project work and dissertations. So it is beneficial for students to feel confident that they will be competent at mathematics and statistics in the future.

2.7.7 Motivation

A simple definition of motivation is '*the process which initiates, guides and maintains goal-oriented behaviours'* (Cherry, 2011, p.1); other definitions are discussed by Kleinginna and Kleinginna (1981) and Ames and Ames (1984). Hannula (2006, Abstract) conceptualised motivation as a '*potential to direct behaviour through the mechanisms that control emotion'* where motivation was structured through needs and goals, such that: goals are derived from needs; beliefs influence the person's view of the accessibility of the goals; and the goals are regulated by emotional reactions. Hannula (2006) considered motivation to be difficult to observe and measure. Much of the motivation literature relates to goals, especially goals of performance and achievement. Wolters (2004) investigated goal structures and orientations in mathematics, as did Middleton and Midgley (1997) who also included '*avoidance'* of demonstration of lack of ability as a goal. Zimmerman *et al.* (1992) found that parental goals, students' personal goals and self-efficacy beliefs predicted achievement in social studies, whilst Eynde *et al*. (2006) investigated emotions, motivation, cognition and mathematics-related beliefs and how these affected students doing mathematical problem-solving.

Bandura (1997) included motivational processes as one of his four mediating processes of self-efficacy (in Section 2.7.4) and categorised motivation theories as attribution theories, expectancy-value theories and goal theories. Attribution theories are based on what past successes or failures were attributed to, for example a person who accredits their successes to personal capabilities and past failures to lack of effort, will undertake a difficult task and persist to accomplish it. Expectancy-value theories predict that the higher an outcome is valued and the more expectation that a behaviour will bring about the desired outcome, the more motivated a person will be to perform the activity. Goal theories define goals in term of characteristics of specificity, proximity and challenge, such that to optimise motivation goals should be clear and specific, proximal (near) rather than distal, and sufficiently challenging, but not unrealistically demanding (Bandura, 1997).

Eynde *et al.* (2006) separated motivation from emotions and beliefs and cognitive processes, as did Cretchley (2008), however, there are others who consider motivation to be a component of affect, and still others who suggest that the components of affect make up motivation (Chamberlin, 2010). In this thesis motivation is regarded as a separate construct, different from beliefs, attitudes and emotions, consistent with Bandura (1997).

2.7.8 Mathematics Anxiety

Mathematics anxiety is another construct which is recognised to affect performance in mathematics as a result of a psychological or emotional state. Cemen (1987) defined mathematics anxiety as

> *'a state of anxiety in response to situations involving mathematics which are perceived as threatening to self-esteem'* (Cemen ,1987, Abstract).

Individuals who have strong self-esteem and task level confidence might possibly control and use the anxiety to enhance performance in the task, but more often, if the anxiety is not controlled it can debilitate performance. Long-term coping strategies can include avoidance of mathematics and adopting the viewpoint that mathematics is not useful (Cemen, 1987).

Richardson and Suinn (1972, p.551) defined mathematics anxiety as *'feelings of tension and anxiety that interfere with the manipulation of numbers and the solving of mathematical problems...*' They created the Mathematics Anxiety Rating Scale (MARS, 98-item version) which has been used extensively for research into mathematics anxiety. This was later shortened, to the MARS 30-item test (Suinn and Winston, 2003), which was found to yield comparable results.

Whilst mathematics anxiety is of interest because it can have a profound effect on some students' competence and is related to confidence in mathematics, it has not been explicitly investigated in the study described. The study of mathematics anxiety is often conducted from the discipline of psychology (for example, Ford *et al.,* 2005 and Sheffield and Hunt, 2006) rather than mathematics education. Ford *et al.* (2005) concluded:

- '*Maths anxiety has an effect on accuracy, particularly when performing a secondary task that puts heavy demands on working memory*
- *High anxiety may lead to errors of greater magnitude*
- *Serial recall declines as problem difficulty increases*' for both high and medium anxiety ' (P<0.01). (Ford *et al.*, 2005, slides 20 and 22)

Trew (2005) explained that Maths anxiety was usually measured on a standardised test but found that these correlated with the single question: *'On a scale from 1 to 10 how maths anxious are you?'* (Trew, 2005, slide 3). Trew states various other findings which will be shown to be in common with the findings in this thesis for self-confidence, which are listed in the Conclusions (Chapter 6).

Hembree (1990) found that anxiety related inversely to positive attitudes toward mathematics and was related directly to mathematics avoidance; Chewning (2002) found that there was no single cause for mathematics anxiety and Warwick (2008b and 2011) investigated and measured maths anxiety. Other literature relating to mathematics anxiety includes: Bai *et al.* (2009), Rossnan (2006), Strawderman (undated) and Sherman and Wither (2003).

2.7.9 Summary of Affect in Mathematics

Whilst mathematics education research has increasingly been interested in *'affect'*, affect has been defined in different ways and with a lack of cohesion and communication between the different theoretical frameworks (Zan *et al.,* 2006). In this thesis affect in mathematics is defined as the sum of a person's beliefs, attitudes and emotions regarding mathematics. This is consistent with Fishbein and Ajzen's (1975) separation of beliefs and attitudes, and McLeod (1992) who divided the affective domain into beliefs, attitudes and emotions.

Pehkonen and Pietilä (2004) considered beliefs to be either subjective knowledge or objective knowledge (formal, official or public knowledge). They state very clearly the characteristics of beliefs, attitudes and emotions, and how these vary in '*stability, intensity, in cognitive involvement and in how long their development takes',* which is encapsulated by *'emotions are "hot", attitudes "cool" and beliefs "cold".*' (Pehkonen and Pietilä, 2004, p.5). Emotions are the most intense, least stable and require least cognitive processing; one such short-term positive emotion is the AHA! experience during problem-solving (Liljedahl, 2005). Chamberlin (2010) commented on the difficulty of measuring psychological constructs such as anxiety and interest, compared to the straightforward measurement of physical characteristics, such as height. Attitudes are relatively intense and rather stable; attitudes form in one of two ways: a repeated emotional reaction can be stabilised into an attitude, or an existing attitude can be assigned to a related scenario (Pehkonen and Pietilä, 2004). Beliefs are cognitive and are formed rather slowly; deeply held beliefs may be the result of considered reflection over a long period of time (Pehkonen and Pietilä, 2004).

Lent *et al.* (1997) found a difference in self-concept and self-efficacy, and mathematics specific self-efficacy using factor analyses. Bong and Clark (1999) reviewed research into academic self-concept and self-efficacy. They concluded that self-concept was a more complex construct from both cognitive and affective factors, involving greater social comparison, than self-efficacy which primarily concerned cognitive judgments of ability to perform in a specific area. Due to the more specific nature of self-efficacy and of self-efficacy research, self-efficacy research has produced superior predictive and explanatory results then self-concept research. Bong and Skaalvik (2003) further investigated the distinction between these two constructs, and concluded that both constructs shared the centrality of perceived competence, use of mastery experiences, social comparison and reflection of information; however that self-concept consisted of more multiple components and sub-processes than self-efficacy, and also that self-efficacy beliefs contribute to the formation of a person's self-concept. Both constructs originate from a study of self, and both 'camps' have demonstrated that desirable outcomes are produced by positive perceptions of self. They point out that more effort has been made to look for the relationship between self-concept and achievement rather than finding ways to successfully improve students' perceptions of themselves.

All three Mathematics Self-confidence Domains proposed in this thesis would be termed *self-efficacy* by Bandura (1997), whose *operative capability* is equivalent to *Overall Confidence in Mathematics*, and whose *sub-skill efficacy* relates to the *Topic confidence*, with *Applications Confidence* being a self-efficacy under different conditions. Pajares and Miller's (1994) *self-efficacy* is similar to *Topic confidence* and *self-concept* is equivalent to *Overall Confidence in Mathematics*. Whilst Parsons, Bandura, and Pajares and Miller use different terms for these *self-confidences*, there is a common distinction between the *self-confidence* to perform a specific task and an overall *confidence* in mathematics. The *Overall Confidence in Mathematics* was of particular interest in this thesis because it provided a single measure of students' perceived capability in mathematics. In Pajares (1996), domain-specific confidences (e.g. *'confidence to learn mathematics'*) have better predictive power than '*omnibus measures',* but the most predictive are the *'task-specific judgements',* however he notes that different insights may be gained from these different judgements.

Cretchley (2008) clarifies the distinction between self-efficacy, self-confidence (usually just called confidence) and self-concept, placing self-confidence in between self-efficacy and self-concept. She also analyses recent instruments to measure both self-confidence and intrinsic motivation, commenting on the usefulness of such research to inform course development and classroom practices.

Whilst there are clear links between knowledge, competency, and self-efficacy and self-concept beliefs, there are also exceptions to this, for example someone of low-self-efficacy beliefs may be highly motivated, work hard and perform well (Carmichael and Taylor, 2005).

The distinction between academic self-efficacy and academic self-concept was investigated by Ferla *et al.* (2009). These were confirmed to be two distinct and separate constructs, both conceptually and empirically, even when studied in the same domain (e.g. mathematics). Secondary data of a mathematics test and student questionnaires results from 8796 Belgian school children at 277 schools was analysed; mathematics self-efficacy and mathematics self-concept influenced each other reciprocally, but the impact of mathematics self-concept on mathematics achievement was weak and was mediated through mathematics self-efficacy and mathematics anxiety. Mathematics self-efficacy almost exclusively mediated the effect of gender and past achievement. Other differences found were that self-concept was more past-oriented, whilst self-efficacy was more context specific and forward-looking; academic self-concept was a better predictor of mathematics anxiety and mathematics interest (affective-motivational variables), whereas self-efficacy was a better predictor of academic achievement (Ferla *et al.,* 2009). This recent work by Ferla *et al.* demonstrates the high level of interest in self-efficacy and self-concept, and helps to provide a clearer definition and understanding of these two personal beliefs.

Whilst there was much literature about the structure and composition of the different constructs of self-confidence, self-concept and self-efficacy, this thesis was more concerned about investigating whether students' self-confidence (and self-concept and self-efficacy) does affect their achievement in mathematics and statistics. For example, Gore (2006) reported on two incremental validity studies with college students who found that (beyond what would be expected from ability standardised test scores) self-efficacy beliefs did predict college outcomes, but that the relationship also depended on when the self-efficacy beliefs were measured and the type of self-efficacy beliefs being measured. Examples of literature which found a correlation, association or predictions of achievement with self-confidence are given in the Conclusions (Chapter 6).

In summary, affect in this thesis is considered to comprise emotions, attitudes and beliefs, with motivation as a separate related construct.

2.8 Dyslexia, Dyscalculia and Specific Learning Difficulties

In 2005 there was a high proportion of students at Harper Adams who had declared some form of disability, 16.5%, and approximately 14% of students were known to be dyslexic and a smaller unknown number, possibly around 1%, were thought to be dyscalculic (although those dyscalculic students known to the study were also known to be dyslexic). In 2011 these percentages had risen to approximately 17% students with a disability and 16% students with dyslexia. The opportunity was seized in this study to investigate the experiences of the high proportion of dyslexic students learning mathematics at Harper Adams, especially amongst engineering students where there was a particularly high incidence of dyslexia (Chapter 4) and information was also gathered about students with dyscalculia, as is explained in the Methodology (Chapter 3). It was also considered that the number of known dyscalculic students was likely to be less than the actual number due to diagnosis of the condition occurring very rarely. The number of students in the College believed to have dyspraxia was low, hence investigation of the effects of dyspraxia on learning mathematics was not included.

In order to place these investigations within a theoretical framework, definitions of the various terms will be presented in this subsection.

A Specific Learning Difficulty (SpLD) is a general term which includes dyslexia, dyscalculia and dyspraxia, among other conditions. These can occur individually or co-exist (co-morbidly), and the severity of effect occurs across a continuum. Youngs (2003) defined a Specific Learning Difficulty as follows.

> *'Pupils may have difficulty in reading, writing, spelling or manipulating numbers, which are not typical of their general level of performance. Pupils may have difficulty with short-term memory, with organisational skills, with hand-eye coordination and with orientation and directional awareness.'* (Youngs, 2003, p.274)

Dyslexia is the most common Specific Learning Difficulty, and relates to the use of language and words. Dyslexia commonly causes difficulties in '*learning to read, write and spell'*, '*use of short term memory, concentration, personal organisation and sequencing'*. Other areas which can also be problematic are '*poor comprehension, handwriting and punctuation'* (Youngs, 2003, p.274). A similar definition can be found on the DfE web-site, which also points out the discrepancy between difficulties in literacy compared to other areas: *'Pupils with dyslexia have a marked and persistent difficulty in learning to read, write and spell, despite progress in other areas.'* DfE (2011). Some dyslexic children do not experience problems learning mathematics, but many others have problems with both literacy and numeracy (Sharma, 2003).

Dyscalculia is the specific learning difficulty related to mathematics and numbers. A dyscalculic person would experience difficulties with '*numbers and remembering mathematical facts as well as performing mathematical operations.'* (Youngs, 2003, p.275). Other related areas may also be affected, such as '*abstract concepts of time and direction, recalling schedules, and sequences, … as well as with mathematical* *concepts, rules, formulas and basic addition, subtraction, multiplication and division.'* (Youngs, 2003, p.275). Chinn (2001) summarised Dyscalculia as *'a lower achievement in mathematics than would be expected from general ability.'* (Chinn, 2001, p.282). Dyspraxia is defined as '*an impairment or immaturity in the organisation of movement'* (Youngs, 2003, p.275).

2.9 Effect of Gender on Student Self-confidence and Learning Mathematics and Statistics

This sub-section describes a selection of research into gender differences starting from the early 1990's, when there appeared to be considerable interest in this area, up to the current time. It appears that before and during the 1990's lower achievement in mathematics by females compared to males was a generally accepted finding, and there was also some interest in females' poorer attitudes, beliefs and confidence. More recently the gender gap in achievement appears to be much less robust with some studies not finding any such gap, but the difference in attitudes and beliefs, and stereotyping of mathematics (and science) as male domains, appears, unfortunately, to have persisted.

In 1992, McLeod found that student beliefs about mathematics affected their performance, and that males tended to have more positive views than females. Fennema and Leder's book (1990) reported various studies and a model which suggests that females had *'lowered participation in autonomous learning behaviours which both require and develop one's ability to work independently in high-cognitive-level activities*.' (Fennema and Leder, 1990, Abstract). Consistent with these, Sax (1994) reported that the previous decade's research had found persistent gender gaps in mathematics achievements (women scoring less in mathematics tests), and suggested that differences in mathematics self-concept were the underlying cause, that women were simply less confident in mathematics. Sax's large US study examined the development of mathematical self-concept during college for a sample of 8997 women and 6053 men, which revealed both an overall decline in self-concept and a widening gender gap in mathematics self-concept during college.

Brown *et al.* (2003b) reported that females in English universities preferred to remain invisible in mathematics lectures, and Skaalvik and Skaalvik (2004) found that male students in Norway had higher mathematics self-concept, performance expectations, motivation and self-enhancing ego orientation than female students did**.** Frid *et al.*

(1997) on the other hand, however, found to the contrary, that some females became generally more confident than males whilst learning university mathematics. Tapia and Marsh (2004b) did not find any gender effect on attitudes toward mathematics in a sample of 134 students enrolled in mathematics classes in a state university in the US.

Use of the '*Mathematics and Technology Attitudes Scale'* (MTAS) in Pierce *et al.* (2007) and Barkatsas (2004) revealed clear gender differences in attitudes (as has already been described earlier in this chapter). Boys had significantly higher scores for four areas: Mathematics confidence, Confidence with technology, Attitude to learning mathematics with technology, Affective engagement, but not for Behavioural engagement. Boys were much more confident in mathematics than girls ($t=6.13$, $df=155$, $p=0.000$).

Hyde *et al.* (2006) reported gender differences in attitudes and affect specific to mathematics. Complex meta-analyses found that, when a difference existed, females held more negative attitudes, and that males held more stereotyped attitudes. Gender differences in self-confidence and general mathematics attitudes were greater among high school and college students compared to younger students. Such differences were considered important and were recommended to be considered, along with other social and political influences, as explanations for gender differences in mathematical performance.

Mendick (2005) suggested that the view that '*doing mathematics'* was tantamount to *'doing masculinity'* provided an understanding of why more boys chose to study mathematics at AS level in England than did girls and why mathematics was so male dominated. The UPMAP project (Understanding Participation in Mathematics and Physics) results indicated that girls were less likely than boys to be encouraged by their families and social circles to study mathematics post-16 (Mujtaba, 2011). Higher intrinsic motivation was strongly suggested as being the crucial underlying factor for whether a pupil (independent of gender) wanted to continue with mathematics post-16.

In this sub-section a selection of relevant literature has been presented to demonstrate the current field of knowledge and interest in gender differences in students' learning of mathematics and statistics. Gender was not specified as a factor for investigation in the research questions, partly because much of the author's original awareness of the issues originated from experience with engineering students learning mathematics, for which the cohorts were almost 100% male, and gender differences did not exist.

Neither had any gender differences been apparent in the author's experience of supporting mixed groups of students learning statistics. However, as will be shown in Chapter 5, Questionnaire results for students learning statistics, some gender effects were found and it will be reported in this thesis that some females lacked confidence, but were not less high achieving, than their male counterparts.

This concludes the literature in this chapter. The following section will present a discussion of the areas where there is a lack of literature and research, to which this study aims to make a contribution.

2.10 Gaps in the Background Literature

It can be seen that, at the start of this research in 2004, only eleven studies on student attitudes and confidence in their mathematical abilities were found, a relatively small number, of which only four were in the U.K. Eleven main studies were described in Table 2.1 which originated from a range of countries, spread over 15 years and related to various mathematical subject areas. Statements about the scarcity of studies into students' learning of mathematics and statistics were also found in the published literature: Brown *et al.* (2003b) suggested the need for a comparison of attitudes and progress of students in newer universities with a wider range of backgrounds. Gal and Ginsburg (1994) found that there was only a '*very small and problematic'* collection of research into students' attitudes and beliefs directly related to learning statistics. The report Participation in A Level mathematics (QCA, 2006a) noted that despite this being an area of high profile concern there had '*been surprisingly few pieces of published research looking at the issue of A level mathematics, and in particular involving students in the research.'* (QCA, 2006a, p.14). Cretchley (2008) stated that while many qualitative studies had been conducted '*few studies have taken on the difficult task of quantifying and monitoring key affective factors, and assessing their role in mathematics learning.'* (Cretchley, 2008, p.152). Frid *et al.* (1997) recommended further research into students' self-confidence and the cause of differing levels of confidence among different student groups.

Whilst the body of research into university mathematics learning has expanded greatly during the course of this study, there is still a need for further evidence-based research in this important, national and international area of concern. The current study is unique in that it provides new data, representing different student types in a different setting, i.e. non-specialist mathematics and statistics students, in a small, specialist

University College. This study also reports on those students' experiences at school before they came to university and their expectations for the future. It is believed that this study was the first in England to investigate students' *Overall Confidence in Mathematics* rather than *Topic Confidences* (these terms were defined and explained in this chapter). The part-time nature of this research has enabled data to be collected during a longer time frame (five years) so more longitudinal analysis of data has been possible, than would be the case in a traditional three year PhD timescale. The researcher's dual role as both PhD student and a staff member has also provided some additional opportunities, for example access to data which might not have been possible otherwise. This is discussed further in the methodology (Chapter 3) in particular in the Ethics section.

This research is thus suggested as a useful and timely contribution to both theoretical and empirical research into this important and problematic area of university students' learning mathematics and statistics, particularly regarding their self-confidence and their experiences at the transition to university. It is hoped that the literature presented in this chapter has provided the reader with an understanding of the major areas of interest (for example self-confidence) and also a range of other topics (for example dyslexia) which were relevant but not the primary focus of enquiry, all of which will be referred to throughout the remainder of this thesis. Some of this literature described empirical studies and findings, whilst other literature was of a more theoretical nature (for example papers explaining the distinction between self-confidence, self-efficacy, and self-concept). Leading on from this literature review the Methodology adopted for this thesis will be described in the next chapter (Chapter 3).

3 METHODOLOGY

3.1 Methodology Overview

This chapter describes the methodology adopted for the study in this thesis, and this section introduces the methodology. The methodology principally comprised the design, administration and analysis of three years of student surveys of first and second year students about learning mathematics and statistics, then interviews were conducted with final year students during the next two years (although these interviews are not fully reported in this thesis); this followed two cohorts of students from their first year to their final year. There were also additional student interviews which were conducted as the study progressed and secondary data was collected and utilised. A more detailed description of the methods utilised in the study is found in the next Section, 3.2. Subsequent sections in this chapter will then explain and justify the ethical considerations which were duly followed, the research philosophy and approaches which were adopted, and the data collection methods with reference to appropriate literature. In the proceeding chapters (Chapters 4-5) the results, analysis and findings from the collected data will be presented.

The periods of activity for the data collection were the academic years 2004/5 to 2008/9. As explained in the Introduction chapter, the study was located at Harper Adams University College and it was the Harper Adams students who were the main subjects of, and contributors to, the study.

Overall a mixed methodology was adopted, this methodology is summarised here, but will be explained further and justified in Section 3.4 of this chapter. The research philosophy adopted was realism, which combines elements of positivism and interpretivism; and the main research approach was deductive, but some parts of the research (for example the student interviews and open questions in the questionnaires) were inductive. The strategy was surveys and the time horizon was both cross sectional and longitudinal. There was predominantly a cross-sectional element to the research which was present in the surveys when a cross-section of a wide range of students on different courses, and in different years of their courses, were all surveyed in the same brief time period. The longitudinal element also existed as the study spanned five academic years, during which time two student cohorts progressed from being first year students to being final year students just about to finish their courses. The details of the student cohorts are shown in Table 3.1.

Educational research follows a broadly similar paradigm to social science research; the nature of social science research is summarised by the Research Process Onion diagram in Figure 3.1 below (adapted from Saunders *et al.*, 2003, p.83). In the diagram the different layers of the onion represent different aspects of the methodology, which are labelled by arrows from below. Within each layer the different possible types are shown. The methodology adopted in this study has been shown in bold text on the diagram. A brief overview of the application of these terms to this study has already been given in this section, and further explanation and justification is given later in this chapter, in Section 3.4.

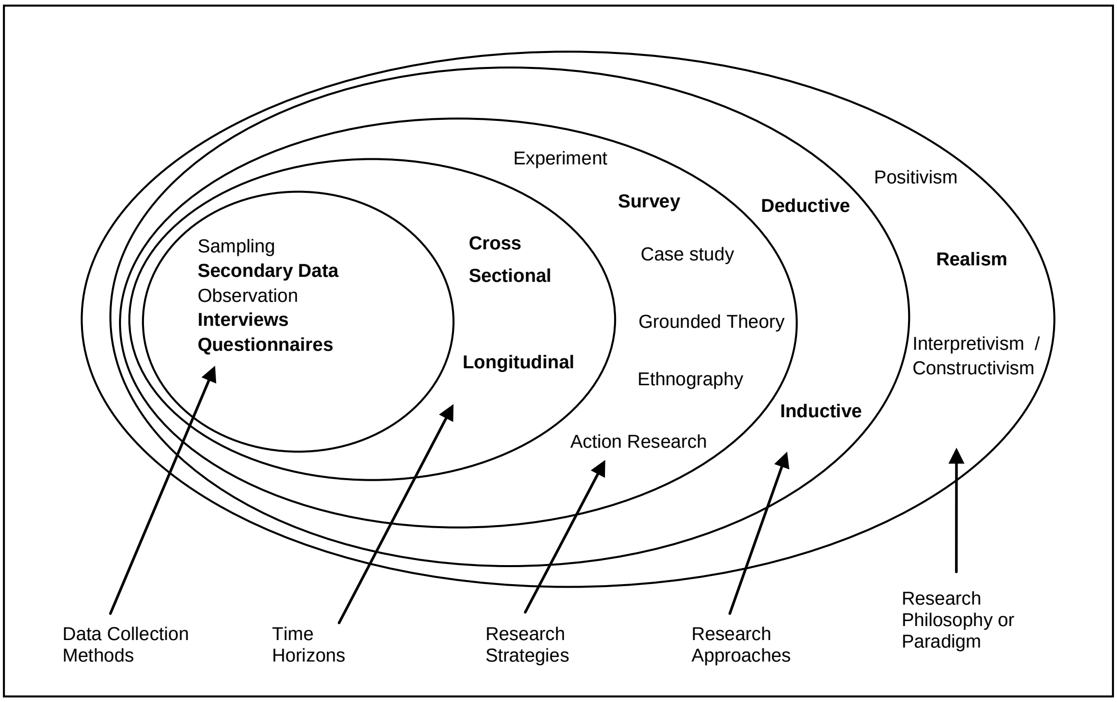

Figure 3.1 Research Process Onion (Adapted from Saunders *et al.,* 2003, p. 83)

Predominantly primary data was used in the study, which was gathered through student questionnaires and student interviews. Questionnaires were conducted to assess characteristics of whole groups of students and to generalise the types of students within the cohorts, as well as to find responses of interest from individuals, whereas the student interviews provided a more detailed understanding of a smaller number of individual students' experiences and perspectives. Secondary data was also obtained and used in the form of student marks. Students' numeracy screening test results and final degree marks and classifications were also obtained, but are not reported on in this thesis. The researcher also taught mathematics to a small number of the students and thereby originated their examination marks (this is referred to again in the section regarding ethical considerations). Most of the student groups surveyed, however, were taught by different members of staff who have assisted the study by administering the questionnaires.

Consideration was given as to whether there was any inadvertent bias in the data collected and what effect this would have had on the findings. One area which was considered was data which it was not possible to obtain (i.e. missing data). For example, it was not possible to interview students who had left part-way through their courses nor those who did not volunteer to be interviewed, nor was it possible to survey those students who did not attend the lectures when the questionnaires were administered. Overall it was felt that there was probably a positive bias in the data collected (because it was the more positive and engaged students who had attended the lectures when the questionnaires were administered), but that this was unfortunately unavoidable. Some work was done in the analysis of student marks to compare the marks of the students surveyed against the marks of those not surveyed in an attempt to identify whether there was an inadvertent bias from the method of data collection. Consideration was also given as to whether the method of data collection could have influenced the students' responses, which it was possible it might have. Efforts were made to keep any bias or intervention from the process of the study to the minimum possible, to be aware of any pre-conceptions, and to triangulate the data where appropriate (see sub-section 3.4.3).

In this chapter the methods which were adopted are explained, so that other researchers could replicate these methods if desired. The questionnaires and interviews were repeated in a similar form in consecutive years, giving similar results, so it was considered that the methods used were reliable. As every effort was made to understand the epistemological and ontological viewpoints of the researcher (which were explained in Chapter 2), and to eliminate, or at least identify, any bias from the data collection methods, it was also considered that the results obtained were valid. As always, however, any findings should be considered bearing in mind the origins of the data. Whilst the study was undertaken in an atypical HEI, it was also considered that the results and findings could still have application to the wider HEI sector. The aspect of the HEI which made it atypical was the small class sizes and each lecture consisting of a combination of delivery and students workings on problems in two hour teaching sessions (and not a one hour lecture to a larger group of students as was typical of many universities); this aside the students' confidence and attitudes towards mathematics for engineers and statistics for non-specialist students would still have wider application than in the institution studied, being of potential relevance to those teaching any non-specialist student studying mathematics or statistics.

A positive consequence from the fact that the study was undertaken part-time was that it enabled a longer period of data collection than a traditional full-time, three year doctorate research project would have permitted. This enabled the time period to span the whole course length of two student cohorts, and also enabled a large quantity of data to be collected. A consequence of the large amount of data collected was that some judgement then had to be made as to the depth to which the data was analysed, and in general the data was analysed to varying degrees. For example, all of the Mathematics Learning Questionnaires were transcribed, and a general summary made and analysis was performed. Some student groups, or years of their study, were then analysed further to a greater depth because these were of particular interest; for example, the engineering students were of interest because they studied more mathematics than students on other courses, or because some groups of students had secondary data more readily available. For example the second year social science students' exam marks were available by question for both 2006 and 2007. The result of the data analysis was that a complete overall picture was obtained, but greater depth was then achieved by focussing on specific sections of the data.

3.2 Data Collection

3.2.1 Data Collection Outline

This sub-section describes which student groups were involved in the study, and how and when those student groups participated. The study commenced during the academic year 2004/5 and was designed to last 5 years until 2008/9, during which time two student cohorts progressed through their four year courses. Table 3.1 details the student cohorts which were available to the study during the 5 years, one academic year per row; the principal cohorts A and B have been shown with the columns shaded. The text in each cell states which stage of their course those students were studying in which year. Degree students at Harper Adams spent their first and second years studying at the college, attending lectures, etc., then in their third year they were away from the College to undertake a year's relevant work placement, the students then returned to the College for their final year, which was usually their fourth year. Some students were not registered for a BSc degree, but instead studied for an HND or FdSc, which was a shorter, three year course. HND/FdSc courses comprised one year at the College, one year on work placement and a final year back at the College, which was their third year (and had some modules in common with the second year degree courses). After completing their HND/FdSc, some of these students then opted to continue at the College to study a fourth year in order to 'Top-Up' to a BSc degree. The College also catered for postgraduate students studying for PhD, MSc and PgD awards, one PgD student participated in the study by volunteering to be interviewed.

Table 3.1 Student Cohorts Available to the Study

<table>
<tr><th>Academic Year</th><th>Cohorts Pre-A</th><th>Cohort A 2004 entry</th><th>Cohort B 2005 entry</th><th>Cohort C 2006 entry</th></tr>
<tr><td>2004/5</td><td>2nd, 3rd & 4th Years</td><td>1st Year</td><td>-</td><td>-</td></tr>
<tr><td rowspan="2">2005/6</td><td rowspan="2">3rd & 4th Years</td><td>2nd Year Degree</td><td rowspan="2">1st Year</td><td rowspan="2">-</td></tr>
<tr><td>HND/FdSc Placement</td></tr>
<tr><td rowspan="2">2006/7</td><td rowspan="2">4th Years</td><td>Degree Placement</td><td>2nd Year Degree</td><td rowspan="2">1st Year</td></tr>
<tr><td>HND/FdSc 3rd Year</td><td>HND/FdSc Placement</td></tr>
<tr><td rowspan="2">2007/8</td><td rowspan="2">-</td><td>Degree 4th/Final Year</td><td>Degree Placement</td><td>2nd Year Degree</td></tr>
<tr><td>HND/FdSc Top-up Year</td><td>HND/FdSc 3rd Year</td><td>HND/FdSc Placement</td></tr>
<tr><td rowspan="2">2008/9</td><td rowspan="2">-</td><td rowspan="2">-</td><td>Degree 4th/Final Year</td><td>Degree Placement Year</td></tr>
<tr><td>HND/FdSc Top-up Year</td><td>HND/FdSc 3rd year</td></tr>
</table>

The timing of the periods of activity for the data collection are shown in Table 3.2 below. This details the questionnaires and interviews conducted during the study with the year and month when the activity was carried out, and with which student groups. The 147 in the first row includes the pilot questionnaires.

Table 3.2 Primary Data Collection Activity by Year and Month

Year	Month	Questionnaires / Interviews	Cohort	Student Groups	No.
2004/5	May	Mathematics Learning Questionnaires	A	Cohort A Degree & HND/FdSc 1st years	147
	May	Mathematics Learning Questionnaires	Pre-A	Pre-Cohort A Degree 2nd years	98
	June	Volunteer Interviews – I	Pre-A	Final year students	5 *
2005/6	May	Mathematics Learning Questionnaires	B	Degree & HND/FdSc 1st years	133
			A	Degree 2nd and 3rd years	144
	June	Volunteer Interviews – II	Pre-A	Mixture of students	2
2006/7	May	Mathematics Learning Questionnaires	C	1st year engineering students, plus 3 others	35
		Mathematics Learning Questionnaires	B	Degree 2nd years	141
	June	Volunteer Interviews – III	Pre-A	Mixture of students	9 *
2007/8	June	Final Year Student Interviews	A	Final year students	15
2008/9	June	Final Year Student Interviews	B	Final year students	22

* In addition three fourth year students also completed questionnaires during their interviews, two in 2005 and one in 2007.

3.2.2 Mathematics Learning Questionnaires

This sub-section describes further in which year of their course and on which modules the students completed the Mathematics Learning Questionnaires, with some explanation of the courses and types of students. A description is then provided of the structure (in sub-section 3.2.3) and content of the questionnaires (in sub-section 3.2.4) and other relevant details of the questionnaire design, pilot (for initial versions) and administration. A summary of the data obtained and the results of the data analysis and findings are then presented in later chapters (chapter 4 onwards).

The questionnaire surveys were conducted in the first three years of the study, and the aim was to survey as many students as possible who were studying a mathematics or statistics module, which was generally students in their first and second years (but also included some third year HND/FdSc students). All of these mathematics and statistics modules were compulsory. A diagrammatic representation of the various mathematics and statistics modules (as they were in 2006) is given in Figure 3.2, and these modules are then described in this section.

The first year engineering students studied a mathematics module all year (tailored to their engineering needs). All first year students were required to study statistics in their first year as part of the APD module (Academic and Professional Development module). The BEng and MEng engineering students continued to study engineering mathematics in their second year, whereas, all other second year students on degree courses studied a research methods module which included some statistics. The second year natural and social science students studied separate versions of the research methods statistics; these different versions were designed to prepare students for the analysis they were most likely to carry out as part of their final year research project. For social science students the focus was on Chi-squared tests and Regression analysis and use of the statistics package SPSS (this module will be referred to as RMSS); whereas for natural science students the focus was on ANOVA tests and use of the statistics package GenStat (this module will be referred to as RMNat). These Research Methods modules were introduced in 2006 and were broadly similar to their preceding modules, which in 2005 were called Research Design and Analysis for the natural science students, and Intermediate Research Methods and Advanced Research Methods for the social science students. The second year BSc engineering students studied a different version again of the Research Methods module which included a Mathcad element for the second half of the year, which was similar to the BEng students' Analytical Techniques. As can be seen there was a range of mathematics and statistics modules which were designed to be relevant to the courses which the students were studying.

Figure 3.2 illustrates the different student groups and the mathematics and statistics modules, with a capital letter (A, B, C etc.) denoting the version of the Mathematics Learning Questionnaires which was completed by that group of students. There were three first year versions of the questionnaires, and three or four second year versions depending on the year. The student groups shown in Figure 3.2 are shown again in Table 3.3 with the questionnaire letter code, and in addition, Table 3.3 also contains the total number of questionnaires completed by chronological year.

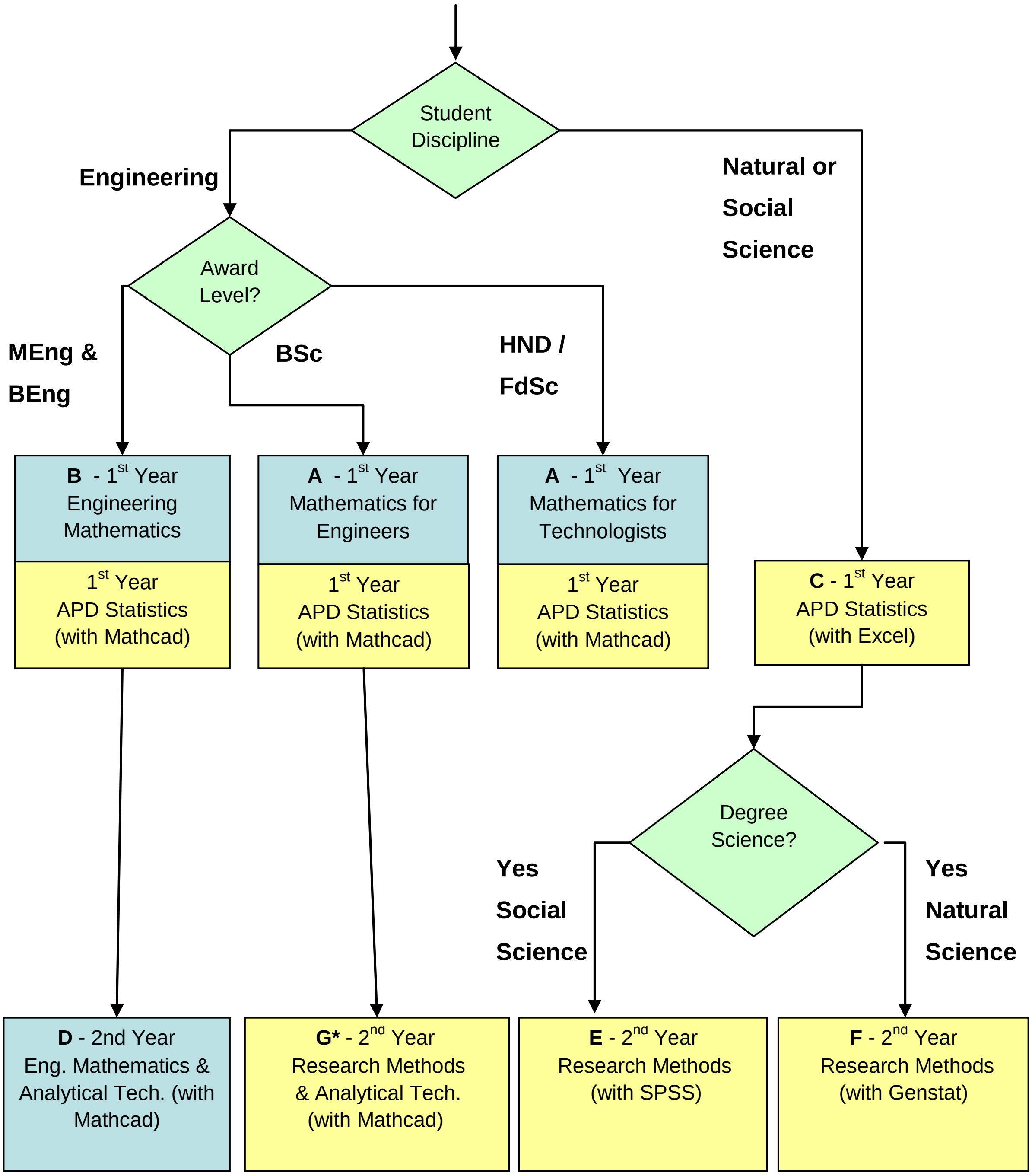

Figure 3.2 Flowchart of Student Types and 2006 Mathematics and Statistics Modules with Questionnaire Letter Codes (Source: Author's own)

Capital letters (A, B, C …G) shown in bold represent different versions of the questionnaires.

* New module introduced for 2nd year BSc Engineers in 2005/6 (version G), which was only surveyed in 2007.

Table 3.3 Numbers of Students Completing Mathematics Learning Questionnaires by Year and Module

Student Course Year	Code*	Module Surveyed	2004/5	2005/6	2006/7	Total
1st Year	A	BSc Mathematics for Engineers	Pilot 15	20	12	47
	A	FdSc Mathematics for Technologists	8	Pilot 13	5**	26
	B	M/BEng Engineering Mathematics	6	17	15	38
		Total 1st year Engineering students - engineering mathematics **	29	50	32	111
	C	Natural and social science students - APD statistics	118	83	(3)	204
		Total 1st year	**147**	**133**	**35**	**315**
2nd Year	D	M/BEng engineering students – Engineering Mathematics & Analytical Techniques (with Mathcad)	17	8	20	45
	G	BSc engineering students - Research Methods & Analytical Techniques (with Mathcad)	-	-	13	13
	E	BSc social science students - Research Methods Statistics (with SPSS)	29	33	55	117
	F	BSc natural science students - Research Methods Statistics (with GenStat). Includes some 3rd years	52	103	53	208
		Total 2nd (& 3rd) year	**98**	**144**	**141**	**383**
4th Year		**Total 4th year**	**1**		**2**	**3**
		Grand Total	**246**	**277**	**178**	**701**

* Questionnaire Code

** Three of the students surveyed in the FdSc class had transferred to the BSc award. Table 3.3 above shows the class in which the questionnaires were completed, however Table 4.1 is arranged by type of student.

The different versions of the questionnaires are then described in sub-section 3.2.3. The second year BSc engineering students only completed a Mathematics Learning Questionnaires in May 2007 (as this version of the module was introduced in 2005/6 and was not initially known to the researcher). These are, however, not included in the results chapters in this thesis, because as the sample size was small (n=13) and these students were non-typical of those reported on in either Chapter 4 or 5.

3.2.3 Mathematics Learning Questionnaire Design, Timing, Structure and Questions

The first questionnaire to be designed in April 2005 was for the first year BSc engineering students. The researcher taught this group mathematics and asked the students to complete the questionnaires in a lecture as a pilot (then in 2006 the BSc group piloted the slightly revised version of the questionnaire). Their responses were then read through to check whether the questionnaires had been filled in sensibly and also the researcher was present to check whether the students had any difficulties at the time of completing the questionnaires. There was only a very short period of time in which to produce and conduct all of the questionnaires before the end of the teaching weeks of the summer term, so there was not sufficient time to conduct a complete analysis of the pilot data. This pilot did, however, successfully trial the administration of the questionnaires and as a result some small revisions were made to the later versions; for example two extra questions were added (e.g. about their past enjoyment of mathematics), and two Y/N/U responses were changed to 1-5 Likert scales to gather more sensitive responses. Different versions of the questionnaires, for the other student groups, were then drafted and shown to the module leaders, who made suggestions and requested some small changes. As a result, some additional questions were added to the second year questionnaires (for example, regarding where the students had looked to for help and whether they felt they had used any of their first year statistics knowledge for their second year statistics modules). Several of these module leaders were very experienced in producing questionnaires and their suggestions were deemed helpful. This process also ensured that the modules leaders were well informed and in agreement with the content of the questionnaires which they (and other staff delivering the modules) would administer.

Once permission had been obtained from the overall module leaders, requests were then made to the individual lecturers who administered the questionnaires, which most of the mathematics and statistics lecturers were willing to do. Guidelines for the lecturer and multiple copies of the questionnaires were produced and distributed and the completed ones duly returned. Samples of the 2005 questionnaires can be seen in Appendices I and II, and the Guidelines for Lecturers are in Appendix VI (2006 version). Approximately fifteen different lecturers administered the questionnaires and some of these administered the questionnaires in multiple classes. The questionnaires took around 10 minutes to complete, plus further time was taken to introduce the questionnaires, hand them out and then collect them in again when completed. So, overall the process took around 20 minutes to complete out of the normal lecture time of two hours. There was a short period of a couple of weeks in May when the questionnaires were administered, in the last few weeks of lectures, in each of the three years (2005, 2006 and 2007).

In years 2006 and 2007 minor revisions were made to the questionnaires to investigate lines of enquiry which had developed in the research, but most of the questions in the questionnaires were left unchanged so that a comparison would be possible across the three years of the surveys. A more detailed description of the questions in the different versions of the questionnaires follows in the next sub-section.

3.2.4 Mathematics Learning Questionnaires' Content

In the Mathematics Learning Questionnaires there were open and closed questions which gathered information on qualifications, past experiences, student attitudes, student confidences and student views on aspects of the modules and in the first year versions (A, B and C) there were also questions which asked about the mathematics support provision. See the samples of the questionnaires in Appendices I – V.

The first group of questions at the start of the questionnaires asked for objective, demographic data, which included Award Level, Course Name, Age, Gender, whether the student had dyslexia or dyscalculia, Mathematics GCSE Grade, and whether the student had studied 'A' level Mathematics. Questions asking for more subjective data, such as confidences and attitudes were then asked using a mixture of closed questions, which were generally 5 point Likert scales (e.g. asking students to rate their overall confidence in mathematics on a scale of 1 (low) to 5 (high)), and open questions such as ‘How would you describe your *attitude* towards learning mathematics?’ All of these questions can be seen in the samples in the Appendices.

The students’ names were not asked for on the questionnaires, but the students’ id numbers were; this was so that their responses could be matched with their achievement in that module. The intention was for the questionnaires to be anonymous as far as possible. When the students did provide their id number, had a lecturer or the researcher wanted to identify the respondent, this was then possible, so these questionnaires were not strictly anonymous. The researcher, however, respected this ‘anonymity’ and did not trace the identity of any students (other than linking their responses to their module performance), and all subsequent reporting of the responses was done anonymously, with care taken not to reveal any individual’s identity. The student id no. question was optional, so that if a student had wanted to ensure their anonymity they could have left this field blank, which a few students chose to do; this subsequently excluded those questionnaires from all analysis involving university achievement because the responses could not then be linked to the students’ mark(s). Out of the 111 first year engineering students’ questionnaires, three chose not to provide their student id number. There is further discussion and reflection on the students’ id number and students’ anonymity in the section on ethical considerations, Section 3.3.

In considering students’ self-confidence’ in mathematics, questions were asked relating to the three Mathematics Self-confidence Domains defined in sub-section 2.7.6. There was a question asking students to rate three *Overall Confidences*:

‘How confident would you describe yourself overall?

In Mathematics

In Statistics

In Life in General’

This gathered data on students’ *Overall Confidence in Mathematics* and also separately for their *Overall Confidence in Statistics*. Later in the questionnaire there were 11 questions asking the student to rate their confidence for each of 11 different ***topics*** studied, in order to measure students’ *Topic Confidences.* In 2005 there was another 11 questions asking students for their confidence to ***apply*** these topics in the future, for example for a project or at work, in order to measure students’ *Applications Confidence(s)*. However in 2006 and 2007 these *Applications Confidence* questions were simplified to two questions: a single rating as to whether their *Applications*

Confidence would have increased or decreased, and an open question explaining why the student thought this. The lists of topics in each questionnaire varied according to the module being surveyed and comprised approximately eleven topics which had been covered in the module; this was the main difference between the different versions of the questionnaires. The predominant aim of the questions about students' confidences was to quantify students' confidences in these respects, but in 2005 an important aim was also to validate the three Mathematics Self-confidence Domains.

Students' confidence in 'Life in general' was also asked for, for use as a benchmark against which to compare other confidences. It was believed that people varied as to how positively or negatively they rated their beliefs in their capabilities in general, so the purpose of this question was to have a measure of how the person rated themselves overall, against which to compare their other confidences asked for in the questionnaires. The analysis of the 2005 questions found that this question produced some useful responses.

Other questions asked students about whether their experiences before university had affected their confidence or liking of the subject, and about whether the students liked mathematics, whether they liked statistics, what their attitude was towards learning mathematics and their motivation in the module surveyed compared to other modules which they were studying.

Open questions asked about any effects of being dyslexic or dyscalculic, and which aspects of the module had particularly helped or hindered their learning.

In 2005 a question asked whether the student had experienced an occasion when a topic suddenly became a lot clearer (like a light switching on). The intention of this question was to find out whether students had had a 'Eureka' moment which it was thought could help to accelerate improvements in confidence.

In the first year questionnaires there were questions which asked about the mathematics support provision, whether the students had used it, in what form and to rate different aspects of the support. At that time the support was predominantly aimed at and used by the first year students. Second year students were also asked to rate doing calculations by each of: hand, calculator and the computer packages they had studied. They were asked whether they considered that learning statistics was important; and how their confidences, attitudes or ability had changed from their first to their second year and why.

The questionnaires ended with some open questions which asked when students had last enjoyed mathematics, if they could suggest anything that could improve their confidence, attitudes and ability in mathematics; and for any other comments. Finally the questionnaires contained text thanking the students for their participation and provided the researcher's contact details should any students want to discuss anything. These were quite long questionnaires; each containing approximately 50 questions spread over 5 pages. In 2005 all of the questionnaires were printed onto cream A4 paper, but in the subsequent years different student groups questionnaires were printed on different coloured paper which helped to identify which student group the questionnaire was for.

3.2.5 2004/5 Questionnaire Response Rates and Module Assessment Regimes

In May 2005, 250 questionnaires were completed, of which 46 were completed by engineering students; 29 by first years and 17 by second years. The total annual entry into engineering programs is relatively small, approximately 50, and only the BEng students, approximately 20, continue to study mathematics into the second year. Thus the number of questionnaires completed was a good response rate from the engineering student cohorts (approximately 67%). First year engineering students' responses related primarily to their mathematics for engineering modules, however the first year engineers had also taken the Mathcad based Academic and Professional Development (APD) statistics module. The *Topic Confidences* in their questionnaires related to their mathematics lectures, but there were also some questions about statistics (to rate their confidence at doing statistics, and to rate their liking of statistics), which these students would have related to their statistics lectures.

In 2005, 118 first year natural science and social science students (35% of 341) completed questionnaires relating to the APD module which had a compulsory 10 weeks statistics element. Of the 118 questionnaires completed 110 students provided their student id number and could then be linked with their associated statistics assignment mark. 29 second year social scientist students completed questionnaires regarding the Advanced Research Methods and Intermediate Research Methods modules, which were compulsory modules containing research methods instruction, inferential statistics and use of SPSS statistical computer package. The marks used for analysis of these modules were from an end of year assignment, of which statistical analysis formed only a small portion of the marks and the remaining marks were given for a research report. The assessment changed in 2006 and 2007 to be a research methods examination, more is written about this later.

52 second and third year natural science students (73% of 71), primarily on agriculture and animal health courses, completed questionnaires regarding their Research Design and Analysis (RDA) second semester module, which contained experiment design and primarily ANOVA techniques using GenStat statistical computer package. The marks analysed for the RDA module were for the end of semester examination which was an open book computer based exam, primarily assessing use of ANOVA analysis and the writing of results and conclusions.

Questionnaire responses were analysed using Microsoft Excel, SPSS and GenStat computer packages for quantitative data, and by identifying themes and frequent responses for open questions. Interim results produced from the 2004/5 data were published in Parsons (2006a) and Parsons (2006b).

3.2.6 Questionnaire Revisions and Module Assessment

In May 2006 Questionnaires were again administered to first year, second year and third year students taking mathematics and statistics modules. There was at this time a change from semester to term-based tuition, which changed the name and content of some of the modules and changed some of the student assessment regimes. So whilst in principle the modules surveyed in 2006 were the same as those surveyed in 2005, these were affected by the revised curriculum structures. Additionally in 2006 there was a new second year research methods module for BSc engineering students which was introduced but was unknown to the researcher at the time, so that module was not surveyed until 2007. In 2005 seven versions of the questionnaires had been administered, and in 2006 this was slightly simplified to 6 versions by combining the first year BSc and HND engineering students' versions.

The contents of the 2006 questionnaires were identical to the 2005 versions except for the following:

- A change was made to all the versions of the questionnaires regarding confidence to apply mathematics/statistics in the future. 11 questions which asked students in 2005 to rate their confidence to apply each of 11 topics to future work or a project were replaced by 2 questions: a single question rating how they expected their confidence will change in future and an open question asking why they thought this. This change was considered helpful in providing space and time for the extra Scale questions described below. This change provided information as to why students would predict their confidence to have improved or otherwise, which had been difficult to deduce from the 2005 results. The 2005 results had shown that people had generally either put all topics as expected to have improved or all topics were expected to have worsened in confidence, i.e. that people chose one or the other. Thus it seemed simpler and clearer to only ask students once to rate how their confidence was expected to have changed in the future (and not by topic), and this also prompted the question of why they thought this.

- In all first year questionnaires (A, B and C, see Table 3.3) a bank of 11 questions (based on Fogarty *et al.,* 2001) were added to further measure students' confidence in mathematics. These questions are listed in Table 3.4 below and hitherto are called the *Scale questions*. Some of the other pre-existing Self-Efficacy instruments (which were described in Chapter 2) were much longer and more time consuming to administer, and so were not considered for use in this research. The 11 Scale questions used are listed in Table 3.4 below and were intended to be a more sensitive instrument for measuring students' self-confidence. These were analysed using Factor Analysis and Cluster Analysis techniques, and were also compared with the single rating for Confidence in Mathematics. It was also intended to compare the Scale question responses with students' single self-rating of self-confidence in mathematics. It was hoped that the single self-rating would be shown to be valid, and that a deeper understanding of different aspects of self-confidence in mathematics would be gained. It was also hoped that a relatively short but effective list of such questions could be identified, and even possibly the 'ideal' single question.

- All of the second year modules surveyed, except the second year BEng and MEng Engineering Mathematics and Analytical Techniques second year module, changed their name to Research Methods. These were previously called Research Design and Analysis for natural science students and Advanced Research Methods for social science students.

- The first year HND engineers were the first to complete questionnaires containing the above 2006 changes, and were considered to be the pilot group for these changes. Due to considerable time constraints (as in 2005) it was not possible to complete a detailed analysis of the results before further versions of the questionnaires were produced and administered to other student groups, but the use of these new Scale questions with this initial group demonstrated that the questions were answered successfully and apparently without any difficulty by this initial group.

Table 3.4 2006 First Year Questionnaire Scale Question Statements

Q.	**Statement to rate agreement with**
40	I have less trouble learning maths than other subjects
41	When I meet a new mathematics problem I know I can handle it
42	I do not have a mathematical mind
43	It takes me longer to understand mathematics than the average person
44	I have never felt myself able to learn mathematics
45	I enjoy trying to solve new mathematics problems
46	I find mathematics frightening
47	I find many mathematics problems interesting and challenging
48	I don’t understand how some people seem to enjoy mathematics problems
49	I have never been very excited about maths
50	I find maths confusing

(Adapted from Fogarty *et al.,* 2001)

Overall a similar total number of questionnaires were completed in May 2006 (277, compared to 250 in 2005), however fewer were completed by first years and more by second year students. This change can be explained by the optional attendance which was allowed for the first year APD statistics modules in 2005/6 resulting in reduced attendance, and in the larger number of second and third year students taking the second year modules that year due to the change from semesters to terms. As part of the analysis of the first year statistics students’ responses, work was done to assess whether the students who completed the questionnaires were representative of the whole cohort, or whether those students attending the final lectures were, for example, higher achievers. There is some evidence that this was the case, as will be discussed in Chapter 5.

2006 questionnaire responses were analysed using Microsoft Excel, SPSS and GenStat computer packages for quantitative data and by looking for themes and frequent responses for the qualitative data (in a manner similar to the 2005 data). Factor Analysis and Cluster Analysis were also carried out using SPSS on the first year students' responses. These results were useful for further understanding of the data and some of these were published in the Aspire Development Fellowship report Parsons (2008b). In this thesis, however, it is predominantly the results from the combined years' data sets, and not of individual years, that have been described, except where stated in a very few instances.

The original intention was to only survey the second year students in 2007, thus following cohort B through their second year, and not to survey the first year groups again. However, due to the engineering students being of particular interest because they studied more mathematics than other students, and due to the accessibility of the engineering students to the researcher, the first year engineering students were surveyed again, which expanded the previously small data set. The first year social science and natural science students were, however, not surveyed again in their APD statistics lectures as had been done in 2005 and 2006, but a small number (three) of questionnaires was completed by these first year students when they were interviewed in 2007.

One change which was made to the 2007 questionnaire versions was to re-order some of the questions; some of the later questions (including those which asked which features had helped or hindered the students' learning) were moved forwards in the hope that more detailed responses would be obtained from students, where previously students might have only been inclined to give more brief answers as they approached the end of the questionnaire.

Another change which was made to the 2007 questionnaires was to the bank of 11 Scale questions. These were reduced to four questions plus two additional new questions, see Table 3.5 below. At this stage in the study it seemed useful to pursue a line of inquiry to find the most effective questions to ask students about their self-confidence or self-efficacy. Based on the results of the analysis of the 2006 questionnaires, the questions which had been found less useful from the Cluster and Factor Analysis from the 2006 questionnaires were omitted from the 2007 questionnaires. Although, with hindsight, it might have been more useful to have kept the questions identical to the 2006 set so that the sets of results could have been combined. This bank of six questions was included in the first year engineering questionnaires (versions A and B) and the first five were included in the second year natural and social science students' questionnaires (versions E and F), but not in the second year engineering students' versions of the questionnaires (D and G), for reasons of limiting the overall length of the questionnaires.

Table 3.5 2007 Questionnaire Scale Question Statements

Q.	Statement to rate agreement with
33	I usually do well in mathematics
34*	I do not have a mathematical mind
35*	It takes me longer to understand mathematics than the average person
36*	I have never felt myself able to learn mathematics
37*	I enjoy trying to solve new mathematics problems
38	Mathematics is useful (for 1st year engineering students only)

(* Adapted from Fogarty *et al.,* 2001)

3.2.7 Combined Multiple Year Data Sets

The questionnaire responses were entered into Excel spreadsheets and analysed using Excel, SPSS and GenStat for quantitative data, and by identifying themes and common responses for open questions. Initially the May 2005 questionnaires were administered, analysed and reported on, then the May 2006 questionnaires were similarly administered, analysed and reported on; in addition the 2006 and 2005 results were compared and found to be broadly consistent for all of the student groups. When the 2007 results had been recorded, these too appeared broadly similar. It was also known that there was no particular change in the student intake or assessments over the three years for the first and second year engineering students and first year students studying APD statistics. However, there were changes to the second year social science and natural science student assessments, which were detailed earlier in this chapter and were taken into account in the data analyses. In this thesis, data for all the years was combined, analysed and reported on for each of the first and second year engineering student data and the APD student data. Whilst both the second year natural science and social science data were also each combined for the different years, extra care was taken with how the data was analysed (as explained below).

Combining the three years' data avoided unnecessary repetition of similar findings. As larger data sets, the combined years' data sets were more likely to, and did, yield more statistically significant results. Where appropriate, findings specific to an individual year were also reported, for example, the analysis of the 11 Scale questions posed in 2006.

In order to formally check that it was valid to combine the different year data sets ANOVA tests were carried to test whether there was a significant difference in student marks for the different years, which found no significant difference between the years' marks, except for the second year natural science student data (for which the examination had been made more difficult and the marks were lower each year). See Appendix VIII for detailed results of these tests. The data analysis for the second year natural science student marks was carried out on only the 2006 data, or was carried out with the year also being taken into account (in a 2-Way ANOVAs or multiple regression). The second year social science statistics question marks were only present for 2006 and 2007 data when the assessment was an examination, so analysis of these marks automatically excluded the 2005 assignment marks. The squared RMSS marks were also compared for the different years by ANOVA test (in Appendix VIII) as these marks were transformed (squared) to produce normally distributed data for the ANOVA tests. Kruskal Wallis tests were also carried out which found no significant differences between the *Confidence in Mathematics* values for the different years in any of the student groups, see Appendix VIII for details. Thus overall it was ensured that, as far as was possible, only like-for-like data was combined for the different years and used for the statistical tests.

Longitudinal aspects of the data were explored by matching first year and second year results for students who had completed questionnaires in both their first and second years, and comparing their responses. The students' own descriptions of how they had changed with time and exposure to university teaching were also utilised from the second year questionnaires.

The results of the questionnaire surveys from 2005, 2006 and 2007 are presented in Chapters 4 and 5: Chapter 4 describes the results and analysis of the engineering students' questionnaires and Chapter 5 describes the results and analysis of the social and natural science students' questionnaires.

3.2.8 Student Interviews

A mixed methodology was originally adopted for the study, comprising a combination of surveys and students interviews. The questionnaires, which have been described in the previous sub-section, produced more structured, mainly quantitative data which is reported on in this thesis. 52 student interviews were carried out over a five year period with a range of students from different courses and various years of their courses, mainly final year students (as shown in Table 3.6). The interviews produced less structured, mainly qualitative data. Earlier versions of this thesis included detailed analysis and findings from seven engineering student interviews, and these were published (Parsons *et al.*, 2011) and presented at a conference. The final version of this thesis, however, does not include detailed interview data analysis in order to focus more fully on 'the main narrative', which was the findings related to self-confidence which were judged to be more effectively extracted from the questionnaire data.

It was positive that a very diverse range of student types and experiences were recorded in the interviews. These have informed this study and contributed to providing a more detailed understanding of the range of different student viewpoints. It was judged, however, that there was unfortunately not sufficient space in this document to do justice to the interview data, given the vast quantity of interview scripts.

The interviews were conducted to gain a deeper understanding of the experiences and perspectives of a smaller number of students. Kahn and Cannell (in Saunders *et al.,* 2003, p.245) describe an interview as a *'purposeful discussion between two or more people'.* Saunders *et al.* (2003, p.248) describe the purpose of interviews as follows:

> *'Semi-structured and unstructured interviews are used in qualitative research to conduct discussions not only to reveal and understand the 'what' and the 'how' but also to place more emphasis on exploring the "why".'*
>
> *'Semi-structured interviews can be used to explore and explain themes which have emerged from your questionnaires.'*

Student interviews were conducted over the five years of the study and were conducted in the summer term as the final year students approached the end of their time at university. Semi-structured interviews were the principal data collection method in the years 2008 and 2009. In the earlier years the interviews were unstructured, but progressively fixed questions were scripted. Interviews were the main data collection method in the final two years (2008 and 2009) and semi-structured interviews were conducted from a clearly laid out script of pre-set questions and also included an introduction explaining the outline of the interview and the recording process and a conclusion thanking the student for their participation (which can be seen in Appendix VII).

Table 3.6 Student Interview Numbers Conducted by Year

Year	No. of Interviews Conducted
2004/5	5
2005/6	2
2006/7	8
2007/8	15
2008/9	22
Total	**52**

A wide range of student views, perspectives and experiences was gathered. In fact, an enormous wealth of data was obtained in hundreds upon hundreds of pages of interview scripts. Overall it was a privilege to spend the time with these students, and to listen and learn as they shared the details of their past lives, their experiences learning mathematics and statistics, and their hopes for the future. Hopefully some of them found the experience as beneficial as this researcher did, not just in terms of the data gathered but also from the interview experience, which often felt a rare opportunity to glimpse the real heart of a matter. The questionnaires were kept anonymous as far as possible (except for collection of id number) and were mostly collected by other members of staff. However, these interviews were all conducted first hand by the researcher and the interviewees also gave their names, although their details were later anonymised. Students' whole body language was also visible as well as the spoken word. So not only did the interviews provide a greater level of detail than the questionnaires, but there was also a much greater level of personal reality associated with the data arising from the interaction with the real person. Whilst these interviews further informed this study, and were included in earlier drafts, the detailed analysis of the student interviews will not be presented in this thesis, in order to focus more on the various student group questionnaire results. Analysis of seven engineering student interviews is, however, available from Parsons *et al.*, (2011).

3.2.9 Module Marks Secondary Data

The student marks were obtained for the mathematics and statistics modules which were surveyed, and then analysis was undertaken to compare the student achievement with their questionnaire data, including self-confidences, entry qualifications and other characteristics. In each case the module leaders were asked first for their permission to use the module results for comparison with the questionnaire responses, which they gave. In the earlier years of the study the module leaders provided the results to the researcher themselves, either on paper or in spreadsheet files. Later in the study the module results became readily available through the College's computerised student record system. Once the questionnaires had been transcribed into spreadsheet files and the student marks had been obtained and matched with their student id no., the student mark was then typed into the questionnaire data file.

3.2.10 Limitations of Methods and Methodology

This sub-section describes possible limitations of the methodology and methods and how the author has reflected on these limitations. A mixed methodology was adopted which has already been described in this chapter (3), and the methods used in this study were questionnaires, interviews and secondary data the limitations of which will now be described.

Questionnaires were an efficient method for obtaining data from large numbers of people in a short time, as in 10-15 minutes a whole class participated in the survey. The first questionnaires were designed in spring 2005, early in the research process. At that time there was a dearth of relevant studies, and certainly not as many as existed upon completion of the research reported in this thesis. This limited the extent to which the design of the survey instrument could draw on and be informed by other work. The fairly short time period before conducting the first survey did, however, limit the opportunity for extensive piloting and revision of the questionnaires. Pilots were carried out, and because only minor changes were implemented afterwards the data from the pilots were able to be combined with the other data. The majority of questions were kept unchanged across the five different student groups and three survey years. This enabled the different years' data to be compared and combined, where appropriate, but also limited the opportunity for revision, although some revisions were made which are explained in the Methodology sub-section 3.2.4.

The questionnaires were administered by lecturing staff (including the author of this thesis) which facilitated their administration, but could have limited the questions and responses. Questions specifically about the lecturer were not posed, and students might have been reluctant to give negative comments about their lecturer (who was yet to mark their work). Whilst instructions and guidance was provided to the lecturers, those who were not involved with the questionnaire design may not have been able to answer student queries regarding how to complete the questionnaires (the module leaders surveyed were however familiar with the questionnaires). Some respondents might have given responses which were socially desirable rather than completely honest, or which might have been affected by cultural sensitivities. Other issues could have included: respondent boredom; coasting though a bank of questions and selecting similar responses; or respondents choosing the neutral mid-point e.g. choosing 3 on a 1 to 5 rating scale. Bandura (2006) gave advice about minimising response bias. Bandura, (2006, p.314-15) suggested recording of self-efficacy judgments privately without personal identification; to inform respondents that their responses will remain confidential and anonymous (only identified by codes); to explain how their responses are important to the research and will increase understanding in order to help people by development of future programs. Whilst students completed the questionnaires in class there was the opportunity to do this without other students seeing their responses, which could be considered somewhat in private. Students did not give their names, but were asked for their unique student id number which was a code, which some students chose to leave blank (as it was explained to them that completing the questionnaire and any details in it were entirely optional). The purpose of the research was to better understand how students learn, which was explained to the survey respondents. So it can be seen that much of what Bandura (2006) advised to minimise bias was carried out.

The response rates for some student groups were high (e.g. 83.3% of second year engineering students responded), whereas other groups had lower response rates (e.g. the 2006 first year APD response rate was only 24%). Accidentally, a couple of lecturers were not asked to survey their classes, but it is thought that all lecturers who were asked did survey their classes. Not only did lower response rates result in less data that could be analysed, and made it harder to achieve significant results in hypothesis testing, but there was the possibility of bias being introduced. As Grix (2004, p.129), explains non-respondents are likely to hold different views from respondents and suggests that other methods could be used to correct such a bias. The students' university marks were used to investigate and assess the effect of any bias in the questionnaire results. The 2006 APD surveyed BSc students' university marks were compared with the non-surveyed BSc students' marks, and it was found that surveyed BSc students had significantly different (higher) APD marks (56% compared to 50%, by z-test, n=60, 226, P=0.005, two-tailed test). This would be expected as less conscientious students were more likely to be absent, less work usually results in lower marks, and less attendance and instruction would also be expected to lower marks. As higher marks at university were associated with higher confidences and better attitudes, it was therefore considered that the issues found with the surveyed APD students' lack of confidence and poor attitudes would understate, rather than overstate, the issues for the whole cohort. It is also suggested that the same bias, of better results for the surveyed samples than for the wider populations, would also have occurred in all of the other student groups. This therefore implies that all of the findings of lack of confidence are likely to be understated (rather than overstated), i.e. that the lack of confidence is likely to actually be greater.

Interviews were much more time consuming than questionnaires to arrange, conduct (each were approximately 40 minutes long), to transcribe (approximately 6 hours each according to Wisker 2001, p.165) and analyse. Wisker (2001, p.165) advises

'Do not try to do too many interviews as they are very time consuming.'

Wisker (2001) recommends six interviews, for example three for and three against a particular viewpoint. The number of interviews reported in the published paper (Parsons *et al.*, 2011) related to this thesis was seven. The interviews were not reported in detail in this thesis because the additional information this would have revealed was not considered to yield further important insights. As Wisker (2001, p.165) states *'Not all interviews are either worth such an expense of time (and perhaps money…'* So the time consuming nature of fully analysing interviews was a factor which limited and reduced the use of the interview data. Interviews are also limited by what a person is prepared to talk about and what they are aware of (Wisker, 2001), although it appeared that the interviewees for this study were genuinely frank and open about their experiences. There was also the potential for bias in the interview data due to the use of volunteers; it was possible that students who did not volunteer could have held different views from those who did, although those volunteering appeared to represent a wide range of viewpoints, including very confident and those who lacked confidence.

The questionnaires and interviews were limited to capturing people's immediate responses, and neither gave the opportunity for extended time to consider the questions and give more well thought through responses. In some questions only the participants' first thoughts were given, when more, or different, points might have been given after more consideration and reflection.

Use was made of both closed and open questions, both of which served a valid purpose, but both also had some limitations which will now be discussed. Closed questions tend to elicit short answers and limit the responses, so they will obtain exactly the types of answers sought for, but they do not encourage deeper thinking. Open questions, on the other hand, encourage an infinite range of different responses which are then harder to analyse and quantify. Open question responses were analysed qualitatively, however the results of such analyses are affected by the categories chosen by the researcher, an inductive or deductive approach and the level of detail versus summarisation adopted, and variation in these produces different results. Being sensitive to the effects of the approach taken, this author endeavoured to reduce the detail to a manageable level whilst still retaining sufficient detail, and in some instances also produced summary statistics stating what percentage of responses were positive or negative.

In questionnaires the question design is always important, especially for closed questions so that the question type is appropriate and can accommodate the full range of possible, or useful, responses. The six types of closed questions as given by Saunders *et al.* (2003, p.316) were: list, category, ranking, rating (scale), quantity and grid. Overall it was felt that the questionnaire design worked fairly well, credit for which is partly due to the feedback from the surveyed module leaders, some of whom were very experienced in questionnaire design. However, as the study progressed the emphasis on self-confidence grew, and had this been known at the start then some of the questions might have been worded differently. For example one question asked about three different attributes; with hindsight this question could have been more useful had it focussed solely on self-confidence. Asking specifically for the students' A level Mathematics grade would also, with hindsight, also have been very useful, rather than the open question which was intended to capture the variety of different qualifications including A level mathematics grade(s), Scottish Highers, BTEC National Diploma, and the Irish Leaving Certificate.

Grix (2004) recommends triangulation, which is to use more than one method in order to assess subjects from different angles in order to demonstrate the validity of findings and to minimise any bias. Analysis of the early interviews (in 2005-7), whilst not detailed in this thesis, did help to verify the range of responses gathered in the questionnaires. Likewise, the later interviews (in 2008-9) also verified the range of responses, but to a lesser extent, as these focussed more on the viewpoints of final year students whilst the questionnaires were aimed at first and second year students.

Student marks (secondary data) provided additional information rather than corroborating responses from the other methods.

The timing of the data collection could also have influenced the responses. In most cases the data collection was in May–June when students could have been getting anxious about approaching examinations, and in most cases they did not know the final results of their modules. It was, however, also a suitable time to collect the data as the modules were almost finished so students could comment on almost the whole year whilst it was still fresh in their minds.

Notwithstanding the aforementioned overall limitations, the author believes that the instrument(s) used and the methods adopted have enabled valuable data to be successfully collected and the findings have produced new insights into student learning and their various beliefs and attitudes. This concludes the discussion of limitations of the methods and methodology.

3.3 Statistical Techniques: Choice, Purpose and Limitations

This sub-section describes the types of data which were collected and the statistical techniques which were carried out, why these techniques were chosen, what they were designed and intended to achieve, and any limitations. The on-going debates regarding use of Likert scales and single-items compared to multiple-item scales are also reviewed.

The data collected and used for quantitative analysis was of various types. Stevens (1946) defines *Nominal, Ordinal, Interval* and *Ratio* data types. Students' mathematics marks at university and student age were ratio data which had precisely defined values and an absolute zero. Affective variables measuring student confidences and attitudes were collected by use of 5 point Likert scale questions and were ordinal data, having an inherent rank. Other ordinal data included: students' GCSE Mathematics Grades and whether a student had taken A level mathematics. Nominal data (or categorical data), was collected for other variables, including Gender and whether the student had dyslexia.

After data collection and data entry into Excel spreadsheets, exploratory analyses were carried out to summarise data in tables with descriptive statistics and produce diagrams. Results included: summary tables of counts, totals and means, frequency distributions and histograms of confidence values. Percentages were used for response rates and proportions of respondents who gave particular responses. Means were used to indicate central location of various key variables including students' university mathematics marks and confidences (which will be discussed further later). Standard deviations of marks were used to describe the spread of marks.

Inferential statistics were used to test for significant differences (using ANOVA, Kruskal Wallis Mann-Whitney U and Wilcoxon Matched Pairs tests) and for linear relationships between variables (using Correlation analysis, Simple Linear Regression and Multiple Regression Analysis). Factor Analysis and Cluster Analysis were also carried out to explore, simplify and classify the data. These various tests and types of analysis are now described in more detail below.

It was of particular interest in this study to determine which variables were significantly related to the students' university mathematics and statistics marks using ANOVA tests, and to determine which variables were significantly related to students' *Confidence in Mathematics* (and sometimes *Confidence in Statistics*) using Kruskal Wallis tests.

An ANOVA test is a parametric test designed to determine whether values for two or more groups are the same, the result of which is a probability that the given data (in this case the sets of marks) could have occurred based on the assumption (Null Hypothesis) that there was no difference in the groups being analysed. An ANOVA test was used, for example, to test whether there was a difference in the marks for Male and Female students, or for students with/without dyslexia. Although the test is called ANalysis Of VAriance the ANOVA test compares the means of the different groups and not the variances. The between groups variation (differences in means) is compared to the within groups variation (also known as residual or error variation). A significant result is obtained when there is a large difference between the means of the different groups compared to smaller variation within the groups and large enough sample sizes. Although as Norman (2010) points out there is no minimum sample size requirement, smaller sample sizes make achieving significance harder. An example of interest in this thesis was to determine whether GCSE Mathematics grade (ANOVA factor, equivalent to regression independent variable) had an effect on marks at university (ANOVA variate, equivalent to regression dependent variable). A one-way ANOVA test looks for the effect of one single factor (e.g. age), whilst a two-way ANOVA (also called Factorial Factor ANOVA) test looks for the effect of two factors simultaneously (e.g. age and questionnaire year).

Underlying pre-requisite conditions for the variate in an ANOVA test are: random sampling, independent values, equal variances and normally distributed data (Townend, 2002). However, Norman (2010) points out that it is the sample means which are required to follow a normal distribution rather than the original data. These conditions were satisfied as the student marks were interval data, were independent values and the normal distribution condition was satisfied by visually checking the shape of the histogram of residuals produced by GenStat with each ANOVA test. The histogram of residuals was satisfactory in every case except for the second year Social Science (RMSS) students' statistics questions marks which were negatively skewed and so were then transformed using a power transformation (squared) which produced a normal distribution of residuals.

A limitation of these ANOVA tests (and all of the other significance tests which will be described below) is that there is the small chance, equal to the stated P-Value, of Type I Errors, i.e. of concluding that there was a relationship when no relationship actually existed. There was also the chance of Type II Errors, i.e. of concluding that no relationship existed when in reality a relationship did exist. Type II Errors were more likely for smaller sample sizes; it is very possible that for some tests, which produced P-values only slightly greater than 0.05, had the sample size been larger then a significant result might have been produced.

Similar data across questionnaire years was often combined to produce larger sample sizes, and the results for the combined years' data generally produced more significant results than the smaller separate year data sets. Particular care was taken to ensure that it was valid to combine several years' data. Initially it was checked that the students and assessments were similar across the years. ANOVA tests were then carried out which found that the students' marks were not significantly different across the three years for every student group except the second year natural science students. It was already known that the second year natural science Research Methods assessments were changed each year so the combined three years' data was analysed using a two-way ANOVA, where the second factor was the questionnaire year, but also, 1-way ANOVAs were used with the 2006 data, the largest single year data set. Similarly, because the second year social science assessment was different in 2005, these marks were also excluded from the ANOVA tests (even though these were not significantly different from the 2006 and 2007 marks).

Kruskal Wallis tests are the non-parametric equivalent of a One-way ANOVA test and do not require interval data nor normally distributed values, and were thus suitable for analysis of ordinal data including *Confidence in Mathematics* and *Confidence in Statistics* ratings. Kruskal Wallis tests are based on an underlying Chi-Squared test, for which the low frequencies condition has to be satisfied, i.e. that less than 20% of expected values are below 5 (Saunders *et al.*, 2003, p.358). In many cases this condition was not satisfied initially, and counts for different categories had to be combined (for example, Mathematics GCSE grades A* and A) as necessary in order to remove the low frequencies. So unfortunately some detail in the data was lost when categories were combined, which could have resulted in significant relationships that did exist not actually becoming apparent. Kruskal Wallis tests were also carried out to check whether *Confidence in Mathematics* ratings varied significantly by questionnaire year for any of the student groups, which provided some justification for the combining of several years' questionnaire data. Although the second year Natural Science students' confidences were analysed by Kruskal Wallis tests for only the 2006 data simply for consistency with the 1-way ANOVA tests for marks.

ANOVA tests were used when in some instances when an independent samples t-test could have been carried out (e.g. for a dichotomous variable such as Gender: M and F), however, ANOVA tests were used instead purely so that the results table headings were simplified (i.e. all tests were ANOVA for that column). Similarly Kruskal Wallis tests were carried out even when some Mann Witney U tests (non-parametric equivalent to two independent samples t-tests) might have been used when there were only two groups being compared; again this was for consistency and ease of results table column labelling. Some Mann Witney U tests were carried out initially and then replaced by Kruskal Wallis tests and it was noted that exactly the same P-Values were obtained by the two tests.

Correlation analysis was used to produce individual correlations and correlation matrices to test for linear relationships between variables. The student marks were ratio data, but other variables were ordinal data which is discussed further below. The resulting R values (Pearson's Correlation Coefficient) can range from 1 (perfect positive correlation, i.e. as one variable increases so the other does proportionately) to zero (no correlation found) to -1 (perfect negative correlation). The significance of the correlation (P-Value<=0.05) was checked to ensure that the relationship found was better than one which could have arisen purely by chance.

Regression analyses were carried for each main student group to produce a model for the student marks (as the dependent variable). A linear model was produced if just one independent (or explanatory) variable was used, or a multiple regression model produced when 2 or more independent variables were specified. The P-Values and significance of the resulting model and coefficient of each explanatory variable coefficient were checked. The purpose of these Regression analyses was not to produce a model (regression equation) which could be used to predict precisely the student marks; the purpose was to gauge an approximate effect size for the different explanatory variables (and not to seek precise values for the coefficients). For example, three models were produced for first year engineering students' mathematics marks and in all three models an increase in the students' GCSE mathematics grade was found to produce an approximately 12-13% increase in mark, whilst each increase in an affective variable such as *Confidence in Mathematics* or *Liking of Mathematics* produced an approximately 5-6% increase in mark. This demonstrated that a 'measurable' effect was produced by the affective variables, which was novel, as well as effects produced by past qualifications which were already well-recognised.

A limitation of regression analysis is that the calculations are carried out on the numerical values and the process cannot make an informed judgement whether a real cause and effect relationship existed as this required knowledge of the real world context of the data. If there was no significant relationship/model produced then that indicated no causal relationship, however a significant relationship/model provided supporting evidence to indicate, but could not prove, a causal relationship.

Factor Analysis and Cluster Analysis were used to reduce and classify the results from the student surveys. Factor Analysis (in this case Principal Component Analysis) aims to group and simplify the measured variables into a smaller number of underlying factors, which were then named by the author after consideration of the variables and strength of correlations in each factor. Cluster Analysis groups individual cases or subjects (i.e. students) into groups called 'Clusters' such that the cases in each cluster were more similar to each other in terms of specified attributes than to the cases in different clusters. Clusters were also named by the author reflecting the characteristics of students within the cluster. Shaw and Shaw (1997 and 1999) used Cluster Analysis to categorise students into five clusters in both studies and used Factor Analysis to identify three independent causes for performance in their second study (Shaw and Shaw, 1999). It was hoped to achieve similar helpful classification and data reduction in this thesis.

A limitation of both Factor Analysis and Cluster Analysis is that the results are totally dependent on which variables are included in (or excluded from) the analysis. The number of variables that can be included in Factor Analysis is constrained because there is a requirement for an adequate number of cases in relation to the number of variables analysed (10-15 times the number of variables, Field, 2009, p.647). Details of such requirements and how they were satisfied are given with the results in Chapters 4 and 5. Field (2009, p. 628) listed three uses of Factor analysis: '*1) to understand the structure of a set of variables … 2) to construct a questionnaire to measure an underlying variable … and 3) to reduce a data set to a more manageable size whilst retaining as much of the original information as possible.'*, of which 1) and 3) were intended uses of Factor Analysis in this thesis.

This concludes the description and purpose of the types of statistical analyses carried out. The discussion will now continue regarding limitations and differing viewpoints regarding analysis of Likert scale data. In the 5-point Likert scale questions in this thesis "1" usually represented the most negative response (e.g. not confident), "3" was neutral, and "5" was the most positive, although some questions were worded in the opposite sense. Clearly this data is ordinal, and treating it as 'interval' makes the assumption that the distances between responses (intervals) are equal; it was not possible to establish whether this was the case (or not). Alternatively, one could suggest that the two positive responses ("4" and "5") might have been more similar to each other than "4" was to the neutral response "3", and likewise for the two negative responses (making "2" closer to "1" than to "3"), however this cannot be established either.

There has been an ongoing debate since the 1930's among researchers from different disciplines regarding analysis of Likert scale data (Stevens, 1946). There was no controversy over Likert scale data being utilised for frequency distributions and non-parametric tests such as Kruskal Wallis, Mann Whitney-U and Wilcoxon Matched pairs tests which are designed for ordinal data. However, in some other techniques the Likert scale data was treated as 'interval' data; so the following techniques would be considered controversial by some researchers (for example Jamieson, 2004 and Allen and Seaman, 2007): means, as independent variables in Regression analyses and in Cluster Analysis and Factor Analysis.

Carmines and Zeller (1994) point out that many concepts which are of interest in social science are abstract. These are not events or objects which can be seen or touched, and as such are unobservable and therefore unmeasurable. Measurement then becomes a process of linking an abstract concept to an empirical indicant, in this case the students' response. So measurement requires a '*crucial relationship between an empirically grounded indicator(s) – that is the observable response - and the underlying unobservable concept(s)*' (Carmines and Zeller, 1994, p.2). If such a relationship is strong then useful inferences can be made about the underlying concepts. The author of this thesis considered this viewpoint very applicable to the use of Likert scale questions for the affective constructs in this study. The students' beliefs and attitudes were abstract concepts which could not be seen or measured as physical quantities; it was not possible, for example, to put a ruler inside a person's head and physically measure these attributes.

Considerations were made regarding reliability, validity and use of single-item or multi-item scales (particularly for *Confidence in Mathematics*) which will be discussed in Section 4.2.6.2. In general it was expected that the same person would give the same response on repeated occasions in similar circumstances. The validity of responses (whether the true value is obtained) was assisted by the simplicity of questions (parsimony, particularly for *Confidence in Mathematics*), but different persons' ratings might not calibrate well for example different people could rate the same level of confidence differently.

Likert scales are often the instrument of choice for assessing affective variables (e.g. Field, 2009, p. 646). It is the subsequent analyses that would be considered controversial by Jamieson (2004) and Allen and Seaman (2007), although, there is also wide-spread support for the use of these techniques. Jamieson (2004) and Allen and Seaman (2007) do allow use of parametric techniques under certain conditions. Allen and Seaman (2007, p.2-4 and p.3.) state that it is most important to include at least five response categories, that the '*'intervalness' is an attribute of the data not the labels', and* recommend that initial analyses should not involve parametric statistics, but when scales are combined into indexes this adds variation and that parametric statistics can be carried out if assumptions of normality are met. Jamieson (2004, p.1217-18) states that the mean is *'inappropriate for ordinal data'* but does permit use of parametric tests providing that attention is paid to the sample size and normal distribution of the data when the researcher is confident that the data may be considered interval. Many examples of the use of means on Likert Sale data can be readily found, for example:

Becker *et al.* (2009) in Marketing, Usher (2007) and Usher and Pajares (2009) in Psychology and Mathematics Education. Singer and Willett, (2003, p.16-19) explain the formation of a multi-item by creating the mean of nine 4-point scales (and encourage researchers to undertake exploratory descriptive statistics before fitting statistical models). The author of this thesis would like to point out the inconsistency in Jamieson (2004) who frowns upon means of single-items (same question, but different respondents), but permits multi-items which are created from means of single-items (different questions, but same respondent), for which the same issues with *'intervalness'* should surely apply.

Carifio and Perla (2007) counter Jamieson's (2004) arguments. Carifio and Perla (2008) describe empirical evidence for the acceptance of parametric techniques (especially the F-test and Pearson's Correlation Coefficient), although preferring summative scales, and their article title '*Resolving the 50-year debate around using and misusing Likert scales'* demonstrates the longevity of the debate. The length of debate, however, is actually eighty years; Stevens (1946), Rossi (2007) and Rossi and Berglund (2011) all describe the British Association for the Advancement of Science Committee appointed in 1932, composed of Mathematics and Physics experts and Psychology experts, to consider '*quantitative estimates of sensory events'*. Unfortunately agreement eluded the committee for eight years and the *'schism'* between these opposing viewpoints '*has impeded coordinated progress in the various disciplines involved'* (Rossi and Berglund, 2011, p.820). Knapp (1990) described the pro-Stevens camp as conservative and the anti-Stevens camp as liberal, however even Stevens (1946), like Jamieson (2004) allows some concessions:

> '*As a matter of fact, most of the scales used widely and effectively by psychologists are ordinal scales. In the strictest propriety the ordinary statistics involving means and standard deviations ought not to be used with these scales, for these statistics imply a knowledge of something more than the relative rank-order of data. On the other hand, for this 'illegal' statisticizing there can be invoked a kind of pragmatic sanction: in numerous instances it leads to fruitful results.'* Stevens (1946, p.679).

Norman (2010, p.3) points out that

> *'If Jamieson and others are right and we cannot use parametric methods on Likert scale data, and we have to prove that our data are exactly normally distributed, then we can effectively trash about 75% of our research on educational, health status and quality of life assessment.'*

Norman's (2010, p.627) chief argument in favour of treating ordinal Likert data as interval data is based on robustness, i.e. the right answer is usually produced even when assumptions are violated. Norman (2010) responds to three main objections to the use of parametric statistics for Likert scales: 1) the sample size is too small, countering this by explaining that a small sample size makes the significance hurdle higher and harder to get past, but does not rule it out; 2) normal distribution of data, explaining that ANOVA tests and Pearson's correlation for example are very robust with respect to skewness and non-normality; 3) interval data by suggesting summative scales, considering a viewpoint that conclusions are based on the numerical values, and refers again to the robustness of tests to non-normality. Overall Norman concluded that *'Parametric statistics can be used with Likert data, with small samples, with unequal variances and with non-normal distributions with no fear of coming to the wrong conclusion'* (Norman, 2010, p.631) and urges that researchers do take advantage of these powerful and versatile tests.

Clason and Dormody (1994), consistent with Carmines and Zeller (1994), refer to Likert scale questions being used to measure an underlying continuous variable by a discrete response. The underlying variables for confidences and attitudes in this thesis are assumed to be continuous, and this assumption has both advantages and disadvantages. The real latent variable would thus be eligible for calculation of the mean and for use in correlation, regression, cluster and factor analyses. However, the process of simplifying this continuous variable into discrete values causes some loss of accuracy, but has enabled these variables to be treated as factors for the ANOVA and Kruskal Wallis tests, which would otherwise have been impossible.

The frequency distributions for *Confidence in Mathematics* and *Confidence in Statistics* presented in the results Chapters 4 and 5 can be seen to approximate to normal distributions and were not polarised distributions. Early analyses of *Confidence in Mathematics* (Likert scale) included some ANOVA tests (subsequently all replaced by Kruskal Wallis tests) and it was interesting to note that the results of the two tests were very similar. Normality was checked for as part of the early ANOVA tests (by visually checking the shape of the histogram of residuals) and was generally satisfied by this data. Clason and Dormody (1994) also pointed out that there are no set rules to stipulate what is classified as sufficiently 'normal', which is especially difficult with small samples, and also argue that in general single Likert-type items can be skewed and may show a floor or ceiling effect. The slight skew in some of the confidences and attitudes was precisely why the mean was a more useful and interesting representation of central location (for example, mean of 3.2 for *Confidence in Mathematics* compared to 2.7 for *Confidence in Statistics*) than the median (or mode) which would have invariably come out as '3', thus losing any helpful differentiation between the affective variables of interest.

Clason and Dormody (1994), Jamieson (2004), Seaman and Allen (2007), Carifio and Perla (2008), Norman (2010) and Diamantopoulos *et al.* (2012) all advocate summations of single-items into multiple-items arguing that this produces interval data and better reliability, although the author of this thesis would suggest that creating a multi-item scale makes the data more *'continuous',* but not necessarily more *'interval'*. Use was made in this thesis of the Fogarty *et al.* (2001) Scale questions, and a discussion of this multi-item construct is given in section 4.2.6.2. The following authors have found single-items to be valid under certain conditions (and preferable to ease respondent effort and time required): Robins *et al.* (2001), Trew (2005), Davey *et al.* (2007), Bergkvist and Rossiter (2007 and 2009), Fuchs and Diamantopoulos (2009) and Christophersen and Konradt (2011). For example Trew (2005) refers to correlation between results of a standardised test to measure Mathematics anxiety and a single Likert scale question *'On a scale of 1 to 10 how maths anxious are you?'.* Davey *et al.* (2007) state the correlation between results from a single Likert scale question and results from the State Trait Anxiety Index (STAI), Correlation R=0.75.
Bergkvist and Rossiter (2009, p.607-8) encourage use of single-items for '*doubly concrete'* constructs where the *'object of measurement and the attribute of measurement are clear and unambiguous'* for those rating them. Bergkvist and Rossiter (2007, p.183) describe attitudes, beliefs and perceptions as concrete attributes, and in Bergkvist and Rossiter (2009, p.607) conclude that their findings are further empirical evidence that '*multiple-item scales are unnecessary for validly measuring basic constructs*.' Pampaka *et al.,* (2011) constructed a uni-dimensional scale for mathematics self-efficacy thus demonstrating the possible uni-dimensional characteristic of self-efficacy (called *self-confidence* in this thesis). In further support of single-item use, Lucas and Donnellan (2012, p. 323) state that *'life satisfaction is often measured using single-item measures'*.

Jamieson (2004) acknowledges that assuming Likert-type categories '*constitute interval-level measurement'* has become common-place, and that practice in the analysis of this type of data differs from textbooks. Clason and Dormody (1994, p.34) conclude that *'it is not a question of right and wrong ways to analyse data from Likert-*

type items' and suggest that *'Statistical procedures that meaningfully answer the research questions, maintain the richness of the data and are not subject to scaling debates should be the methods of choice in analysing Likert type items.'* It is interesting to note that in Field's widely used statistics text book his Factor Analysis example is based entirely on Likert scale questions (Field, 2009, p. 646 and p. 672) indicating his approval of such. To conclude these discussions, whilst care has been taken to use Kruskal Wallis, Mann Whitney U and Wilcoxon Matched Pairs tests for ordinal data (and not ANOVA), Stevens' (1946) '*pragmatic sanction'* is invoked for other analyses in this thesis where assumptions of '*intervalness'* of single-item Likert scales have been applied, particularly as the results of such analyses were primarily to produce approximate, rather than precise, effect sizes.

3.4 Ethical Considerations

This research has been conducted according to the following ethical codes of practice, which were considered in early 2005, at the time the study was commencing:

- British Educational Research Association (BERA) Revised Ethical Guidelines for Educational Research (2004). (BERA, 2004)
- RESPECT - a voluntary code of practice covering the conduct of socio-economic research in Europe. (RESPECT Project, 2004)
- The British Sociological Association 'Statement of Ethical Practice'
  and also the Code of Good Professional Conduct. (British Sociological Association, 2002).

Subsequently the Harper Adams' policy 'A Policy for Research Ethics', was issued in January 2006 (Cobb, 2006). This policy was obtained and checked and was found to be in accordance with the codes of practice previously consulted. After this study was mostly completed the College also introduced a Research Ethics Form, but this study was not required to complete such a document retrospectively.

At the time of designing the study the Loughborough University Guidelines were not made available, however the following documents have subsequently been consulted via the Loughborough University web-site: Code of Practice on Investigations Regarding Human Participants; Guidance Notes for Investigators: Compliance with Data Protection Requirements and Additional Information and resources, from which the following word documents were accessed: Ethical Clearance Checklist; Participation Information Sheet Template; and the Informed Consent Template

(Loughborough University, undated a, b, c and d). This research has been covered by a Loughborough University Generic Protocol approved explicitly for use with research projects undertaken from within the Mathematics Education Centre at Loughborough, which covered *'Focus groups, interviews, questionnaires (on-line and on paper), and observations on/with undergraduate and postgraduate students at Loughborough and other Universities.'* In this research the process and details of the questionnaires and interviews have been carried out under the supervision of Prof. Tony Croft (named as the responsible investigator in the Generic Protocol, p.2 Item 3.) and Dr. Martin Harrison (named as an additional investigator with extensive experience in the Generic Protocol, p2. Item 4.). The Generic Protocol was created after the data collection activities had been carried out for this study, but has subsequently been made available and taken into account during the writing up of this thesis.

The main principles of the ethical Codes of Practice which were followed throughout the study are described in this sub-section. The RESPECT code of practice (RESPECT Project, 2004) was based on three main principles:

- *Upholding scientific standards*
- *Compliance with the law*
- *Avoidance of social and personal harm* (Huws, 2004, p.vi)

The three main principles of the RESPECT code of practice above were enlarged upon in 18 guidelines, of which the following nine were considered key in this study:

1. *Researchers should endeavour to ensure factual accuracy and avoid falsification, fabrication, suppression or misinterpretation of data.*
2. *Researchers should endeavour to ensure that reporting and dissemination are carried out in a responsible manner.*
3. *Researchers should endeavour to reflect on the consequences of research engagement for all participants, and attempt to alleviate potential disadvantages to participation for any individual or category of person.*
4. *Researchers should endeavour to ensure that methodology and findings are open for discussion and peer review.*
5. *Researchers should endeavour to ensure that any debts to previous research as a source of knowledge, data, concepts and methodology should be fully acknowledged in all outputs.*
6. *Researchers should endeavour to ensure that participation in research should be voluntary.*

7. *Researchers should endeavour to ensure that decisions about participation in research are made from an informed position.*
8. *Researchers should endeavour to ensure that all data are treated with appropriate confidentiality and anonymity.*
9. *Researchers should endeavour to ensure that research participants are protected from undue intrusion, distress, indignity, physical discomfort, personal embarrassment, or psychological or other harm.* (RESPECT Project, 2004, p.1).

It was found that the British Educational Research Association (BERA) and the British Sociological Association guidelines contained similar principles for research and also for behaviour towards participants in general.

The methodology text by Saunders *et al.* (2003) also contained very clear guidelines on the ethical conduct of research, in particular for the processes of performing the interviews, which were considered and followed. (Saunders *et al.*, 2003, p.245-279). The anonymity of participants was viewed as paramount in this study, information given by *students and staff* remained anonymous in publications and discussions. Student identifying details were only given in terms of their course and year of study, chronological year and other descriptive details, for example whether dyslexic or not, background qualifications, gender, etc.

The researcher's role as a member of staff, as module tutor to some students and as the mathematics support provider to many more students, may have influenced students' participation and responses. However, as has already been written earlier in this chapter, every effort was made to keep any such influence to a minimum. For example, when students were interviewed, the questions regarding the mathematics support were carefully chosen to be neutral questions and actually very few questions were asked because the interviewer was the provider of this support provision.

The administration of the questionnaires during students' lectures did produce a high response rate, but it also meant that the lecturer who would mark their work (which for the second year and third year students counted towards their degree) would have the opportunity to read their responses. If the lecturers had read their students' responses there were potentially positive and negative consequences; on the positive side reading students' responses would have enabled the lecturers to gain valuable insight into the background and learning experiences and feedback from the students in their group. On the other hand, on the negative side, had a student written something critical this might have been upsetting for the lecturer, or such a student might have felt constrained that they could not have written such honest criticism in case it could have adversely affected their marks. As has already been explained, the questionnaires only contained the students' id numbers and not their names; and at the time of the questionnaire surveys it was actually quite difficult to look up a student's name from their id number, especially for courses with a large number of students, but it was theoretically possible. Overall it was considered that the positive benefits of the high response rate and enabling the lecturers to be better informed by the feedback of their students outweighed the possible disadvantages of the arrangements. One of the lecturing staff, who administered questionnaires in his lectures, reflected that whilst participation was theoretically optional, 'Did the students really have a choice whether or not to participate?' This researcher would suggest that the students option not to participate was most easily exercised by leaving their responses to the questions blank. There was a case of one student who did not hand his questionnaire back to his lecturer but who completed it and handed it directly to the researcher at a later date. At this College students were routinely asked for feedback on their modules and opinions on a wide range of facilities and provision at the College, so the questionnaires for this study would have been of a genre which was familiar to the students and was therefore unlikely to be considered offensive or intrusive.

Occasionally there were sensitive comments made in the questionnaire responses by students about their lecturers' professional duties. In these situations, whilst these results have not been suppressed, such comments have been reported in a careful manner which preserved the anonymity of all participants, including staff, but which presented the characteristics which were criticised as a general approach which it was desirable to avoid. Fortunately such criticisms were in the minority and overall a wide range of constructive and predominantly positive comments were received from the questionnaires. It was also clear that there was a wide range of student experiences in the student groups surveyed, including many who had found mathematics and statistics difficult and who were lacking in self-confidence in these subjects.

It was recognised from early in the study that adhering to ethical best practice would in some instances prevent beneficial use of the information. For example, had a student need been discovered on a questionnaire, for which the students had been given assurance that their information would be treated anonymously, then it was not appropriate to relay this information to the relevant tutor who could have provided support or investigated the need. Thus in such a situation it would have been necessary to obtain express permission from the participant before information identifying that person was disclosed. Early in the study such a situation arose, where very negative questionnaire responses were obtained from a student who was clearly lacking confidence in mathematics and having difficulties with their studies. In this case the student was contacted by e-mail with suggestions of how to seek some help, and the e-mail was sent using the student id no. from the questionnaire without looking up their name, thereby maintaining the students' anonymity.

Another example of careful ethical practice which was followed was in the selection of trusted people who helped to transcribe the student interviews. These helpers were chosen as people who did not have current direct involvement with the College so who would not know the members of staff being spoken about or the students who were interviewed.

It was considered by the researcher that the processes of the questionnaires and interviews were conducted ethically and that the experience was generally positive for the participants. The interview process was a particular example of the well-being of the participants being considered. Whilst the objective of the interviews was to gather information, it was also very much a requirement that as far as possible the interviewee should find it a pleasant and positive experience; if possible their self-esteem and self-confidence would be boosted through the process of reflecting back over their course and achievement at this College. This was slightly at odds with the role of the researcher as a neutral observer and made the observer slightly more of an active participant with the aim of encouraging the student participants through the interview process. However, as the interviewees were usually students about to leave university and embark on a career in the wider world, this seemed the most ethical approach. For example, there was one particular student who had a very good job to go to but who was apprehensive about their capability to do the job competently from the outset. In this case the interviewer tried to give some assurance that a settling-in period and some initial support in the job was to be expected, and that the student was actually very capable of doing the role. The good rapport which the interviewer aimed to develop with the interviewees during their interview hopefully also made the interview process more enjoyable as well as being good ethical practice. With regard to the Mathematics Learning Questionnaires some students wrote *'Thank you'* at the end of their questionnaires, which was interpreted as a 'Thank you' for the opportunity to express their views, also indicating their approval of the questionnaire process.

The need to conduct the research ethically was taken seriously in this study and was considered important for all participants and the researcher. The RESPECT, BERA and the British Sociological Association's ethics codes of practice (as considered earlier in this section) were considered and complied with from the outset of this study, before any questionnaires or interviews were conducted in this study. Subsequently The Harper Adams' Policy for Research Ethics (Cobb, 2006) and the Loughborough University Ethical Advisory Committee's Codes of Practice and the Generic Protocol for the Mathematics Education Centre (Loughborough University, undated a-d) were also consulted and considered, and thereafter conformed to and reflected upon. Ethics guidelines were also contained in several of the methodology texts which were consulted (including Saunders *et al*., 2003, p.129-142 and Grix, 2004, p.142-148). Overall, this ensured that, the well-being of participants and good ethical practice was adhered to throughout the study.

3.5 Justification and Theory of the Methodology

Overall a mixed methodology was adopted for this study, and the method (what was done) has already been described in this chapter. What now follows is a classification, discussion and justification of the methodology adopted with reference to appropriate literature. In Section 3.1, a brief outline was given of this study's research philosophy, approach, strategies, time horizons and data collection methods. These were also shown graphically in Figure 3.1. The Research Process Onion (adapted from Saunders *et al*., 2003, p. 83) showed the terms applicable to this study in bold text. These terms will now be explained and discussed in this section, covering the research philosophy, approach, strategies, time horizons and data collection methods (starting with the outer layers of the onion and progressing inwards). As will be seen in all aspects more than one term applied, as the study had different characteristics at any single point in time, and the study changed in nature as it progressed.

3.5.1 Research Philosophy

The research philosophy adopted for this study was primarily positivism, however it will be shown in conclusion that realism was the more appropriate philosophy. The methodology followed many characteristics of positivism, including: causal relations, highly structured replicable methodology, operationalisation of concepts into quantifiable variables and quantitative data analysis. Causal relations between concepts were expected and tested for, with the desire to make generalisations from the findings. Such causal relations regarding learning mathematics are proposed and described in Chapter 2 in Ernest's Success and Failure cycles in mathematics shown in Figure 2.1 (Ernest, 2000) and by Fishbein and Ajzen's (1975, p.15) causal relationships between beliefs, attitudes, intentions and behaviour, see Figure 2.2.

A highly structured methodology was used, which would facilitate replication (Gill and Johnson, 1997 in Saunders *et al*., 2003, page 83). Concepts such as self-confidence in mathematics, liking of the subject(s) and motivation, etc. were operationalised, that is, were converted to measurable variables (Grix, 2004, page 171). The variables which were considered by the study are shown in Figure 3.3. These variables produced quantitative data which were collected and subsequently analysed, using Microsoft Excel, SPSS and GenStat computer packages, and tested for significant relations between these and many other variables. All of these processes were compatible with a positivist research philosophy. A positivist philosophy, however, requires the researcher to be an independent and unbiased observer of the physical and social reality observed (Gall *et al*., 1996, p.14), producing what can also be called value-free or bias-free observations. In this study the observer played an active role, both teaching and supporting some of the participants (students). Whilst the observer did endeavour to make only objective and value-free judgements, the researcher's involvement with the students could have had two effects incompatible with positivism, namely:

a) that the researcher's involvement with the participants could in some way influence the data gathered, for example constrain the type of responses and comments students felt able to give; and
b) that the researcher might unwittingly show bias in any conclusions formed.

Both of these two effects were considered in section 3.3 relating to ethical considerations and as has already been written these effects were minimised as far as possible.

There was also an important advantage of the researcher being known to many of the students, which was that this facilitated the gathering of data. For a good number of the students interviewed the researcher had been a 'friendly helper' through being the provider of the mathematics support provision; this may well have enabled the students to speak more frankly and fully about their experiences than they would have done to a complete stranger. Saunders *et al.* (2003, p.98) described the case of practitioner researchers who have the advantages of avoiding difficulties in access to data and

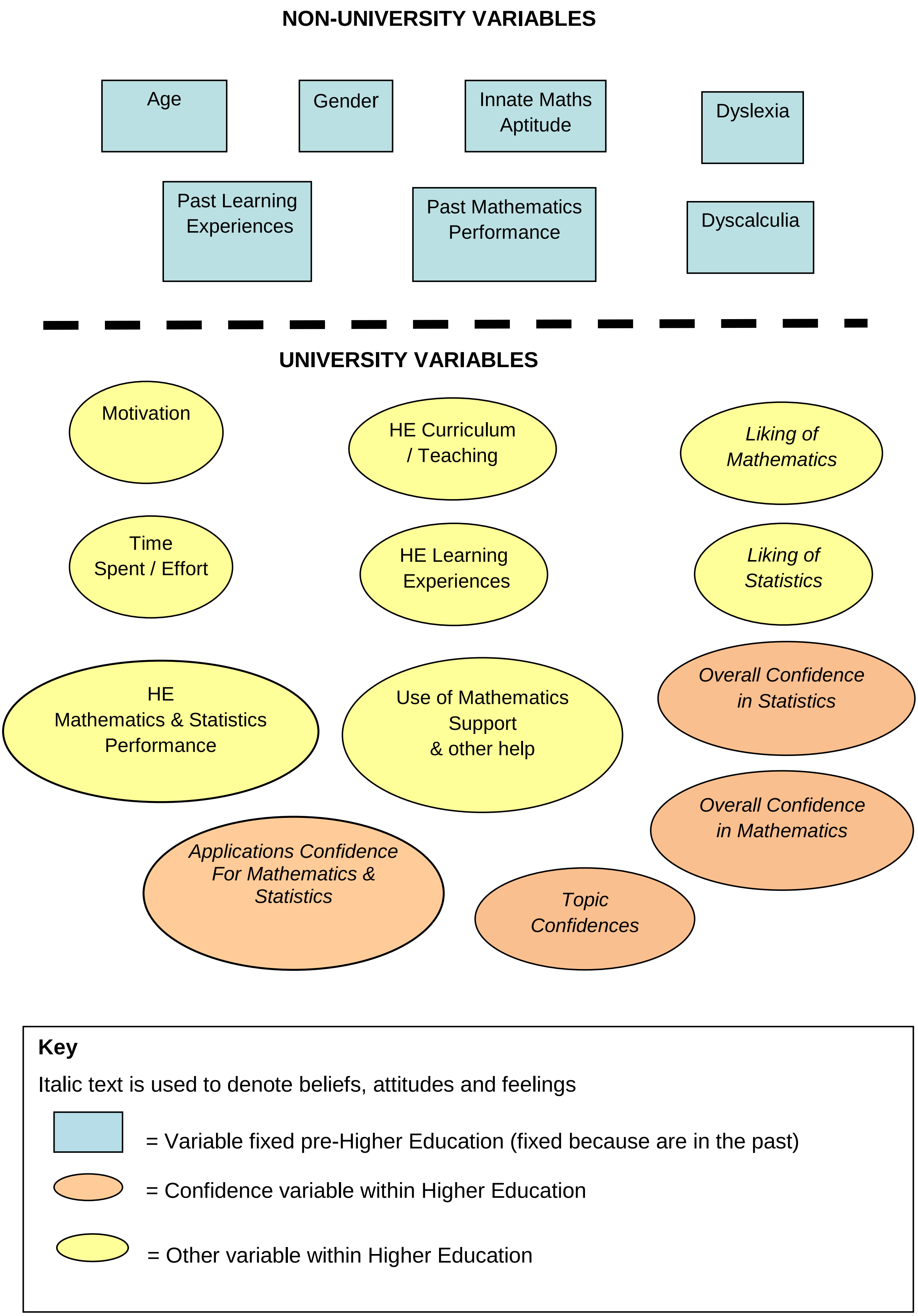

Figure 3.3 Variables Considered by the Study (Source: Author's own)

have no requirement to spend time becoming familiar with the research context. However, such practitioner researchers do need to be aware of any assumptions or pre-conceptions which they may hold.

Grix comments on the ideal of the neutral observer as follows. '*This ideal has come to be seen as impossible in social science research, as all investigators have particular perspectives.'* (Grix, 2004, page 177). The explicit statement of the underlying ontological and epistemological assumptions (in chapter 2) aimed to declare the position and perceptions from which the researcher observed, and by understanding these (and if required) any bias could be compensated for.

Elements of the study also followed an interpretivist / constructionist / social constructionist philosophy or paradigm, where these three terms were considered to have equivalent meanings, which were that social reality and meanings are *'constructed by the individuals who participate in it'* … and *'constructed differently by different individuals'* and are less constant across time and space. (Gall *et al*., 1996, page 15). Certainly it was found that different individuals on the same course or in the same lecture did have quite different opinions and experiences based on their own constructed realities. Meaning was sought to be found from qualitative interview data and open questions in questionnaires, both of which are consistent with an interpretivist philosophy (and an inductive approach).

A compromise between the apparently opposing philosophies of positivism or interpretivism can be found in realism. Saunders *et al*. (2003, p.85) describe realism as recognising *'the importance of understanding people's socially constructed interpretations and meanings, or subjective reality, within the context of seeking to understand broader social forces, structures or processes that influence, and perhaps constrain, the nature of people's views and behaviours.'* Gall *et al.* (1996, p.22) consider realism to present a model of the world consisting of *'layers of causal structures, some of them hidden from view, that interact to produce effects that may or may not be observable'.* Both of these definitions of realism are applicable to the philosophy which was adopted.

3.5.2 Research Approach, Strategy and Time Horizons

The research approach was generally deductive in that theories and hypotheses were postulated and the research sought to verify these with empirical evidence. For example, it was expected that past experiences and qualifications in mathematics would influence confidences, attitudes and achievement at university. By contrast inductive research '*draws conclusions from specific empirical data (the particular) and attempts to generalise from them (the general), leading to more abstract ideas, including theories.'* (Grix, 2004, p. 168).

The major differences between Deductive and Inductive approaches to research can be summarised as follows (Saunders *et al*., 2003, p. 89):

***'Deduction** emphasises: scientific principles; moving from theory to data; the need to explain causal relationships between variables; the collection of quantitative data; the application of controls to ensure validity of data; the operationalisation of concepts to ensure clarity of definition; a highly structured approach; researcher independence of what is being researched; and the necessity to select samples of sufficient size in order to generalise conclusions.'*

'Induction, on the other hand, *emphasises; Gaining an understanding of the meanings humans attach to events; A close understanding of the research context; The collection of qualitative data; A more flexible structure to permit changes of research emphasis as the research progresses; A realisation that the researcher is part of the research process; Less concern with the need to generalise.'*

In reality a mixture of both deductive and inductive approaches were used. Several of the methodology texts referenced in this section would concur that such a mixture is helpful and often occurs. Ragin reflects that *'while the deduction - induction distinction is a simple and appealing way to differentiate kinds of social research, most research includes elements of both*'. (Ragin, 1994, in Grix, 2004, p.114). Similarly, a combination of deductive and inductive inferences is used in most investigations according to Phelan and Reynolds (1996). '*Neither approach should be thought of as better than the other. They are better at different things.'* (Saunders *et al*., p.89)

The analysis of the questionnaires inclined more towards a deductive approach, whilst conducting and analysing the interviews was more inductive. However both data collection methods contained some elements of both deductive and inductive approaches.

The hypothetico-deductive method shown in Figure 3.4 combines both deductive (initially) and inductive reasoning. An initial conjecture is the basis for a hypothesis which is then tested and the results subsequently evaluated. This may produce different conjectures, thus the process might be repeated cyclically. Note: the dotted arrow was not in the original figure.

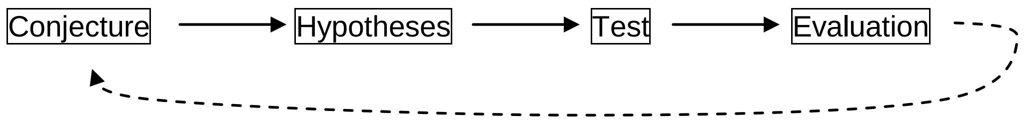

Figure 3.4   Hypothetico-deductive method
(Adapted from: Phelan and Reynolds, 1996)

The research strategy was survey, see Table 3.3, and the time horizons for the study were both cross-sectional and longitudinal. One of the advantageous features of the study was the longitudinal aspect of the research which was conducted over a period of five years and followed two cohorts through their whole university courses. However, within the longer time frame, particularly in the first three years of the study there was a cross-sectional element in that multiple surveys were conducted at the same time to investigate different groups of students, who were on different courses and at different stages of their courses.

3.5.3 Data Collection Methods and Triangulation

Both quantitative and qualitative types of data collection methods were used. Questionnaires (quantitative method) and student interviews (qualitative method) were conducted. Different types of methods were used in order to achieve different purposes and methodology literature generally approves of such mixtures:

> *'If you wish to collect quantitative data you are probably measuring variables and verifying existing theories and hypotheses or questioning them.'* … '*However, often collections of statistics and number crunching are not the answers to understanding meanings, beliefs and experience, which are better understood through qualitative data.'* (Wisker, 2001, p.137)
>
> *'It is not clear that quantitative and qualitative research are necessarily incompatible or that one type has a greater claim to truth than the other. Both approaches have helped educational researchers make important discoveries.'* (Gall *et al*., 1996, p.27)

Some triangulation of the data was performed to cross-check to '*limit the chance of bias in the methods or sources employed*' (Grix, 2004, p.176). For example the mix of closed and open questions in the questionnaires permitted some cross-validation of responses. However, more often the data obtained from different methods, sources and types was not triangulated, because it was not observing exactly the same phenomena. The different methods were deliberately employed to collect different data which would shed light on different aspects of the subjects. The summaries that were made of whole course cohorts from the survey data provided a totally different level of detail compared to individuals' experiences retold in an interview. Similar questionnaires were used for students in their first year and then again in their second year, but the repeat of the questionnaire was not intended to reproduce the data, or to check that it was the same, but was intended to enable any changes from the first year to the second year to be investigated.

3.5.4 Descriptive, Exploratory, Explanatory and Predictive Research

An alternative categorisation of research distinguishes between descriptive, exploratory, explanatory and predictive kinds of research (Wisker, 2001, p.118, and Saunders *et al*., 2003, p.96). To summarise, each of these categories asks different types of questions, namely:

- Descriptive research - '*What?'*;
- Exploratory research - *'What and Why?'*;
- Explanatory research *'What, Why and What are the causal relations between variables?'*; and
- Predictive research - *'What if?'*.

This study aimed to be primarily explanatory, seeking to understand *what* and *why,* and also to propose and verify *causal relations between variables* (such as achievement and confidence, motivation and achievement, etc.). It was originally hoped that once the causal relations were verified, it would also be possible to make predictions. This was in fact possible, multiple regression models were produced which modelled students' first and second year mathematics and statistics marks on their past mathematics qualifications and level of self-confidence or other affective variables. This could have future uses, for example to determine which students are likely to succeed or fail.

Overall a mixed methodology was followed which enabled quantitative and qualitative data to be collected for different purposes. The data was analysed using different approaches: both deductive and inductive. Large scale surveys provided a broad view of the student groups at the macro level, whilst interviews with individual students provided details at a micro level. In the proceeding chapters (4 and 5) the results of the questionnaire surveys will be presented.

4 ENGINEERING STUDENTS' QUESTIONNAIRES

4.1 Introduction to the Engineering Students' Questionnaires

This chapter is the first of two chapters which will present, analyse and discuss the results of the primary data collected by the study, and this follows on from the description of the Methodology for the study in the previous chapter, Chapter 3. The results from the engineering students' questionnaires are presented in this chapter, which are followed by the results of the natural and social science students' questionnaires in Chapter 5.

The engineering students were of particular interest to this study because they studied a more mathematical curriculum than the other student groups and because a relatively high proportion of these students used the mathematics support provision in the College. The author had more working contact with the engineering students than students on other courses; the author had personally taught and supported some of the students who completed questionnaires and was very keenly interested in understanding these students' views and experiences. The importance of, and the measures taken to, maintain independence and neutrality in the research have already been discussed in the Methodology (Chapter 3), along with the benefits which arose from the researcher already having an understanding of the environment in which the students learnt mathematics. It will be shown that while the engineering students were often positive about mathematics and the necessity of mathematics for engineering courses, they exhibited a range of abilities and experiences, both before and at university. The first year and second year engineering students' questionnaires have been grouped together in this chapter (4), and separated from the other types of students' questionnaires (in Chapter 5), who studied statistics rather than mathematics and were generally found to have different attitudes and study habits (often more reluctance and avoidance) towards mathematics and statistics.

This opening section introduces the engineering students' questionnaire results and provides an overview of which questionnaires were administered when and to which engineering students. The results of the analyses of the questionnaires are then presented, initially detailing the first year engineering students' questionnaire results (in Section 4.2), followed by the second year engineering students' results (Section 4.3), and the changes between the first year and the second year (Section 4.4). Finally Section 4.5 summarises the findings and rounds off the chapter.

Mathematics Learning Questionnaires were administered to first and second year engineering students at Harper Adams in May 2005, 2006 and 2007, seeking their views on learning mathematics and statistics. The questionnaires were administered by four different lecturers in the final mathematics related lectures of the year. The numbers of questionnaires completed by each engineering student group is summarised in Table 4.1 below. Further details regarding the questions posed, timings and amendments from one year to the next were given in the Methodology (Chapter 3) and sample whole questionnaires can be viewed in the Appendices (I-V). A brief version of a first year questionnaire is provided in Table 4.2, which also reiterates, for convenience, the related Research Questions. The full Research Questions were listed in the Introduction Chapter, Section 1.3.

The annual entry into first year engineering programs was relatively small, approximately 55, thus a good response rate (approximately 50-60+ %) was achieved for the first year questionnaires. For the second year BEng questionnaires a response rate of 83.3% was achieved. Students' responses related primarily to their mathematics modules; however the first year students had also studied statistics using Mathcad software and the second year students had also used Mathcad for Analytical techniques, to which some responses referred. The engineering students were all also studying mechanics and other modules which had a high mathematical content in all years of their courses, so these would have potentially been in the students' minds whilst filling in the questionnaires. More recently a final year engineering student when talking with a member of staff referred to his final year mechanics module as 'the maths'!

The 2005 first year BSc engineering students' questionnaires were the very first questionnaires completed, and were used as a pilot questionnaire, after which small modifications were made for the other 2005 questionnaires. In 2006 the FdSc first year engineers' questionnaire was the pilot version used to test the 11 Scale questions (based on Fogarty *et al.*, 2001) which replaced the 11 *Applications Confidences* (which were simplified into two questions). In 2006 and 2007 the first year BSc and HND/FdSc engineering groups completed identical versions of the questionnaires. However, there were different first year and second year BEng/MEng questionnaires reflecting the more challenging BEng/MEng syllabus for *Topic Confidence* questions.

Table 4.1 Number of Engineering Students Completing Mathematics Learning Questionnaires by Year and Module in 2005, 2006 and 2007

Student Course Year	Module Surveyed	2004/5	2005/6	2006/7	Total
1st Year	BSc Mathematics for Engineers	Pilot 15	20	15	50
	FdSc Mathematics for Technologists	8	Pilot 13	2 *	23
	M/BEng Engineering Mathematics	6	17	15	38
	Total 1st year Engineering Students	**29**	**50**	**32**	**111**
2nd and 3rd Year	2nd year M/BEng Engineering Mathematics & Analytical Techniques (with Mathcad)	17	8	20	45
	2nd year BSc with 3rd year FdSc Research Methods & Analytical Techniques (with Mathcad)	-	-	13	13
	Total 2nd & 3rd year Engineering Students	**17**	**8**	**33**	**58**
	Total Engineering Students' Questionnaires	**46**	**58**	**65**	**169**

Notes: * Three of the 1st year FdSc students had transferred to the BSc award, and are shown above as BSc students. Difference from Table 3.3 was explained after Table 3.3 and was due to FdSc students transferring to BSc.

The questions in the 2007 first year questionnaires were broadly similar to those in 2005 and 2006, but some of the free text questions were moved forwards (for example, one that asked which features helped students to learn) and the 11 Scale questions were reduced to five questions plus a new question about the usefulness of mathematics. 111 students completed the first year engineers' questionnaires over the three years, and of these 108 could be linked to the module marks. 45 BEng and MEng second year students and 13 second year BSc engineering students completed questionnaires. Some of the findings described in Section 4.2 have been published (Parsons *et al.*, 2009).

In addition to the *Topic Confidences* being different, the other differences between the second year and first year BEng and MEng questionnaires were an extra question about ways in which students had changed from the first year to their second year and fewer questions about the mathematics support. The support was at that time very much targeted at first year students, although this is no longer the case, and only a minority of second year students used it, often those who had a National Diploma qualification rather than A level Mathematics. The second year BSc students (who were taught with the third year FdSc) did not have a second year mathematics module; they were only surveyed in 2007 after a new Research Methods module was introduced which contained some statistics. These students were not included in the analysis presented in this chapter because they were not learning mathematics and it was only a small data set. The data entry into Excel spreadsheets, use of Excel, GenStat and SPSS software for analysis, and combination of three year's data, where appropriate, has already been explained in Section 3.2.7

4.2 Results of First Year Engineering Student Questionnaires 2005 - 2007

Section 4.2 describes the results of the first year engineering students' questionnaires which were administered in May 2005, 2006 and 2007. As previously stated, example questions are given in Table 4.2 below (excluding the biographical data questions) along with the coded values for the students' responses and a cross-reference to the related Research Questions as listed in Section 1.3. See also the Methodology section (3) and Appendices I-V. Every Research Question has been addressed, to varying degrees, by these questionnaires.

In Section 4.2.1 the results of the closed questions are presented, followed by the results of the open questions in Section 4.2.2. Analysis of relationships between the students' mathematics marks at university and their confidence in mathematics with other details is presented in subsections 4.2.3, 4.2.4 and 4.2.5 showing that not only do the students' entry qualifications significantly affect their achievement at university, but also their confidence and other attitudes and motivation are shown to have significant relationships (and possibly causal effects). Analysis of the 11 Scale questions is presented in subsection 4.2.6, and Factor and Cluster Analysis in subsection 4.2.7.

Table 4.2 2005 BEng/MEng First Year Engineering Students' Mathematics Learning Questionnaire Questions with Response Codes

No.	Question Text	Response Codes	RQ
10	Given a choice would you have chosen to study this module?	Y/N	IIa
	How confident would you describe yourself overall?		
11	in mathematics?	1-5	Ia & b
12	in statistics?	1-5	Ia & b
13	in life in general?	1-5	Ia & b
14	For how long have you held this opinion of your self-confidence in mathematics?	Free text	Ic & d
15	How do you think that your experiences of mathematics *before* coming to university have affected your confidence or liking of the subject?	Free text	Id
16	Has this module helped you to feel more confident than previously?	1-5	Id & e
	Do you like the subject?		
17	Like Mathematics?	1-5	IIa
18	Like Statistics?	1-5	IIa
19	Has this module helped you to *like* the subject more?	1-5	IIa
20	How would you describe your *attitude* to learning mathematics?	Free text	IIa & b
21	How would you rate your *motivation* in this area?	1-5	IIa & b
22	Is this more or less motivation than for your other modules overall?	More / Less / Same	IIa & b
23	How much time have you spent outside lectures working on this module on average in hours per week?		
	0 / 1 hour / 2 hours / 3 hours / 4+ hours		IIb
	How would you describe your ability to do *(or confidence in doing)* the following topics in the module?		
24	Using equations and formulae	1-5	Ia & b
25	Rearranging equations & formulae	1-5	Ia & b
26	Simultaneous equations	1-5	Ia & b
27	Trigonometry (Sin, Cos, Pythagoras)	1-5	Ia & b
28	Partial fractions	1-5	Ia & b
29	Differentiation (basic)	1-5	Ia & b
30	Differentiation of products, quotients	1-5	Ia & b
31	Integration	1-5	Ia & b
32	Complex numbers	1-5	Ia & b
33	Matrices	1-5	Ia & b
34	Differential equations	1-5	Ia & b

	How confident do you feel about *applying these* in the future, for example to analyse your project/dissertation data or at work? (Please tick one box per topic)		
35-45	The 11 topics shown above were repeated in 2005 for an Applications Confidence ratings	1-5	Ia & b
46	What effect has your dyslexia or dyscalculia had?	Free text	IId
47	Which aspects of the module particularly *helped* your learning?	Free text	IIc
48	Which aspects of the module particularly *hindered* your learning?	Free text	IIc
49	Have you experienced an occasion when a topic suddenly became a lot clearer than before (e.g. like a light switching on)?	Yes / No	IIc
	Details:	Free text	IIc
50	Have you had any support from other sources? Can tick as many as apply.		
	Lecturer / Friends / Family / Mathematics support / Books / Web-sites / Other / None and Free text		IIc & e
	If Mathematics support was used then please answer the questions below. Otherwise please continue on the next page.		
51	Was the Mathematics support for group or individual help?	Group / Individual / Both	IIe
	How would you rate the Mathematics support?		IIe
52	Helpfulness of support	1-5	IIe
53	Clear teaching	1-5	IIe
54	Relevance to your needs	1-5	IIe
55	Arrangements / Timing	1-5	IIe
56	Other comments on the mathematics support (e.g. suggestions)	Free text	IIe
57	When did you last enjoy doing something in maths?	Free text	IIa
58	Can you suggest anything that would improve your confidence, attitudes or ability in mathematics?	Free text	Id
59	Any other comments	Free text	All

4.2.1 Results of First Year Engineering Students' Closed Questions

This subsection details the results from the analysis of the combined results of the 2005, 2006 and 2007 first year engineering students' questionnaires. Mean student responses from the 2005-7 questionnaires' closed questions regarding confidences, attitude and motivation and mean mathematics module marks are shown by award group in Table 4.3 below, and in Figures 4.1 and 4.2. Student confidences, *Liking of Mathematics* and *Liking of Statistics*, and Motivation were measured using Likert scales, from 1 to 5 (where 5=high). Use of means on this data has already been discussed in Section 3.3.

Table 4.3 Summary of 2005, 2006 and 2007 First Year Engineers' Responses

		Confidence				Attitude			Motivation		
Year and First Year Student Group	**No. Students**	**Confidence in Mathematics**	**Confidence in Statistics**	**Confidence in Life**	**More Confident?**	**Like Mathematics**	**Like Statistics**	**Like Maths More After Module**	**Motivation Rating**	**Would Choose to Study Maths**	**Mean Mark %**
2005											
M/BEng	6	3.3	3.0	3.7	4.2	4.0	3.0	4.0	4.0	83%	85.3%
BSc	15	3.2	2.7	3.9	4.1	3.3	2.6	3.7	3.4	100%	65.9%
HND/FdSc	8	3.4	3.0	3.8	3.9	3.4	2.9	3.3	3.4	50%	47.9%
Total	29	3.3	2.9	3.8	4.0	3.4	2.8	3.7	3.5	81%	65.0%
2006											
M/BEng	17	3.9	3.1	3.9	3.8	3.5	2.5	3.4	3.4	88%	77.3%
BSc	20	3.6	3.1	3.6	4.3	3.6	2.8	3.8	3.4	70%	69.5%
HND/FdSc	13	3.3	2.9	4.0	3.7	3.1	2.4	3.2	3.3	31%	41.5%
Total	50	3.6	3.0	3.8	3.9	3.4	2.6	3.5	3.4	66%	65.1%
2007											
M/BEng	15	3.3	3.1	3.5	4.1	3.5	2.9	3.6	3.5	87%	77.0%
BSc	15	3.6	3.0	3.8	4.5	4.0	3.1	4.0	3.6	60%	72.3%
HND/FdSc	2	2.0	2.0	4.5	3.0	2.0	2.0	2.5	2.5	0%	38.5%
Total	32	3.4	3.0	3.7	4.2	3.7	2.9	3.7	3.5	69%	72.4%
2005-7 Totals											
M/BEng	38	3.6	3.1	3.7	4.0	3.6	2.7	3.6	3.6	87%	78.4%
BSc	50	3.5	2.9	3.7	4.3	3.6	2.8	3.8	3.4	76%	69.3%
HND/FdSc	23	3.2	2.9	4.0	3.7	3.1	2.5	3.1	3.3	35%	43.5%
Grand Totals	**111**	**3.5**	**3.0**	**3.8**	**4.0**	**3.5**	**2.7**	**3.6**	**3.4**	**71%**	**67.2%**

Considering the totals and overall mean responses, the first year engineering students had medium to good confidence in their ability to do mathematics, as demonstrated by mean ratings above 3 in all cases (for example, mean *Overall Confidence in Mathematics* is 3.5). 72% of students responded that they felt more confident in mathematics at the end of the first year, and the mean response to whether students felt more confident after the mathematics module was 4.0 (out of 5). It is very encouraging that so many of the students felt more confident after their first years' mathematics at Harper Adams.

Student's mean *Liking of mathematics* was fairly high (3.5 out of 5) and their attitudes (open question) were generally positive towards mathematics. See the responses to the open question regarding 'Attitude' in the next Section (4.2.2.1).

First year engineers were fairly motivated: their mean *Motivation* was 3.4 (out of 5) and overall 71% (79) of the respondents would choose to study mathematics. 26% (29) would not have chosen to study mathematics (and 3 were blank), which is a much better percentage than in Gordon (2004) who reported that 73% of the psychology students surveyed would not have chosen to study statistics in their psychology course, and similarly 74% of the non-engineering students in this thesis would not have chosen to study statistics. The mean time spent working on mathematics outside of lectures was 1.3 hours per week according to the student responses.

Student responses regarding statistics were lower than for mathematics. Both students' confidence in their ability to do statistics (mean value 3.0), and their *Liking of Statistics* (mean value 2.7, the only mean rating less than 3) were lower than the equivalents for mathematics. It was not clear whether this related to statistics as a subject or to the use of Mathcad for statistics.

The overall mean first year mathematics mark, the average of three termly examinations, was 67.2%, indicating good achievement for those students who completed the questionnaires.

From the mean values for the three years of first year questionnaire data (shown in Table 4.3) it can be seen that the three years were broadly consistent. There was some variation, for example, only 2 HND students completed questionnaires in 2007 and these were particularly lacking in confidence and low achieving, whilst the 2006 BEng/MEng students were more confident on average than in the other years. However, from looking at the mean values for the three separate years' data in Table 4.3 the three years' results do appear to be fairly similar. As already mentioned in Section 3.2.7, ANOVA and Kruskal Wallis tests all found that the Engineering students' marks and Confidence in Mathematics were not significantly different across the three years (see Appendix VIII). It was also known that there were no particular changes in recruitment, teaching and assessments over the three years for the analysed data.

Mean student ratings by award group are shown in Table 4.3 above and also below in Figure 4.1. Briefly, the MEng/BEng students were the most confident, liked mathematics and were the most motivated in mathematics, even though the MEng/BEng curriculum and exams were harder. The BSc students' confidence, liking and motivation were higher than those of the HND/FdSc students. The BSc students reported the greatest mean *Liking of mathematics* and mean increase in *Confidence in mathematics* (based on responses to the question *'Has this module helped you to feel more confident than previously?*).

Confidence in Life was often found to follow an opposite pattern to *Confidence in Mathematics*, high *Confidence in Mathematics* was often found in students with lower *Confidence in Life* and vice versa. The HND/FdSc students reported the lowest *Confidence in Mathematics* (3.2) and lowest *Confidence in Statistics* (2.9), but the highest *Confidence in Life* (4.0) which further highlights the potential for improvement in their confidence in their ability to do mathematics and statistics. The HND/FdSc students were generally the least mathematically qualified, thus these findings were consistent with findings shown later regarding GCSE mathematics grades (i.e. that lower achievement at university is associated with lower past achievement in mathematics, in this case GCSE Mathematics grades, and with lower *Overall Confidence in Mathematics*).

Overall students' *Confidence in Life* was greater than for *Overall Confidence in Mathematics*, which was greater than their *Confidence in Statistics* (i.e. their ability to do statistics). Almost all mean ratings were over 3 (the middle value), except the *Overall Confidence in Statistics* and *Liking of Statistics* ratings which were lower, almost all below 3. See Figure 4.1 below. See Appendices I and IV for wording of the questions shown on the horizontal axis, and *Topic Confidences* on Figure 4.4 and 4.5.

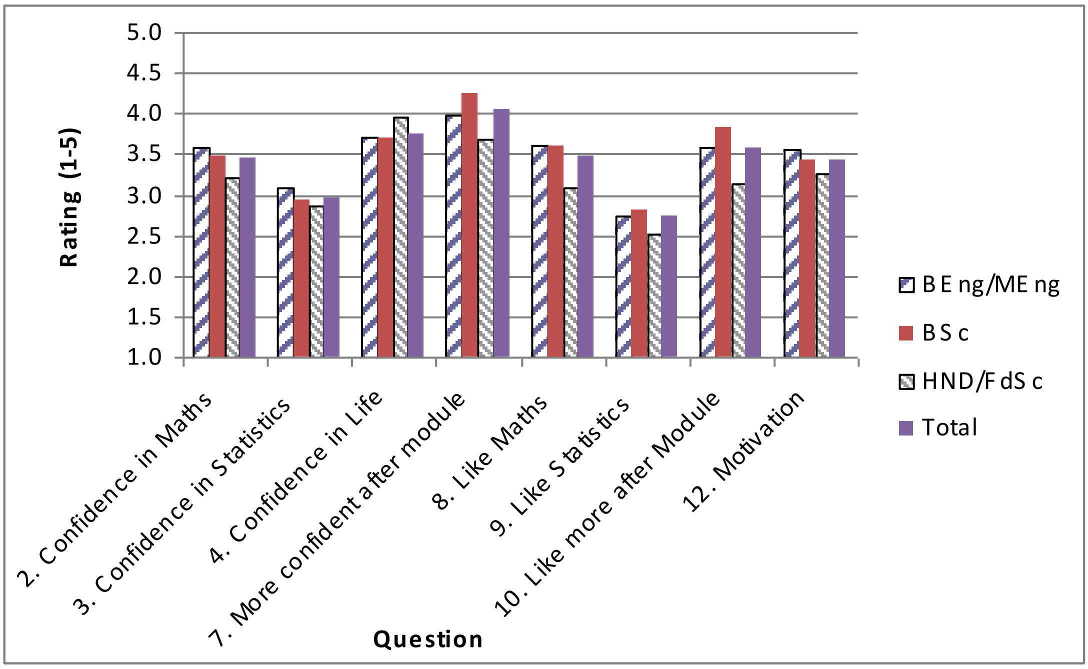

Figure 4.1 2005, 2006 and 2007 Confidences, Liking and Motivation Mean Ratings for First Year Engineering Students by Award Group

Student achievement for the MEng/BEng and BSc students surveyed was good with high mean examination marks, whereas HND/FdSc students achieved lower results, as shown in Table 4.3 earlier and Figure 4.2 below.

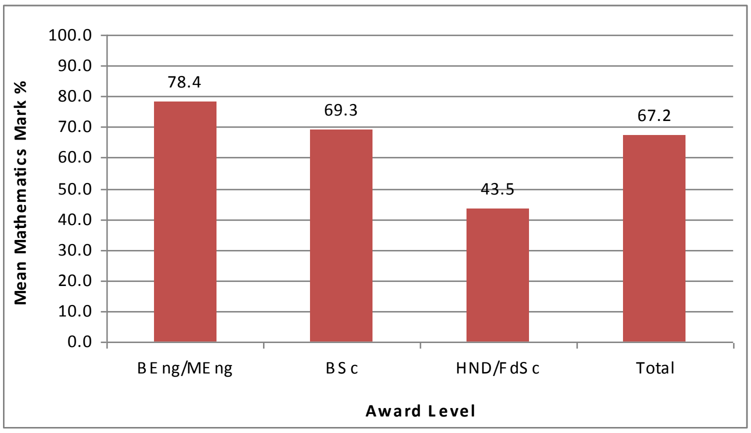

Figure 4.2 Surveyed First Year Engineering Students' Mean Mathematics Mark 2005-7 by Award Level

The results for the eleven *Topic Confidences* were varied, as expected, and unsurprisingly harder topics were given lower confidences than easier topics, as was also found in Armstrong and Croft (1999). These *Topic Confidences* were often slightly higher than the students' *Overall Confidence in Mathematics,* as one might hope for as the students had recently been taught and practised these topics. This helps to confirm the difference between the three Self-confidence Domains in mathematics.

Student open responses regarding *Applications Confidence* fell into two categories: less confident which some explained that they would have forgotten the mathematics by the time they would need it in the future, whilst others would be more confident because they would have learned and practised the mathematics more. The 11 *Applications Confidence* question responses in 2005 were averaged and then combined with the single *Applications Confidence* rating responses from 2006 and 2007. A histogram of the *Applications Confidence* values is shown in Figure 4.3 below. More first year engineering students were positive about their future capability in mathematics than were negative. It can also be seen that the distribution for these values was not bi-modal, which would have resulted in a mean value which would have been misleading, however this was not the case.

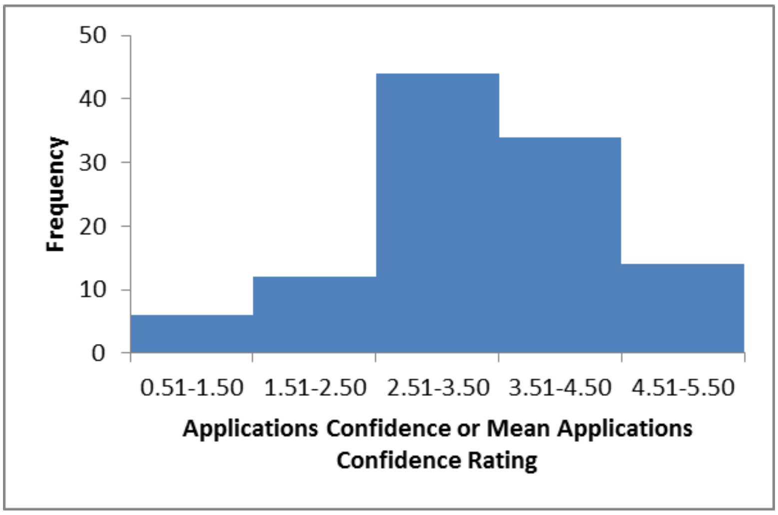

Figure 4.3 Applications Confidences for First Year Engineering Students 2005-7

The mean values for the three confidence domains are shown in Figure 4.4 for BSc and FdSc students and Figure 4.5 for the BEng and MEng first year engineering students. As can be seen the BEng/MEng confidences were generally higher than the BSc/FdSc confidences, as would be expected. Also the mean *Topic Confidence* (solid bar) was higher than the *Overall Confidence in Mathematics* (dotted bar), which was higher than the *Applications Confidence* (striped bar) for both students types. These findings relate to Research Question Ia, defining and measuring students' self-confidence.

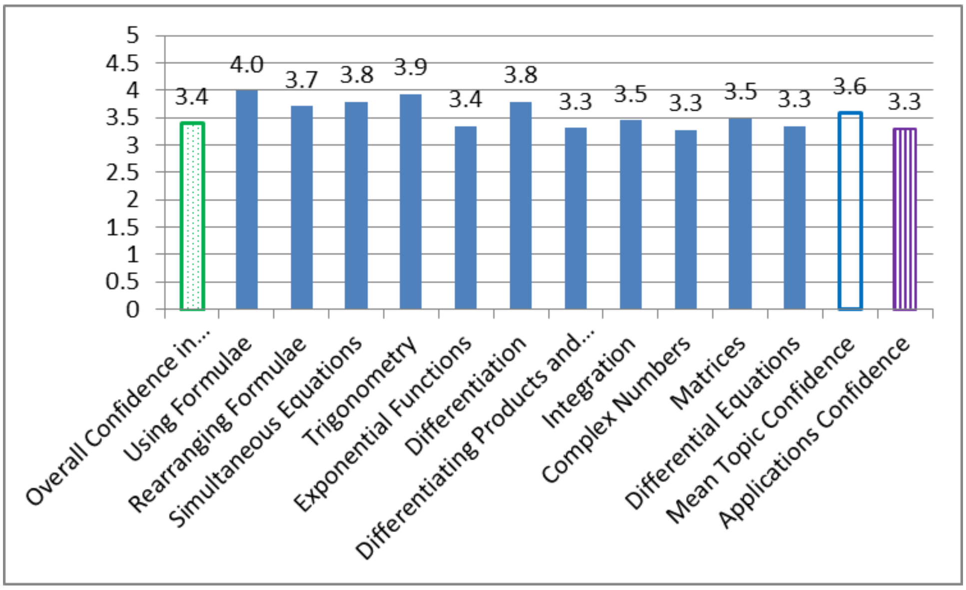

Figure 4.4 Mean Mathematics Self-confidence Domains for First Year BSc and FdSc Engineering Students 2005-7

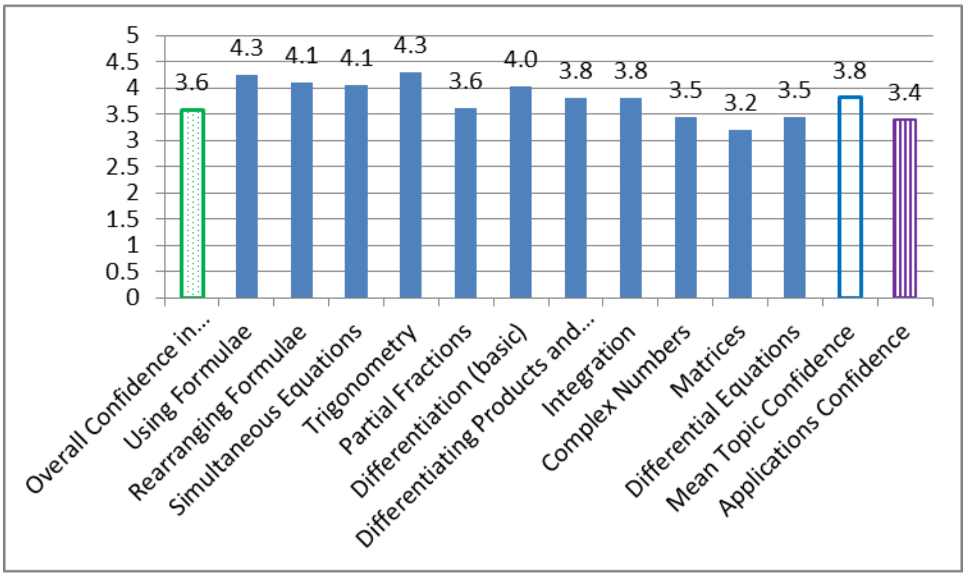

Figure 4.5 Mean Mathematics Self-confidence Domains for First Year BEng and MEng Engineering Students 2005-7

This section has presented the results of the closed questions for the first year engineering students. The next section will now present the results of the open questions for these same student groups, expanding on the closed question responses.

4.2.2 Results of First Year Engineering Students' Open Questions

Open questions on the first year engineering students' questionnaires revealed varied responses which were overall more positive than negative, and were generally consistent with the closed question responses presented in the previous sub-section. The question wording is given with the results (and in Appendix I and briefly in Table 4.2). Responses are presented for the following areas:

- How long students had held their opinion of their self-confidence in mathematics (Q. 14)
- How their past experiences of mathematics had affected their confidence or liking of mathematics (Q. 15)
- Students' attitudes to learning mathematics (Q. 20)
- Aspects of the module which had *helped* their learning of mathematics (Q. 47)
- Aspects of the module which had *hindered* their learning of mathematics (Q. 48)
- Suggestions for what would improve their confidence, attitudes or ability (Q.58)
- Any other comments (Q. 59).

Student responses to the question

> '***For how long have you held this opinion of your self-confidence in mathematics?'***

are shown in Table 4.4 below in order of frequency and with a quoted example of each type. As can be seen, the most frequent types of responses were for a long period of time, either 'at secondary school' or 'always' type responses, which together accounted for over 50% of all the responses (50.9%). However, the next most frequent type of response which was a sizeable proportion of the responses was that their confidence had changed recently or since being at Harper Adams. As was shown in Table 4.3 (the summary of first year engineering students' closed question responses) the average change in confidence during their first year at Harper Adams was an increase in confidence (mean change 4.0 out of 5, i.e. an increase, where 3 indicated same confidence).

Whilst it was good that the average change in self-confidence was an increase during their first year, it was also true that approximately 60% of the students stated that their level of confidence was established before coming to Harper Adams, and a third (35%) consider this was from a long time ago, either '*Always'* or *'Since Primary school'.* These findings are consistent with the premise that '*Overall Self-confidence',* called ‘*math self-concept’* by Pajares and Miller (1994) is a stable construct (or attribute) which is slow and difficult to change. Research Question 1d asked ‘How is students’ self-confidence formed’ and part of the answer to this question is that their overall confidence in mathematics is formed slowly and is hard to change, unlike the *‘Topic Confidences’*, which is in agreement with Kent and Noss (2003).

Table 4.4 Summary of First Year Engineering Student Responses to 'For how long have you held this opinion of your self-confidence in mathematics?'

Type of Response	Frequency	%	Example Response
Secondary School	28	25.9	*Since secondary school*
Always/ Forever	27	25.0	*All the time*
Recently/ at Harper	22	20.4	*Since starting at Harper*
?/ Blank	15	13.9	
Primary school	8	7.4	*Since primary school*
A Level/ Last year	8	7.4	*Since the end of AS level*
Total	**108**	**100.0**	

Student responses to the question

> ***‘How do you think that your experiences of mathematics before coming to university have affected your confidence or liking of the subject?’***

are shown in Table 4.5 below. Some student responses were counted in more than one category if there were multiple parts to the response.

It can be seen that often there were contrasting experiences; an equal number of students reported experiences of positive teachers (6) as reported experiences of negative teachers (6). The number of students who categorised their past experiences overall as Good (22) was almost equal to the number who described their past experiences overall as ‘Bad’ (20). *‘A lot’* and ‘*Not much’* types of responses were also equally matched (8 responses each). One aspect for which the positive and negative responses were not equally matched was the students’ experiences with A level mathematics. In this survey there were more than twice as many students with negative experiences with A level mathematics as those with positive experiences of A level mathematics.

The first year students' experiences before university have been further summarised as: 33 (28.4%) positive, 44 (37.9%) neutral and 39 (33.6%) negative. The frequencies for these three types were not greatly different and the highest category was the neutral type of responses (such as 'not a lot' or 'a great deal'), but unfortunately the negative responses did outnumber the positive responses (39 to 33). This is a contrasting finding to that at Harper Adams for which there were more positives than negatives.

Table 4.5 Summary of First Year Engineering Student Responses regarding How Experiences of Mathematics before University affected Confidence or Liking of Mathematics

Response Type	Frequency	%	Example Response
Blank / ?	28	24.1	
Good Experiences	22	19.0	*I have studied a lot of math throughout my education and I have enjoyed it which has built my confidence up a lot*
Bad experiences	20	17.2	*Bad experiences have put me off*
A level - negative experience	9	7.8	*Struggled at AS, hence dropped it and didn't do A2, but that was because it was too hard and too much at once.*
A lot	8	6.9	*Massively*
Not much	8	6.9	*Not affected*
Good teacher	6	5.2	*Liked it already, had a good teacher at GCSE and A2*
Bad teacher	6	5.2	*Some of the teachers at school made subject areas more difficult than needs be.*
			Didn't like previous teacher put me off maths
A level - positive experience	4	3.4	*A2 level prepared me well for this module*
			A-level teacher gave me confidence
No A level	2	1.7	*Didn't do A level maths so not prepared for some of the new topics*
Lack of Maths at College	2	1.7	*College - lack of maths. I forgot a lot from school. I have had to do extra work to keep up.*
Confident before	1	0.9	*Confidence carried through from high school*
Total	**116**	**100.0**	

Student responses to the question

'How would you describe your attitude to learning mathematics?'

are summarised in Table 4.6 below. Student attitudes have been further categorised as Positive, Fairly Positive, Necessary, Neutral, Negative and Blank. There was a predominance of positive responses to this question. The two most frequent response types (other than blank) were: 'Positive'/'Good' (23.7% of responses, i.e. those which included the words '*positive*' or '*good*') and Maths is 'Necessary' (18.4% of responses). This perception that Mathematics is necessary was similar to a finding in schools in a study by the QCA on A level mathematics students: pupils with lower grades at GCSE mathematics were more likely to have selected A level mathematics because they needed mathematics rather than for enjoyment of the subject (QCA, 2006a). The QCA study also found that boys stressed factors around usefulness of mathematics more than girls (QCA, 2006a).

Table 4.6 Summary of First Year Engineering Student Responses to 'What is your Attitude towards Learning Mathematics'

Response Type	Frequency	%	Example Response	Category
Positive / Good	27	23.7	*Good as I wanted to learn and pass it*	Positive
Blank	22	19.3		Blank
Necessary / Have to do it	21	18.4	*It has to be done*	Necessary
OK alright	13	11.4	*Alright*	Fairly Pos.
Keen / eager	8	7.0	*Always eager to learn*	Positive
Interested	6	5.3	*A fair interest in the area makes the topics easier to learn.*	Positive
Enjoy Maths	5	4.4	*Love it*	Positive
Do not like	3	2.6	*I will do it but don't like some parts or understand*	Negative
Poor	3	2.6	*Poor*	Negative
Better / Improved	2	1.8	*Better than before*	Positive
Find Hard	1	0.9	*I try but do find it hard*	Negative
Easy	1	0.9	*Relaxed get on with problems easily*	Positive
Depends if can do it	1	0.9	*Depends if I can do it or not.*	Neutral
Hesitant	1	0.9	*Hesitant*	Negative
Total	**114**	**100.0**		

A further summary of these responses has been shown in Table 4.7 below and the types of responses which went into each category are also listed. Overwhelmingly there were a majority of positive and fairly positive responses, total of 72.8% (which is an agglomeration of the positive, fairly positive and necessary responses), and it can be seen that only 7% of these students' attitudes were negative. This finding of mainly positive attitudes of first year engineering students will be shown to be in contrast to the findings for other types of students in the College, in Chapter 5.

Table 4.7 Categorised Summary of First Year Engineering Student Responses regarding their Attitude towards Learning Mathematics

Categories	Frequency	%	Type
Positive	49	43.0	Positive/Good, Keen/eager, Interested, Enjoy maths, Better/improved, Easy
Fairly Positive	13	11.4	OK alright
Necessary	21	18.4	Necessity / Have to do it
Neutral	1	0.9	Depends if I can do it
Negative	8	7.0	Don't like, Poor, Hesitant
Blank	22	19.3	-
Total	**114**	**100.0**	

These results contribute towards answering Research Question IIa about students' attitudes and views.

Student responses to the question

'Which aspects of the module particularly helped your learning?'

are summarised in Table 4.8 below. One third of the students surveyed chose not to write anything at all in response to this question which was a bit disappointing. It may have been that students were weary of responding by the time they reached this question which was number 47 of 59 in 2005 and number 38 out of 51 in 2006. In order to encourage more student responses this question was moved forwards in 2007 to question 12 out of 54. This improved the response rate for this question, from less than 60% in the two previous years, up to 75%.

Table 4.8 Summary of First Year Engineering Student Responses to 'Which aspects of the module particularly helped your learning?'

Response Type	Frequency	%	Example Response
Blank	40	33.1	
Good lecturer	17	14.0	*Excellent lecturer with good notes*
Extra Maths	12	9.9	*Extra Maths*
Hand-outs	11	9.1	*Clear hand-outs at the beginning of every lecture*
Topic	11	9.1	*Differential Equations cos it has boosted my confidence* *[6 of the 11 responses stating specific topics were about the helpfulness of practising rearranging equations]*
All / everything	6	5.0	*All*
Doing work / practice	6	5.0	*Doing the work*
Application to other modules/practical situations	6	5.0	*Anything that can be applied to other modules*
More challenging maths	3	2.5	*complex numbers and more challenging maths*
Past papers	2	1.7	*past papers for revision*
Small classes	2	1.7	*Small group sizes*
Self-learning	2	1.7	*Self learning*
A level Revision	1	0.8	*Cover A2 level work for a 2nd time*
Visual Displays	1	0.8	*Visual displays*
Stats-Mathcad	1	0.8	*Stats-mathcad*
Total	**121**	**100.0**	

Overall it can be seen that the list of features which helped students learning are the types of things that one would expect. It is positive to see that the lecturers were deemed helpful, as was the maths support. Students appreciated the lecture handouts, and also that they themselves needed to do work. A feature helpful to learning mathematics which has not been included by these first year students was 'working with friends' which the researcher found from other areas of investigation to be a feature which helped students to learn.

Approaches which appear to help improve student motivation are: to emphasise the necessity and relevance of the module, and practical applications. A similar finding was reported for Perth, Australia engineering students (Frid *et al*., 1997).

Student responses to the question

'Which aspects of the module particularly hindered your learning?'

are summarised below in Table 4.9. Overwhelmingly the most frequent response (49.5%) was to leave the answer blank, but one fifth (19.8%) of students expressly wrote *'nothing'* or *'none',* together both these types of response clearly demonstrate that for the majority of first year engineering students surveyed (69.3%) they considered that their first year mathematics module had not been a hindrance to their learning. However, two particular hindrances were evident which were that: for some students the speed of delivery was too fast and was an issue (7.2% of responses); and that some students felt hindered by not knowing enough mathematics when they arrived (3%) as well as a few other responses; fortunately these students were in the minority. The full range of responses can be seen in Table 4.9 below.

Table 4.9 Summary of First Year Engineering Student Responses to 'Which aspects of the module particularly hindered your learning?'

Response Type	Freq.	%	Example Response
Blank	55	49.5	
None	22	19.8	*Nothing*
Too fast	8	7.2	*Going too fast through some sections of the module*
Topic	8	7.2	*Complex no. (x3), various others*
Lack of previous Experience / maths	3	2.7	*Lack of previous maths experience. Long time since in a maths lesson*
Room / Time of day	2	1.8	*Early Tuesday morning learning*
Alcohol	2	1.8	*Nights out - social*
Poor teaching	2	1.8	*Too much waffling on*
Repeating what students already knew	2	1.8	*Basic equations, just repeating what I already know*
Other	7@1	7@0.9	Various: *Lack of motivation, repetition, mathcad, missing a lecture, solution not on VLE, jump in question level, >2 people*
Total	**111**	**100.0**	

Student responses to the question

> ***'Can you suggest anything that would improve your confidence, attitudes or ability in mathematics?'***

are summarised below in Table 4.10. Overwhelmingly the most frequent response (67.3%) was to leave the answer blank, and whilst there are a relatively small number of suggestions made by students, many of those in Table 4.10 below are sensible. In general these suggestions are consistent with what helped students to learn or are the opposite of what had hindered them, e.g. the suggestion to *'Going through topics slowly'* or that the student *'should do more'*.

Table 4.10 Summary of First Year Engineering Student Responses to 'Can you suggest anything that would improve your confidence, attitudes or ability in mathematics?'

Response Type	Frequency	%	Example Response
Blank	76	67.3	
Nothing	10	8.8	*No, sorry*
Clearer explanations	4	3.5	*Clearer explanations and more worked examples when teaching. Also having more easy examples would help*
Practical Applications	3	2.7	*A clear idea of what it would be used for in real life*
More 1-1 help	2	2.7	*More one to one tuition*
Student do more work/practice	2	1.8	*I should do more*
Make it easier / easier questions	2	1.8	*Easier questions*
Lecturer slow down	2	1.8	*Going through topics slowly / more clearly*
Better memory / brain	2	1.8	*A better brain!*
More lectures	1	0.9	*More lessons, 1 per week not enough*
Other	8	7.1	
Total	**111**	**100.0**	

The answer to Research Question IIc about the characteristics of teaching is contributed to by these results for what has helped or hindered these students' learning, and what would improve their confidences, attitudes or ability in mathematics, as was given in Tables 4.8, 4.9 and 4.10.

Student responses to the open question

'Any other comments'

are summarised below in Table 4.11. Overwhelmingly the most frequent response (91.0%) was blank, but three students wrote the equivalent of 'Thank you'. It is not totally clear whether the students are grateful for the opportunity to air their views in the questionnaire or whether they are expressing gratitude for the teaching and support during their first year; either way, it was positive to read these expressions of thanks. The other five specific responses, whilst these are infrequent, they could be grouped together with the students' suggestions for improvement and are again sensible comments.

Table 4.11 Summary of First Year Engineering Student Responses to 'Any Other Comments?'

Response Type	Frequency	%	Example Response
Blank	101	91.0	
Thank you	3	2.7	*Thanx for everything*
No	2	1.8	*No*
More help	1	0.9	*More help for people with no maths experience at all*
Exam papers	1	0.9	*Make exam papers and answers easily available for revision*
Give work to do outside lectures	1	0.9	
Feels more confident	1	0.9	
Improve teaching	1	0.9	
Total	**111**	**100.0**	

The first year engineering students' responses to various open questions have been described in the above sub-section, and the main findings are now briefly summarised. The students' attitudes towards studying mathematics were often positive, 43.0% of responses (e.g. 'hard working and positive'), 11.4% of responses were fairly positive (e.g. 'OK'), and in 18.4% of responses students understood that mathematics was necessary for engineering, which added together was 72.8% of first year engineering students expressed favourable attitudes towards learning mathematics, and only 7.0% of student attitudes were negative (see Table 4.7).

Students' experiences before university were very mixed and were sometimes contrasting and some students, 9 (8%) of first years described past problems specifically arising during A level mathematics. Unfortunately overall there were more negative reports of past experiences with mathematics than there were positive, but fortunately the students were generally more positive about learning mathematics at Harper Adams.

Two thirds of students reported that their self-confidence in mathematics was established before age 16, and some a very long time ago (25%) and 20% of responses described their level of confidence being established since coming to Harper Adams. This is somewhat inconsistent with closed question responses which showed that on average students had gained confidence at university (the mean score on the question asking whether they were more confident after the module was 4.0 out of 5, where 3 = no change and 5 = maximum increase in confidence).

The students' responses to what had *helped* their learning included: good teaching, Mathematics Support, and handouts, students doing the work and other sensible observations. The lecturer going too fast was identified as a hindrance for some students' learning.

The open questions drew out responses from students which have helped to expand and clarify the closed question responses. In the following sections further work will be presented which looks predominantly at numerical data again and seeks to find relationships between different types of data, in particular to try to explain students' university mathematics marks and their Overall Confidence in Mathematics.

4.2.3 First Year Engineering Student ANOVA and Kruskal Wallis Tests

Using the combined 2005, 2006 and 2007 first year engineering students' results an inductive approach was taken to analyse the questionnaire responses. A wide range of ANOVA and Kruskal Wallis tests were conducted to see what relationships could be identified from the collected data, the results of which are presented in Table 4.12 below. The results are shown in the form of probabilities (P values), where a significant relationship is represented by a P-value <= 0.05, and shown in bold.

The mathematics module marks and *Overall Confidence in Mathematics* were the two main variables of interest. The student marks had high variability; however this does not appear to have prevented some significant results in Table 4.12. Because the *Overall Confidence in Mathematics* responses were ordinal data (ranks) these were analysed using Kruskal Wallis tests which are non-parametric tests suitable for ordinal data, not requiring normal distribution of values (as was explained in sub-section 3.3).

Table 4.12 First Year Engineering Students 2005-7 Mathematics Marks and Overall Confidence in Mathematics ANOVA and Kruskal Wallis Tests

Factor (with the permitted values)	**Mathematics Module Mark ANOVA P-Value**			**Overall Confidence in Mathematics Kruskal Wallis P-Value**	
Award (MEng, BEng, BSc, HND)	**<0.001**	*******		0.234	
Course (ORVD,AGENG,EDD,AEMM)	0.185			0.570	
Age (in years)	0.731			0.369	
Dyslexic (Y/N/U)	0.151			0.084	
Dyscalculic (Y/N/U)	0.181			-	
GCSE Grade (A*/A/B/C/D/E)	**<0.001**	***		**<0.001**	***
GCSE Tier (H/I/F)	**<0.001**	***		**0.015**	*
Whether students had A level mathematics (1,2,3,4)	**<0.001**	***		**0.005**	**
Whether would choose to study maths (Y/N)	**<0.001**	***		**<0.001**	***
Confidence in mathematics (1-5)	**<0.001**	***		-	
Confidence in statistics (1-5)	**0.045**	*		**<0.001**	***
Confidence in life in general (1-5)	0.211			0.11	
Whether more confident after module (1-5)	-			**<0.001**	***
Liking of mathematics (1-5)	**<0.001**	***		**<0.001**	***
Liking of statistics (1-5)	0.169			**0.002**	**
Whether like subject more after module (1-5)	**0.011**	*		**0.021**	*
Motivation (1-5)	**0.005**	**		**<0.001**	***
Whether motivation same as for other modules (M/S/L)	**0.028**	*		0.185	
Time spent working outside lectures (hrs)	0.616			0.424	
Applications Confidence (1-5)	0.164			0.058	
Used Maths Support Group/Individual/Both/None	0.201			0.177	

P values <=0.05 indicate significant relationships which are also marked with asterisks: * indicates P<=0.05, ** indicates P<=0.01, *** indicates P <= 0.001 significance.

For Mathematics Marks: n=108, α=0.05, two-tailed tests

For *Confidence in Mathematics* Kruskal Wallis tests some factor values had to be combined to remove low frequencies so that the underlying Chi Squared test was valid.

e.g. for *Confidence in Mathematics* by GCSE Grade the following were combined: confidence 1 with 2, confidence 4 with 5, and GCSE grade C with D/E

Initially ANOVA tests were carried out to test for the effects of the factor variables on the *Confidence in Mathematics*. The results of these initial ANOVA tests were very similar to the results of the Kruskal Wallis tests; the only factor variables for which the two tests produced a different outcome for whether significant, were GCSE Tier (for which ANOVA P=0.071 and Kruskal Wallis P=0.015) and *Applications Confidence* (ANOVA P=0.024 and Kruskal Wallis P= 0.058), and it can be seen that these P-value results were still fairly similar. For the other 19 factor variables the ANOVA and Kruskal Wallis tests produced the same outcome (whether significant or not). Histograms of residuals were produced with the ANOVA test output which satisfied a visual check for normality, both for the mathematics marks (for which normality was required) and for the Confidence in Mathematics (for which normality was not required as Kruskal Wallis tests were ultimately used).

Student mathematics marks were found to be very highly significantly (P<0.001) related to award level (M/BEng, BSc, HND/FdSc), GCSE mathematics grade, GCSE mathematics tier, whether students had studied A-level mathematics, whether students would choose to study the mathematics module, *Overall Confidence in Mathematics* and *Liking of Mathematics*. This analysis did not, however, prove cause and effect, but provided supporting evidence for these relationships.

The following factors were also considered, and tested using ANOVA tests, but did not give significant relations with mathematics marks: University Course, Age, Dyslexia, *Confidence in Life*, Time spent working outside of lectures and whether students used Mathematics Support.

The Kruskal Wallis test results showed that students' *Confidence in Mathematics* was significantly related to mainly the same variables as the students' marks, but showed stronger relationships for *Confidence in Mathematics* with students' *Confidence in Statistics* and *Liking of Statistics* (than for the marks).

The results of the ANOVA tests and Kruskal Wallis test were that significant relationships were found to be consistent with sections 4.2.1 and 4.2.2, that higher achievement in mathematics at university was associated with higher past achievement in mathematics and higher *Overall Confidence in Mathematics* at university.

4.2.4 Relationships between First Year Engineering Students Mathematics Module Marks, GCSE Mathematics Grades and Confidence in Mathematics

Students with higher GCSE mathematics grades generally achieved higher marks in the mathematics modules. GCE A-level mathematics details were not present for all students surveyed, because not all the students had studied A level mathematics (e.g. Scottish or Irish students had not, neither had most of the BSc and FdSc students), and therefore could not be used in these analyses. Because only one student reported achieving GCSE mathematics grade A*, grades A and A* were combined. Likewise, due to a single grade E, grades D and E were also combined. Ten students had blank or numeric GCSE mathematics grades (possibly Scottish students) which were excluded, as were those students who had not provided their student id number and could not be linked to their marks.

In Figure 4.6 it can be seen that the mean mark for students with GCSE mathematics grade A or A* was 81%, and that mean university mathematics marks decreased for lower GCSE grades, down to 40% for mathematics grades D or E (fortunately still a pass, just!). The numbers of students are shown in brackets after the mean percentage mark.

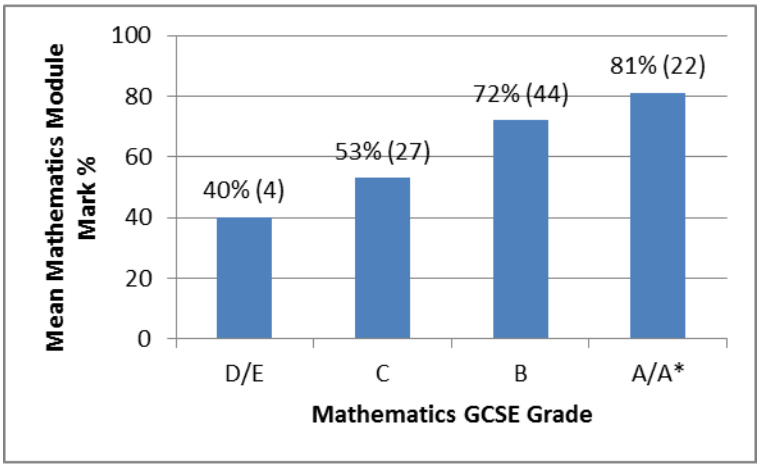

Figure 4.6 2005-7 Mean Mathematics Marks by GCSE Mathematics Grade for First Year Engineering Students

A scatter plot of all first year students' mathematics marks against their coded GCSE mathematics grades is shown in Figure 4.7 below showing the full variation of students' marks by coded GCSE mathematics grade.

The GCSE grades have been coded to convert ordinal data (A, B, C, etc.) into a pseudo-interval scale of integer values (as shown in the key below Figure 4.7). The purpose of this coding was so that a scatter plot could be produced and linear regression could be carried out. It can be seen that the resulting scatter plot based on the integer coding produces a horizontal x axis in Figure 4.7 which closely resembles that of Figure 4.6 (on which no re-coding was necessary). A similar observation can also be made of Figures 4.9 and 4.10 for which a similar coding was carried out. As already explained in Section 3.3 the purpose of this coding was to enable a model to be produced to show the approximate effect sizes (and not for the purpose of obtaining precise coefficient values). This Simple Linear Regression model equation (shown on Figure 4.7) is useful for comparison with the Multiple Regression models produced later in subsection 4.2.5.

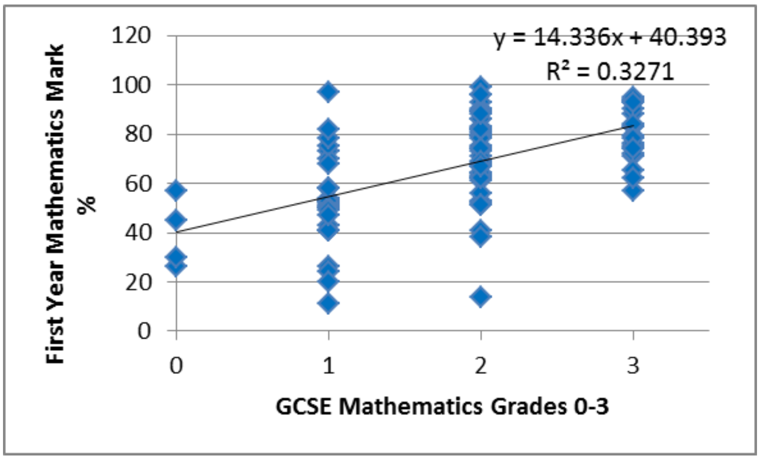

Figure 4.7 All First Year Engineering Students' Mathematics Module Marks against Coded GCSE Mathematics Grades

Key: GCSE Grade A/A*=3, B=2, C=1, D/E =0.

It has already been shown that there was a significant difference between the university marks in mathematics for students with different grades at GCSE Mathematics (by ANOVA test $P<0.001$ in Table 4.12). Figures 4.6 and 4.7 both illustrate that students with higher mathematics GCSE grades generally achieved higher first year mathematics marks.

Students with higher GCSE mathematics grades generally reported higher confidence in their ability to do mathematics. From the Kruskal Wallis test in Table 4.12 it was already known that there was a significant difference between the confidences of students with different GCSE Mathematics grades ($P<0.001$). Figure 4.8 below shows the mean *Overall Confidence in Mathematics* by GCSE mathematics grade (with the number of students shown in brackets). Mean *Confidence in Mathematics* was 3.7 for students with GCSE mathematics grade A/A* and mean confidence decreased as GCSE grade decreased, down to 2.8 for grades D/E. The students rated their confidence at the end of their first year at university and not straight after GCSE, which might have produced a clearer trend.

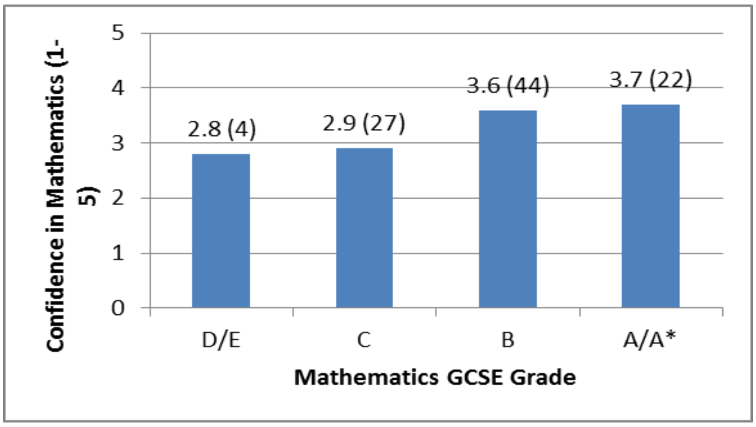

Figure 4.8 2005-7 Mean Confidence in Mathematics by Mathematics GCSE Grade for First Year Engineering Students

Students with higher *Overall Confidence in Mathematics* achieved higher marks in first year engineering mathematics. An ANOVA test had already confirmed there was a significant difference between the marks achieved by students with different *Confidences in Mathematics* (P<0.001 in Table 4.12). Figure 4.9 below shows a mean mark of 43% for students with the lowest *Confidence in Mathematics* (1), and that mean marks increased as *Confidence in Mathematics* increased, up to 80% mean mark for students with the highest *Confidence in Mathematics* (5).

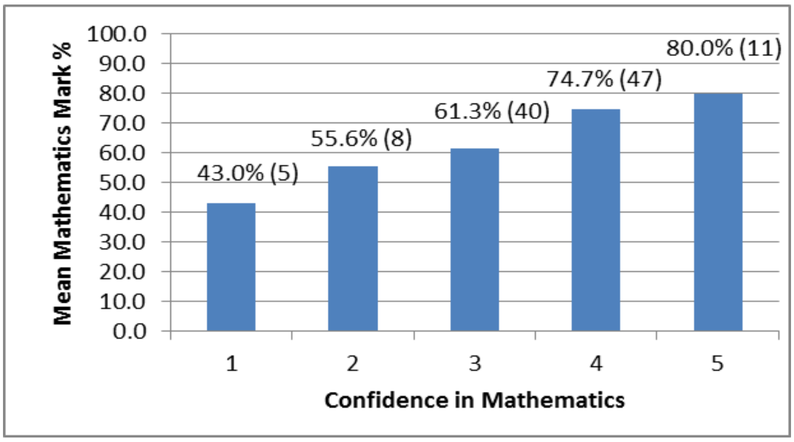

Figure 4.9 2005-7 Mean First Year Engineering Students' University Mathematics Mark by Confidence in Mathematics

Figure 4.10 below is a scatter plot showing the full variability of students' marks against their confidence in mathematics. It is not possible to see how many points have been superimposed on Figure 4.10, so there is not a clear view of how many students are represented by the points shown, which does not show the weighting of the number of values near to the trend line, particularly for Confidences 3 and 4. It can however be clearly seen that there was a minority (three students) who had very low confidence in mathematics, but who obtained very high marks (the data points represented by a square on Figure 4.10).

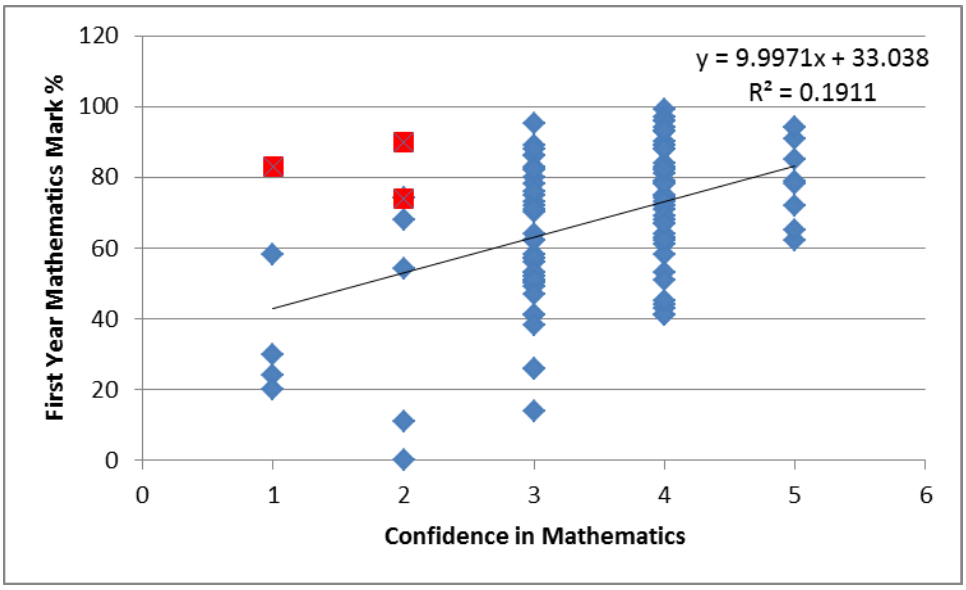

Figure 4.10 All First Year Engineering Students Mathematics Module Marks against Confidence in Mathematics

It has been shown that there are very clear significant links between first year engineering students' achievement in mathematics at university and their *Overall Confidence in Mathematics* and their GCSE mathematics Grade. These links will now be explored using Multiple Regression Analysis to further quantify the effects of past qualifications (GCSE) and confidence on students' achievement in engineering mathematics. Additional similar models are also presented with independent variables of whether the students liked the subject and their motivation, in Section 4.2.5 below.

4.2.5 First Year Engineering Students Correlation and Multiple Regression Analysis

Correlation and regression analysis was carried out to find a model to explain the first year engineering students' university mathematics marks based on their GCSE mathematics grade, *Confidence in Mathematics*, *Liking of Mathematics* and *Motivation* rating. Scatter Plots, with some Simple Linear Regression results, have already been presented in the previous subsection in Figures 4.7 and 4.10. For the purpose of this regression analysis the independent variables were recoded: GCSE Mathematics grades were coded as A/A*=3, B=2, C=1, D/E=0 and the 5 point Likert scale values were reduced by 1 to 0-4 (from 1-5). The use of integer values for GCSE grades have transformed ordinal data into interval data, as required for the Regression analyses, (and likewise was also done with A level Grades and Types in subsection 4.3.3 and 4.4.3 for second year models). Whilst the exact mark ranges for the different grades was not known, the interval data was considered to be an approximate representation of the increase in achievement represented by higher grades and awards.

Table 4.13 below shows that each of these variables was found to be significantly correlated with the mathematics module marks (the dependent variable). The 'independent' variables are listed in order of the correlation coefficient (R), showing that mathematics GCSE grade was the most correlated with the mark and explained the highest percentage variation in the mark, followed by *Confidence in Mathematics*, then *Liking of Mathematics*, then *Motivation*. These results were obtained from correlation and regression analyses for each variable (individually and separately) with the maths module mark. Where two values for R^2 are shown, the first is the value found from regression analysis of the 107 students with a Maths Module Mark (recall that three out of the 111 did not provide an id number and therefore their module mark was not available and one other student had no mark). The second value (shown in brackets) resulted from separate analysis of the 97 students which excluded the ten students without a Mathematics GCSE Grade (due to being Scottish or Irish, etc.). It can be seen that the R Squared values given in the first two rows match the R Squared values shown on Figure 4.7 and Figure 4.10.

Table 4.13 Correlation Coefficients for Correlations with First Year Engineering Students' Mathematics Module Marks

Independent Variable	Pearson Correlation Coefficient (R)	% Variation Explained (R^2)	Significance
Mathematics GCSE Grade	0.572	32.7	.000
Confidence in Mathematics	0.437	19.1 (16.2)	.000
Liking of Mathematics	0.347	12.0 (14.5)	.000
Motivation in Mathematics Module	0.274	7.5 (8.2)	.004

A correlation matrix was also produced to check the correlations between the 'independent' variables, and the result was that these were not independent variables due to significant correlations between them (multicollinearity). Thus it was not possible to produce a model to predict the module mark which contained all the above variables with significant coefficients for each independent variable. The cause of this could be explained by considering that although *Confidence in Mathematics*, *Liking of Mathematics* and *Motivation* were different attributes of students, their responses to these questions were often numerically similar. Consider, for example, a person's income and expenditure which are different things, but will often be numerically similar.

It was, however, possible to produce models to predict the module mark using (as independent variables) the GCSE mathematics grade and only one of the other variables: *Confidence in Mathematics*, *Liking of Mathematics* or *Motivation*. The resulting R and R-Square values are shown in Table 4.14 below, showing broadly similar values for the three models.

Table 4.14 Multiple Regression Model Summaries for First Year Engineering Students' Mathematics Module Marks (n=107)

Independent Variables		**R**	**% Variation Explained (R^2)**	**Adjusted R -Square**
Mathematics GCSE Grade	Confidence in Mathematics	0.609	37.1	0.358
	Liking of Mathematics	0.607	36.8	0.355
	Motivation in Mathematics Module	0.611	37.3	0.360

The model using GCSE mathematics grade and *Confidence in Mathematics* explained 35.8% (Adjusted R^2) of the variation in student marks. The equation to predict the mathematics module mark produced by this model was:

Mark % = 31.9 + 12.3 x GCSE Grade + 5.2 x *Confidence in Mathematics*

This model shows a baseline mark of 31.9% for a student with the lowest GCSE mathematics grade and lowest confidence. Each higher grade achieved at GCSE adds 12.3% to the student's predicted mark, and each higher *Confidence in Mathematics* adds 5.2% to the student's predicted mark.

This model seems very reasonable when compared to the actual mean marks by GCSE grade, where some of the differences between marks for each grade are similar to 12%. See Figures 4.6 and 4.7. Likewise, the actual increases in mark for increased *Confidence in Mathematics* can also be seen to be similar to or larger than the 5.2% predicted by the model above. See Figures 4.9 and 4.10.

The other multiple regression models produced to predict the mathematics module mark (%) were similar to that shown above, but were produced using GCSE mathematics grade with either *Liking of Mathematics* or *Motivation*.

Mark % = 30.5 + 12.6 x GCSE Grade + 5.5 x *Liking of Mathematics*

Mark % = 28.2 + 13.6 x GCSE Grade + 5.7 x *Motivation*

In all three models there is a baseline mark of approximately 30% for the students with low GCSE mathematics grade and low Confidence or Liking or Motivation. Each higher GCSE mathematics grade adds approximately 12-13% to the mark, and each higher confidence, liking or motivation adds approximately 5-6% to the mark. All three models are similar in explaining approximately 36% of the variation in student marks. The Adjusted R-Square values allow the comparison of models with differing numbers of variables and again all three models are approximately equivalent (Adjusted R-Square approximately 0.36). The purpose of creating these models was to attribute approximate or relative portions to the effects of different factors (independent variables), and was not to obtain precise values for the coefficients.

Students' mathematics GCSE grade is fixed. However their confidence, liking and motivation can be changed at university, albeit slowly according to Kent and Noss (2003). These models indicate that whilst past qualifications produced the greatest effect, the effect of these subjective and potentially modifiable attributes was also measurable and worth paying attention to.

A further model was produced for the first year BEng and MEng students with an A2 grade as shown below (where grade A=5, B=4, C=3, D=2, E=1 and F/U=0. Note: This data pre-dated the existence of the A* grade at A level). This model predicts that a first year BEng or MEng student with the highest possible A2 Grade (A) would achieve a 19.5% higher mark than one with the lowest grade. This model is an example of use of a more proximal variable. For example, a shopper's choice of items could be predicted using their previous purchase details (more proximal details) or by a more general characteristic (such as age).

Mark % = 71.8 + 3.893 x A Level Grade Code [Adjusted R^2 = 42.6%, n=19]

Sections 4.2.3 and 4.2.4 have presented results of cross-analysis of different variables, and this section has quantified approximately the effect of first year engineering student self-confidence on their learning of mathematics and statistics. These subsections contribute towards answering Research Question Ib about the effect of students' self-confidence on their learning of mathematics and statistics.

4.2.6 First Year Engineering Students' 2006 11 Scale Questions

4.2.6.1 First Year Engineering Students' 2006 11 Scale Questions relationships

In 2006 the 11 Scale questions (based on Fogarty *et al.*, 2001) were included in the first year engineering student questionnaires. The responses to these Scale questions were compared to the students' mathematics mark using ANOVA tests and their single *Overall Confidence in Mathematics* rating using Kruskal Wallis tests. The results are shown in Table 4.15 below. As can be seen the mathematics marks were only significantly related to just three of the Scale questions. However, it can be seen that there was a significant relationship between all except three of the Scale questions and the single *Overall Confidence in Mathematics* rating.

Thus, as there were more significant relations between the responses to the Scale questions and *Overall Confidence in Mathematics* than between the Scale questions and mathematics module marks, the Scale questions and the single confidence ratings pertained to more similar underlying characteristics than was represented by the mathematics module mark. More detailed work, however, comparing the single-item rating for Overall Confidence in Mathematics with the 11 Scale questions, a multi-item scale (adapted from Fogarty *et al.*, 2001), is given in the following section 4.2.6.2.

Table 4.15 First Year Engineers 2006 Scale Question ANOVA and Kruskal Wallis Tests

Mathematics Scale Questions (Questions 40-50)	Mean Value **	Mathematics Module Mark ANOVA P-Value	Overall Confidence in Mathematics Kruskal Wallis P-Value	Correlation w. Confidence in Mathematics R and P-Value	
Q40. I have less trouble learning maths than other subjects	3.420	0.154	**0.011**	**.412**	**.005**
Q41. When I meet a new maths problem I know I can handle it	3.300	0.114	**<0.001**	**.579**	**.000**
Q42. I do not have a mathematical mind	(3.380)	0.098	0.054	**.412**	**.005**
Q43. It takes me longer to understand mathematics than the average person	(3.380)	**0.001**	**<0.001**	**.471**	**.001**
Q44. I have never felt myself able to learn mathematics	(3.940)	**<0.001**	**<0.001**	**.580**	**.000**
Q45. I enjoy trying to solve new mathematics problems	3.400	0.365	0.769	.161	.164
Q46. I find mathematics frightening	(3.840)	0.183	**0.001**	.231	.078
Q47. I find many mathematics problems interesting and challenging	3.480	0.699	0.582	.188	.126
Q48. I don’t understand how some people seem to enjoy mathematics problems	(3.320)	0.549	**0.011**	**.414**	**.004**
Q49. I have never been very excited about maths	(2.980)	0.542	**0.009**	**.460**	**.002**
Q50. I find maths confusing	(3.400)	**0.01**	**<0.001**	**.587**	**.000**

Notes for Table 4.15: ** The mean values shown relate to the Scale questions with positive phrasing, i.e. the values shown in brackets were reversed for the negatively worded questions. The mean value for *Confidence in Mathematics* was 3.620. Sample size = 50 for the mean calculations.
In order for the Kruskal Wallis tests to run the following ratings had to be combined: Q40 1&2, Q41 1&2 4&5, Q42 4&5, Q43 -, Q44 3&4 (no 5’s), Q45 1&2, Q46 4&5, Q47 1&2, 4&5 Q48 4&5, Q49 1&2, Q50 4&5.

4.2.6.2 Investigation of Single-Item and Multiple-Item Scales

The current debate regarding use of single-item scales and multi-item scales has already been explained in Section 3.3. Using the first year engineering student results an investigation was carried out into the differences between the single-item

(*Confidence in Mathematics*) and the 11 Scale question responses. As this author was particularly interested in Self-confidence, one aim of this investigation was to determine whether the multi-item Scale questions (based on Fogarty *et al.*, 2001) were all measuring self-confidence and how consistent the responses to the 11 different Scale questions were. The Scale questions (as shown in Table 4.15) can readily be classified as to whether these refer to self-confidence, attitudes, emotions or amount of time taken. Five questions were considered to relate specifically to self-confidence, these are shown below with a ranking based on the results from Table 4.15.

Q50	I find maths confusing	1st
Q44	I have never felt myself able to learn mathematics	2nd
Q41	When I meet a new maths problem I know I can handle it	3rd
Q40	I have less trouble learning maths than other subjects	4th
Q42	I do not have a mathematical mind	5th

Five other questions were deemed to pertain to different attitude and emotion constructs (and not confidences), because these contained words such as *interest, enjoyment, excited* and *frightening* (Q45, Q46, Q47, Q48, Q49). A final question (Q43) was viewed to relate to speed of working (Q43. It takes me longer …) and whilst this was significantly related to, and correlated with, *Confidence in Mathematics* it was about *time* rather than confidence.

Several means were calculated for each student respondent: mean of the 11 Scale questions (overall mean = 3.444), mean of the five Scale confidence questions (Q40, Q41, Q42, Q44, Q50) and mean of the five Scale attitude and emotion questions (Q45, Q46, Q47, Q48, Q49), and also a mean of the two single-items for *Confidence in Mathematics* and *Liking of Mathematics*. Values of these new data sets are shown on Figure 4.11 below together with *Confidence in Mathematics* (where the y axis value is a dummy variable used solely to position the values).

It can be seen on Figure 4.11 that the 11 Scale question means were different values compared to the *Confidence in Mathematics* values. Whilst the multi-item values do appear to resemble continuous data (diamonds and crosses) these have a smaller range compared to the single-item (squares). The mean *Confidence in Mathematics* was 3.620, whereas the mean of the 11 Scale question means (for all respondents) was 3.444, slightly lower. One possible explanation for this could be the effect of mixing confidences, attitudes and emotions in the 11 Scale questions. A histogram of frequencies for *Confidence in Mathematics* and the 11 Scale question means is shown in Figure 4.12 below, further illustrating the difference between these data sets.

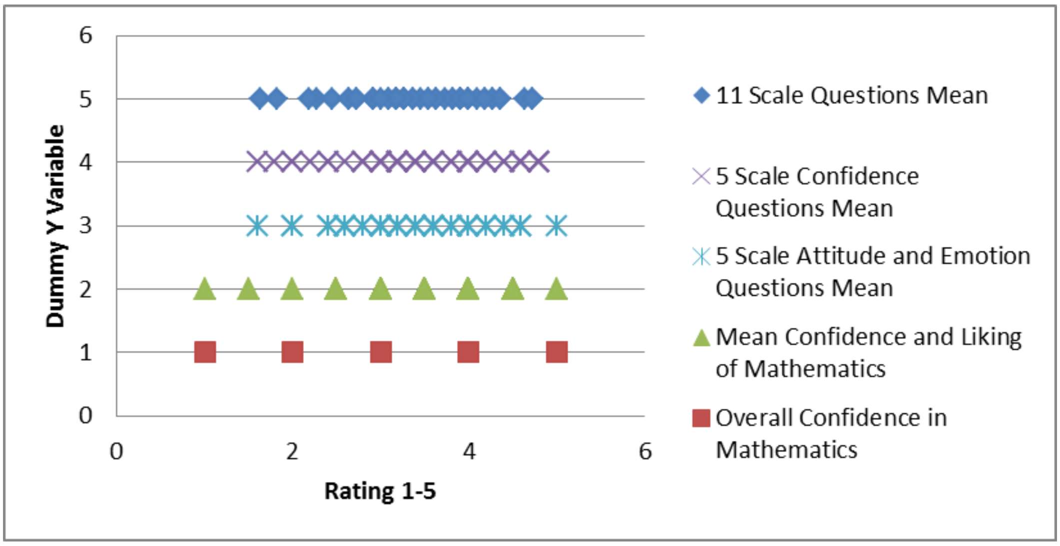

Figure 4.11 Comparisons of Single-Item and Multi-Item Values for 2006 First Year Engineering Students

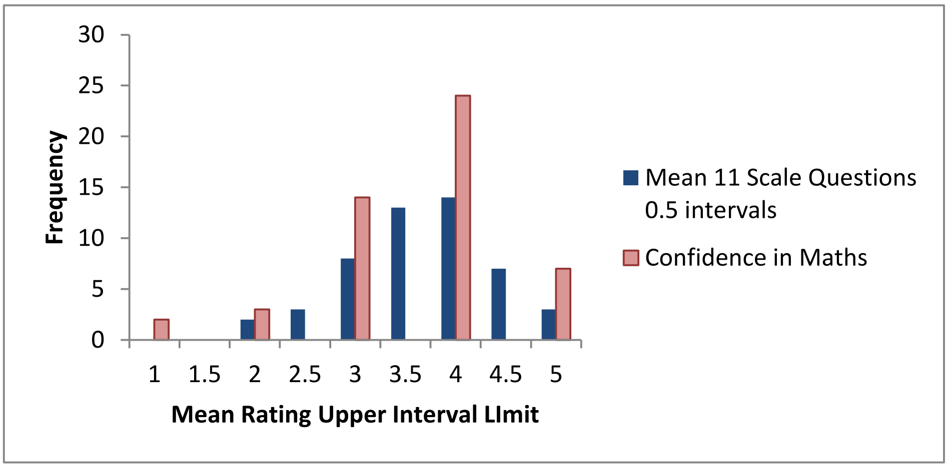

Figure 4.12 Histogram of Single-Item and Multi-Item Values for 2006 First Year Engineering Students

In Figure 4.13 below the multi-item 11 Scale question means were plotted against the *Confidence in Mathematics* values (R^2 = 46%), and then in Figure 4.14 the multi-item values were plotted instead against combined (mean) *Confidence in Mathematics* and *Liking of Mathematics* values (R^2 = 59%). If there was a perfect fit the Regression line would have R^2 = 1.0, slope=1 and zero intercept. It can be seen that a better fit was produced for the combined *Confidence in Mathematics* and *Liking of Mathematics* values, than for the single-item *Confidence in Mathematics*.

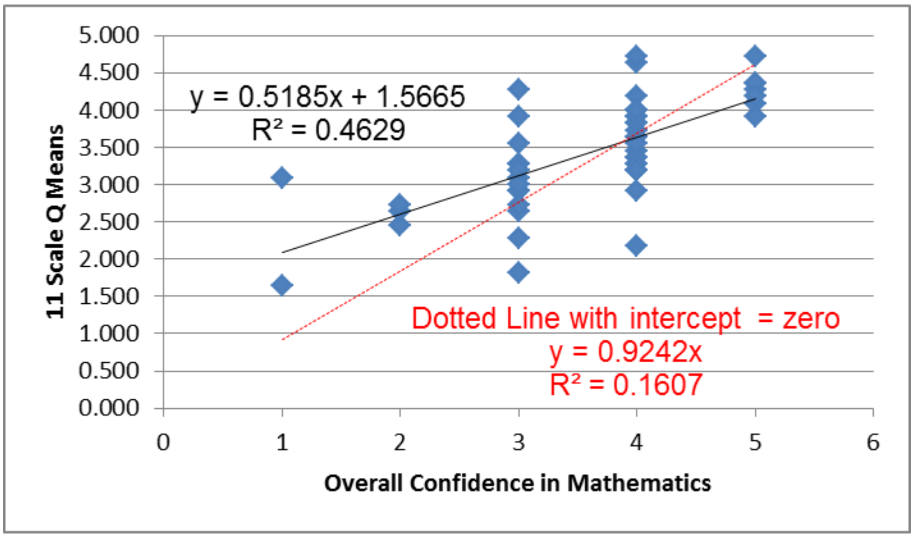

Figure 4.13 Multi-Item Values Plotted against Single-Item Confidence in Mathematics for 2006 First Year Engineering Students

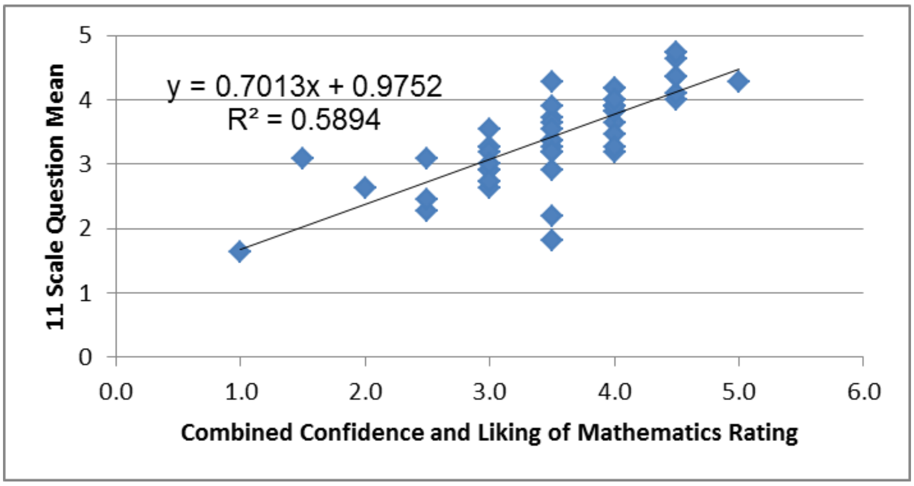

Figure 4.14 Multi-Item Values against Combined Confidence in Mathematics and Liking of Mathematics for 2006 First Year Engineering Students

Three Wilcoxon Matched-Pairs tests (two-sided test) were carried out which produced the following results.

- *Confidence in Mathematics* was found to be significantly different from the multi-item 'Mean of the 11 Scale Questions' (t=346.5, n=46, P=0.028). This indicated that the multi-Item scale, based on 11 Scale question means, was not representing the same latent variable as was represented by the single-item.

- No significant difference was found between the mean value for *Confidence in Mathematics* and *Liking of Mathematics* and the multi-item 11 Scale question means (t=457.0, n=47, P=0.236). This indicates that the 11 Scale items were measuring characteristics which resembled the combined *Confidence in Mathematics* and *Liking of Mathematics.* The 11 items thus represented a combination of confidences and attitudes, which is consistent with the discussion at the start of this subsection based on the question text.

- A very highly significant difference was found between the responses to two of the Scale Questions: 'Q44 I have never felt myself able to learn mathematics', which is a confidence question, and 'Q49 I have never been very excited about mathematics' which is a question about an emotion (t=57.0, n=37, P<0.001).

To summarise, the following conclusions were drawn from these comparisons of the single-items and multi-item data:

- The data sets have some differences. The single-item *Confidence in Mathematics* was ordinal data (but treated as interval data in some analyses) and had a larger range, whilst the multi-item appeared more continuous, but had a smaller range. Whilst more values appeared in the multi-item data-set, this author would contend that the averaging process, which created the multi-item data, did not really convert the multi-item data into true interval data any more than the single-item.
- The multi-item (mean of 11 Scale questions) values were found to be significantly different from the single-item *Confidence in Mathematics.* (P=0.028).
- The multi-item scale was more closely correlated to the combined *Confidence in Mathematics* and *Liking of Mathematics* values.
- The multi-item scale was multi-dimensional (containing cognitive, attitude and emotion components) and contained items which were significantly different from each other (Q44 and Q49, P<0.001).
- An advantage of the single-item was that it unambiguously measures only *Confidence in Mathematics* thus the single–item can be considered valid and parsimonious.

As a result, it was concluded that use of the single-item, *Confidence in Mathematics,* for the regression models in Section 4.2.5 had the advantage that, one could, at least, be certain that it was confidence in mathematics that was being measured and analysed, and not a mixture of constructs as was found in the multi-item data from the surveys. It should also be noted that Regression analysis does not require the independent variable to be continuous, only the dependent variable.

4.2.7 First Year Engineering Students Factor and Cluster Analysis

4.2.7.1 First Year Engineering Students Factor Analysis

Principal Component Analysis (PCA), a type of Factor Analysis, was conducted on the first year engineering student data using 13 variables, which produced four components explaining 62.3% of the variance. The intention of this analysis was both to reduce the 13 variables into a smaller set of underlying characteristics (latent variables or factors) and to understand the variables better and not for the purpose of producing a questionnaire (Field, 2009, p.628). Table 4.16 below contains the Rotated Component Matrix produced by Varimax rotation (orthogonal rotation), for which rotations converged after 6 iterations. Correlations of at least 0.4 and those less than -0.4 have been highlighted.

Consideration of the components of the factors has led to these being named as follows:

1. **High Achievement in Mathematics –** this factor has grouped together: having A level mathematics, a high GCSE Grade, being on a course requiring higher qualifications e.g. MEng or BEng course, getting a high mathematics module mark and not being dyslexic (whilst associated here with higher achievement, not being dyslexic is clearly a different characteristic).
2. **Confident in Statistics and Mathematics** – this factor has grouped *Confidence in Statistics*, *Liking of Statistics* and *Confidence in Mathematics*.
3. **Motivated and Like Mathematics** – this factor has grouped together high motivation, with *Liking of Mathematics*, choosing to study mathematics and older students. It is interesting that older students were associated with higher motivation, perhaps because some have left paid employment in order to study.
4. **Time spent outside of lectures –** this factor is almost solely comprised of the time spent working outside of lectures, but interestingly (and somewhat harder to explain) it also includes being a younger student.

The above PCA was confirmed valid by checking the following criteria. The sampling adequacy for the analysis was confirmed as the Kaiser-Meyer-Olkin measure was .669, which is above the acceptable limit of 0.5 (Field, 2009, p.647) and for which values close to 1 are desirable and above 0.7 is preferable. The Kaiser-Meyer-Olkin measure was used as there were 7 cases per input variable, somewhat less than the frequently used rule of thumb recommendation of ten cases per variable. Bartlett's Test of Sphericity resulted in Chi squared = 369.742, df = 78, P<.000, which indicated that the correlation matrix was significantly different from a unit matrix, which confirmed that the

Table 4.16 First Year Engineering Students PCA Rotated Component Matrix (using Varimax Rotation)

	Component			
	1	2	3	4
Variables Analysed	**High Achievement in Mathematics**	**Confident in Statistics and Mathematics**	**Like Mathematics and Motivated**	**Time spent**
A Level Type	-.832	-.053	-.185	.109
GCSE Mathematics Grade	.748	.259	.083	.054
Award	.696	-.192	.039	.010
Mathematics Module Mark %	.600	.253	.397	-.200
Dyslexia	-.407	-.144	-.021	-.347
Confidence in Statistics	.210	.834	-.077	.055
Like Statistics	-.240	.768	.187	-.023
Confidence in Mathematics	.396	.644	.331	.025
Motivation	.095	-.024	.840	.128
Like Mathematics	.210	.388	.659	.245
Choose to Study Module	.214	.168	.582	-.105
Age	-.233	-.212	.497	-.472
Time Spent	-.196	-.074	.122	.826
Eigenvalues	2.713	2.122	2.091	1.172
% of variance explained	20.867	16.326	16.084	9.0181
Cronbach's Alpha	0.736	0.752	0.605	0.012

Notes: Shading indicates correlations greater than 0.4 and less than -0.4

Sample size n = 92

The Eigenvalues and % variance explained relate to the rotated components.

Cronbach's Alpha values shown are based on the standardised items.

correlations between the different input variables were sufficiently large for PCA. Four components had eigenvalues above 1 (Kaiser's criterion) which cumulatively explained 62.3% of the variance. Field (2009) suggests that Kaiser's criterion produces an accurate number of factors when the number of variables is below 30 (in this case 13). The scree plot also indicated a four factor solution.

Factor 1 (High Achievement in Mathematics) also included high *Confidence in Mathematics* (correlation with Factor 1 was 0.396, almost 0.4). Factor 2 (Confidence) also included *Liking of Statistics* which is understandable as this would be closely linked to *Confidence in Statistics* (and almost included *Liking of Mathematics,* R=0.388). Dyslexia and Age are known to be measuring different characteristics to the affective variables, however, these were of interest for inclusion in the model. It was interesting to see that not being dyslexic was associated with high achievement, even though the ANOVA tests had not found a significant difference in marks for dyslexic students.

The most important aspect of the four factor solution obtained was that a meaningful set of underlying characteristics emerged which separated and distinguished between achievement in mathematics, *Confidence in mathematics* (a belief), *Liking of Mathematics* (an attitude) and the time spent. This is consistent with the theoretical stance taken in this thesis that achievement, confidences (beliefs), attitudes and time are different constructs.

The Cronbach's Alpha values represent the reliability (or the consistency) of the items included in the component, for which higher values are preferable. Field (2009) explains that acceptable values are generally at least 0.7 and it can be seen that Factors 1 and 2 have Cronbach's Alpha over 0.7. Internal consistency is required for subscales in questionnaires. However, because the Factor Analysis in this instance was exploratory, a more diverse mixture of variables have been analysed in order to investigate the relationships between the input variables. It is very reasonable that Factors 3 and 4 have lower Cronbach's Alpha values, especially Factor 4 for which a very low Cronbach's Alpha was obtained because it is totally correct that Age and Time spent are measuring completely different underlying latent variables. Similarly, whilst most of the Communalities were above 0.6, a few were not (including for Age and Dyslexia) which was also considered acceptable for the exploratory purpose. The Cronbach's Alpha results for the first year APD (non-engineering) students Factor Analysis were higher than these found for engineering students.

The acceptability of the 62.3% of the variance explained by the four factors in Table 4.16 is also demonstrated by its comparability with the variance explained in other studies. Shaw and Shaw (1999), Fogarty *et al*., (2001) and Tapia and Marsh (2004a), had all contributed to the original motivation to do Factor Analysis. Shaw and Shaw's (1999) three factors explained 64.5% of the variance. Fogarty *et al*.'s (2001) initial seven factor solution explained 61% of the variance, although the three factors adopted for their questionnaire explained less (48%). Tapia and Marsh's (2004a) ATMI four factors explained 55% of the variance.

Further Factor Analysis was also carried out which included the 11 Scale Variables. However, because all the 11 Scale variables were only used in 2006, this reduced the number of cases analysed to only 39. So for 26 input variables (which also included the use of Mathematics Support and Mean Topic Confidence) there was a very low ratio of only 1.5 cases per variable. However, the other adequacy measures were all satisfied: Kaiser-Meyer-Olkin=0.672, Bartlett's Test chi squared=682.8, df=325. P=0.000 and all communalities were above 0.6. Seven factors had Eigenvalues over 1, which cumulatively explained 74.8% of the variance, and are described briefly below:

1. **High Confidence in Mathematics and high achievement at university** (including Scale questions Q41 When I meet a new mathematics problem I know I can handle it and Q44. I have never felt myself able to learn mathematics).
2. **Fairly Confident in Mathematics**, which included four Scale questions (Q43, Q50, Q42 and Q40) which asked about confidence in a slightly less direct manner and also included *Confidence in Statistics.*
3. **Attitudes and Emotions** towards learning mathematics Scale questions (Q45, Q47-finds problems interesting and Q46-maths not frightening) and *Liking of Statistics* and Time Spent.
4. **Enjoyment and Excitement:** Do not understand how other people enjoy mathematics (Q48), and not excited about mathematics (Q49).
5. **High past qualifications in mathematics**.
6. **Older and use Mathematics Support**.
7. **Dyslexic and would choose to study mathematics**.

The Scale questions were split across four different components, which was consistent with the discussion of Scale questions in 4.2.6.2. The Scale questions about confidence (Q41, Q44, Q50, Q42 and Q40), and also Q43 about time, were grouped in the first two components. These were separated from the attitude and emotion questions which appeared in the 3rd and 4th components. Once again this validated the theoretical stance taken in this thesis which separated confidences (beliefs) from attitudes (such as interest) and emotions (e.g. frightened).

4.2.7.2 First Year Engineering Students Cluster Analysis

Cluster Analysis was carried out on the first year engineering student data, using the following variables: Award, Age, Whether dyslexic, Mathematics mark %; GCSE Mathematics grade code; A Level mathematics type code; Whether would choose to study the module, *Confidence in Mathematics*; *Confidence in Statistics*; *Liking of Mathematics*; *Liking of Statistics*; Motivation and Time spent working outside of lectures. These are the same variables as were used for the PCA shown in Table 4.16.

The resulting Dendrogram is shown in Figure 4.15 below. A four cluster solution was adopted, and the relative sizes of the four clusters (and the cases which were excluded from the analysis) are shown on the pie chart in Figure 4.16 below. In total 92 first year engineering students (of 111) were allocated to the four clusters, which were named: High achievement students (mean mark 92%, 19 students); Good achievement students (mean marks 74%, 42 students); Medium achievement students (mean marks 50%, 25 students); and Students in difficulty (mean marks 21%, 6 students).

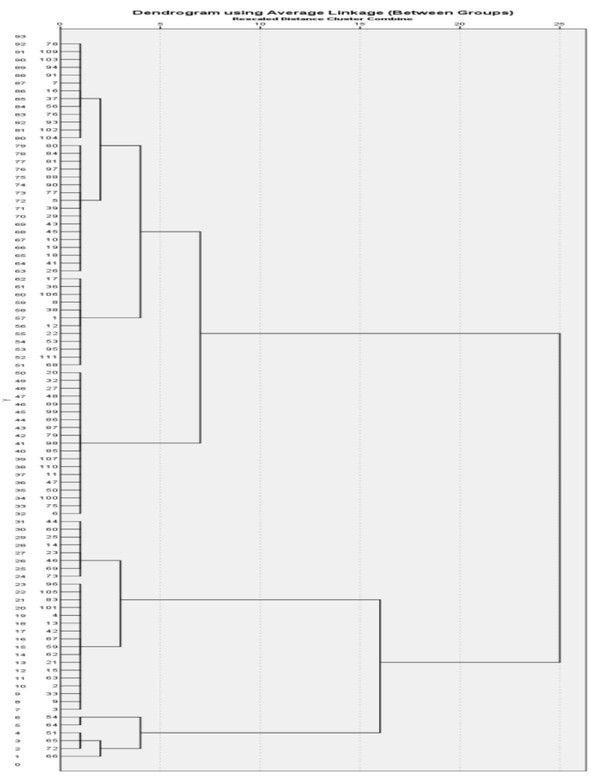

Figure 4.15 Dendrogram of First Year Engineering Students Cluster Analysis using 92 Cases Producing a 4 Cluster Solution

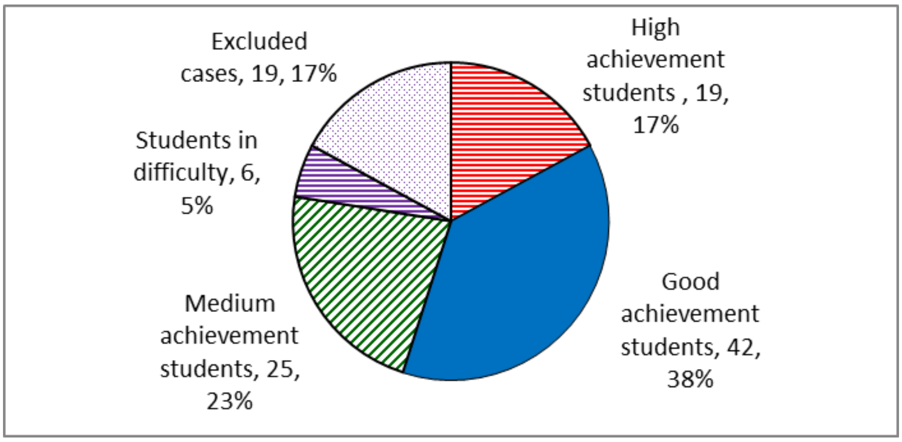

Figure 4.16 Relative sizes of the 4 Clusters and Excluded Cases for First Year Engineering Students 2005-7

Summary details for the four clusters are shown in Table 4.17 below.

Table 4.17 Four Cluster Solution for First Year Engineering Students 2005-7

Cluster Name	No. Students	Age	% Dyslexic	Mean Module Marks	St. Dev. Module Grade	Maths GCSE Grade No.	Level Mathematics	% Would choose	Confidence in mathematics	Liking of mathematics	Motivation	Time Spent	Confidence in Statistics	Liking of Statistics
High achievement students	19	19.4	16	92.2	3.5	2.4	1.7	84.2	3.8	3.9	3.7	1.2	2.9	2.8
Good achievement students	42	19.2	17	73.8	6.7	2.2	2.6	76.2	3.5	3.5	3.4	1.0	3.0	2.8
Medium achievement students	25	19.0	36	49.9	6.1	1.3	3.4	68.0	3.1	3.3	3.2	1.8	2.8	2.7
Students in difficulty	6	19.3	50	20.8	6.6	0.8	3.8	16.7	1.8	2.0	2.5	1.2	2.2	1.8
Excluded cases	19	19.2	16	64.7	25.3	1.8	3.3	68.4	4.1	3.9	3.8	1.5	3.4	2.9
Total	**111**		**23**	**67.2**	**21.0**			**56.8**						

GCSE mathematics codes: A/A*=3, B=2, C=1, D/E=0

A Level mathematics codes: A2=1, AS=2, Other=3, None= 4

More than half of the engineering students were placed in either the High Achievement or Good Achievement clusters which is consistent with the good results obtained by these students at university and before. The mean *Confidence in Mathematics*, *Liking of Mathematics* and Motivation ratings in the clusters increased consistently with the increased achievement before and at university. This is consistent with the correlation and regression analysis results in sections 4.2.4 and 4.2.5. However, it is notable that students' *Confidence in Statistics* and *Liking of Statistics* were almost all below 3 in all clusters, even the High Achievement cluster.

4.3 Second Year Engineering Students' Questionnaire Results

4.3.1 Second Year BEng and MEng Engineering Students' Closed Question Results 2005-7

In this section the results are presented for the combined three years' second year BEng and MEng students' questionnaire data which was gathered in May 2005, 2006 and 2007. The second year BEng and MEng students studied a Mathematics module for the first half of their second year. In the year 2004/5 this was a single semester module, whereas in years 2005/6 and 2006/7 this maths element was taught as the first half of a year-long module, after which the students studied Analytical Techniques using Mathcad software for the second half of the year. In all three years (2005-7) the marks shown and analysed were for the mathematics examination, which contained broadly similar questions. The second year questionnaires were administered towards the end of the academic year, in the same weeks as the first year questionnaires. At the time of completing these questionnaires the students had already taken their second year mathematics examination a few months earlier and had received the results, but had not yet taken the Analytical Techniques Mathcad examination.

A summary of the closed question responses, along with the students' mean examination marks is given below in Table 4.18 and Table 4.19. Over the three years of second year surveys 45 out of the total 54 BEng and MEng students were surveyed, representing an 83.3% response rate. There were good mean examination marks for these groups; the mean mark ranged between 59% and 70% for the three years. In Table 4.18 it can also be seen that the mean marks of the surveyed students was very close to the whole cohort mean mark indicating that not only were most of the students surveyed, but the surveyed students were very representative of the whole cohort.

Table 4.18 Second Year BEng and MEng Engineering Students' Mathematics Marks, Number of Students and Whether they would Choose to Study Mathematics 2005-7

Year	No. Students surveyed	No. in cohort	Age (years)	No. Dyslexic Students surveyed	Surveyed Students Second Year Mean Mathematics Exam %	Second Year Cohort Mean Mathematics Exam %	ALEVEL (mean score*)	% Who would Choose to Study 1st Year Mathematics	% Who would Choose to Study 1st Year Statistics	% Who would Choose to Study 2nd Year Mathematics
2005	17	19	20.9	3	59	57	1.8	82	-	88
2006	8	12	20.4	2	70	70	1.3	88	63	88
2007	20	23	20.2	3	62	60	2.2	90	45	70
All	**45**	**54**	**20.5**	**8**	**62**	**61**	**1.9**	**87**	**50**	**78**

Table 4.19 Second Year BEng and MEng Engineering Students' Mathematics Confidences and Attitudes 2005-7

Year	Confidences (in)									Like						
	Mathematics	Statistics	Engineering	Life in General	Mathematics on Arrival	Life on Arrival	Mathematics minus Life	Now minus On Arrival	Age (years) when Maths Confidence established	Mathematics	Statistics	Mathematics More	Statistics More	Motivation	Importance of Mathematics	Importance of Statistics
2005	3.8	3.3	3.8	4.1	3.5	3.7	-0.4	0.2	13.0	3.5	2.7	3.4	2.9	3.6	4.4	3.5
2006	4.1	3.3	3.9	4.0	3.9	4.0	0.1	0.1	11.9	3.9	2.4	4.0	3.0	3.9	4.4	3.5
2007	3.5	2.8	3.7	4.0			-0.6			3.5	2.4	3.7	3.1	3.3	4.3	3.5
All	3.7	3.1	3.8	4.0	3.6	3.8	-0.4	0.2	12.7	3.6	2.5	3.6	3.0	3.5	4.3	3.5

The students indicated a willingness to study mathematics; 87% responded that they would have chosen to study the first year mathematics and 78% would have chosen to study the second year mathematics, which are both high percentages. Whilst there is not data specifically explaining this slight drop from first to second year, it could be explained by the fact that the students found the second year mathematics harder and the students' mean marks in the examination were found to go down in the second year compared to the first year. Fewer students would have chosen to study the first year statistics and the second year Analytical Techniques.

These BEng and MEng students had predominantly A grade GCSE Mathematics and A2 Mathematics A level. Figure 4.17 below shows the breakdown of how many students had which GCSE mathematics grade.

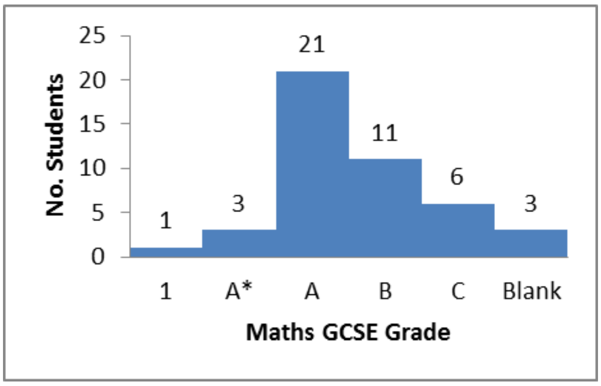

Figure 4.17 Second Year BEng and MEng Student GCSE Mathematics Grades

Figure 4.18 below shows the breakdown of how many students had A level mathematics or other age 16-18 mathematics qualification. 56% had A2 mathematics, but 11% had only AS level mathematics and 9% another equivalent qualification (of which 2 stated they had Scottish Highers and 2 stated they had a National Diploma qualification), and 18% had no A level mathematics or equivalent (whilst 7% left the question blank). The 2007 cohort had a noticeably higher proportion of students without A2 Mathematics A level (most probably due to a higher number of students transferring from the BSc courses). The BEng and MEng students were different in this respect from the BSc and HND/FdSc cohorts who were not required to have A2 Mathematics A level.

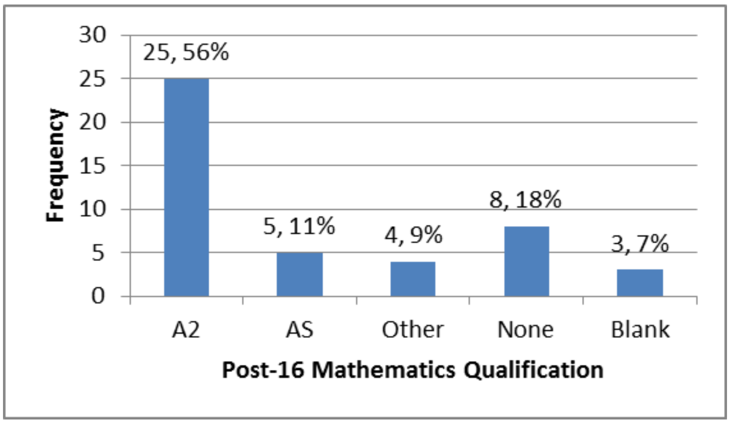

Figure 4.18 Second Year BEng and MEng Student Post-16 Mathematics Qualifications

A summary of the BEng and MEng students' confidences is given in Table 4.20 below and are also presented graphically in Figure 4.19 below. Students were fairly confident in mathematics (mean 3.7 out of 5, where 5 = very confident), and this was more than their confidence in their ability in statistics (mean 3.1). Students were also asked about their confidence in their ability in Engineering (mean 3.8) and in Life in General (mean 4.0); as can be seen these were higher than their *Overall Confidence in Mathematics* and *Confidence in Statistics*. Students were also asked to rate their confidence in mathematics (3.6) and life (3.8) when they had arrived, and it can be seen that both these confidence in mathematics and life had improved in their two years at university (especially if one excludes the 2007 students who were not asked the questions about confidences on arrival, mathematics confidence increased by 0.2, Life confidence increased by 0.3 on average).

Table 4.20 Second Year BEng and MEng Students Confidences 2005-7

Confidence	Mathematics	Statistics	Engineering	Life in General
1	0	1	0	0
2	3	12	2	1
3	15	17	10	6
4	20	13	29	28
5	7	2	4	10
Mean	**3.7**	**3.1**	**3.8**	**4.0**

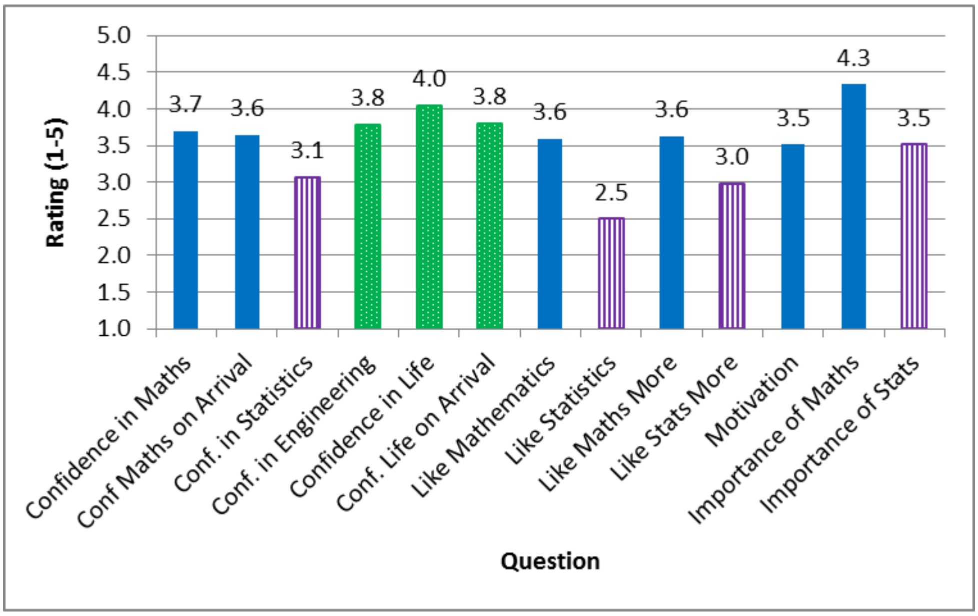

Figure 4.19 Second Year BEng and MEng Engineering Students' Mathematics Confidences and Attitudes 2005-7

Students considered that their *Confidence in Mathematics* had been established at around age 12 – 13 years. In both the first year and second year student questionnaires the students have placed their establishing of confidence back in early secondary school years, while at the same time they have responded that it had changed and improved at Harper Adams. One interpretation of this seeming contradiction is that the forming of their confidence at around age 12-13 years was the major formation of the level of overall *Confidence in Mathematics*, whilst the change at Harper Adams, whilst positive, was for many students on a smaller scale (mean change of 0.2 out of 5 since arrival). The students were fairly positive about liking mathematics (Mean 3.6), about liking it more after their second year module (Mean 3.6) and had fairly good motivation (mean 3.6). However they did not like Statistics as much (mean 2.4) and had not changed in their opinion that year (mean 3.0), which was not surprising as they had not studied any further statistics. What does stand out as the highest values in Table 4.19 and on Figure 4.19 are students ratings for how important they considered learning mathematics (mean 4.3), consistently in each of the three years the students considered mathematics to be *'Definitely important'* or at least leaning towards this, as opposed to *'Not Important'.*

In Figure 4.19 it can be clearly seen that the confidence ratings concerning Confidence in Life and in Engineering (shown as spotted bars) were some of the highest, whereas the statistics-related bars (striped) include the three lowest. The confidences and other ratings related to mathematics (solid bars) were also good, most of the means were 3.6 - 3.7 and the highest bar overall (4.3) represents the students' rating of the importance of mathematics.

The main four types of confidence ratings have been broken down further in Table 4.20 and presented in Figure 4.20 below. Each of the four types of confidence ratings followed an approximately normal distribution which is consistent with the mean values, thus giving further evidence that the relative confidences indicated by the means are a true representation.

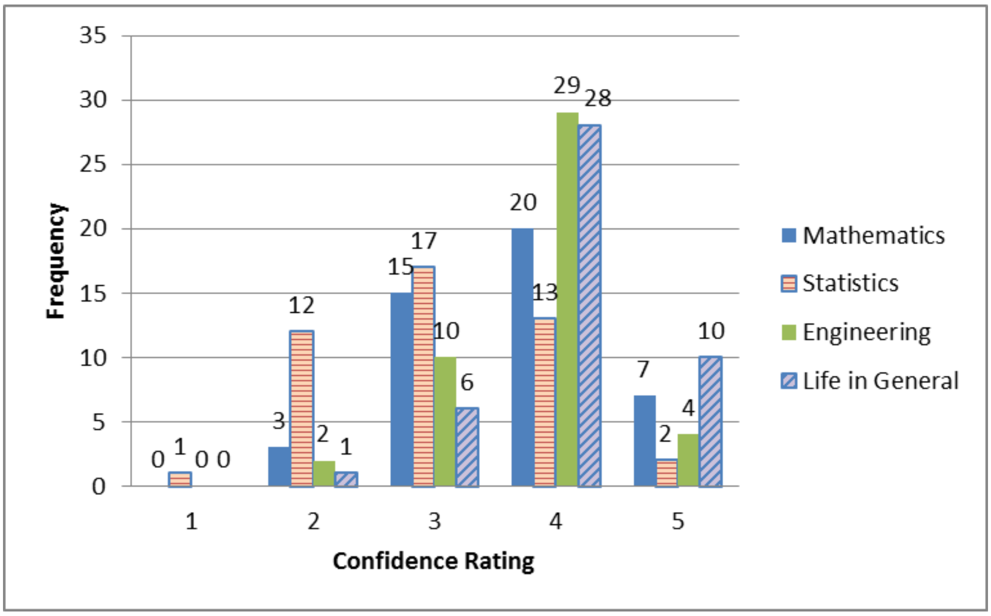

Figure 4.20 Second Year BEng and MEng Student Confidences 2005-7

Figure 4.21 below shows mean values for the various self-confidences in mathematics, showing *Overall Confidence in Mathematics* (dotted bar), *Topic Confidences* (solid bars) with the mean *Topic Confidence* value (bar outlined) and the mean *Applications Confidence* (striped bar). The variation in the *Topic Confidences* is evident and ranges from 4.4 to 2.5. Once again we see the pattern, Mean *Topic Confidence* is greater than *Overall Confidence in Mathematics* which is greater than the mean *Applications Confidence*.

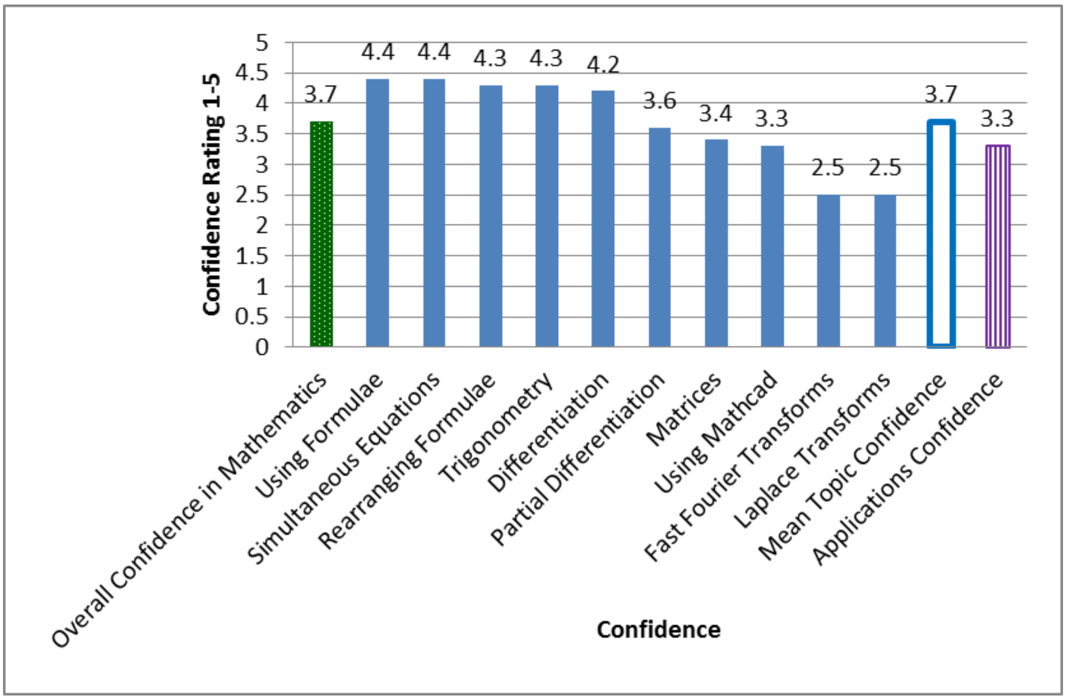

Figure 4.21 Second Year BEng and MEng Student Confidences 2005-7

These results for the students' self-rating of their confidence levels have contributed to answering Research Questions Ia and Ib regarding defining and determining self-confidence in mathematics.

There were questions regarding the support which the second year students had used to help them learn their second year mathematics. The second year BEng/MEng students reported that they had used various sources of support, and these are shown in Figure 4.22 below.

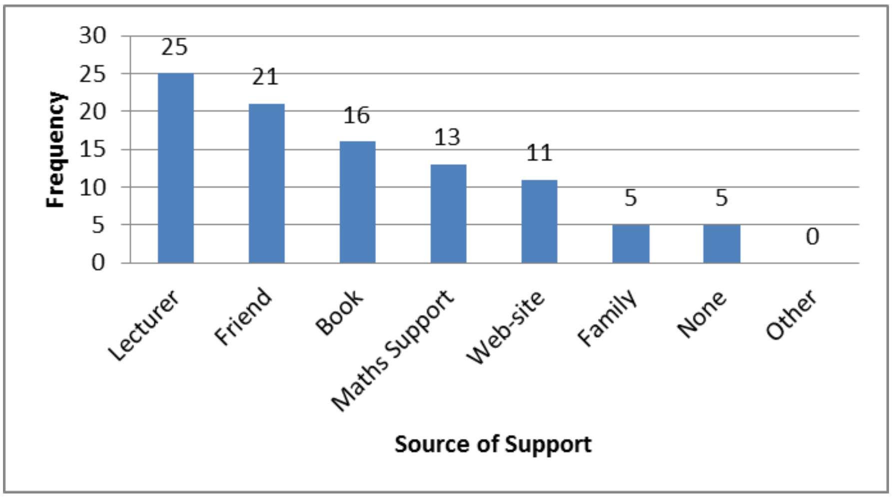

Figure 4.22 Second Year BEng and MEng Student Sources of Support for Mathematics

As can be seen, help from the lecturer was the most frequently used means of support, and followed by help from friends, books and the Mathematics Support. At this time the Mathematics Support was very much aimed at the first year students, but second year students did use it by booking individual appointments. The provision for second year Mathematics Support has since expanded, although the support continues to be aimed primarily at the first year students.

There were very few open question responses regarding the support received, but three meaningful examples of details of the support used were:
'Mathematics Support', '*especially mathcentre'* (re. web-based support) and '*When first starting at Harper'.*

This subsection has summarised the findings from the second year BEng and MEng students' closed questions, the findings for the open questions will now be summarised in the following section.

4.3.2 Results of Second Year BEng and MEng Engineering Students' Open Questions

The second year engineering students were asked similar open questions to those on the first year engineering student questionnaires. A sample questionnaire can be seen in Appendix IV for the exact wording and layout of these questions and the question text is given in each subsection with the results. The details requested by the open questions are listed briefly below (with the 2005 second year BEng and MEng questionnaire question numbers), plus the open question introduced in 2006 about the *Applications Confidence*.

- How their past experiences of mathematics had affected their confidence or liking of mathematics (Q. 18).
- Students' attitudes to learning mathematics (Q. 23).
- Aspects of the module which had *helped* their learning of mathematics (Q. 36).
- Aspects of the module which had *hindered* their learning of mathematics (Q. 37).
- How and why students thought their confidence would change when applying mathematics in the future for a job or project (2006 Q. 37).
- When they had experienced a topic suddenly becoming a lot clearer (Q. 39).
- When they last enjoyed doing something in mathematics (Q. 41)
- Suggestions for what would improve their confidence, attitudes or ability (Q. 49)

A question regarding how students considered that their confidence, attitudes or ability had changed in their second year compared to the first year is reported on in the next section, 4.5

Students' responses to the following question are summarised in Table 4.21.

> ***'How do you think that your experiences of mathematics before coming to university have affected your confidence in or liking of the subject?***
> *(Please describe your experiences if possible)'*

Unfortunately only 17 students wrote a response, but the majority of the responses were positive: 10 (22.2%) positive, 1 (2.2%) neutral, 6 (13.3%) negative responses and 28 blanks. This is much more positive than the summary totals for the first years who overall reported more negative experiences (39 negative compared to 33 positive), however the first year data also included BSc and FdSc/HND students. The most frequent responses for these BEng and MEng second years was that they were confident before university.

Some of these second year students could have been affected by problems with the early modular A level Mathematics, but no specific reference was made to this.

Table 4.21 Second Year BEng and MEng How Student Experiences of Mathematics before University affected their Confidence or Liking of the Subject

Response Type	2nd Year Frequency	2nd Year %	1st year Frequency	1st Year %
Blank / ?	28	62.2	28	24.1
Confident before	5	11.1	1	0.9
Good teacher	3	6.7	6	5.2
Bad experiences	2	4.4	20	17.2
Bad teacher	2	4.4	6	5.2
Good Experiences	1	2.2	22	19.0
Applying the maths helped	1	2.2		
Not much	1	2.2	8	6.9
Not too keen on it any more	1	2.2		
Lack of Maths at College	1	2.2	2	1.7
Total	**45**	**100.0**		

These are some examples of students' positive past experiences:

'Positive past successes (guess helped with confidence)'

'Doing Further Maths at A level has made engineering maths a lot easier to understand'

Some contrasting negative past experiences are shown below.

'Greatly – bad teachers'

'I never liked maths … I lost confidence …'

The main difference between the first and second years as shown in Table 4.21 is that the second years were overall more positive. However, I would suggest that the main finding from this question is that the BEng and MEng students were overall more positive about their past experiences than the whole mixed first year groups in which the BSc and FdSc students were also included.

Students' responses to the following question are summarised in Table 4.22.

'How would you describe your attitude to learning mathematics?'

Students' attitudes to learning mathematics varied, but the majority, 56%, were positive, for example: *'keen', 'enjoy it', 'motivated given time', 'very confident', 'an attitude to want to do it'.* As was found in the first year engineering students' questionnaires, some of these positive attitudes also reflected the understanding that mathematics was necessary, for example *'Something that is needed to enter the industry'.* There was a minority of negative attitudes (only 6 responses), examples of these include *'not very enthusiastic', 'not willing'.* The student attitudes can be summarised as: 25 (55.6%) positive; 12 (26.7%) blank; and 6 (13.3%) negative, whilst two 'Other' responses (4.4%) were excluded as these did not fit into these categories. There were some Attitude responses given by first year students which were not given by second years, these were: *'don't like',* attitude was *'improved', and 'Depends if can do it'.*

Table 4.22 Second Year BEng and MEng Student Attitudes Towards Learning Mathematics

Response Type	2nd Year Frequency	2nd Year %	1st year Frequency	1st Year %	Category
blank	12	26.7	22	19.3	Neutral
Positive / Good	7	15.6	31	27.2	Positive
Keen / eager	6	13.3	8	7.0	Positive
OK alright	4	8.9	13	11.4	Fairly Positive
Necessity/Have to do it	3	6.7	21	18.4	Fairly Positive
Poor	3	6.7	3	2.6	Negative
Other	3	6.7			1 Positive (of 3)
Enjoy Maths	2	4.4	5	4.4	Positive
Interested	2	4.4	2	1.8	Positive
Find Hard	2	4.4	1	0.9	Negative
Hesitant	1	2.2	1	0.9	Negative
Total	**45**	**100**	**113**	**99.1**	

Comparing the first and second years' responses as shown in Table 4.22, a higher proportion of second years were 'keen/eager', but also a higher proportion had a poor attitude or found it hard. Some first year responses were not repeated in the second year. The second year responses are not totally different from the first years'; the differences were possibly a consequence of there being fewer second year students, and the likelihood that students would use slightly different wording for similar attitudes.

The following question was asked in 2006 only.

How confident do you feel about applying these in the future?

When you need to use or apply some of these topics in the future, to your research project, dissertation or at work, how would you expect your confidence in these topics to have changed?

More confident		*unchanged*		*Less confident*
☐	☐	☐	☐	☐

Can you explain why?

Students' responses are summarised in Table 4.23. Overall the students thought that they would be slightly more confident to use and apply the mathematics which they knew in the future. The closed question mean result for this was 3.3 (out of 5, 5 being More confident), the mean in 2006 was 3.6 and mean in 2007 was 3.1. In response to why they thought this would be so five students thought that they would be better, whereas 3 were concerned that after their work placement year they would not have had regular practice and would have forgotten it. This finding is similar and consistent with that for first year engineering students.

Table 4.23 Second Year BEng and MEng Student Reasons for Why Their Confidence in Mathematics will Change in the Future (2006-7)

Reason	Frequency
Blank/Don't know	15
Other	5
Worse will have forgotten it	3
Will know it better	1
Will have done more	2
Better as applying it	2
Total	**28**

The students' reasons for their future confidence were further summarised as: 5 (17.9%) positive; 15 (53.6%) neutral; and 3 (10.7%) negative; and Other 5 (17.9%). Whilst it is good that more were positive than negative, there is some room for improvement. Perhaps students could be given suggested resources or strategies which would help them to be confident that they would be able to do the maths they would need in the future, for example to know of freely available on-line tools (such as mathcentre and other engineering toolbox type applications).

Students' responses to the following question are summarised in Table 4.24 below.

'Can you list any aspects which particularly helped you to learn maths?'

Table 4.24 Aspects that had Helped Second Year BEng and MEng Students' Learning of Mathematics

Response Type	2nd Year	2nd Year %	1st Year Frequency	1st Year %
Good lecturer / Specific lecturer name	**12**	**26.7**	**17**	**14.9**
Blank	**11**	**24.4**	**40**	**35.1**
Extra Maths	**7**	**15.6**	**12**	**10.5**
Examples	**4**	**8.9**		
Application to other modules	**3**	**6.7**	**6**	**5.3**
Past papers	**2**	**4.4**	**2**	**1.8**
Other	**2**	**4.4**		**0.0**
Hand-outs	**1**	**2.2**	**11**	**9.6**
Lectures	**1**	**2.2**		
People available to help	**1**	**2.2**		
Team work	**1**	**2.2**		
Total	**45**	**100**		

The most frequent response from students was that their lecturer had helped them, and (excluding blanks) the next most frequent was the Mathematics Support (i.e. the Extra Maths). When the students wrote '*Examples*' it is not clear whether this means worked examples provided in the teaching of new material, or the students doing the problems themselves. The remainder of the aspects listed in Table 4.24 above are all sensible things listed by the students, and it is interesting to see *'Application to other modules'* as the next most frequent, which included comments referring to applying the mathematics to practical situations.

Although a number of responses given by the first year engineering students were not given by the second years, it can be clearly seen in Table 4.24 above that for the most frequent responses there was good similarity between the first year and second year responses.

Students' responses to the following question are summarised in Table 4.25 below.

Can you list any aspects which hindered your learning of maths?

Table 4.25 Aspects that had Hindered Second Year BEng and MEng Student Learning of Mathematics

Response Types	Frequency	%
Blank	20	44.4
Other	8	17.8
Poor teaching	5	11.1
Lack of worked examples *	4	8.9
Previous bad teachers	3	6.7
Too fast	2	4.4
Lots of assignments	2	4.4
None	1	2.2
Total	**45**	**100.0**

Note * = not regarding Mathematics lectures, but another highly mathematical module.

Poor teaching was the single most frequently occurring hindrance listed by students, and more than half of the aspects listed in Table 4.25 above could be categorised as relating to teaching styles: past and present. There were some very specific comments about the about the lack of worked examples in some mathematics-related lectures (but not actually the mathematics lectures) and how hard this had made learning the new subject material. Overall from the engineering students' questionnaires there was a clear message, from several questions' responses, that hand-outs with worked examples were considered really important and helpful to the students.

There were features stated by the first years which were not listed by the second years which were: *Lack of previous experience of maths*, *Room/time of day*, *Alcohol, specific topics* and *repeating what students already knew (*the second year mathematics content would have been new to all of the students so this would not have applied).

The students were asked the following question:

> ***Have you ever experienced an occasion when a topic suddenly became a lot clearer than before (e.g. like a light switching on)?***
>
> *Yes* ☐ *No* ☐ *Can you describe what happened?*

There were 5 responses, which were quite varied, and it is positive that some students could report having had this type of *'Inspiration'* experience. Two students referred to when their lecturer had explained something to them, one referred to applying the maths to a practical situation (comparing tyre traction prediction models in another module), and two referred to this happening when they were doing revision. Whilst this was a fairly small number of responses there are three quite identifiable types of occasion when this has happened.

- When some mathematics was explained to them (by a teacher, but this would not just be limited to help from a teacher).
- When doing some individual study (in this case it was revision)
- When applying the mathematics to a practical situation.

Work was done using the 2005 data to see whether this type of experience was associated with a higher increase in confidence, but this was not clearly identifiable, unlike in the Liljedahl (2005) study on the effect of 'AHA!' experiences which found that these inspirations were associated with a boost to confidence.

The students were asked the following question:

> ***When did you last enjoy doing something in maths?*** *(Please give details)*

Four students were able to quote something fairly recent or at least in that year: *last week, other week proving a point, Matrices, passing the exam.* Two students referred to using mathematics in a practical situation, one of which was '*analysing drawbar pull'*, but two students referred to a long time ago (GCSE and 1991).

These second year students were overall more positive about mathematics than the first years, but 5 examples is a long way short of all 45 students having something enjoyable in mathematics to report. It would be good if lecturers could devise means by which students would find mathematics more enjoyable.

The students were asked the following question:

> **Can you suggest anything that would improve your confidence, attitudes or ability in mathematics?**

There were only five student responses to this question which were as follows:

- General practice
- Better notes / hand-outs
- Formula sheet in exams which gave the meaning of symbols for dyslexic students
- More help, always available
- Don't think it's possible (to improve).

All of the above responses (except the symbols meanings) are consistent with the earlier question responses, and were especially consistent with the questions about what had helped or hindered students' learning of mathematics.

By the time students were asked '**Any other comments?'** almost all of the students had run out of things to write (probably as a consequence of these being long questionnaires), so unfortunately there were no useful responses to this question.

The second year students generally found that the same things helped and hindered their learning as did the first year engineering students. Mathematics lecturers and the Mathematics Support were the main source of help and students referred to the helpfulness of examples and working with friends. Particular mention was made of the necessity of worked examples to learn from (although these comments originated from a mathematics–related lecture rather than the actual mathematics lectures). Being BEng and MEng students, they were more qualified, and overall more positive, than the first year students reported on in Section 4.2, who were a more mixed group including the BSc and FdSc students. The findings from the open questions were generally consistent with the closed questions and provided more detailed information. Some of the open data produced clear lists of what the students found beneficial (or not) for learning mathematics. In particular, students wanted hand-outs with worked examples and detailed solutions to problems, and this student expectation serves as a motivation to lecturers to provide good lecture hand-outs with plenty of detail. The importance of covering both easy and difficult work was evident. The scarcity of students' experiences of when they had enjoyed mathematics was of some concern, but the aspects which were enjoyable and the types of occasions when the students had a flash of clarity or inspiration both included doing the mathematics themselves and practical applications of the mathematics.

4.3.3 Further Analyses of Second Year BEng and MEng Engineering Students' Data

Second year Engineering students' Mathematics marks were analysed by ANOVA tests, and their *Confidence in Mathematics* was analysed by Kruskal Wallis Tests and the results are shown in the Table 4.26 below.

Table 4.26 Second Year BEng and MEng Students' 2005-7 Mathematics Marks and Confidence in Mathematics ANOVA and Kruskal Wallis Tests

Factor (with the permitted values)	Mathematics Module Mark ANOVA P-Value		Overall Confidence in Mathematics KW P-Value	
Award (MEng, BEng)	0.172		0.851	
Course (ORVD, AGENG)	0.471		0.544	
Age (in years)	0.328		0.164	
Dyslexic (Y/N/U)	0.340		0.515	
Dyscalculic (N/U)	0.232		0.971	
GCSE Grade (A*/A/B/C/D/E)	**0.028**	*	0.066	
GCSE Tier (H/I/F)	**0.034**	*	0.244	
Whether students had A level mathematics (1,2,3,4)	**0.017**	*	0.088	
Whether would choose to study maths (Y/N)	**0.032**	*	**0.017**	*
Confidence in mathematics (1-5)	**0.007**	**	-	
Confidence in statistics (1-5)	0.138		**0.002**	**
Confidence in Life in General (1-5)	0.801		0.457	
Liking of mathematics (1-5)	**0.016**	**	**0.006**	**
Liking of statistics (1-5)	0.161		0.272	
Whether like subject more after module (1-5)	0.363		0.403	
Motivation (1-5)	0.589		0.072	
Whether motivation same as for other modules (M/S/L)	**0.048**	*	**0.009**	**
Inspiration	0.273		0.131	
Imp Maths	0.329		0.127	
Imp Stats	0.874		0.915	
Confidence to apply maths in future (1-5)	-		-	
Questionnaire Year	0.443		0.098	
Used Maths Support (Group/Individual/Both/None)	0.180		0.260	

It can be seen that the marks were significantly related to past qualifications, and to *Confidence in Mathematics* and *Liking of Mathematics*, and motivation. Whilst

Confidence in Mathematics was unusually not significantly related to past achievement anymore, but was related to other confidences, *Liking of Mathematics* and motivation and whether would have chosen to study the module. Overall there were fewer significant relationships found for the second year engineering students than were found for 1st year engineering students, which might have been due to the smaller sample sizes and the more homogeneous nature of the students, as the second year group did not include the BSc and HND students. A comparison of these results and those for other students groups is given in Section 6.3.

Students' mean second year mathematics marks have been analysed with their *Overall Confidence in Mathematics* ratings and a clear trend was found: higher marks were associated with higher *Confidence in Mathematics*. An ANOVA test found that the difference in mathematics marks for the different confidence ratings was significant (P=0.007), and the mean marks for each confidence rating are shown in Table 4.27 and on Figure 4.23 below.

Table 4.27 Second Year BEng/MEng Students' 2005-7 Mathematics Examination Mark by Confidence in Mathematics

Confidence in Mathematics	2	3	4	5
Mean Mathematics Mark %	41	55.4	65.5	79.0
No. of Students	3	15	18	7
Standard error	9.98	4.46	4.07	6.53

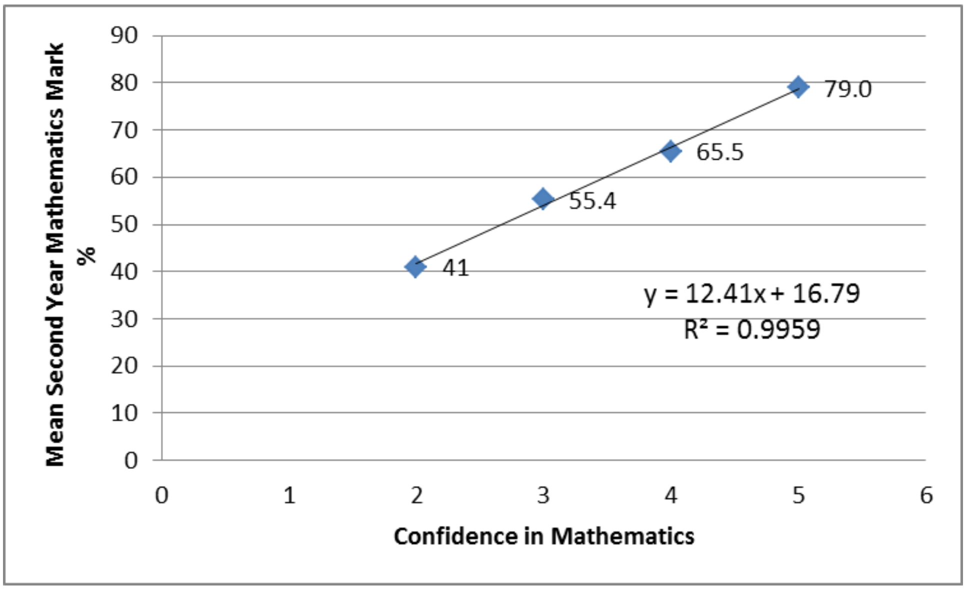

Figure 4.23 Second Year BEng and MEng Students' Mean Mathematics Examination Mark by Confidence in Mathematics 2005-7

Figure 4.23 above shows a trend line which modelled the mean mathematics mark for each *Confidence in Mathematics* rating, which can be seen to follow almost a perfect line. However when all of the individual students marks are plotted the true variability of the marks can be seen (in Figure 4.24 below).

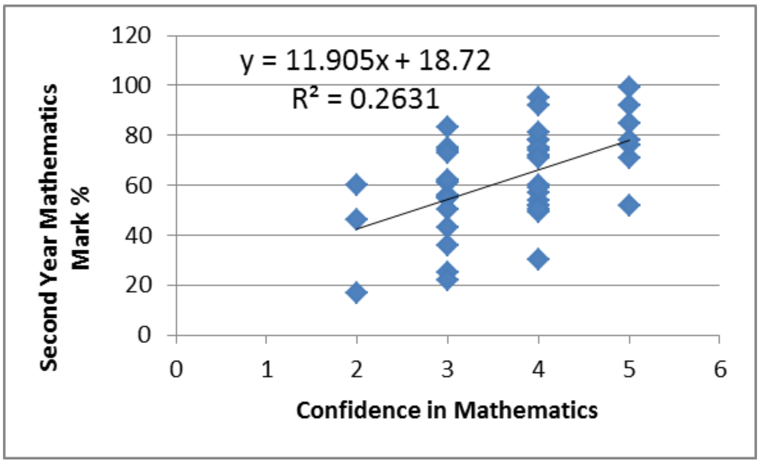

Figure 4.24 Second Year BEng and MEng Students' Mathematics Examination Mark by Confidence in Mathematics 2005-7

Figure 4.25 below shows the variation of student marks when plotted against their A level Mathematics Type (when 1=A2, 2=AS, 3=Other and 4 =no A level), and wide variation in marks is evident, and a downwards trend line is drawn as a line of best fit.

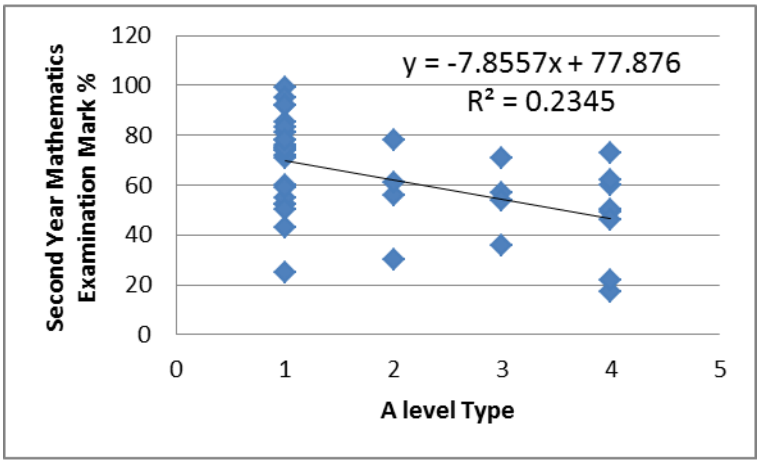

Figure 4.25 Second Year BEng and MEng Students' Mathematics Examination Mark by A Level Mathematics Type 2005-7

Multiple regression analysis of the second year mathematics marks (%) by A level type and students' *Confidence in Mathematics* produced a valid model ($P<0.001$) with all valid coefficients ($P<0.05$) which accounted for 34.3% of the variation in the marks, based on 40 students. The independent variables were recoded from zero, i.e. A Level Mathematics types: A2=3, AS=2, Other =1 and None =0 and Confidence in Mathematics 0-4.

Second Year Mathematics Mark = 25.72 + 5.61 * A level type + 9.43 * Confidence in Mathematics (R^2 = 34.3%, n=40)

In Section 4.2 it was shown that first year mathematics marks could be explained by their GCSE Mathematics Grade and their *Confidence in Mathematics*, i.e. a past qualification and their confidence in mathematics, here for we have shown a similar relationships of marks with past qualifications and *Confidence in Mathematics* for the second year students. It is also interesting to note that the percentage variation explained by these models were comparable, approximately 36% was explained by the first year regression model and here, similarly, 34% of the variation in second year mathematics marks is explained. Other models were tried using the following as independent variables: Motivation, GCSE Mathematics Grade, whether BEng or MEng, whether they had used the Lecturer's help or Mathematics support and none of these produced a better model. Of all the independent variables tried the *Confidence in Mathematics* had not only the largest coefficient, but also the highest level of significance (at best $P<0.001$), which is another example of the importance of the effects of confidence compared to other affective variables.

In order to investigate the effects of various A2 Mathematics grades on student performance a further valid model was produced for just 22 BEng and MEng second year students with known A2 mathematics grades which explained 40.2% (adjusted R squared) of the variation in the second year marks for those students. An additional model based on *Confidence in Mathematics* was also produced for the BEng and MEng second year students with A2 mathematics. A level Grade Codes were as follows: Grade A=5, B=4, etc. and *Confidence in Mathematics*= 0-4. These models predict that a student with Grade A at A2 mathematics would achieve 36.4% more than one with Grade F, and a very confident student would achieve 38.0% more than a least confident (which are similar differences). It is also notable that the percentage variation explained by the A Level Grade model (40.2%) is approximately twice that of the *Confidence in Mathematics* model (18.1%).

Second Year Mathematics Mark = 48.037 + 7.282 * A level Grade Code

(R^2 = 40.2%, n=22)

Second Year Mathematics Mark = 42.972 + 9.495 * Confidence in Mathematics

(R^2 = 18.1%, n=24)

A further valid model was produced for the second year engineering students using their first year mathematics marks (33 students) which explained 58.2% (Adjusted R^2) of the variation in the second year marks. See also Figure 4.26 below. In this model the variation in first year marks is further emphasised in the second year.

Second Year Mathematics Mark = -29.8 + 1.174 * First Year Mathematics Mark

(Adjusted R^2 = 58.2%, n=33)

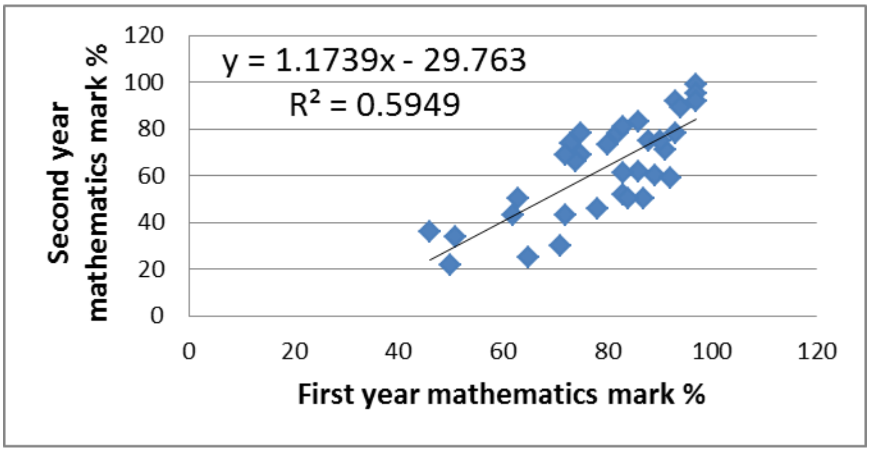

Figure 4.26 Second Year BEng and MEng Students' Mathematics Examination Mark by First year Mathematics Mark (all 2006 and 2007 Students)

In Section 4.2 it was shown that first year mathematics marks could be explained by their GCSE Mathematics Grade and their Confidence in Mathematics, i.e. a past qualification and their confidence in mathematics, here for second year mathematics we have shown a similar relationship for marks with past qualifications and *Confidence in Mathematics*.

A further regression model predicting the change in mathematics marks from the first year to the second year is discussed in the next section 4.4, along with other changes from the first year to the second year.

4.4 Changes between First year and Second Year Engineering Students

There were 15 BEng and MEng students who had completed questionnaires in the first year and then again in the second year; these students had been first years in May 2005 (4 students) and May 2006 (11 students). There were a total of 35 BEng and MEng students in these years (14 started at Harper Adams in 2004/5 and 21 in 2005/6), so 15 students, although a fairly small number did represent a 43% response rate from these BEng and MEng cohorts. Students who could not have their first and second year questionnaires matched included the 2007 first years who were not surveyed in their second year, and the 2005 second years who were first years before the study began. Later in this section another larger dataset is also used which was created from the lists of first and second year student results, to which the A level codes were added from either the second or first year questionnaires.

In this section the difference between students' responses on their first year questionnaires and their second year questionnaires have been investigated and analysed and are discussed. In addition, the students were asked an open question in the second year about how they had changed.

4.4.1 Changes between First year and Second Year Engineering Students' Mathematics Examination Marks and Closed Question Results

The key examination marks, confidences and other key closed question results, for the first year, second year and the changes, are summarised in Table 4.28 below.

Overall it was found that BEng and MEng students achieved lower mathematics marks in their second year compared to the first year, particularly those students without A Level mathematics, and there was greater variability in the marks the students achieved in the second year mathematics than in the first year. On a more positive note, the students were more confident overall in their mathematical ability and liked the subject more in their second year, and especially more as a result of this module, although they were slightly less motivated. The decrease in marks can generally be attributed to a step-change increase in the difficulty of the content, and the students' increased confidence the students themselves attributed to being due to having had more practice at doing the mathematics (as can be seen in the quotes given in Table 4.29).

Table 4.28 Comparison of First Year and Second Year BEng and MEng Students' Achievement, Confidence, Liking and Motivation in Mathematics and Statistics

Variable Compared	First Year	Second Year	Change (2nd year minus 1st year)
Mathematics Mark Mean for matched students	81.60%	65.30%	-16.30%
Mathematics Mark Standard Deviation for matched students	12.10%	20.10%	
Whole BEng/MEng group 2004/5 intake	80.10%	70.30%	-9.80%
Whole BEng/MEng group 2005/6 intake	73.50%	60.40%	-13.10%
Confidence in ability in Mathematics (1-5)	3.67	3.80	0.13
Confidence in ability in Statistics (1-5)	2.93	2.87	-0.07
Confidence in ability in Life in General (1-5)	3.73	3.93	0.20
Confidence in Ability in Engineering (1-5)	-	3.90	-
Like the subject - Mathematics (1-5)	3.67	3.87	0.20
Like Mathematics More after the Module (1-5)	3.53	3.93	0.40
Like the Subject - Statistics (1-5)	2.47	2.33	-0.13
Motivation in Mathematics (1-5)	3.73	3.67	-0.07
% Who would choose to study the Mathematics Module (Y/N) [* 1st or 2nd year questionnaires].	87.0 or 93.3 *	80.0	-13.3

4.4.2 Results of Open Question about Students' Changes between First year and Second Year

The student responses to how they had changed from the first year to their second year (see the question text below) are shown in Table 4.29 below.

> ***'How do you consider that your confidence, attitudes or ability in mathematics have changed during this your second year? Can you describe in what ways and why?'***

Table 4.29 Students' Responses to the Open Question about how they had changed from their First Year to the Second Year

How Changed	Frequency	%	Examples
More confident	11	24.4	More confident due to more practice
Not much / same	3	6.7	About the same
Not as Confident	2	4.4	Confidence has weakened as the difficulty has increased
No	2	4.4	Not really
Other	2	4.4	The level of skills required jumped quite considerably from 1st to 2nd year (and moving from BSc to BEng)
Confident	1	2.2	Confident that I can do the maths required despite previous experiences (this is partly due to the level of maths and in part the teaching methods, i.e. real world not 'pure' maths)
Have struggled more	1	2.2	Have struggled more and therefore not enjoyed the subject
blank	23	51.1	
Total	**45**	**100.0**	

As can be seen the most frequent response was that students considered that their confidence had increased and improved, and the main reason for this was the amount of practice they had had. However, there were some students who felt less confident because the difficulty had increased.

4.4.3 Investigation into Engineering Students' Drop in Mathematics Marks from the First to the Second Year

It was noticeable that the students who had the greatest drops in their marks from the first year to the second year were those who had not taken full A Level (A2) mathematics. The first and second year questionnaires were matched for just fifteen students, and the drop in marks is plotted against the A level code in Figure 4.27 below. The 15 students were made up with students with the following A Level Mathematics Qualifications (and codes): 1= A2 Mathematics, n=10; 2= AS Mathematics, n=2; Other (actually Physics A2), n=1; and 4= None (Studied ND Maths), n=1; and blank, n=1.

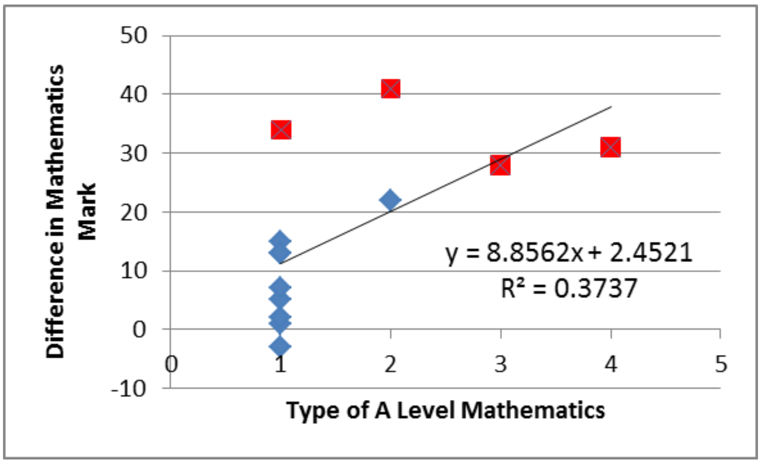

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Figure 4.27 Drop in Mathematics Mark from First to Second Year by Type of A Level Mathematics Studied (for 15 Matched Students)

As can be seen four students' marks dropped between 28% and 41% from the first year to second year mathematics (indicated with squares on Figure 4.27), and three of these four did not have A2 mathematics. The relationship between the type of A level Mathematics the student had studied and the drop in mark achieved in the second year was investigated using Regression analysis (where A2=1, AS=2, Other =3 and none =4). The predictive model for the 15 matched students was:

Drop in Mathematics marks = 2.45 + 8.86 x A level Code [n=15, model not valid]

Unfortunately this model was not valid, whilst the model was significant overall (P=0.021) and the coefficient for the A level code was significant (P=0.021), the Constant coefficient was not significant (P=0.617). However, from the above equation and the trend line shown on Figure 4.27 it appeared that not having A level mathematics, or equivalent, could explain a total drop of 29% in marks from the first year mathematics mark to the second year mathematics mark, which is an extra 27% drop (= 3 x 8.8562) compared to students who had arrived at university with full A2 mathematics. As this was a relatively large difference, further investigation of this was carried out.

In order to investigate this further a new, larger data set was produced based on the records of the first year and second year mathematics marks for 2004/5 and 2005/6 entry cohorts (i.e. second years in 2006 and 2007), which linked with their A Level Type Code from either the first year questionnaires or the second year questionnaires. This produced a slightly larger data set of 30 students (compared to 15), although their grade detail was only known for some students, whose drops in mathematics mark are shown on Figure 4.28 below. In addition students with Grade A at A2 were also separated and given Code 0, as a means to try to separate higher achieving students from the bulk of students with A2 (code=1), which it appeared to do (see Figure 4.28.)

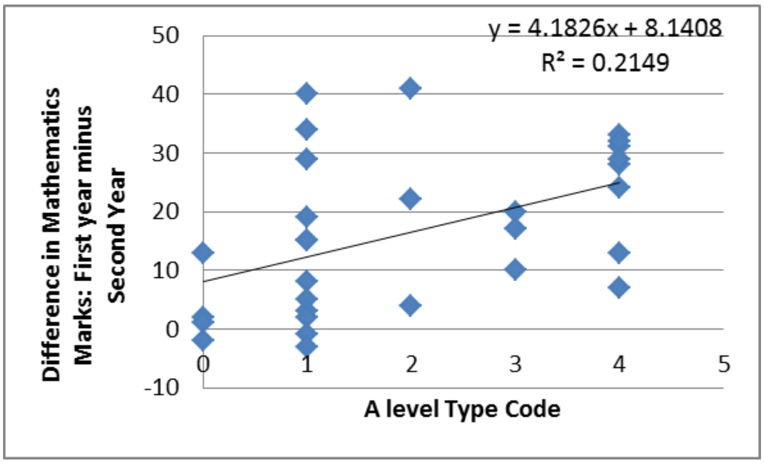

Figure 4.28 Drop in Mathematics Mark from First to Second Year by Type of A Level Mathematics Studied (for 30 Students) with A2 Grade A shown as Code 0

Regression Analysis in GenStat on this dataset did produce a valid model, for which the model and both coefficients were significant, with the following predictive equation:

Model for 30 Second year BEng and MEng Students in 2006 and 2007:

Drop in Mathematics marks = 8.14 + 4.18 x A level Type Code

(Adjusted R^2 = 18.7%, n=30)

The above model was significant in every respect and shows that a clear link can be made between whether or not students have A level Mathematics and by how much their second year mathematics mark goes down in comparison to their first year mark, however the coefficient for the A Level Code is now much lower (4.18 rather than 8.86 for the 15 students with matched questionnaires). This model predicted drops in second year marks for the different pre-university qualifications as follows: a student with an A grade at A2 mathematics would only expect their mark to fall by approximately 8%; with A2 mathematics with Grade B or lower, by 12%; AS Level mathematics, by 17%; Other A level equivalent, by 21%; and without A level Mathematics, by approximately 25% (=8.14 + 4 x 4.18). This indicates that students without A2 mathematics are more vulnerable in the second year mathematics modules and should be targeted for mathematics support.

Models were also tried including the second year confidence in mathematics ratings as well as the type of A level mathematics, however the Confidence in Mathematics was not found to be a significant explanatory variable.

In conclusion the comparison of second year students with their own responses on a first year questionnaire and comparison of whole first and second year cohorts found the following.

- Second year students were, on average, more confident in mathematics and this was evidenced by their open and closed question responses, for individual and for whole cohort means.
- Students liked mathematics more.
- Second year students were also more confident in Life in general, and were the same or less confident in statistics.
- Second year students' achievement in mathematics went down, due to the increase in difficulty, and those students without A2 level Mathematics (i.e. with less prior knowledge in mathematics) dropped their marks by the most in the second year.
- Students were slightly less motivated in their second year, their mean motivation rating and the number of students who would choose to study mathematics both went down.

This section has described the results of first year students (in Section 4.2), second year students (in Section 4.3) and changes from the first to the second year (in this section).

4.5 Conclusions Pertaining to Engineering Student Questionnaires

The experiences of Harper Adams engineering students of learning mathematics before university were mixed, and were more often negative than positive, but were generally more positive at university. The majority of engineers (71% of the first years and 78% of the BEng and MEng second years) would have chosen to study mathematics and they were fairly well motivated. Many described positive attitudes to learning mathematics, and some referred to the necessity of mathematics for engineering, although there was a complete range of attitudes recorded, and some students, albeit a minority, felt negative about the subject.

Students reported a range of levels of confidence in their own ability in mathematics, and the mean *Overall Confidence in Mathematics* was good, almost always above 3 (out of 5); with mean 3.5 for the first years surveyed and mean 3.7 for the second years surveyed. Comparing engineering students' confidence in their abilities gave on average: *Confidence in Life* higher than *Confidence in Mathematics,* which was higher than *Confidence in (their ability in) Statistics*. The students considered that their confidence was mainly formed at age 12-13 year (approx.) and some even considered this personal evaluation to have existed for the whole of their life. This was consistent with the *Overall Confidence in Mathematics* being like Pajares and Miller's math self-concept (1994), which is a stable construct and is slow to form and change.

The *Topic Confidences*, which were called self-efficacy by Bandura (1997) and Pajares and Miller (1994) are a fairly unstable (easier to change than the *Overall Confidence*) construct. Although, somewhat in contradiction, the majority of students (72% of first years) reported an increase in confidence during the year. This was possibly on a smaller scale (for example the change in *Overall Confidence* was 0.2); however this change was still rated as a change of 4 out of 5 by both the first and second years. Another possible explanation for this apparent contradiction could be that the students are referring to increased *Topic Confidences*.

Research Question Ia asked 'How can students' self-confidence be defined and measured?' and Research Question Ib asked 'How self-confident in mathematics and statistics are the students in the study?' In this chapter the three domains of self-confidence (defined in Chapter 2) were successfully converted to variables, and measured by the collection of student data; the results from closed questions have given clear numerical evaluations of levels of confidence whilst the open questions have provided descriptive assessments. The self-confidences were also measured using an 11 question Scale (based on Fogarty *et al*., 2001) and been shown to match the single *Overall Confidence in Mathematics* values.

Students were asked questions about the three domains of confidence: *Overall Confidence in Mathematics*, *Topic Confidences* and *Applications Confidence* (Parsons *et al*., 2009). Meaningful responses were obtained for the three domains, and the numerical values for these were found to be different, thus providing evidence that these three confidence domains were different from each other and could be applied to learning mathematics. As the eleven *Topic Confidences* were rated differently for the different topics, by each student, these were not as easy to analyse as the one single *Overall Confidence in Mathematics* (See Figures 4.4, 4.5 and 4.19). For this reason it was the single *Overall Confidence in Mathematics* (and not the *Topic Confidences* or the *Applications Confidence*) that was analysed further and tested against other variables. One of the unique aspects of this research was the focus on the *Overall Confidence in Mathematics* rather than the *Topic Confidences* which had been investigated previously by past studies (Armstrong and Croft, 1999, Frid *et al.*, 1997, Carmichael and Taylor, 2005, Engelbrecht *et al.*, 2005). The linking of the single *Overall Confidence in Mathematics* with achievement and assigning approximate numerical values to the effects was novel and original work which had not previously been undertaken.

Whilst it is good that students' *Applications Confidences* were more positive than negative, there was room for improvement, for example students could be pointed to resources or strategies to help them with any future mathematics needs, for example to on-line tools or books.

Relationships were found between students' entry qualifications (both Mathematics GCSE Grade for first years and whether they had studied A-level mathematics for second years), students' *Overall Confidence in Mathematics* and their achievement in university engineering mathematics. Higher achievement in mathematics at university was associated with higher past achievement and higher *Confidence in Mathematics* at university. These relationships were tested and found to be significant using ANOVA and Kruskal-Wallis tests, correlations and regression models.

For the first year engineering students the following predictive equation was produced by Regression analysis for their first year mathematics marks.

1st Year Mark = 31.9 + 12.3 x GCSE Grade + 5.2 x Confidence in Mathematics

This model predicts that the first year mathematics marks comprised a baseline mark of approximately 32%, and that marks increased by 12-13% for each higher GCSE mathematics grade, and by 5-6% for each increase in *Confidence in Mathematics*. Similar models were also produced using *Liking of Mathematics* and Motivation in place of *Confidence in Mathematics.*

Second year students were generally more confident and liked mathematics more, however they achieved less well and rated themselves as less motivated in the second year mathematics than in their first year. Second year BEng and MEng students' marks were also analysed using Regression analysis and a valid model was produced which was based on the students' *Confidence in Mathematics* and what type of A level Mathematics the students had studied. The following predictive equation was produced by Regression analysis (for which the A level codes were reversed A2=3, AS=2, Other=1 and None=0) and Confidence in mathematics was recoded to 0-4 (4=high).

2nd Year Mathematics Mark = 25.72 + 5.61 * A level + 9.43 * Maths Confidence
(R^2 = 34.3%, n=40)

It can be seen that, in this model for the second years, the effect of the students' confidence was greater than the effect of the past qualification (type of A level mathematics), almost doubled; each increased confidence rating was associated with a 9.43% increase in students marks. The author suggests that confidence in mathematics was both a cause and an effect, where the effect of achievement on confidence and of confidence on achievement was cyclical in a manner similar to Ernest's Positive and Negative Cycles in Mathematics (Ernest, 2000). Other regression models were also produced to predict second year mathematics marks, and these will be summarized and compared with models for the other student groups in Section 6.4.1, and are listed below

It was found that students' second year mathematics marks were lower than the first year marks and those students without A Level mathematics dropped their mark by the most. The following predictive equation was produced based on the students' type of A Level mathematics. In this model the A Level type code was not reversed (A2 Grade A=0, A2 other grades=1, AS=2, Other =3 and None=4).

Drop in Second Year Mathematics marks = 8.14 + 4.18 x A Level Type Code

This predicted that students without any A level mathematics would drop 25% in their marks in the second year mathematics compared to their first year mark, compared to an 8% drop for students with grade A at A2 level mathematics. When one considers that these students without A2 mathematics would have also achieved lower first year mathematics marks, this makes this drop even more serious. This is further evidence that these students are most at risk of failing the second year mathematics examination, and has provided quantitative evidence for an already recognised problem.

Age, Dyslexia and the time spent working outside lectures were shown to not have a significant effect on first year mathematics marks.

First year students with the lowest GCSE grades were generally the least confident and least successful in mathematics; as were second year students without A Level mathematics. It is recommended that these students should be identified and targeted with extra help and confidence building. At Harper Adams mathematically weaker first year students are identified early in the first weeks of the year by the numeracy screening process and are brought to the lecturers' attention and encouraged to seek support, but more work could be done to follow up at risk second years. These students are targeted with extra help with the taught material and to fill in gaps of knowledge, but more could also be done to help boost these students' confidence.

The students were asked what had '*helped'* and *'hindered'* their learning. There were much fewer hindrances, but these did include the lecturer going too fast and a lack of worked examples for the handouts for another mathematics-related subject. For what had helped their learning, responses included: good teaching, Mathematics Support, student handouts with worked examples, applying the mathematics to practical situations, and working with friends. Bandura's theory of self-efficacy (1997) would suggest that it was predominantly their success at the subject that had contributed to their increased confidence, both when succeeding with examples in class each week during the year and when achieving good examination results, although this was not something that came through clearly in the students' written questionnaire responses. In addition, students listed some other helpful features such as small class sizes, and past exam papers with answers, and both easy and hard work was referred to as helpful by the students (for example, one student wanted more easy examples at the start of mechanics exercises).

These questionnaires have provided extensive insight into the views and experiences of the engineering students at Harper Adams between 2005 and 2007. Whilst these students were broadly positive, confident and successful in mathematics, their individual responses, past experiences and achievement encompassed a wide range. The results in this chapter have contributed to answering all of the Research Questions (I a-d and II a-e) with respect to the engineering students. The results of the natural and social science students will now be presented in the following chapter (Chapter 5).

5 NATURAL AND SOCIAL SCIENCE STUDENT QUESTIONNAIRES

5.1 Introduction to the Natural and Social Science Student Questionnaires

This section will present the results of questionnaires completed by natural and social science students who were studying modules containing statistics in May 2005, 2006 and 2007. Results for closed and open questions will be summarised and presented in tables and graphs, with comments on the findings. Inter-relations between the different variables were sought, particularly between student marks, past mathematics qualifications (usually GCSE mathematics grades) and confidences. Regression analyses were also carried out with the aim of finding explanatory models. This chapter follows on from Chapter 4 in which the results of the Engineering students' questionnaires were presented, and it will be shown that these students learning statistics had different characteristics from the engineering students learning mathematics.

The questionnaires analysed in this chapter were completed by students studying one of the following modules containing statistics:

- Academic and Professional Development statistics (APD) for 1st year students;
- Research Design and Analysis (RDA) in 2005, which was renamed as Research Methods in 2006 and 2007 (RMNat), for 2nd and 3rd year students;
- Research Methods (RMSS) also for 2nd and 3rd year students.

These modules will hereafter be referred to by the abbreviations given above.

The 1st year APD students were from four departments: Animal; Business; Crops; and Rural, Environment and Land Management (REALM) departments. The content of the lectures and assessments were broadly similar for the different departments, but were tailored to the course subject areas to make them more relevant. The RMNat module was taught to natural science students in the Crops and Animals departments, whilst the RMSS module was taught to social science students in the Business and REALM departments, and these modules were also tailored to the different course subject areas. Further descriptions of the timing and content of these questionnaires was provided in the Methodology in Chapter 3.

There were some differences between the 2005, 2006 and 2007 modules and questionnaires, namely:

- The module content, assessment and teaching staff had some differences; particularly for the second year statistics modules. The assessment for the RMSS module in 2005 was a written research methods report (with only 30-40% statistics content), which was replaced in 2006 and 2007 by a written exam (with 50% statistics content, 2 questions out of 4). The assessment for the RMNat module changed each year, from an open book Genstat computer examination in 2005, to a similar exam but no longer open book in 2006, and then made purposely more difficult again in 2007. These assessment changes would be expected to decrease student achievement and confidence as these made the assessments more difficult.
- In 2005 attendance for 1st year APD statistics was compulsory. This compulsory attendance was dropped in 2006 and lower attendance was noted by lecturers, especially in the final lectures. This affected the samples of questionnaires completed by students in their final lectures, thus fewer questionnaires were completed and students with poor attendance were less well represented. A comparison of students' marks for those completing questionnaires with the overall cohort found that BSc students completing the questionnaires had significantly better marks than the whole cohort overall.
- Both second and third year students were taught the same statistics modules in 2006 due to a change from a semester-based to a term-based academic year. Second year students studied Research Methods before taking their work placement year, and third year students studied Research Methods after returning from work placement. Note: final year degree students are fourth years.

It will be shown that overall these students were very lacking in confidence in their ability to learn and do statistics, and were reluctant to study the statistics in these modules (overall only 26% would have chosen to study the statistics). Their negative beliefs and attitudes arose mainly from their past experiences, but, fortunately, the students' marks were generally much better than their low confidences and negative attitudes.

The numbers of questionnaires analysed from the different student groups, together with a summary of the mean values for the student marks, confidences and other variables are shown in Table 5.1 below.

The numbers of students shown are the numbers who completed a questionnaire. Sample questionnaires can be seen in Appendices II, III and V for the exact question wording and layout. The confidences, liking of subjects (which are attitudes) and motivation responses were ratings from 1 to 5 (1=low and 5=high), and 'Whether students would choose to study the statistics in the module' was a Y/N (Yes, No or Blank) response. The students' marks were subsequently obtained from the college records using the student id numbers. These questionnaires were completed before the students had sat their RMSS and RMNat exams and before the APD assignment marks were released.

For each different module in Table 5.1 there were broadly similar results in the different years. One exception was the decreasing marks for the natural science students, which was an intended consequence of the changes to the assessments. Another exception was the very low percentage of RMSS students who would have chosen to study statistics in 2007 stands out; the reason for this particularly low percentage was not known.

Some clear patterns are evident in the mean confidences shown in Table 5.1. Students were fairly neutral about mathematics (mean confidence 3.1, mean *Liking of Mathematics* 3.0), and they were more confident about themselves for 'life in general' (mean 3.8), but they were noticeably less confident about their ability to learn and do statistics (mean confidence 2.7, mean *Liking of Statistics* 2.5 which was the lowest mean rating of all). All of the ratings related to statistics in Table 5.1 were below 3 (i.e. negative); in contrast to the ratings for life in general which were all above 3 (mean 3.8). The students were more confident after these modules (mean 3.3), so must have been even less confident before, but unfortunately they liked statistics slightly less after these modules (mean for Liked More after the module 2.9). A similar pattern can also be seen in each of the three modules separately. Although regarding their *Liking of Mathematics* the second year natural science students responded more positively (mean 3.1) compared to the social science students' overall slight dislike (mean 2.8).

Table 5.1 Summary of Students' Confidences, Attitudes, Motivation and Marks for the Surveyed Modules containing Statistics

		Confidence				Attitude			Motivation		Marks	
Student Group and Year	No. Students	Confidence in Mathematics	Confidence in Statistics	Confidence in Life	More Confident?	Like Mathematics	Like Statistics	Like Subject More After Module	Motivation Rating	% Would Choose to Study Module	Overall Mean Mark %	Statistics Questions Mean Mark %
1st Year APD Statistics with Excel (APD)												
2005	118	3.1	2.8	3.6	3.3	3.0	2.5	2.8	2.7	31	51.4	
2006	83	3.0	2.7	3.9	3.5	3.0	2.6	3.1	2.9	19	50.8	
Total	201	3.0	2.7	3.7	3.4	3.0	2.5	2.9	2.8	26	51.2	
2nd and 3rd Year Natural Science Students' Statistics with Genstat (RMNat)												
2005	52	3.3	3.0	3.7	3.3	3.0	2.8	3.0	2.9	44	71.3	
2006	102	3.3	2.7	3.8	3.1	3.0	2.5	2.7	2.7	23	60.9	
2007	52	3.1	2.7	3.9	3.8	3.2	2.6	3.1	2.7	25	57.7	
Total	206	3.3	2.8	3.8	3.3	3.1	2.6	2.9	2.7	29	62.6	
2nd and 3rd Year Social Science Students' Statistics with SPSS (RMSS)												
2005	29	3.2	2.8	3.7	3.3	2.9	2.4	2.9	2.9	34	59.3	N/A
2006	47	2.7	2.4	3.8	3.2	2.6	2.3	2.9	2.9	33	56.0	68.4
2007	55	3.2	2.5	3.9	3.1	2.9	2.2	2.5	2.5	9	59.8	69.2
Total	131	3.0	2.5	3.8	3.2	2.8	2.3	2.7	2.7	23	58.3	68.8
Total	337	*Total for 2nd and 3rd year statistics questionnaires*										
Grand totals / Means for 1st, 2nd and 3rd year statistics questionnaires												
Total	538	3.1	2.7	3.8	3.3	3.0	2.5	2.9	2.8	26%	57.3	68.8

The students were also lacking motivation in all three modules (mean motivation 2.8) and the percentage of students who would *'choose to study the statistics in this module'* was very low, often in the twenties (mean 26%). This means that overall three quarters of these students would not have chosen to study statistics. The most extreme case shown was that only 9% of the 2007 RMSS students would have chosen to study the statistics in that module. What is not clear is whether the students interpreted this question as meaning would they have chosen this module before taking it or would they choose it now that they had taken it; however this distinction was fairly irrelevant, as both interpretations still lead to the finding that the majority of these students were reluctant to study statistics. It was fortunate that these modules were compulsory, and that attendance was also mostly compulsory, as many students would otherwise have avoided these lectures in which they were taught material which they would later need.

The right hand columns in Table 5.1 contain the mean student marks for these modules. Overall the students were successful and passed these modules (mean mark 57%), with the 2005 RMNat mean mark being impressively high (at 71%). The actual 2006 and 2007 RMSS examination papers were examined and the marks for the two descriptive research methods questions were separated out from the two statistics calculations questions. The marks for the statistical calculations questions were very good, almost 70% in both 2006 and 2007, compared with a mean of approximately 50% for the non-calculation questions, almost 20% lower. Considering that the RMSS students had the lowest confidences and likings of statistics of the three modules this shows the greatest disparity between confidence levels and actual achievement in statistics; this good level of achievement in statistics is very inconsistent with the students' low confidences, negative attitudes and lack of motivation. It is suggested that the good news of past student successes should be passed onto future cohorts to help them to become more confident about passing these modules.

Students' low confidence, liking and motivation for learning statistics was a sad situation, which contrasted with the genuinely good achievement in statistics by these students. This data will be further investigated and presented by module, with analysis of the open question responses, in the following subsections.

5.2 1st Year APD Statistics Questionnaire Results

This section will present further results and analysis of the 1st year APD students' questionnaires which were completed in May 2005 and May 2006. These APD students' marks, confidences and attitudes have already been summarised in Table 5.1. The response rates for these surveys were 35% in 2005 (118 out of 340 students) and 24% in 2006 (83 of 348 students which included 12 students who did not complete the APD assignment). Of the 83 2006 APD questionnaires 77 (22%) could be linked to their assignment mark. Of these 65 students were BSc students (which was 28% of a total of 233 BSc students in 2006) for 60 (26%) of whom their mark was known. 18 were HND/FdSc students (which was 16% of a total of 115 HND/FdSc students in 2006) for 17 (15%) of whom their mark was known. These response rates were fairly low as some lecturers did not give questionnaires to their lecture groups and there were reduced numbers of students present at the final lectures.

Attendance at the final APD lecture of 2006, when the attendance was optional, was reported to be only around 50% in some cases. Analysis including a z-test was carried out to determine whether the sample of students surveyed was representative of the whole cohort. There was found to be a significant difference between the marks obtained by the BSc students surveyed (i.e. those present at the final lecture) and the degree students as a whole (by z-test, n=60, 226, P=0.005, two-tailed test). The surveyed students' mean mark (56%) was significantly different (higher) than, but not greatly different from, that for the whole BSc cohort (mean 50%). From this it could be concluded that either:

- attendance at the final lecture was by better performing students, and/or
- attendance at the final lecture contributed to achieving a higher mark in the assignment.

The final lecture comprised guidance for the APD assignment thus it is likely that the second conclusion was true, but it is possible that the first statement was also true.

The surveyed HND/FdSc students, however, were not found to have significantly different marks compared to the whole HND/FdSc cohort (t-test, n=16,109, P=0.126, two-tailed test). The surveyed students' mean mark (31%) was not significantly different to the mean mark for the whole HND/FdSc cohort (mean 38%). However the Coefficient of Variation was 50%, which indicated a large variation in HND/FdSc student marks. Their maximum APD assignment mark was 85% and the minimum was 0%.

The surveyed BSc students were slightly better performing than the whole cohort, and therefore were likely to have better attitudes. So any findings from these questionnaires (e.g. levels of confidence and attitudes) were expected to be better than had the whole cohort completed questionnaires, and thus the findings from this survey are considered to understate, rather than overstate, the real issues with students' lack of confidence, poor attitudes and lack of motivation.

5.2.1 1st Year APD Statistics Closed Questions and Marks Results

This sub-section will examine the frequency distributions of student responses to confidences, attitudes and motivation for the combined 2005 and 2006 APD questionnaire data. The overall confidence frequencies are presented in Figure 5.1 below, for *Confidence in Mathematics*, *Confidence in Statistics* (with data values), *Confidence in Life* in general and Whether students were more confident after the module.

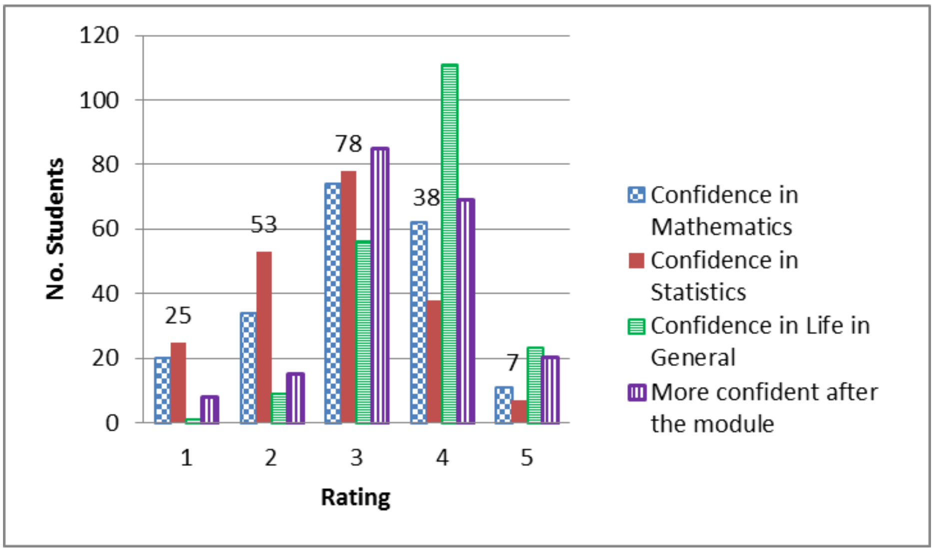

Figure 5.1 APD 2005 and 2006 Overall Confidences (1 to 5, 5 = High)

Both the overall *Confidence in Mathematics* and *Confidence in Statistics* distributions peak at a rating of 3 on Figure 5.1 above, but the *Confidence in Statistics* can be seen to have more ratings of 1 or 2 than for *Confidence in Mathematics*, which is consistent with the lower mean for *Confidence in Statistics*. How much more confident the students felt after the statistics in the module also peaked at 3, but had many ratings of 4. *Confidence in Life* in general peaked at 4 and can be seen to have much higher ratings altogether. These distributions are consistent with the means shown in Table 5.1.

The frequencies for the liking and motivation ratings are shown below in Figure 5.2. The frequency data values shown represent the student ratings for their *Liking of Statistics*. There were more 1 and 2 ratings and very few 5's for all of the attributes on the graph. The highest frequencies in the 1 and 2 ratings represent students' liking (or disliking) of statistics, with the 2 rating frequency standing out as particularly high. Students liked statistics less than they liked mathematics, there were more 4's than 2's for *Liking of Mathematics* and they liked statistics slightly less after the module (mean 2.9). Even for Motivation there were more 1's and 2's than 5's and 4's. This shows an overall dislike for, and lack of motivation in, statistics by these APD students.

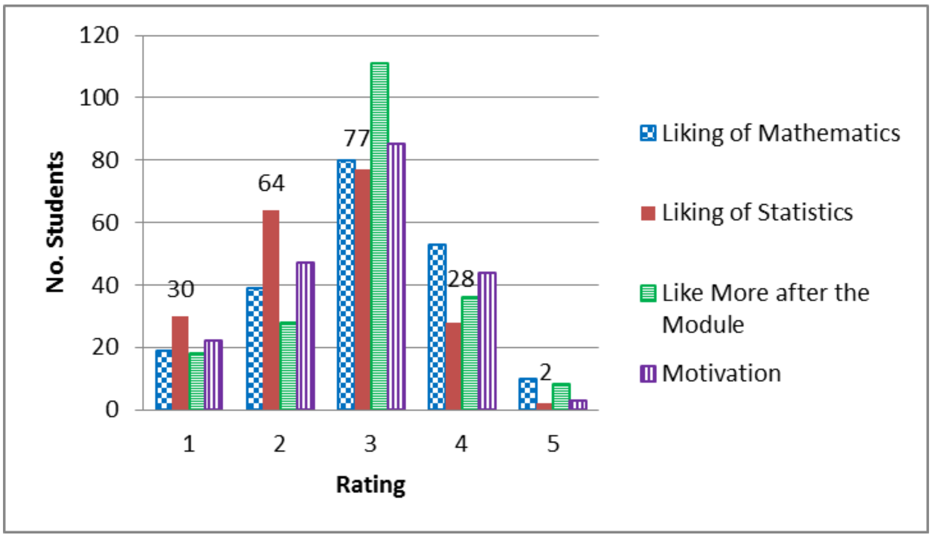

Figure 5.2 APD 2005 and 2006 Students' Liking and Motivation Rating Frequencies

Table 5.2 details the percentages of first year APD statistics respondents who gave negative (1 or 2) responses. Unfortunately, 47% of APD students rated their *Liking of Statistics* as only 1 or 2 out of 5, and slightly fewer, 39%, rated their *Confidence in Statistics* as only 1 or 2 out of 5. Many more students gave lower ratings for statistics than for mathematics in general. This may be due to these students having just completed a module at which their statistics learning was to a higher level (more difficult) than for their last mathematics learning (generally GCSE mathematics). So once again we can see that overall the *Confidence in Statistics* and *Liking of Statistics* by these students was very low and contrasts with their general confidence (as measured by their *Confidence in Life*).

Table 5.2 Percentage of 2005 & 2006 First Year APD Statistics Students with Low Confidence Ratings (1 to 5, 5 = High)

Attribute Being Rated	No. Students with rating 1	No. Students with rating 1 or 2	Mean Rating
Confidence in Statistics	12%	39%	2.75
Liking of Statistics	15%	**47%**	2.54
Confidence in Mathematics	10%	27%	3.05
Liking of Mathematics	9%	29%	2.98
Confidence in Life	0.5%	5%	3.73

88% of the first year statistics students considered that they were more confident (or the same) after the module, which is very positive. Unfortunately this also implies that many students felt worse before (and possibly during) the module, thus the above proportions of students with negative attitudes towards statistics were higher, a worse situation, before studying this APD module.

Students' ages ranged from 18 to 32, with the mean age of 19.2 years. Most students had not studied A level mathematics: 19, 9% had studied A2, 8, 4% had studied AS, 17, 8% had studied some other post-GCSE maths qualification and 157, 78% had not studied any A level Maths or other post-GCSE maths qualification. On average students spent 1.2 hours working per week outside of lectures on this 1st year statistics module.

Table 5.3 below shows the mean *Topic Confidences* for the 1st year APD students. As can be seen there is considerable variation in the students' confidences for the different topics, and as would be expected the students were more confident in the more familiar topics and less confident in the more difficult topics. GCSE topics of: "Mean, Median and Mode" and "Percentages", which all students should have known prior to this module, are the only ones which have come out with a confidence above 4 out of 5, and these also did not receive any ratings below 2 (unlike all of the other topics which did get some 1's).

It is noteworthy that all of these mean ratings are at least 3 (except for linear regression) so these *Topic Confidences* were noticeably higher than the overall *Confidences in Statistics*. In 2006 74 (89%) of the 83 surveyed APD students were more confident on average in their *Topic Confidences* than their overall *Confidence in Statistics* by a mean rating difference of +0.3 out of 5. Only 9 students were less confident in the topics, by -0.36 out of 5. Similar figures were also calculated for the difference between the *Topic Confidences* and their overall *Confidence in Mathematics*. These results demonstrate how students can feel confident to do a particular task (*Topic Confidence* domain, Parsons *et al.*, 2009), but remain lacking in confidence overall, i.e. that their *Overall Confidence in Mathematics* (also called Operative capability by Bandura, 1997, and called mathematics self-concept, by Pajares and Miller, 1994) is a more stable attribute which is harder, and takes longer to change, than their task specific self-efficacies. This was also described by Kent and Noss, (2003) who wrote that it was a slow process to raise students' confidence which could not be done quickly, unlike filling gaps in knowledge. Whilst Kent and Noss were writing about engineering students learning mathematics we can see that the same finding applies here to students learning statistics.

Table 5.3 Summary of Topic Confidences for APD Statistics 2005 and 2006 (1 to 5, 5 = High)

Topic	Mean Confidence Rating 2005 and 2006	Mean Confidence Rating 2005 only	Apply Topic * Rating 2005
Mean, Median, Mode	4.2	4.3	4.0
Percentages	4.0	4.0	3.9
Presenting Data in Excel (e.g. Graphs)	3.9	3.8	3.6
Using Formulae	3.7	3.8	3.6
Calculations in Excel	3.7	3.6	3.4
Data Analysis in Excel	3.4	3.3	3.3
Explaining Results	3.3	3.2	3.2
Correlation	3.3	3.2	3.1
Standard Deviation	3.3	3.2	3.1
T Tests	3.0	3.0	2.8
Linear Regression	2.9	2.7	2.7

Note *: In 2005 11 *Apply Topic* questions were asked, which were replaced by a single *Applications Confidence* question in 2006 and 2007.

In 2005 eleven topic *Applications Confidences* were rated by students, but as can be seen in Table 5.3 above these were slightly lower, but were otherwise very similar to the *Topic Confidences* and did not really provide any useful additional detail, so in 2006 these eleven questions were reduced to two questions: asking students to rate how their confidence would change (increase, remain the same, or decrease) and to explain why. In 2005 the mean *Apply Topic* rating was 3.3 (compared to the mean topic rating of 3.5) and in 2006 the mean *Applications Topic* rating was 3.6, i.e. that overall students thought they would be more confident to apply the topics in the future than they were at the time of the survey. Those who rated themselves as 2 (i.e. less confident in the future) mainly explained that they would have forgotten the statistics by then (3 comments), whereas those who thought that they would be more confident (rating themselves as 4 or 5) wrote explanations such as that they would have had more practice by then, others wrote about the good effects of teaching on the module or help that they expected to receive (15 comments in total).

Eleven scale questions (based on Fogarty *et al.*, 2001) were included in the 2006 APD questionnaires. These questions are listed in Table 5.4 below with the mean student ratings, with the four positive statements shown before the negative statements, and listed in order of the mean response. Overall there were only two scale questions for which mean response indicated an average positive student sentiment towards learning mathematics, two for which the mean was neutral, and seven questions for the mean sentiment was negative.

Table 5.4 APD 2006 Scale Questions with Mean Response and Classification of the statement and the mean response

APD Scale Question 2006	Positive / Negative Question	Mean Rating	Positive / Negative Mean Sentiment
Q45. I enjoy trying to solve new mathematics problems	+	3.00	Neutral
Q47. I find many mathematics problems interesting and challenging	+	3.00	Neutral
Q41. When I meet a new maths problem I know I can handle it	+	2.89	Negative
Q40. I have less trouble learning maths than other subjects	+	2.85	Negative
Q44. I have never felt myself able to learn mathematics	-	3.44*	Positive
Q46. I find mathematics frightening	-	3.34*	Positive
Q50. I find maths confusing	-	2.99*	Negative
Q43. It takes me longer to understand mathematics than the average person	-	2.96*	Negative
Q48. I don't understand how some people seem to enjoy mathematics problems	-	2.96*	Negative
Q42. I do not have a mathematical mind	-	2.77*	Negative
Q49. I have never been very excited about maths	-	2.55*	Negative

Question text adapted from Fogarty *et al.*, 2001.
Values indicated * have been reversed (e.g.1 instead of 5, etc.) so that the responses all apply to positively worded questions for comparison.

Further analysis of these scale questions is presented in subsection 5.2.2.3 for the relationships with the APD marks and *Confidence in Mathematics* and *Confidence in*

Statistics, and these variables are used in Factor Analysis and Cluster Analysis in sub-section 5.2.4.

39 (19%) APD students responded that they were dyslexic, 21 (10%) were unsure whether they were dyslexic and 141 knew that they were not dyslexic (70%) of the 201 students surveyed. Analysis of the number of students who received mathematics support is given in sub-section 5.2.2.4.

In this sub-section the mean results and frequencies have been presented for most of the APD questionnaires closed question variables including confidences, liking of the subject and motivation; the inter-relations between these variables will now be described in the next sub-sections.

5.2.2 First Year APD Statistics Relationships between Variables

5.2.2.1 First Year APD Statistics Significant Relationships with Marks, Confidence in Mathematics and Confidence in Statistics

It was of primary interest to find out which characteristics contributed to enabling students to succeed in their statistics assessments, but what contributed to, or was associated with students' confidence in their ability in mathematics and statistics was also of key interest. Following on from the various summaries of the students' levels of achievement, confidence and other characteristics in the previous sub-section, this sub-section will explore the inter-relations between those characteristics. As a first step the combined 2005 and 2006 1st year APD statistics marks (which were interval data) were analysed by ANOVA tests, and the overall confidences (which were ordinal data) were analysed by Kruskal Wallis tests, against different variables to check for significant relationships and the results are shown in Table 5.5 below. These tests indicate whether the Factor variable had had a significant effect on the APD Statistics Report mark or on the students' *Confidence in Mathematics* or their *Confidence in Statistics*, where a P-value <=0.05 indicated a significant effect and is shown in bold font. Both the overall *Confidence in Mathematics* and *Confidence in Statistics* have been analysed as the questions asked about both of these, and some interesting differences were found.

Significant relations were found between 1st year APD statistics assignment marks and the following variables using ANOVA and Kruskal Wallis tests (as detailed in Table 5.5 below).

- Past qualifications: Maths GCSE Grade, Tier, Award and Course (both award and course are determined to some extent by students' past qualifications). The mean APD assignment mark for BSc students was 52.7%, and for HND/FdSc students it was 43.4%.
- Confidence: *Confidence in Mathematics*, *Confidence in Statistics*, and whether More confident after the module. Higher confidence was associated with higher marks and this is described further in the next sub-section.
- Motivation: Motivation rating, and whether Motivation was the same as for other modules. Higher motivation was associated with higher marks, although there was a wide range of marks for all motivation ratings, for example for motivation rating 2 the APD marks ranged from 0% to 80%.
- Whether students had had a moment of 'Inspiration'. Students who had had a moment of inspiration had significantly lower marks, mean = 48% compared to 54% for those who had not had a moment of inspiration. It is not really understood why this was.

As for the engineering students' findings, there was no significant difference in marks for gender (P=0.461, Male mean = 50% and Female Mean 52%) or age (P=0.076). The mean mark for dyslexic students was 49%, for non-dyslexic students was 51% and for students who were not sure whether they were dyslexic their mean mark 55%, but the differences in these mean marks were not significant (P = 0.329). Other variables which were not significantly related to the APD marks were students' liking of the subjects, the time spent working outside lectures and whether they had used the mathematics support. There were too many different courses to run a Kruskal Wallis test for these.

It can be seen from Table 5.5 that there was a very similar pattern for which variables had significant relations with APD statistics students' *Confidence in Mathematics* and those with significant relations with the students' *Confidence in Statistics*. Significant relations were found with the following variables and *Confidence in Mathematics* (and also with *Confidence in Statistics* except where stated otherwise):

- Past qualifications: Maths GCSE Grade, Tier and whether had studied maths A level
- Confidence and Liking: *Confidence in Statistics*, Whether they were More confident after the module, their *Liking of Mathematics* and *Liking of Statistics*
- Whether they liked the subject more after the module – this was significant for *Confidence in Statistics* but not for *Confidence in Mathematics*.

Table 5.5 First Year APD Statistics 2005 and 2006 ANOVA and Kruskal Wallis Tests

	Statistics Mark		Confidence in Mathematics		Confidence in Statistics	
Factor	**ANOVA P-Value**		**Kruskal Wallis P-Value**		**Kruskal Wallis P-Value**	
Award	**0.002**	**	0.816		0.452	
Course	**<0.001**	***	X		X	
Group	0.279		0.091		0.076	
Gender	0.461		**0.003**	**	**0.047**	**
Age	0.076		0.732		0.285	
Dyslexia	0.329		**0.029**	*	0.409	
Dyscalculic	0.399		X		X	
GCSE grade	**<0.001**	***	**<0.001**	***	**<0.001**	***
GCSE tier	**<0.001**	***	**<0.001**	***	**<0.001**	***
A level	0.203		**<0.001**	***	**<0.001**	***
Would choose to study module	0.101		**0.001**	***	**<0.001**	***
Confidence in mathematics	**0.020**	*	-		**<0.001**	***
Confidence in statistics	**0.019**	*	**<0.001**	***	-	
Confidence in Life	0.707		0.413		0.582	
More confident after module	**0.003**	*	**<0.001**	***	**0.004**	***
Like mathematics	0.071		**<0.001**	***	**<0.001**	***
Like statistics	0.148		**<0.001**	***	**<0.001**	***
Like more after module	0.120		0.061		**0.008**	**
Motivation	**<0.001**	**	**<0.001**	***	**<0.001**	***
Motivation same	**0.034**	*	**0.025**	*	**0.016**	*
Time spent	0.714		0.861		0.911	
Inspiration	**0.005**	**	0.602		0.787	
Mathematics support	0.975		0.508		0.545	

Key: * P<=0.05, ** P<=0.01, *** P<=0.001

X= Kruskal Wallis test could not be run as there were too many Course names and too few dyscalculic students.

- Motivation: Motivation rating, whether would choose to study the module and whether Motivation was the same as for other modules. Motivations ratings of 3 and 4 had the highest mean *Confidence in Mathematics* values, whereas the most motivated (value 5) had a mean confidence of 2.33, showing that some students who are very lacking confidence can be very motivated. This was also found by Carmichael and Taylor (2005).
- Gender: Males were significantly more confident in mathematics than females (*Confidence in Mathematics* male mean 3.3, female mean 2.8, P=0.003, n=201). Males were significantly more confident in their ability in statistics than females (*Confidence in Statistics* male mean 2.9, female mean 2.6, P=0.047, n=201). There is a slightly larger difference in confidence between males and females for mathematics than for statistics. Other studies which found females were less confident included Betz and Hackett (1983), McLeod (1992), Brown *et al.* (2003b) and Carmichael and Taylor (2005).
- Whether Dyslexic: There was a significant difference in the *Confidence in Mathematics* between dyslexic and non-dyslexic students (P=0.029). The mean *Confidence in Mathematics* for non-dyslexic students was 3.2, for dyslexic students was 2.9 and for those who were not sure if they were dyslexic was 2.7. Dyslexia was not found to make a significant difference to students' *Confidence in Statistics*. There was only one self-declared dyscalculic student so the effect of dyscalculia could not be assessed.

5.2.2.2 First Year APD Statistics Analysis by Mathematics GCSE, A level and Confidence

Students' GCSE Mathematics grades have been shown in the previous sub-section to significantly affect their APD marks and *Confidence in Mathematics*. Students' confidences and other variables (as shown in Table 5.1) have been further analysed by GCSE grade and whether the students had studied A2 or AS mathematics, the results of which are presented in Table 5.6 and Figure 5.3 below.

Table 5.6 Summary of 1st Year APD Statistics Students' Confidence Ratings

(Mean student ratings, 1 to 5, 5 = High)

Mathematics A Level / GCSE Grade	No. Students	APD Mark %	Mathematics Confidence	Statistics Confidence	Topic Confidence	Confidence in Life	More Confident	Like Mathematics	Like Statistics	Like Subject More	Motivation	Would Choose %
A2	19	58.1	4.2	3.6	4.1	3.6	3.7	4.1	3.2	3.3	3.5	52.6
AS	8	49.0	3.8	3.5	3.7	3.5	3.8	3.6	3.3	3.1	3.0	37.5
GCSE Grade A/A*	13	62.2	3.7	3.2	3.7	3.7	3.5	3.0	2.5	2.9	3.1	23.1
GCSE Grade B	77	54.7	3.2	2.8	3.6	3.8	3.5	3.0	2.6	2.9	2.8	24.7
GCSE Grade C	64	46.8	2.7	2.5	3.3	3.7	3.2	2.6	2.3	2.8	2.5	20.0
GCSE Grade D/E	16	39.5	2.1	2.2	3.3	3.8	3.3	2.7	2.4	2.9	2.8	31.3
Total	**197**	**51.2**	**3.0**	**2.7**	**3.5**	**3.7**	**3.4**	**3.0**	**2.5**	**2.9**	**2.8**	**26.4**

Nb. Four students did not provide their Mathematics GCSE grade and were excluded from this analysis.

The students' mean *Confidence in Mathematics* and mean *Confidence in Statistics* are shown on Figure 5.3 below, on which the trend that confidence decreases with decreasing levels of pre-university achievement in mathematics can be clearly seen.

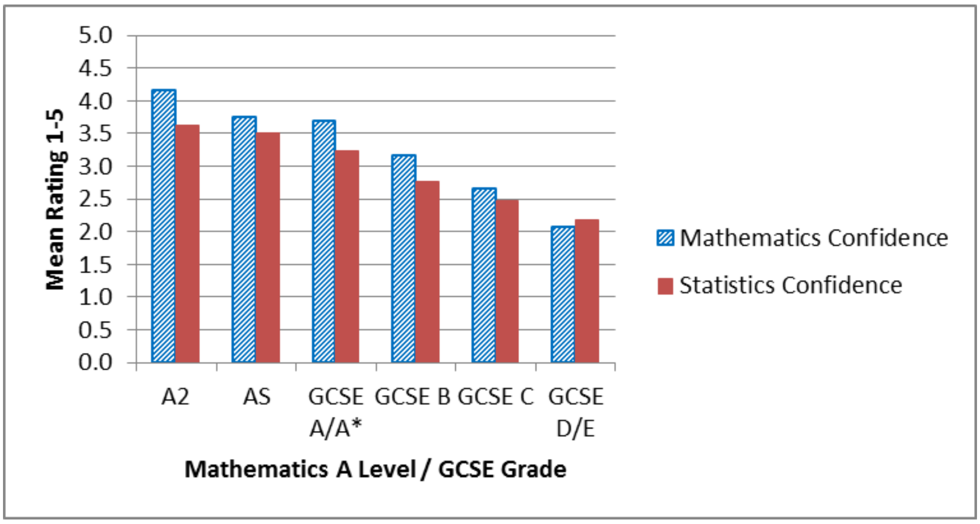

Figure 5.3 APD Students' Confidence in Mathematics and Statistics by Mathematics A Level / GCSE Grade

Figure 5.4 below presents the overall *Confidences in Mathematics* and *Confidences in Statistics* together with students' likings for these subjects and their mean *Topic Confidences*. For almost every student group a similar pattern can be seen as was shown in Table 5.1 (and is shown again as the Overall means on Figure 5.3), i.e.

- that *Confidence in Mathematics* is higher than *Confidence in Statistics*;
- the lowest rating of all is students' *Liking of Statistics* (or dislike);
- For GCSE grades B and below the mean *Topic Confidences* are the highest of the ratings shown for that Mathematics GCSE grade.

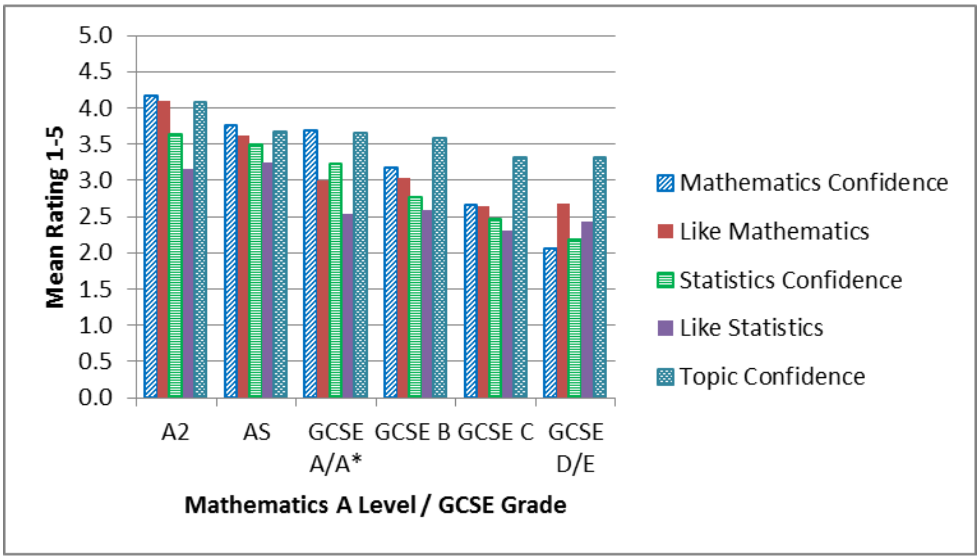

Figure 5.4 APD Students' Confidence and Liking Rating by Mathematics A Level / GCSE Grade

The APD Assignment mean marks by confidence ratings are shown below in Table 5.7 and on Figure 5.5. A clear linear trend can be seen in that marks increase as confidence increases. There is a clearer linear trend for *Confidence in Mathematics* than for *Confidence in Statistics*. This linear trend will be investigated further in the correlation and regression analysis in Section 5.2.3.

Table 5.7 Summary of 1st Year APD Statistics Assignment Marks by Confidence Ratings

	Confidence Rating	1	2	3	4	5
Confidence in Mathematics	Mean mark %	42.7	47.6	51.7	54.2	57.8
	No. students	20	31	68	58	10
Confidence in Statistics	Mean mark %	42.9	49.5	52.3	55.8	55.7
	No. students	25	45	74	36	7

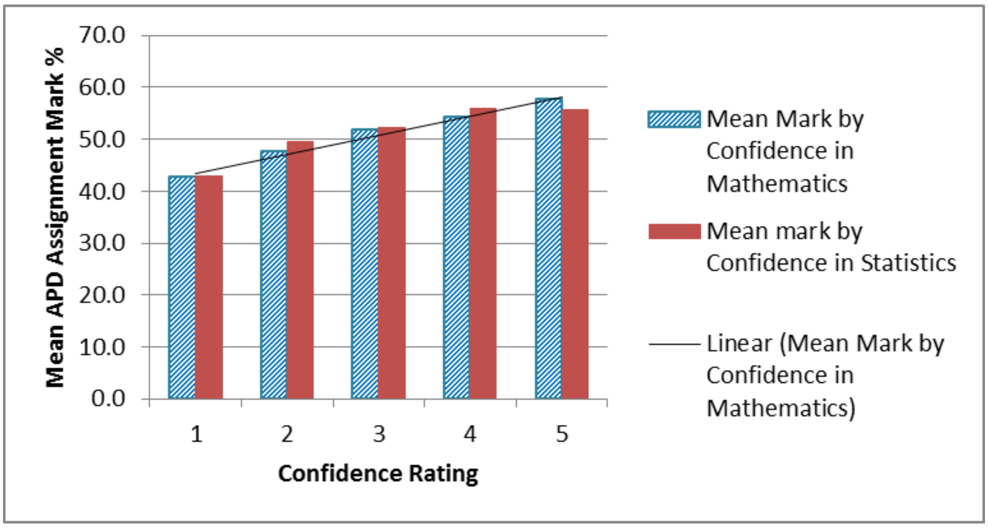

Figure 5.5 APD Students' Confidence and Liking Rating by Mathematics A Level / GCSE Grade

5.2.2.3 First Year APD Statistics 2006 Scale Question Relations to Marks and Overall Confidence in Mathematics and Statistics

The eleven Scale questions (based on Fogarty *et al.,* 2001), the mean responses for which were summarised in sub-section 5.2.1 in Table 5.4, have been further analysed to investigate relations between the responses to these scale questions and the students' APD marks, *Confidence in Mathematics* and *Confidence in Statistics*. The results are shown below in Table 5.8.

Table 5.8 First Year APD Statistics 2006 Scale Question and APD Mark, Confidence in Mathematics and Confidence in Statistics ANOVA and Kruskal Wallis Tests

Maths Scale questions - Questions 40-50	Statistics Report Mark % ANOVA P-Value		Confidence in Mathematics Rating Kruskal Wallis P-Value		Confidence in Statistics Rating Kruskal Wallis P-Value	
Q40. I have less trouble learning maths than other subjects	0.107		**<0.001**	***	**<0.001**	***
Q41. When I meet a new maths problem I know I can handle it	0.061		**<0.001**	***	**<0.001**	***
Q42. I do not have a mathematical mind	0.061		**<0.001**	***	**<0.001**	***
Q43. It takes me longer to understand mathematics than the average person	0.128		**<0.001**	***	**<0.001**	***
Q44. I have never felt myself able to learn mathematics	**0.003**	**	**<0.001**	***	**0.002**	**
Q45. I enjoy trying to solve new mathematics problems	0.515		**<0.001**	***	**0.002**	**
Q46. I find mathematics frightening	0.232		**<0.001**	***	**<0.001**	***
Q47. I find many mathematics problems interesting and challenging	0.698		**<0.001**	***	**0.004**	**
Q48. I don't understand how some people seem to enjoy mathematics problems	0.637		**<0.001**	***	**<0.001**	***
Q49. I have never been very excited about maths	0.555		**<0.001**	***	**<0.001**	***
Q50. I find maths confusing	0.465		**<0.001**	***	**<0.001**	***

Key: * P<=0.05, ** P<=0.01, *** P<=0.001. n=80

All the mathematics confidence Scale questions gave highly significant relations with the students' *Confidence in Mathematics*, and also with students' *Confidence in Statistics*, as shown in Table 5.8 above, but not, with one exception, with the Assignment Mark. Thus the Scale questions and the single confidence ratings are pertaining to very similar underlying characteristics. See also the similar findings for first year engineering students in 2006 in Chapter 4.

Only the responses to the statement '*I have never felt myself able to learn mathematics'* gave a significant relation with the statistics assignment mark (and for this reason the question text was shown in bold). Thus for these students studying statistics these results indicate that the Scale questions do not measure the same underlying characteristic as the statistics assignment mark. Interestingly students' responses to this '*never able'* statement is more significantly related (P=0.003) to their statistics assignment mark than either of *Confidence in Mathematics* (P= 0.049 for 2006 data, P=0.020 for combined 2005 and 2006 data) or *Confidence in Statistics* (P=0.078 in 2006 or P=0.019 for combined 2005 and 2006 data).

5.2.2.4 First Year APD Statistics Students' Use of Mathematics Support

Mathematics Support was reported on by 37 of the 201 APD students surveyed, representing an 18% take-up of the help offered amongst the surveyed students. In 2005 55 students, 16% of the total 341 students on the module, received support for APD statistics which was for a mixture of individual and/or group support, but only 22 of these completed questionnaires. Table 5.9 below details the student numbers and the mean ratings for the support provided to surveyed students; the means were very good, all above 4 out of 5. There were only a few comments about the mathematics support which have been reported in Table 5.26.

Table 5.9 Numbers of Surveyed APD Students Using the Mathematics Support and Mean Ratings for the Support

Year	No. Students Using the Mathematics Support	Percentage	Both Group and Individual Support	Group	Individual	Rating for Helpfulness	Rating for Clarity	Rating for Relevance	Rating for Timing
2005	22	18.6	6	5	7	4.2	4.3	4.0	4.0
2006	15	18.1	6	1	5	4.6	4.5	4.4	4.5
Total	37	18.4	12	6	12	4.4	4.4	4.2	4.2

It has been found that the students who used the mathematics support had generally lower GCSE mathematics grades, but performed at least as well as those who did not use the support, despite lower GCSE grades being very highly significantly related to lower APD marks. The number of APD students by mathematics GCSE grade is shown on Figure 5.6. below, and it can be seen that supported students had a higher proportion of Grade C and D, than those who did not take up support, and none of the supported students had A* grades.

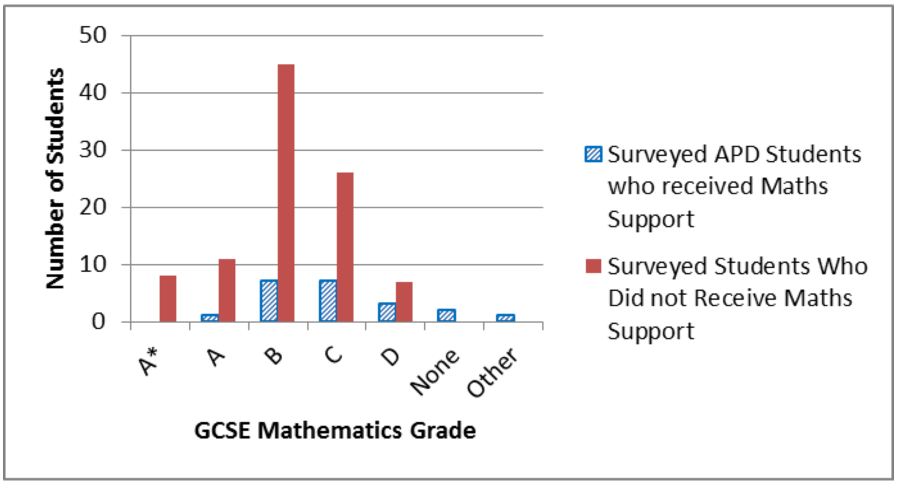

Figure 5.6 Number of 2004/5 Surveyed APD Students by Mathematics GCSE Grade and whether Students received Mathematics Support

Table 5.10 details the number of 2005 APD Statistics students and the mean mark achieved by GCSE Mathematics grade, shown separately for students' who received mathematics support and those who did not. It was found that the median GCSE Mathematics grade for supported students was a Grade 'C', whilst the median grade for unsupported students was higher, a Grade 'B'. Supported students were found to have significantly lower Maths GCSE grades than unsupported students (Mann Whitney U test, P= 0.044, U= 618, n= 18, 96).

It can be seen in Table 5.10 that for grades A, B and C the mark achieved by supported students is slightly higher than for not supported students (except for Grade D for which there was only a small number of students), however the difference between the supported students' marks and the unsupported students' marks was not found to be significant, either by paired t-test or ANOVA tests. This lack of significant difference is possibly due to the wide variation in student marks, the small numbers of students for some GCSE grades and the fact that the assessment was a report so the marks are not only representing ability in statistics, but also ability in report writing which is quite possibly clouding these results.

Table 5.10 2005 APD Statistics Student Numbers and Marks by Mathematics GCSE Grade shown separately for Supported and Not Supported Students

	Maths Supported Students			Not Maths Supported Students			All Surveyed ADP 2005 Students
Maths GCSE Grade	**No. Students**	**% of Students**	**Mean APD % Mark**	**No. Students**	**% of Students**	**Mean APD % Mark**	**Mean APD % Mark**
A*	0	0.0	-	8	8.2	61	61.4
A	1	4.8	65	11	11.3	61	61.6
B	7	33.3	57	45	46.4	54	54.0
C	7	33.3	48	26	26.8	44	45.1
D	3	14.3	39	7	7.2	41	40.5
None	2	9.5	45	0	0.0	-	45.0
Other	1	4.8	60	0	0.0	-	60.0
	21	100.0	-	97	100.0	-	-

Note: For eight students marks were not available.

5.2.3 First Year APD Statistics Correlation and Linear Regression Analyses

5.2.3.1 First Year APD Statistics Correlation Analyses

Correlation matrices were created to assess the correlations between most of the variables collected. Correlation analysis was concerned with establishing whether linear relations existed between variables, whereas the ANOVA tests, described in sub-sections 5.2.2.1 and 5.2.2.3, were used to investigate whether more general effects were found which had made a difference to the variable being assessed. Overall many variables were found to be significantly correlated with other variables, especially the confidence and attitudes variables which were almost all significantly correlated with each other.

The variables which were significantly correlated with the APD assignment marks are shown in Table 5.11 below.

Table 5.11 APD 2005 and 2006 Assignment Mark Correlations with other Variables

Variable	R Value	P Value	Sample Size
Maths GCSE Grade	0.435	0.000	182
I have never felt myself able to learn mathematics	-0.373	0.001	74
Don't have a mathematical mind	-0.302	0.009	74
I take longer to understand mathematics	-0.301	0.009	74
Motivation	0.287	0.000	187
More confident after module	0.260	0.000	183
Confidence in mathematics	0.246	0.001	187
Confidence in statistics	0.239	0.001	187
Like mathematics	0.149	0.042	187

Correlations have been shown in order of absolute R value in Table 5.11 above. Several of these variables have then been used to develop Multiple Regression models for the APD mark which are described in the next sub-section. There are fewer correlations with the APD% mark shown in Table 5.11 above than there are shown in Table 5.12 below for the *Confidence in Mathematics* and *Confidence in Statistics*.

Table 5.12 APD Correlations between Overall Confidence in Mathematics and Overall Confidence in Statistics and the Scale Variables and Other Variables (in Confidence in Mathematics R Value sequence)

Variable	Confidence in Maths R	Confidence in Stats R	Sig. (2-tailed)	N
Confidence in mathematics	1	.713	.000	201
Don't have a mathematical mind	-.733	-.560	.000	80
Confidence in statistics	.713	1	.000	201
I take longer to understand mathematics	-.694	-.512	.000	80
I have less trouble learning maths than other subjects	.668	.591	.000	80
I have never been very excited about maths	-.663	-.491	.000	80
Liking of mathematics	.661	.483	.000	201
I have never felt myself able to learn mathematics	-.648	-.459	.000	80
I find maths confusing	-.643	-.563	.000	80
When I meet a new maths problem I know I can handle it	.630	.627	.000	80
I enjoy trying to solve new mathematics problems	.587	.446	.000	80
I find mathematics frightening	-.545	-.514	.000	80
Mean Topic rating	.542	.648	.000	201
Maths GCSE Grade (coded numerically))	.524	.371	.000	196
I find many mathematics problems interesting and challenging	.524	.468	.000	80
I don't understand how some people seem to enjoy mathematics problems	-.523	-.483	.000	80
Liking of Statistics	.408	.578	.000	201
A Level (A2/AS/Other/None)	-.375	-.332	.000	201
Motivation rating	.345	.410	.000	201
More confident after the module	.255	.266	.000	197
Mark for APD Statistics Assignment %	.246	.239	.001	187
Whether would choose stats	.236	.257	.001/ .000	196
Like subject more after the module	.222	.258	.002/ .000	201

Grey shading indicates Scale variables (Fogarty *et al.*, 2001). As can be seen in Table 5.12 above there are many significant correlations between the confidences and other variables. The Scale Questions correlate well with *Confidence in Mathematics*, and with *Confidence in Statistics*, but slightly better with *Confidence in Mathematics*. The

Scale variables correlate better with these confidences than with the APD mark (as shown in Table 5.11).

5.2.3.2 2006 1st Year APD Statistics Regression Analyses

Regression analysis was carried out in SPSS with the aim of quantifying the contribution made to the APD student marks by different independent variables. Various valid models were produced, two of which are presented below. The main difficulty encountered with the regression analysis was the overlapping effects of the different variables. It was shown by the correlation analysis that many of the variables were significantly correlated with each other, and even if they were pertaining to different characteristics in real life they often contained similar values as they were so inter-related. For example *Liking of Mathematics* and overall *Confidence in Mathematics* would usually have similar values, and another example of a similar pair would be income and expenditure, whilst these are different things their values are often the same or similar.

Various models were tried using different variables, but only the following two models were found for which all of the coefficients were statistically significant. The following variables were used in the two regression models produced:

- GCSE Mathematics Grade number, for which the grades were recoded as numbers: A*/A=3, B=2, C=1, D/E=0.
- Motivation (rating 1-5, 5=high), which was recoded as 0-4 so that the baseline mark for the lowest motivation can be seen clearly in the model.
- Response to *I have never felt myself able to learn mathematics* (Strongly agree = 5, Strongly disagree =1), which was also re-coded to 0-4.

Model I – APD Statistics mark modelled on GCSE Mathematics Grade and Motivation

The linear regression analysis produced the following equation to predict the APD assignment mark:

APD Mark % = 34.451
+ 6.887 x GCSE Mathematics Grade number
+ 3.052 x Motivation

This model explained 22.4% of the variation in the students' marks.
(ANOVA P=.000, Durbin Watson = 1.652, R= 0.473 and R^2 = 22.4%, n=182).

Model II - APD Statistics mark modelled on '*I have never felt myself able to learn mathematics'* Response and Motivation

The linear regression analysis produced the following equation to predict the APD assignment mark:

APD Mark % = 47.717
+ 5.432 x Motivation
- 4.900 x 'I have never felt myself able to learn mathematics'

This model explained 20.6% of the variation in the students' marks.
(ANOVA P=.000, Durbin Watson = 1.495, R= 0.454 and R^2 = 20.6%, n=74).

The models produced for the 1^{st} year APD statistics marks are not as effective at explaining the marks as were produced for the 1^{st} year engineering students in Chapter 4, for whom multiple regression models were produced which explained approximately 37% of the variation in marks. The APD assignment requires a range of skills, not just ability in statistics, but also requires general writing, report writing and research skills. Thus the lower percentage variation explained with these models was to be expected and is consistent with Pajares and Miller (1995) and demonstrates the need for specificity, i.e. that the confidence being evaluated should be well matched to the skills being assessed.

The main variable contributing to the APD mark is the students' mathematics GCSE grade (a past qualification), and in Model I this can been seen to have a higher coefficient than how motivated the students were. However when both the GCSE grade and 'Never able' variables were put into the same model with motivation, then both GCSE grade and 'never able' became insignificant, which it is suggested demonstrates the relative strength of the 'never able' confidence rating to predict the mark almost as strongly as the GCSE grade.

Two significant models for the APD mark have been presented; both of these models include a past qualification, with either a confidence or a motivation. Past qualifications were fixed before university, however, student confidence and motivation can be influenced during university teaching and so teaching staff should also give consideration to improving students' confidence and motivation.

5.2.4 First Year APD Statistics Factor and Cluster Analysis

5.2.4.1 First Year APD Statistics Factor Analysis

Principal Component Analysis was conducted on the APD data using 27 variables, which included the 11 Scale questions (from Fogarty *et al.*, 2001). The intention of this analysis was exploratory with the aim of finding patterns in the data and to reduce the 27 variables into a smaller set of underlying characteristics (latent variables or factors). Many of the variables have had the phrase and values reversed (i.e. 5 converted to 1, etc.) to make the correlations positive so that the reliability of the resulting factors could be checked by the Cronbach's Alpha coefficients. Table 5.13 below contains the Rotated Component Matrix produced by Varimax rotation, for which rotations converged after 8 iterations. Six factors were identified by the analysis which explained 68.8% of the variation. Correlations of a least 0.4 and those less than -0.4 have been highlighted.

Table 5.13 APD Rotated Component Matrix (using Varimax Rotation)

Variable Description	Component					
	1. Feels Positive about Maths	2. Confident in and likes statistics and maths	3. High Achievement	4. Spends lots of time	5. High achievement before uni / Likes maths / Male	6. Dyslexia
Q50. I *don't* find maths confusing	.791	.253	.177	-.209	.071	-.009
Q48. I *do* ~~don't~~ understand how some people seem to enjoy mathematics problems	.787	.169	.104	.292	.082	-.157
Q47. I find many mathematics problems interesting and challenging	.768	.279	-.073	.160	.136	.107
Q45. I enjoy trying to solve new mathematics problems	.709	.230	-.078	.081	.199	.173
Q43. It *does not take* ~~takes~~ me longer to understand mathematics than the average person	.683	.279	.280	-.141	.299	-.082
Q44. I have *always* ~~never~~ felt myself able to learn mathematics	.670	.237	.391	-.120	.122	-.108
Q46. I *don't* find mathematics frightening	.657	.398	.105	-.166	-.029	-.067

Q42. I *do* ~~don't~~ have a mathematical mind	.652	.343	.234	-.201	.294	.019
Q49. I have *always* ~~never~~ been very excited about maths	.630	.266	-.006	-.032	.460	-.181
Confidence in Statistics	.379	.774	.095	.011	.054	-.055
Like Statistics	.274	.759	-.099	.054	.013	-.076
Motivation	.037	.748	.312	.311	.030	-.179
Mean Topic Confidence	.301	.731	.290	.040	.083	.021
Q41. When I meet a new maths problem I know I can handle it	.481	.639	.065	-.207	.072	.153
Confidence in Mathematics	.477	.599	.193	-.139	.357	-.083
Q40. I have less trouble learning maths than other subjects	.540	.578	-.027	-.038	.160	.083
Like Mathematics	.485	.547	.031	.099	.400	.064
APD Assignment mark %	.085	.219	.775	-.016	-.118	-.038
Award	-.112	-.020	-.763	-.036	.008	.152
Age	-.017	-.113	-.030	.749	.103	-.001
Mathematics Support	-.005	.038	-.028	.624	-.295	.330
Time Spent	-.381	.222	.227	.612	.034	-.177
Choose to Study Module	.358	.230	-.224	.544	-.139	-.285
A level	-.275	-.120	.134	-.080	-.638	.107
GCSE Grade	.306	.117	.549	-.130	.631	.077
Gender	-.093	-.002	.164	.226	-.512	-.471
Dyslexia	-.037	-.053	-.124	.047	-.060	.809
Eigenvalues	6.28	4.57	2.24	2.14	2.01	1.34
% of variance explained	23.25	16.92	8.30	7.92	7.43	4.98
Cronbach's Alpha	.951	.914	.701*	.397	.692	.271

Key: * Standardised Cronbach's Alpha shown. Non-standardised Alpha = 0.084

Note: n=68. Red shading indicates correlations greater than 0.4, and green shading indicates correlations less than -0.4. n=68.

Consideration of the components of the factors has led to these being named as follows:

1. **Confident in and likes mathematics –** this factor groups all of the 11 scale questions, with *Confidence in Mathematics* and *Liking of Mathematics* (but not statistics).
2. **Confident in and likes statistics** – this factor is related foremost to *Confidence in Statistics* and *Liking of Statistics*, and also *Confidence in Mathematics* and *Liking of Mathematics* (but less than for statistics, but more strongly correlating with Factor 2 than Factor 1).

3. **High achievement –** this factor relates more to university achievement in statistics, but also includes students' GCSE mathematics grade (although that is more highly correlated with factor 5).
4. **Spends lots of time –** This factor groups: higher aged students; students who take up the mathematics support; students who indicated higher amounts of time spent outside of lectures; and those who would choose to study the module.
5. **A level Mathematics –** This factor selects students who have done A level mathematics. Students with A level mathematics also tend to have high GCSE grades, are generally male, like maths and are excited about maths. It will also be shown that students with A level mathematics are identified as a cluster in the Cluster analysis in the next sub-section.
6. **Dyslexia –** This factor identifies students with dyslexia, and it also relates to male students, although gender is more strongly associated with Factor 5 (A Level mathematics).

The factor analysis was considered valid after consideration of the following details. Although the sample size was only 68 (although there were 83 questionnaires some did not contain all of the variables being analysed) which is considered small and was less than three times the number of variables (27), the communalities were almost all above 0.6, which according to MacCallum, Widaman, Zhang and Hong (1999) indicates that this relatively small sample (less than100) could be perfectly adequate. There were only four variables which had communalities less than 0.6, these were A level, Gender, Age and Maths support and the communalities for these were: .533, .570. .586 and .588 respectively, which were not far away from 0.6. The Kaiser-Meyer-Olkin measure was .803, which verified the sampling adequacy for the analysis (Field, 2009). Bartlett's Test of Sphericity resulted in Chi squared = 1180.332, df = 351, P<.000, which indicated that the correlation matrix was significantly different from a unit matrix and that the correlations were sufficiently large for PCA. Six components had eigenvalues >1 (Kaiser's criterion) which cumulatively explained 68.8% of the variance. The scree plot was ambiguous so the 6 factor solution was adopted.

There were some variables which had lots of correlations below 0.3 in the Correlation matrix (APD mark, Maths GCSE grade, A level, Award, Gender, Dyslexia, Age, Time spent, Would choose and Whether used mathematics support) and these variables were considered for exclusion from the Factor analysis. As these variables were of particular interest they were kept in the analysis, but it can be seen though that these variables did not directly measure confidence or attitudes towards learning mathematics. Every variable in this APD PCA analysis did, however, have at least one correlation of 0.5 or greater.

The 6 factors produced by the analysis were meaningful. It is interesting that the single *Overall Confidence in mathematics* rating and *Liking of Mathematics* were put in the same factor as all of the Scale variables, thus indicating that these were pertaining to the same underlying characteristics. It is interesting that the *Confidence in Statistics* was put in a separate factor from the scale questions, probably because the wording in the Scale questions referred to mathematics, and not to statistics. It was also interesting to see that Dyslexia was neither associated with strong confidence or a lack of confidence, and neither was it associated with positive or negative attitudes, high or low motivation, or high or low achievement.   Negative correlations were shown for Award and A level because the higher values of these variables indicated lower underlying achievement/ability, i.e. for Award: 1=BSc and 2=FdSc/HND, and for A Level: 1=A2 Mathematics, whereas 4=No A level or other post-GCSE mathematics qualification.

The Cronbach's Alpha values were good for Factors 1, 2 and 5, indicating high overall reliability of these scales (Field, 2009 states that around 0.8 are good values for Cronbach's Alpha, or around 0.7 for ability data). This is understood to mean that these variables were considered to be measuring similar underlying characteristics. It was decided to use the standardised Alpha coefficient of 0.701 for Factor 3, which was so different to, and much better than, the unstandardized value for Alpha of .084, however to improve the unstandardized value it would have been necessary to remove the APD mark variable from the analysis which was one of the key variables that it was intended to include, so for this reason the analysis was not re-run excluding this variable.   Although the other factors (4 and 6) had relatively low Alpha values (approximately .4 and .3) there were no variables in those scales for which the removal would improve the Alpha value. However the low Cronbach's Alpha values are understandable, as it is easily recognised that Dyslexia and Gender (in Factor 6) are not measuring the same characteristic. Neither are the variables in Factor 4 measuring the same characteristic (APD mark, Age, Time spent, etc.), so one can agree that neither Factor 4 nor Factor 6 are coherent scales. There was only one variable whose removal would improve the Alpha value, and this was the Gender Number variable. However the improvement would have only been fractional (from .692 to .714) so it was not deemed necessary to remove Gender, as this was also a variable of particular interest to include. The aim of this analysis was exploratory, and not with the intention of validating the internal reliability of questionnaire scales with for which high Cronbach's Alpha values would have been required.

Overall the 6 factors produced by the Factor analysis do represent a useful reduction of the original 27 variables into a simpler set of latent underlying characteristics.

Gender was sufficiently correlated with Factor 5 and Factor 6 to be highlighted. In Factor 6 it appeared with Dyslexia and in Factor 5 with GCSE Grade and A level mathematics, which prompted further investigation. Frequency tables for the 2005 and 2006 APD students were produced as shown in Table 5.14 below, and it can be seen that more male students were dyslexic, had studied A level mathematics and had high GCSE mathematics grades. Chi Squared tests were carried out to test whether there were significant associations between these characteristics, however, no significant associations were found: between Gender and Dyslexia (Chi Squared=2.88, df=2, P=0.237), between Gender and whether students had studied A level mathematics (Chi Squared=4.98, df=3, P=0.173) or between Gender and GCSE mathematics grade (Chi Squared=7.38, df=3, P=0.061).

Table 5.14 APD 2005 and 2006 Student Frequencies by Gender for Dyslexia, A Level Mathematics and GCSE Mathematics Grade

	Dyslexia			A Level				GCSE Grade			
Gender	**No**	**Unknown**	**Yes**	**A2**	**AS**	**Other**	**None**	**A/A***	**B**	**C**	**D/E**
Female	70	8	14	5	2	8	77	8	38	35	9
Male	71	13	**25**	**14**	6	9	80	**23**	**46**	29	8

The male figures which were slightly higher than expected are shown in bold font in Table 5.14 above.

5.2.4.2 First Year APD Statistics Cluster Analysis

Cluster Analysis was carried out on the APD data. Initially the analysis was based on 27 variables (the same variables as were used for the Factor Analysis) including the 11 Scale variables. A three cluster solution was chosen which included only 67 of the 201 APD students. The majority of the APD students had been excluded from the analysis because they had some details missing; in particular the 11 Scale questions were only in the 83 2006 questionnaires. The resulting three clusters are summarised in Table

5.15 below, and have been simply named as Top, Middle and Bottom students. Fortunately there are more top students than there are bottom students, however it has already been shown that the students who were surveyed in 2006 were a better sample than the overall cohort. Due to the very small number of students analysed and the bias in the data the cluster analysis was re-run excluding the 11 scale variables, which produced four clusters containing 170 APD students, which was a much more useful result, and the details of these four clusters have been analysed more extensively and are described after Table 5.15.

Table 5.15 Three Cluster Summary for APD Statistics (67 Cases)

Cluster	No. Students	APD %	Standard Deviation	Maths GCSE Code *	Confidence in Mathematics	Confidence in Statistics	Liking of Mathematics	Liking of Statistics	Motivation	Don't have a Mathematical Mind	Felt Never able to Learn Mathematics
Top	18	57.3	19.7	2.28	4.2	3.8	3.8	3.3	3.6	1.9	1.4
Middle	43	50.4	9.5	1.51	2.9	2.6	2.9	2.5	2.9	3.4	2.7
Bottom	6	43.0	16.5	0.83	1.2	1.2	1.7	1.7	2.3	5.0	4.0
All Cases	**67**	**51.6**	**17.7**	**1.66**	**3.1**	**2.8**	**3.0**	**2.7**	**3.0**	**3.2**	**2.5**

*   GCSE mathematics codes: A/A*=3, B=2, C=1, D/E=0

The Cluster Analysis which produced the four clusters was based on the following variables: APD Mark%; GCSE Mathematics Grade code; A Level Mathematics code; HND/BSc; Whether Dyslexic; Gender; Age; *Confidence in Mathematics*; *Confidence in Statistics*; *Liking of Mathematics*; *Liking of Statistics*; Mean *Topic Confidence*; Motivation; Time spent working outside of lectures; Whether would choose to the study the statistics; and Whether they used the maths support. The resulting Dendrogram is shown in Figure 5.7 below. A four cluster solution was adopted, and the relative sizes of the four clusters (and the cases which were excluded from the analysis) are shown on the pie chart in Figure 5.8 below. In total 170 APD students (of 201) were allocated to the four clusters. Summary details for the four clusters are shown in Tables 5.16 and 5.17 below, after which a detailed description is given for each cluster.

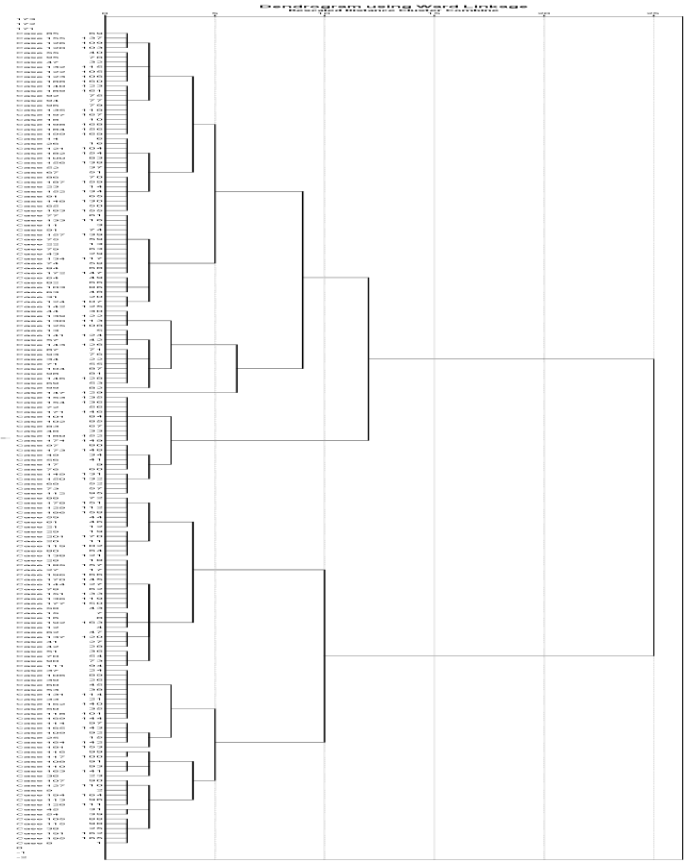

Figure 5.7 Dendrogram of APD Cluster Analysis using 170 cases producing a 4 cluster solution

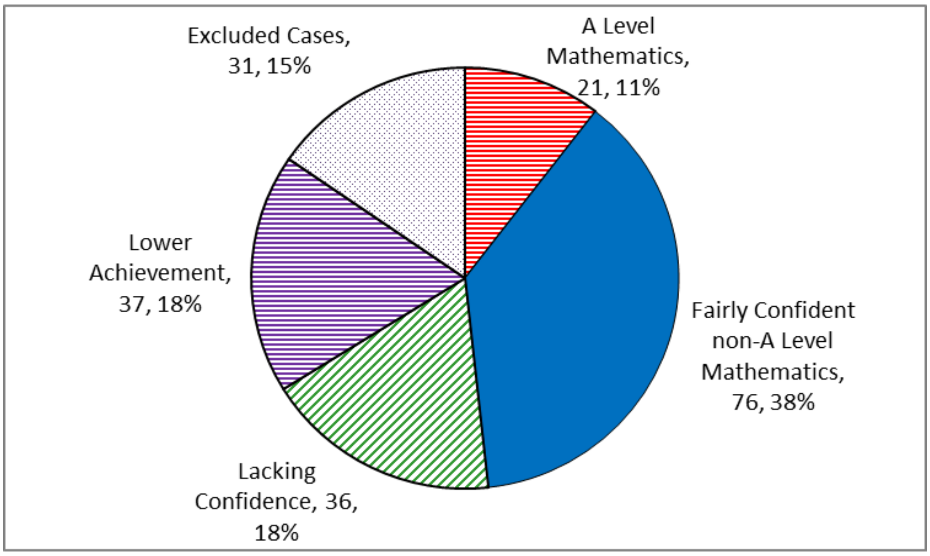

Figure 5.8 Relative sizes of the 4 Clusters and Excluded Cases for APD Statistics Students 2005 and 2006

Table 5.16 Four Cluster Solution for APD Statistics Students 2005 and 2006 – Part I - Types of Students

Cluster	No. Students	% in cluster of the total	HND	%HND	Age (years) *	% Male	% Female	% Dyslexic	Time Spent (hours)
A Level Mathematics	21	12.4	1	4.8	19.0	**71.4**	28.6	4.8	1.2
Fairly Confident non-A Level Mathematics	76	44.7	4	5.3	19.2	52.6	47.4	15.8	1.3
Lacking Confidence	36	21.2	1	2.8	18.8	25.0	**75.0**	25.0	1.5
Lower Achievement	37	21.8	35	94.6	19.8	56.8	43.2	32.4	1.3
Total / Mean (analysed)	**170**	**100**	**41**	**24.1**	**19.2**	**50.0**	**50.0**	**20.0**	**1.3**
Excluded Cases	31	-	10	32.3	19.5	77.4	22.6	13.0	0.8
Total/Mean (all APD)	**201**	**-**	**51**	**25.4**	**19.2**	**54.2**	**45.8**	**18.9**	**1.2**

Table 5.17 Four Cluster Solution for APD Statistics Students 2005 and 2006 – Part II - Achievement and Confidences

Cluster	Mean Mark %	Mark Standard Deviation %	% Students who Passed	Maths GCSE Code *	A Level mathematics code **	% who would choose	Motivation	Confidence in Mathematics	Confidence in Statistics	Liking of Mathematics	Liking of Statistics
A Level Mathematics	59.7	6.5	100	2.8	1.2	52.4	3.5	4.2	3.9	4.0	3.3
Fairly Confident non-A Level Mathematics	56.9	11.0	96	1.8	3.9	35.5	3.2	3.3	3.0	3.2	2.9
Lacking Confidence	52.2	9.8	94	1.4	3.9	16.7	2.3	2.1	1.8	2.2	1.8
Lower Achievement	35.7	18.3	41	1.0	3.8	8.1	2.2	2.7	2.5	2.6	2.1
Total / Mean	**51.6**	**15.1**	NA	**1.7**	**3.6**	**27.6**	**2.8**	**3.0**	**2.8**	**3.0**	**2.6**
Excluded Cases	46.7	18.9	NA	1.6	3.6	19.4	2.7	3.2	2.6	3.1	2.4
Total/Mean (all APD)	**51.2**	**15.6**	NA	**1.7**	**3.6**	**26.4**	**2.8**	**3.0**	**2.7**	**3.0**	**2.5**

* GCSE mathematics codes: A/A*=3, B=2, C=1, D/E=0

** A Level mathematics codes: A2=1, AS=2, Other=3, None= 4

Description of the Four APD Clusters

A Level Mathematics Students

All of the students in this cluster had A2 or AS mathematics (76% A2, 24% AS), and good GCSE mathematics grades (38% A*, 43% A and 19% B). The majority were male students (71% male) and these were 95% BSc students (see Table 5.16 above). This was the highest achieving, most confident and motivated cluster (see Table 5.17 above). The mean APD assignment mark for this cluster was 59.7%, the highest of any cluster; the students' confidences were high (e.g. *Overall Confidence in Mathematics* 4.2) and motivation was the best (mean 3.5) and over half, 52%, would have chosen to study the statistics. However, this was the smallest cluster (only 21, 12% of the students analysed, although this cluster was shown as 11% on the pie chart because the pie chart also includes the students excluded from the cluster analysis).

Fairly Confident non-A Level Mathematics Students

The mean marks and mean confidences for this cluster were fairly good overall, better than average but not quite as high as for the A level mathematics cluster students (which is as would be expected). See the values in Tables 5.16 and 5.17 above. This cluster was the largest of the 4 clusters (45% of the students analysed), and contained almost equal numbers of male and female students (40 and 36 respectively). It is positive that nearly half of the APD students analysed were fairly confident and successful, mean *Confidence in Mathematics* 3.3 and mean APD mark 56.9%.

Lacking Confidence Students

The students in this cluster had the lowest mean values for the confidences and liking variables entered into the cluster analysis (see Table 5.17 above), e.g. mean *Confidence in Statistics* and *Liking of Statistics* were both only 1.8, and only 1/6th of the students in this cluster would have chosen to study the statistics. The majority of students in this cluster were female students (75%). The mean mark for this cluster was actually slightly above average 52.2% (compared to the overall mean of 51.6%) with less variability than the whole 170 cases, so in terms of achievement these students achieved fairly well and did not have cause to be as lacking in confidence as they were. The mean time spent outside of lectures was slightly higher for this cluster, but actually the amount of time spent was very variable in all 4 clusters. Approximately one fifth of the students analysed were placed in this cluster (21%), it was the same size as the HND students cluster.

Lower Achievement Students

This was the lowest achieving cluster; 59% of the students in this cluster failed their APD statistics assignment and the mean mark for the cluster was only 35.7%. The marks in this cluster also had the most variation (standard deviation 18%). These students also had the lowest GCSE mathematics grades (mean Grade C) and no A level mathematics. The students in this cluster were 95% HND students and only 5% were BSc students. This cluster also had the highest proportion of dyslexic students (32%), but had fairly equal numbers of male and female students (see Tables 5.16 and 5.17 above). Approximately one fifth of the students analysed were placed in this cluster, 21.8%. The students in this cluster were generally lacking in confidence; all the confidences, liking and motivation mean values were below 3 (e.g. overall *Confidence in Mathematics* 2.2, *Liking of Statistics* 2.1), but they were not quite as lacking in confidence as Cluster 3 described above. The students in this cluster, however, were the least motivated students and only 8% would have chosen to study statistics.

Excluded Cases

31 students were not included in the Cluster Analysis because they had at least one details missing, e.g. 14 did not provide their id no., 5 did not give a GCSE grade and 4 did not give their age. Summary statistics have been produced for these students, and it can be seen that this group were approximately one third HND students, and were slightly below average but were otherwise fairly representative of the total 201 students.

In the above descriptions of the four clusters it has been shown which values of the various variables were associated with different clusters. Chi Squared tests and one Fisher's Exact Test were also carried out to check whether there was an association between the allocated cluster numbers and the various characteristics referred to in the above cluster descriptions. Significant associations were found for all of the variables (as shown in Table 5.18), except for whether students were dyslexic (P= 0.100). Some of these variables had columns combined to remove low expected frequency values. It was necessary to use a Fisher's Exact Test for the A level Mathematics counts by Cluster due to low expected frequencies, as all of the students in the A Level cluster had A level Mathematics (and none did not) and only 2 had A level maths (compared to 147 who did not) in the other 3 clusters combined.

Table 5.18 Four Cluster Solution for APD Statistics Students 2005 and 2006

Variable	P Value	Chi Squared	df
Gender	**0.003**	13.74	3
Pass/Fail	**<0.001**	67.53	3
Confidence in statistics	**<0.001**	70.15	6
Award	**<0.001**	128.43	3
Dyslexia (not significant)	0.100	6.25	3
Would choose	**<0.001**	18.01	3
A Level Mathematics (Code)	**<0.001**	*	*
GCSE Mathematics Grade (Code) **	**<0.001**	37.92	3

Note * Fisher's Exact Test (Two times one tailed significance level P-Value) used instead of Chi squared for A level test.

Note ** GCSE grades were combined to remove low frequencies.

It has been possible to explain the four clusters produced by the Cluster analysis as recognisable student groups. For lecturing staff it could be helpful to be aware that the students in their classes could be categorised as belonging to one of the four clusters, for whom different needs would arise.

This sub-section concludes the analysis of the closed questions from the APD 1st year student questionnaires. A summary of the results of the open questions will be presented in the following sub-section.

5.2.5 First Year APD Statistics Open Questions

This sub-section will present the results from the open question analysis. For each open question the responses have been categorised, sorted and counted. The response types are presented in tables in descending frequency sequence.

A summary of the responses to

> '***For how long have you held this opinion of your self-confidence in mathematics?'***

are shown in Table 5.19 below. The most frequently occurring response was that students had always felt their level of confidence, but there were also some specific points at which students felt their confidence was formed, for example when put into sets for GCSE mathematics. The top four categories account for most of the responses (84%).

Table 5.19 Summary of How Long APD Students had held their Opinion of their Self-confidence in Mathematics?'

Type of Response	Frequency	Example Comment(s)
Always	65	*As long as I can remember, I have always been comfortable with numbers, I have never been confident with Maths*
GCSE	48	*Since starting GCSE, Since I got my B at GCSE*
Secondary school	30	*Since I started High School*
Primary school	26	*Ever since my first maths test when I was 5*
Blank	11	
A Level	5	*Since A levels*
Since leaving school	4	*Since I left school*
Couple of years	3	*Over the last few years*
Don't know	3	*Don't know*
Improved	3	*Gradually increasing*
A while	2	*Quite a while*
Not specific	1	*Since discovering I wasn't very good*
Total	**201**	

A summary of responses to

> ***'How do you think that your experiences of mathematics before coming to university have affected your confidence or liking of the subject?'***

is shown in Table 5.20 below. There was a wide range of responses given from very positive, e.g. '*Really enjoyed maths at school',* to very negative, e.g. '*Always found it difficult.'* Overall there were more positive statements (63, 31.3%) than negative ones (50, 24.9%), and 35 (17.4%) neutral comments. However, there were definitely more negative comments about past mathematics teachers compared to good ones, unlike the engineering students whose comments about their teachers were more equally balanced between positive and negative.

Table 5.20 Summary of APD Responses to Question regarding How Experiences of Mathematics Before University affected Confidence or Liking of Mathematics

Type of Response	Frequency	Example Comment(s)
Blank	53	-
Helped	38	*Greatly, good grades give higher confidence*
Bad experience	15	*Bad experiences with maths previously have made me have little confidence in my maths ability now. So don't try very hard as believe will get it wrong anyway.*
Other	13	*GCSE maths gave me the impression it was not relevant to later life, but I found the maths in physics more applied.*
Dislike maths	12	*Still dislike it and have difficulties. Lack of confidence*
Enjoyed maths	12	*Really enjoyed maths at school*
Bad teachers	10	*Had useless teachers all the way through school so I have always been easily confused with maths*
No	6	*No hasn't really affected myself or my confidence*
Not much	5	*Little effect*
A lot	5	*Considerably*
Avoid	4	*Always found it difficult and therefore put me off. Try and avoid it when I can.*
Don’t enjoy maths	4	*Didn’t enjoy it at school, so didn’t look forward to it here*
OK	4	*Didn't mind it previously*
Don't know	3	*Can't remember*
Good experience	3	*Good experience because I got a good grade at GCSE*
Tutor helped	3	*Having a tutor from an early age has increased my confidence*
Good teacher	2	*Had a very good teacher at school for last two years*
Working slowly helped	2	*I've always struggled but if and when I work slower and have someone to ask it usually turns out ok.*
Maths difficult at uni	2	*Probably a little, but the work here was quite difficult in maths from the beginning which doesn't help*
AS level	1	*Failing the tests at the beginning of A-level took a while to realise I'm OK on basic stuff*
Despondent	1	*Due to me not getting on with maths in general I have given up in thinking I will ever be able to do well in maths*
Good and bad teachers	1	*Have had some good teachers and some bad*
Like maths	1	*A lot I like Maths because I feel I am good at it.*
Like maths not stats	1	*I don't mind mathematics, it's the statistics that I don't like*
Total	**201**	

A summary of responses to the following question are shown in Table 5.21 below.

'How would you describe your attitude to learning mathematics?'

Table 5.21 Summary of APD Student Responses to 'What is your Attitude towards Learning Statistics'

Type of Response	Frequency	Example Comment(s)
Blank	26	-
OK	19	*Average*
Willing	15	*Willing to learn and understand more*
Good	11	*Good*
Interested	11	*Find interesting and helps me to understand the figures by the way it is set out*
Not interested	11	*Not very interested in it*
Poor	10	*Poor attitude due to previous experience with all maths subjects*
Positive	10	*Positive, would be useful in later life.*
Finds difficult	9	*I try but get nowhere*
Keen/Motivated	9	*Eager and enjoyable. It comes more easily now.*
Try hard	9	*Hard working, but takes a while to understand it*
Other	9	*Benefitted / Just another subject*
Dislikes stats	7	*I don't really like statistics*
Negative	6	*Quite negative as although it is necessary and useful but is very tedious*
Bored	5	*I find it quite boring*
See relevance	5	*I wouldn't say that I really enjoyed it but I realise how important it is.*
Does because has to	4	*I turn up so I don't get chucked off the course*
Enjoys it	4	*Have thoroughly enjoyed it, best so far out of APD.*
Could be better	3	*OK, but I could be more positive as it does help us in the future*
Necessary	3	*Necessary evil*
Not relevant	3	*I find it irrelevant for everyday life*
Unwilling	3	*Reluctant*
Confusing	2	*Confusing*
Finds speed too fast	2	*OK at first but it is generally taught far faster than I can tune in, so give up.*
Relaxed	2	*Laid back*
Struggles, Dyslexia	2	*Not great due to the dyslexic factor and struggling*
Finds easy	1	*Find it easy once I remember the basics*
Total	**201**	**Total not blank = 175**

These results contribute towards answering Research Question IIa about students' attitudes and views. Once again there are more positive attitudes (80, 39.8%), than negative attitudes (60, 29.9%) and 35 (17.4) neutral responses, but the positive were still in the minority.

A summary of responses to

'What effect has your dyslexia or dyscalculia had?'

is shown below in Table 5.22. There was a range of responses from no effect, e.g. *'It hasn't really affect(ed) me mathematically'*, to a large effect, e.g. *'Every possible affect'.* There are, however, no positive responses. Of the 43 respondents to this question none of them has listed a positive effect of their dyslexia. The most frequent response was that their dyslexia made them take longer and be slower at learning initially.

Table 5.22 Summary of APD Student Descriptions of the Effects of Dyslexia

Category	Frequency	Example Response
Makes slower/takes longer	13	I am a bit slower at picking things up and it is a quite fast learning subject!!
Makes harder	4	Just makes it more difficult to understand
Not much	4	I don't feel it really effects me
Difficulty with reading	3	Dyslexia reading what is being asked or explained
Difficulty concentrating	2	Lack of concentration
Makes slower and harder	2	Makes me struggle much more and seems to take me so much longer and so I get left behind
Maths not affected	2	It hasn't really affect me mathematically
Memory problems	2	A lot, I find remembering things hard
Difficulty with spelling	1	Made it difficult to spell
Difficulty with spelling reading and writing	1	Can't spell read or right as well or fast
Difficulty with written work	1	Hinders progress in assignments and other written work
Doesn't help	1	It's not helped, but it never will.
Every effect	1	Every possible affect
Grammar affected	1	It has had an effect on my grammar
Harder to learn formulae and methods	1	Makes learning formula/methods difficult
Less motivated	1	It affects one's motivation
Transposition of numbers	1	None that I've noticed maybe occasional transposition of numbers
Understands a different way	1	I can't understand the way other people do, I understood all the stats at school but now I've done this module I'm really confused, I'm going to learn it all again the way I got taught before.
Total	**42**	

A summary of responses to

'Which aspects of the module particularly helped your learning?'

is shown below in Table 5.23. By far the most helpful feature of the module was the use of Excel, which could do most of the calculations automatically. At the time of the questionnaires the calculations were mostly all done by hand as well, although this was no longer the case. Some responses described more than one feature.

Table 5.23 Summary of APD Student Responses to 'Which aspects of the module particularly helped your learning?'

Type of Response	Frequency	Example Comment(s)
Excel	62	*Use of computers for Excel*
Blank	55	-
Specific Topics	26	*Correlation (7) / t-Test lecture (6) /* Standard deviation (4) */ Regression (3) / Formulae (2) / Percentages (2) / Graphs (2)*
Doing exercises/questions	12	*Working through sheets and exercises*
Teacher	11	*The teacher; Good teaching; friendly teachers; help from lecturer*
Statistics	9	*The work done on statistics and analysis techniques*
None	7	*None*
Other	6	*Report writing*
All	5	*All of the module was useful*
Lecture followed by exercises	4	*The mix of classroom work and computer room work*
Assignment	3	*Assignment*
Basic calculations	2	*The basics for confidence building*
Individual help	2	*Tutorials and one-to-one with XXXX*
Most of it	2	*Most have helped in some way*
Practical things	2	*Practical sessions combined with talking*
Step by step explanations	2	*Going through each method step by step so that it was easy to understand*
Applying to real Life	1	*Applying stats to real life examples*
Difficult things	1	*Formulae and more difficult things*
Learning from mistakes	1	*Learning from the mistakes I made*
Maths	1	*Maths*
Total	**214**	
Total not blank or None	**152**	

A summary of responses to the following question is shown below in Table 5.24.

'Which aspects of the module particularly hindered your learning?'

Table 5.24 Summary of APD Student Responses to 'Which aspects of the module particularly hindered your learning?'

Type of Response	Frequency	Example Comment(s)
Blank	99	-
None	23	*None really*
Specific topics	15	*Linear regression / t-tests / Standard Deviation, still not fully clear, but notes help / Pearsons coefficient / Numbers / Percentages*
Other	12	
Already knew it	7	*Covering old ground*
Excel	7	*Using the computers so much*
Formulae	7	*My own panic when faced with Formulae*
Timing of lecture	6	*Lessons on Thursday morning*
Not understanding	5	*Not fully understanding what was said in lectures*
Slow pace	3	*Too slow, taking too much time explaining simple things*
Statistics	3	*Statistics*
Too fast	3	*Lecturer whizzing through all aspects of module*
Difficult	3	*Don't see the point of doing work that is so hard - and not do anything with it ever again / Fact I can't do it*
Lecture too long	2	*The length of lecture is 2hrs, I find it tiring, it would be better in separate 1 hr lectures as may concentrate more*
Prefer pen and paper to Excel	2	*Using Excel. Would rather use pen and paper.*
Bored	1	*Tedious, relevance, tiring examples*
Confused	1	*The confusion it caused*
Don't like it	1	*The fact that the module has no appeal to a Mech student*
Lack of enthusiasm	1	*Lack of enthusiasm*
Maths	1	*Maths based topics*
Not enough lecturer attention	1	*Other students who needed constant lecturers attention*
Teacher interrupting exercises	1	*Being stopped halfway through doing something to look at something on the board*
Won't use again	1	*Don't see the point of doing work that is so hard - and not do anything with it ever again*
Total	**205**	
Total not blank or None	**83**	

The most prevalent response was to leave this question blank or to write 'None', which appears positive, however if there was clear agreement from the students as to what had hindered their learning that would make these hindrances simpler to remedy. In the responses given there are, however, a whole range of different complaints by relatively small numbers of students, and some students described more than one feature. It should be remembered that the students differed and also the lecturers were quite varied in their teaching styles, so it is reasonable to have some students write that it was too slow, whilst others wrote that it was too fast (both had 3 entries). It is probably impossible to please everyone all of the time. However, there are some very valid points made, for example being stopped whilst working to look at the board would hinder learning.

A summary of the APD students' responses to the open question

> ***'Have you experienced an occasion when a topic suddenly became a lot clearer than before (e.g. like a light switching on)?'***

is shown below in Table 5.25. Only 36 students gave details of such a moment of inspiration.

Table 5.25 Summary of APD Student Inspiration Experiences

Type of Response	Frequency	Example Comment(s)
Various Topics	13	*t-tests (5) / Pearson's Correlation (3) / When I first broke through the barrier doing standard deviation it seemed a lot easier(2) / Statistics (2) / formulae (1)*
Excel	8	*Calculations using Excel*
Other	8	*A truly 'Road to Damascus' experience / Most of this module / Once for not very long*
A level	1	*Mostly during higher level maths at A-level when it suddenly clicks*
After doing exercises	1	*After completing examples given in class*
Think harder than it is	1	*I often think it's harder than it is and I click*
Valuations	1	*With reports and valuation. If I don't understand something I ask someone to explain then once I do I'm fine.*
When a topic is repeated using a different scenario	1	*When a topic example is repeated using a different scenario*
When explained clearly	1	*When a subject is set out clearly you realise it can't be that hard.*
When it can be applied to real life	1	*But only in subjects like Animal Production when I can actually apply it to my work at home.*
Total	**36**	

The APD students' responses to

'Other comments on the mathematics support (e.g. suggestions)'

are shown below in Table 5.26. There were only ten responses, which are shown in alphabetical order.

Table 5.26 Other APD Comments on the Mathematics Support

Response
A bigger working room, not a cramped cubicle
Assignment support
I know it's there if I need it which is a reassurance
I really think I should get some now so you'll probably be seeing me soon!
Maybe set work to be done outside of the classroom to increase confidence
More logical steps towards the aim.
More on-line facilities
No it's great
None
None really. Think there is plenty of support available to students

A summary of the APD students' responses to the open question

When did you last enjoy doing something in maths?

is shown below in Table 5.27.

Table 5.27 Summary of APD Responses to When Last Enjoyed Something in Maths

Type of Response	Frequency	Example Comment(s)
Blank	70	
GCSE	27	*During my GCSE's / GCSE course work / GCSE C result - teacher called Mr. Addy!! I think that may have helped*
When understand/can do it	14	*Doing t-tests last week because I understood it! / WHEN I COULD DO IT!*
Practical applications	13	*Calculating application rates for fertiliser*
Don't know/ can't remember	12	*?*
APD	9	*APD SESSIONS*
Specific task	9	*Pearsons, Spearmans / I quite enjoy the mean etc.*
Never / Don't enjoy maths	12	*Never ever ever! Why was it ever invented? (8) / Don't enjoy Maths (4)*
Early secondary school	5	*At the start of secondary school, before the teacher had a mental breakdown*
Excel	5	*Excel work*
Other	3	*Don't mind maths but currently disillusioned with covering old ground*
Recently, Now	4	*The other day / Now!!*
A level	2	*A level / When I did A-level maths*
A level (not maths)	2	*A level technology - electronic circuit formula*
Calculating Wages	2	*When I add up how many hours I have worked for money*
Leaving	2	*My last lesson - leaving*
Statistics	2	*Statistics/graphs*
Very long time ago	1	*A very long time ago - addition and subtraction only!*
Various singly occurring responses	Total 11	*All the time / I did a simple mathematics programme called Kumon to raise my level of knowledge / 2002 I had a very good tutor / Last year studying for leaving certificate / Years ago / MATHS CHALLENGE / Subject material that was more challenging. Group's dependant on ability so not having to wait for others if they are not as quick / At primary school when you got to weigh things or each other / SUDOKU*

A summary of the students' responses to the open question

> ***'Can you suggest anything that would improve your confidence, attitudes or ability in mathematics?'***

is shown below in Table 5.28. The most frequently occurring responses were: more practice, application to real life scenarios, and more help. Whilst many responses were given by only one student, some of these seem very useful so the full list of these has been retained in the table below.

Table 5.28 Summary of APD Student Responses to 'Can you suggest anything that would improve your confidence, attitudes or ability in mathematics?'

Type of Response	Frequency	Example Comment(s)
No	15	No
More practice	9	More practice; No just 'Practice makes perfect'
Apply to real life/future	6	Practical application to real life scenarios
Individual help	6	To have maths support or some sort of help / more one on one help; struggling students to have 1 hour extra sessions soon after the lecture (within a few days)
Students do more work	4	Just keep bashing away at it and learning more.
Be more confident in stats	3	I feel confident in all areas of maths except stats; Feeling confident and able to do it.
Good notes / revision notes	3	Good revision notes; Keep using clear notes
More help	3	Motivating myself to get more help; More patience and time/explanation
More time	3	More time
More maths	3	More maths
Not do it	3	Not doing it; remove it from the course
Better understanding	3	Being able to understand it more
Group by ability	2	Further practice in groups of similar ability so there isn't such a wide range in the levels of understanding
Step by Step	2	Break it down more; explain any large calculations step by step
Make formulae easier, make simpler	2	Making formulae easier / Simplifying things
2 shorter classes	1	2x a week lessons
Already confident	1	I'm already fairly confident
Being reminded of methods	1	Being reminded of methods helped
Better mental arithmetic	1	Better mental arithmetic
Connect harder areas to easier areas	1	Making harder areas more connected to easier areas of the subject.
Difficult subject	1	I just find aspects hard

Do more maths before university	1	Carrying on doing mathematics as an AS subject
Don't think can ever do it	1	Not really. Don't think I'll ever like it or be good at it.
Don't want to do it	1	Not really because I'm very stubborn and stick to my beliefs and stick to my beliefs and opinions. Maths and me just don't mix at all and I just don't want to have to do it EVER again when I leave.
If more interested	1	Just don't find it interesting so this probably won't change
Keep up with the APD lessons	1	Just keeping up with APD stats lessons to improve my ability.
Learn maths all year	1	Yes maybe if we had maths continuously throughout the year and not just a small duration so it would be less rushed.
Learn more, better understanding	1	Learning more and understanding
More computer work	1	More computer work
More group work	1	To work in groups more
More interactive teaching style	1	More interactive / lively lectures
Make harder	1	Having to work at a higher level rather than covering old ground.
Notes on H drive	1	Put the notes on the H-Drive so we can do them in our own time as well.
Prefer a handwritten test, not computer	1	Instead of coursework a handwritten test as I feel this module tests your computer skills and NOT your maths
Pretty teachers	1	Really pretty teachers
Revision classes to fill gap from GCSE	1	To have revision classes right from GCSE standards
Smaller groups	1	Smaller groups
Success breeds confidence	1	Success breeds confidence
Work at own pace	1	Being able to work at our own pace
Total	**90**	
Non-blank	**75**	

Examples and a summary of the students' responses to the open question

'Any other comments'

is shown below in Tables 5.29. Overwhelmingly the most frequent response (91.0%) was blank, but three students wrote the equivalent of 'Thank you'. It is not totally clear whether the students are grateful for the opportunity to air their views in the questionnaire or whether they are expressing gratitude for the teaching and support during their first year; either way, it was positive to read these expressions of thanks. The other five examples shown could be grouped together with the students' suggestions for what would improve their learning and are sensible comments. There were only 23 responses to the Any Other Comments question, and six examples of these (with the frequencies) have been shown in Table 5.29.

Table 5.29 Examples of APD Student Responses to 'Any Other Comments?'

Example Responses	**Frequency**
No comment	4
Well taught module that helped make it easier by refreshing memory of statistics previously used.	4
Currently going for extra help. Very helpful and should be continued	1
Only work between lectures when required for assignments	1
I feel I will never use stats in the line of work I want to do.	1
Should be more practical	1

This concludes the analysis and presentation of the first year APD students' responses to the open questions. Analysis and results of the questionnaires completed by second and third year students learning statistics will be presented in the next section, 5.3.

5.3 2nd/3rd Year Students' Statistics Questionnaire Results

This section will present the results of the 2nd and 3rd year natural science and social science students' questionnaires which were completed in May 2005, 2006 and 2007, along with changes between the first year and the second year.

5.3.1 2nd/3rd Year Closed Questions and Marks Results

206 questionnaires were completed by second and third year natural science students studying Research Methods (RMNat) and 131 by social science students (studying RMSS) over three years. The response rates were fairly high. E.g. in 2007 52 out of 69 students (75%) completed RMNat questionnaires, and 55 of 88 students (63%) completed RMSS questionnaires. A summary of the student numbers, mean marks, confidences, attitudes and motivation responses is presented in Table 5.30 below. The second year details in Table 5.30 are an extract from Table 5.1 at the start of this chapter. For comparison, details of the BSc APD questionnaires (completed by BSc students in their first year) are also included, which have been further split into natural science courses (denoted as Nat), and social science courses (denoted as SS). An additional column showing the percentage of students which were male has also been added to Table 5.30. Approximately two thirds of the RMNat students were male (mean 67%), whilst about half (51%) of the RMSS students were male.

Other mean values for the 2nd RMNat students were: mean age was 21.1 years, mean GCSE mathematics grade was slightly below a B, i.e. between B and C, and most of the RMNat students had not studied A level mathematics. The median time spent working outside of lectures each week was 1 hour. For RMSS students the mean age was 20.3 years. The mean RMSS GCSE mathematics grade was also slightly below a B, but was significantly lower than for RMNat students (by Z test: $Z = 1.960$, $P=0.047$). The grades of the two types of BSc APD students are shown in Figure 5.9 below, and it can be seen that there were more A/A* grades in the RMNat students. The RMSS students had mostly not studied A level mathematics and the time spent working outside of lectures was 1.1 hours.

Table 5.30 Summary of Students' Confidences, Attitudes, Motivation and Marks for the Research Methods Module and comparison with First Year BSc APD Students

			Confidence				Attitude			Motivation		
Student Group and Year	**No. Students**	**% Male**	**Confidence in Mathematics**	**Confidence in Statistics**	**Confidence in Life**	**More Confident?**	**Like Mathematics**	**Like Statistics**	**Like Statistics More After Module**	**Motivation Rating**	**% Would Choose to Study Module**	**Overall Mean Mark %**
2nd and 3rd Year Natural Science Students' Statistics with Genstat (RMNat)												
2005	52	65	3.3	3.0	3.7	3.3	3.0	2.8	3.0	2.9	44	71.3
2006	102	65	3.3	2.7	3.8	3.1	3.0	2.5	2.7	2.7	23	60.9
2007	52	75	3.1	2.7	3.9	3.8	3.2	2.6	3.1	2.7	25	57.7
Total	206	67	3.3	2.8	3.8	3.3	3.1	2.6	2.9	2.7	29	62.6
Change from 1st year			-0.1	-0.2	-0.1	-0.1	=	=	=	-0.2	=	
2nd and 3rd Year Social Science Students' Statistics with SPSS (RMSS)												
2005	29	52	3.2	2.8	3.7	3.3	2.9	2.4	2.9	2.9	34	59.3
2006	47	55	2.7	2.4	3.8	3.2	2.6	2.3	2.9	2.9	33	68.4*
2007	55	47	3.2	2.5	3.9	3.1	2.9	2.2	2.5	2.5	9	69.2*
Total	**131**	**51**	**3.0**	**2.5**	**3.8**	**3.2**	**2.8**	**2.3**	**2.7**	**2.7**	**23**	68.8*
Change from 1st year			+0.1	-0.1	+0.1	-0.2	-0.3	-0.1	-0.2	-0.1	+2	
1st Year APD Statistics with Excel (APD) – BSc Students and Total APD												
Nat	70	70	3.4	3.0	3.7	3.4	3.1	2.6	2.9	2.9	29	53.7
SS	80	33	2.9	2.6	3.7	3.4	2.9	2.4	2.9	2.8	21	54.1
All BSc	**150**	**50**	**3.2**	**2.8**	**3.7**	**3.4**	**3.0**	**2.5**	**2.9**	**2.8**	**25**	**53.9**
Total APD	201	54	3.0	2.7	3.7	3.4	3.0	2.5	2.9	2.8	26	51.2

Key: Nat = Natural Science students, SS = Social Science Students,

*= Mean RMSS statistical calculation question marks shown, not total examination marks.

Figure 5.9 RMNat (left) and RMSS (right) GCSE Mathematics Grades Proportions

The values for the 2nd year natural science students in Table 5.30 are fairly similar for the separate years, except for the module marks which get progressively lower due to the changes to the examination, as was described previously in sub-section 5.1. The 2nd year social science assessment was changed from an assignment in 2005 to an examination in 2006 and 2007, and the student marks increased. These second year marks are higher than the 1st year marks on average, showing very good achievement in this module, especially in 2005. In Table 5.1 it appeared that the RMNat students were more confident than the 1st year APD students, but the summary for natural science BSc students in Table 5.30 enables the 2nd year students to be compared with similar student groups in their 1st year and from the very small changes shown (e.g. -0.1) it can been seen that there is very little difference between the 1st year BSc natural science students and the RMNat 2nd years. Their *Confidence in Mathematics* (mean 3.3) is fairly good, but is down slightly (-0.1); their *Confidence in Statistics* is slightly lacking (mean 2.8, down 0.2), but their Confidence in Life is very good (mean 3.8). Students' *Liking for statistics* is once again the lowest mean rating (2.6) showing an overall dislike for statistics. All three Liking ratings were unchanged from the first year (and represent a dislike of statistics), as was the percentage who would have chosen to study the statistics (only 29%).

A summary of ratings etc. for 1st year APD BSc social science students has also been included in Table 5.30. It can be seen that these were noticeably lower than the values for APD BSc natural science students. This may be caused by the different ability levels of the course groups (the GCSE mathematics grades were significantly lower for the APD social science students) or it may be another demonstration of the gender effect which was found for APD as the natural science APD students were predominantly male (70%), whereas the social science APD BSc students were predominantly female (only 33% male), and APD males students have already been shown to be significantly more confident than the females (in sub-section 5.2.2.1). It is believed that the natural science students were required to have a Science A level which the social science students were not, although there was no detailed data available on this. Alternatively it may just have been that these APD (and also RMSS) social science students were less confident than their natural science equivalents.

Table 5.31 below shows the mean *Topic Confidences* for the RMNat students. Only the familiar topics of 'Calculate the Mean' and 'Percentages' were given mean ratings above 4, and more difficult topics were given lower mean ratings as would be expected. All the mean topics ratings were, however, above three, in contrast to the mean *Confidence in Statistics* which was below 3 (mean 2.8). Once again there are much higher *Topic Confidences* than overall confidences, which provides further evidence that *Topic Confidences* are a different construct to the overall confidences (different confidence domains), as proposed by Parsons *et al.* (2009).

Table 5.31 Summary of Topic Confidences for 2005-7 RMNat Student Ratings 1 to 5 (5 = High)

Topic	Mean Confidence Rating
Percentages	4.1
Use Formulae	3.9
Calculate the mean	4.4
Calculate number of replicates	3.5
Skeleton ANOVA degrees of freedom	3.3
Factorial ANOVAs	3.1
t – tests	3.1
Interpret a C.V. %	3.2
Use of Genstat	3.4
Plot dose response result graphs	3.1
Interpret an F Prob value	3.5
Mean Topic Confidence	3.5
Mean Apply Topic Confidence	3.3

The mean topic ratings for the RMSS students are shown in Table 5.32 below. These were much more varied than for the APD or RMNat students. Although there are some higher *Topic Confidences* and the mean is 3.2, there are six *Topic Confidences* below 3, which were the topics being learnt in the RMSS module. This indicated that the students were lacking in confidence for these new topics, and is consistent with the very low overall *Confidence in Statistics* ratings for these students (mean 2.5). Even the mean of these six low *Topic Confidences* is 2.7 which was also higher than the overall mean of 2.5. This is another situation where the *Topic Confidences* were higher than the overall *Confidence in Statistics* (but not higher than overall *Confidence in Mathematics*, mean 3.0).

Table 5.32 Summary of Topic Confidences for 2005-7 RMSS Student Ratings 1 to 5 (5 = High)

Topic	Mean Confidence Rating
Percentages	3.9
Using Formulae	3.5
Mean, Median, Mode	4.1
Standard Deviation, Variance	3.0
Deciding which test to use	2.7
Correlation and Regression	2.8
t – tests	2.7
Chi Squared test	2.7
Multiple Regression	2.4
Use of SPSS	2.7
Presenting Data in Excel	3.9
Explaining Results	3.5
Mean Topic Confidence	3.2
Mean Apply Topic Confidence	3.4

A limited set of five more descriptive confidence questions were included in the 2007 RMNat and RMSS questionnaires. These were instead of the 11 Scale questions (based on Fogarty *et al.*, 2001) used in the APD questionnaires, although four of the five questions came from the Scale questions. Q37. '*I usually do well in Mathematics'* was a new question. These questions and the mean responses are shown in Table 5.33 below, with whether the question was a positive or negative statement. All of the mean responses indicated that the RMNat students were positive about their confidence to learn mathematics, unlike the RMSS students who once again indicated some lower confidences, although the RMSS mean for these questions was still positive, above three.

Table 5.33 RMNat and RMSS 2007 Five Scale Questions with their Mean Response and Classification

Question Statement	Question Polarity	RMNat Mean Rating	Response for positive question	Positive / Negative Mean Response	RMSS Mean Rating	Response for positive question	Positive / Negative Mean response
Q37. I usually do well in mathematics	+	3.47	3.47	Positive	3.40	3.40	Positive
Q38. I do not have a mathematical mind	-	2.76	3.24	Positive	3.20	2.80	Negative
Q39. It takes me longer to understand mathematics than the average person	-	2.78	3.22	Positive	2.85	3.15	Positive
Q40. I have never felt myself able to learn mathematics	-	2.20	3.80	Positive	2.36	3.64	Positive
Q41. I enjoy trying to solve new mathematics problems	+	3.06	3.06	Positive	2.64	2.64	Negative
Mean of 5 Scale Questions			**3.4**			**3.1**	

Source of question text Q38-41: Fogarty *et al.*, 2001

The mean responses for the students' ratings of different methods for doing statistics calculations are shown in Table 5.34 below. It can be seen that both RMNat and RMSS students rated all four methods of doing statistics calculations very highly, close to 4 out of 5 (and some above 4), which was in contrast to their confidence ratings. Rather than these questions revealing the students' preferences for which methods they considered most helpful, these results indicate that both the RMNat and the RMSS students thought that all methods were helpful, in short they valued doing the calculations by whichever method. This is consistent with open question responses which revealed that students know that they learn by doing and practising. There was less agreement however about how useful their 1st year APD statistics had been. RMNat students gave lower responses than RMSS students, which can be explained by the fact that the topics studied by the RMSS students did follow on more closely from first year topics than for the RMNat students. The RMNat students gave a higher rating for the importance of statistics (mean 3.5) compared to the RMSS students (mean 3.1). 61% of the 2005 RMNat responses rated the importance of statistics as 4 or 5 (out of 5). This was also evident in the students open questions where more of the RMNat students expressed the view that statistics would be useful for their later studies and life than the RMSS students who sometimes wrote that statistics would have no use or relevance to them later on. The importance of statistics to these students is a message that should be emphasised frequently by lecturers.

Table 5.34 2005-7 Research Method Students' Calculation Methods, APD Knowledge Usage and Importance of Statistics Ratings (1 to 5, 5 = High)

Method for learning and doing statistics or Feature being rated	RMNat Mean Confidence Rating	RMSS Mean Confidence Rating
Method: Calculations by hand	3.6	3.8
Method: Using a calculator	4.0	4.1
Method: Using Excel	3.7	3.9
Method: Using Genstat / SPSS	4.0	3.5
Whether had used what learnt in APD from memory	2.8	3.0
Whether had used what learnt in APD from notes	1.9	3.1
Importance of statistics	3.5	3.1

5.3.2 Research Methods Students' ANOVA and Kruskal Wallis Tests

The purpose of this sub-section is to look for characteristics which had a significant effect on, or relationship with, the students' marks or their overall confidences in mathematics and statistics, and is the equivalent for second years of sub-section 5.2.2.1 for 1st year APD students. The second year RMNat students' marks were shown in Table 5.30 (and Table 5.1) to have decreased each year due to the examination changes, and whilst the RMSS students' marks appear fairly consistent across the three years, that assessment had also changed between 2005 and 2006. So extra considerations were made about how to analyse these relationships, and for the RMNat data it was decided to analyse the marks by 2-Way ANOVA's with the questionnaire year as one factor and the variable of interest as the second factor, and the results are shown in Table 5.35. However, as Kruskal Wallis tests are only single factor non-parametric versions of ANOVA tests, it was not possible to do the equivalent of the 2-Way ANOVA and take account of the variation between the years for the RMNat confidences. So it was decided to analyse just the 2006 data for the

Confidence rating Kruskal Wallis tests, and for completeness the student mark ANOVAs were also carried out on the 2006 RMNat data; these results are shown in Table 5.36. For the RMSS student marks the statistics question marks were considered to represent achievement more closely aligned to the overall *Confidence in Statistics* than the total examination mark, so the statistics question marks were used for the ANOVA tests. As the Statistics questions marks were only present in the 2006 and 2007 data, the ANOVA tests excluded the 2005 data and so there was no issue with the different assessment in 2005. The confidences for the three years of RMSS data were considered to be sufficiently similar so the Kruskal Wallis tests did however include the data from all three survey years.

5.3.2.1 Research Methods Natural Science Students ANOVA and Kruskal Wallis Tests

The different RMNat marks for the three survey years were included in Table 5.30 and are shown on Figure 5.10 below. An ANOVA test confirmed that this difference was significant (F=79.58, Residual df=189, P<0.001).

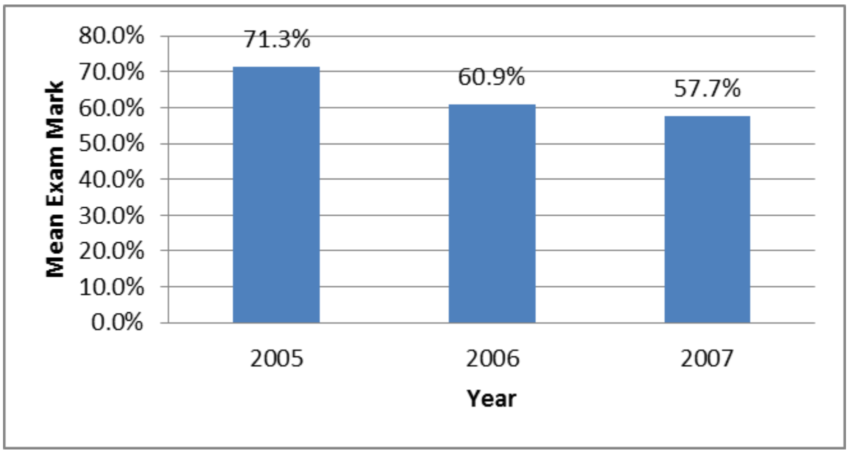

Figure 5.10 RMNat Mean Module Mark by Questionnaire Year

2-Way ANOVA tests were carried out on the three years' RMNat examination marks to look for relationships with a range of other variables, with the questionnaire year also specified as a factor, and the results are presented in Table 5.35 below.

From Table 5.35 below it can be seen that, from analysing the combined three years' data, the questionnaire year was always highly significant. The other variables which had a significant effect on the marks (also taking into account the year effect) were:

- Past qualifications: GCSE Mathematics Grade and tier, and whether the student had studied A level mathematics

Table 5.35 Natural Science 2005-7 Research Methods 2-Way ANOVA tests for Students' Marks, Various Variables and Questionnaire Year

Factor	ANOVA - 1st Factor		2nd Factor - Questionnaire Year		Total df
	P-Value	Sig	P-Value	Sig	
Group	0.164		0.002	**	191
Gender	0.120		**<0.001**	***	190
Age	0.730		**<0.001**	***	187
Dyslexia	0.087		**<0.001**	***	191
GCSE Grade	**<0.001**	***	**<0.001**	***	180
GCSE Tier	**<0.001**	***	**<0.001**	***	171
A level	**<0.001**	***	**<0.001**	***	167
Would Choose to Study Statistics	**<0.001**	***	**0.002**	**	187
Confidences in Mathematics	**<0.001**	***	**<0.001**	***	190
Confidences in Stats	**<0.001**	***	**<0.001**	***	190
Confidences in Life	0.324		**<0.001**	***	190
Confidences in More	0.007	**	**<0.001**	***	188
Liking of Mathematics	**<0.001**	***	**<0.001**	***	189
Liking of Statistics	**<0.001**	***	**0.001**	***	189
Like More after Module	**0.018**	*	**<0.001**	***	187
Motivation	**0.005**	**	**<0.001**	***	188
Motivation Same	**0.007**	**	**<0.001**	***	189
Time Spent	0.935		**<0.001**	***	188
Inspiration	0.474		**<0.001**	***	184
Importance of Statistics	0.172		**<0.001**	***	186

- Confidences: *Confidence in Mathematics* and *Confidence in Statistics*
- Attitudes: *Liking of Mathematics* and *Liking of Statistics*
- Motivation: Motivation and whether their motivation was the same as for other subjects, and whether the student Would choose to study statistics.

Variables which were not significantly related to the marks were: Group, Gender, Age, Dyslexia, Confidence in Life, Whether the student was more confident, Amount of time spent working outside of lectures, Whether the students had had a moment of inspiration and their view of the Importance of statistics.

The results of these ANOVA tests are fairly similar to those found for the ANOVAs for the APD statistics marks. However, there was no test for Award as these were all BSc students, or for Course because there were too many different course names. The

Group variable indicated whether these students were from the Agriculture group or the Animal group; the Agriculture group students had slightly higher marks on average than the Animal group students, but the difference in marks was not significant.

A similar, but slightly different pattern of significant relationships was found when only the 2005 marks were analysed by ANOVA tests (n=52, α=0.05, two-tailed tests). Highly significant relationships with the mark were found for: *Confidence in Statistics* (P<0.001) and *Liking of Statistics* (P<0.001). Significant relationships with the mark were found for: *Confidence in Mathematics* (P=0.020), *Liking of Mathematics* (P<0.001), Mathematics GCSE grade (P=0.020); A Level mathematics (P=0.027); and Age (P=0.042). Variables which did not have a significant effect were: Confidence in life (P=0.133); Time Spent (P=0.382); Dyslexia (P=0.403); and Whether students had had a moment of Inspiration (P=0 .517).

102 second year natural science students completed questionnaires in May 2006, for whom 93 were able to be matched with their Genstat examination mark, and the results of ANOVA tests are shown in Table 5.36 below. Significant relations were found between the marks and the following variables:

- Past qualifications: Maths GCSE Grade, Tier and whether had studied A level mathematics.
- Confidence: Overall *Confidence in Statistics*
- Attitude: *Liking of Statistics.*

This was fewer relationships for the 2006 data than for the three years' data in Table 5.35, possibly due to there being fewer data values, or it may be that the 2006 cohort was slightly different from the data for the three years combined. It is interesting that for the 2005 data and the 2006 data, when each year's data was analysed separately, the effects of the students' *Confidence in Statistics* and *Liking of Statistics* were stronger than those for mathematics on the RMNat students' marks.

As was explained at the start of this sub-section, the Kruskal Wallis tests for relationships between the overall confidences and other variables were carried out using only 2006 data so as to avoid any differences in the years clouding the results, and the results are shown in Table 5.36 below. Significant relations were found between the May 2006 second year natural science students' *Confidence in Mathematics* and the following:

- Gender: Males were more confident than females.

- Past qualifications: Maths GCSE Grade and Tier, whether had studied maths A Level, higher confidence was associated with higher past qualifications.
- Confidences: *Confidence in Statistics*, Confidence in life and Whether more confident after the module.
- Attitudes: *Liking of Mathematics* and *Liking of Statistics*

Table 5.36 Natural Science 2006 Research Methods ANOVA and Kruskal Wallis Tests

Factor	Genstat exam mark - ANOVA		Confidence in mathematics - Kruskal Wallis		Confidence in statistics - Kruskal Wallis	
	P-Value	Sig	P-Value	Sig	P-Value	Sig
Group	0.408		0.088	*	0.970	
Gender	0.301		**0.002**	***	0.407	
Age	0.055		0.099		0.387	
Dyslexia	0.632		0.575		0.201	
GCSE grade	**<0.001**	***	**<0.001**	***	**0.003**	***
GCSE tier	**0.003**	**	**<0.001**	***	**0.004**	**
A level	**0.014**	*	**<0.001**	***	**0.009**	*
Would choose to study statistics	0.053		0.218		**0.010**	
Confidence in mathematics	0.137		**-**		**<0.001**	***
Confidence in statistics	**0.004**	**	**<0.001**		**-**	
Confidence in life	0.708		**0.014**	*	0.356	
More confident after module	0.097		**0.043**		**<0.001**	
Liking of mathematics	0.081		**<0.001**	***	**<0.001**	***
Liking of statistics	**0.028**	*	**<0.001**	***	**<0.001**	***
Like more after module	0.195		0.084	*	**0.005**	
Motivation	0.543		0.098		**<0.001**	***
Motivation same	0.201		0.106		0.089	
Time spent	0.679		0.159		0.353	*
Inspiration	0.568		0.139		0.446	
Importance of statistics	0.073		0.423		**0.036**	

The significant relationships with *Confidence in Statistics* were very similar to those with *Confidence in Mathematics*, except there was no effect of Gender or Confidence in life, but there was a clear link with the students' level of Motivation and their view of the Importance of statistics.

5.3.2.2 2nd/3rd Year Social Science Significant Relationships

In order to look for significant relationships for the social science students, further ANOVA tests and Kruskal Wallis tests were carried out on the students' statistics question marks (2006 and 2007 data) and confidences (all three years' data), and the results are detailed in Table 5.37 below.

Table 5.37 Social Science 2005-7 Research Methods ANOVA and Kruskal Wallis Tests

	Statistics Questions Mark * - ANOVA		Confidence in Mathematics - Kruskal Wallis		Confidence in Statistics - Kruskal Wallis	
	P-Value	Sig	P-Value	Sig	P-Value	Sig
Course	0.090		**0.005**	**	**0.012**	*
Gender	0.401		0.175		0.933	
Age	0.091		0.901		0.943	
Dyslexia	0.159		**0.011**	*	0.305	
GCSE grade	**<0.001**	***	**<0.001**	***	**<0.001**	***
GCSE tier	**0.042**	*	**<0.001**	***	**<0.001**	***
A level	**0.036**	*	**<0.001**	***	**<0.001**	***
Would choose to study statistics	0.172		0.243		**0.024**	
Confidence in mathematics	**0.028**	*	-		**<0.001**	***
Confidence in statistics	0.149		**<0.001**	***	-	
Confidences in life	0.632		0.128		0.654	
More confident after module	0.524		**0.017**	*	**0.002**	**
Liking of mathematics	0.150		**<0.001**	***	**<0.001**	***
Liking of statistics	0.234		**<0.001**	***	**<0.001**	***
Like more after module	0.405		0.245		**0.002**	**
Motivation	0.330		0.728		0.719	
Motivation same	0.203		0.573		0.206	
Time spent	0.940		0.373		0.737	
Inspiration	0.590		0.314		0.547	
Importance of statistics	0.915		**0.012**	*	**0.012**	*

*= The RMSS statistics question marks had to be transformed (squared) to produce a normal distribution of residuals.

The RMSS marks were significantly related to past qualifications (mathematics GCSE grade and tier, and whether had studied A level mathematics) and to *Confidence in Mathematics*, but not to *Confidence in Statistics* or any of the 'Liking' variables, as shown in Table 5.37 above. This was unexpected as these marks related specifically to achievement in statistics; however this can possibly be explained by the low values in the *Confidence in Statistics* and Liking variables, so these variables also have very low variation, which perhaps prevented clear differences being found. Fewer significant relations were found between the RMSS statistics question marks and other variables than for the APD and RMNat marks.

The significant relationships between the *Confidence in Mathematics* and other variables, and between *Confidence in Statistics* and other variables, follow a more expected pattern. There were clear groups of variables which were significantly related to *Confidence in mathematics*: Past qualifications; Confidences; Attitudes (Liking variables); and the Importance of statistics. The significant relationship with course is understood to be another past qualification effect; a Kruskal Wallis test was carried out which found that there was a significant difference in the Mathematics GCSE grade for the three different courses surveyed ($H= 12.36$, $df = 2$, $P<0.001$).

Table 5.38 below shows further analysis of the 5 scale questions, the mean responses for which were previously presented in Table 5.33, along with a description of these questions. In this further analysis ANOVA and Kruskal Wallis tests have been carried out looking for relationships with the marks, *Confidence in Mathematics* and *Confidence in statistics*, to assess which of these questions were best at measuring students' *Confidence in Mathematics* (as specified in Research Question I.a). Questions 38-41 were chosen because these were considered the most effective questions in the 2006 APD questionnaire analysis and it was not surprising that these questions again have very strong relationships with *Confidence in Mathematics* (all $P<.001$). Q 37 '*I usually do well in mathematics'* also appears to be equally effective, and had a better relationship with *Confidence in Statistics*. Considering the wording of questions 39 and 41 these have a slightly different emphasis being about time and enjoyment rather than just confidence. So, in addition to questions asking students directly to rate their confidences, three other questions have been found to be effective at assessing *Confidence in Mathematics*: Q37 *'I usually do well in mathematics;,* Q38 *'I do not have a mathematical mind';* and Q40 *'I have never felt myself able to learn mathematics'.* The question rating the statement '*I find maths confusing'* was also found to be a useful question in Chapter 4.

Table 5.38 Research Methods 2007 Marks, Confidences and the 5 Scale Questions ANOVA and Kruskal Wallis Tests

Question Statement	RMNat Genstat Exam Mark % ANOVA P-value	RMNat Confidence in mathematics KW P-Value	RMNat Confidence in statistics KW P-Value	RMSS Statistics Questions Mark % ANOVA P-value	RMSS Confidence in mathematics KW P-Value	RMSS Confidence in statistics KW P-Value
Confidence in mathematics	**<.001**	**-**	**-**	**0.010**	**-**	**-**
Confidence in statistics	**<.001**	**-**	**-**	**0.005**	**-**	**-**
Q37. I usually do well in mathematics	0.506	**<.001**	**<.001**	**0.003**	**<.001**	**0.001**
Q38. I do not have a mathematical mind	0.052	**<.001**	**0.002**	**0.050**	**<.001**	**0.010**
Q39. It takes me longer to understand mathematics than the average person	0.527	**<.001**	**0.035**	0.144	**<.001**	0.086
Q40. I have never felt myself able to learn mathematics	0.054	**<.001**	**0.019**	0.114	**0.003**	0.113
Q41. I enjoy trying to solve new mathematics problems	**0.046**	**<.001**	**<.001**	0.087	**0.010**	0.059

Key: KW = Kruskal Wallis test. P-Values <= 0.05 have been shown in bold font.

5.3.3 2nd/3rd Year Students Studying Statistics' Regression Analysis

In this sub-section regression models will be presented for the student marks in the RMNat and RMSS modules. A Multiple regression model was obtained for the natural science students' marks, but only a Linear regression model based on a single dependent variable (GCSE grade code number) could be produced for the social science students' marks.

5.3.3.1 2nd/3rd Year Natural Science Statistics Regression Analysis

The following Multiple Regression model was produced to predict the natural science students' marks and is based on the Questionnaire year, GCSE mathematics grade (where A/A*=3, B=2 etc.) and *Confidence in Statistics* (coded 0-4). The percentage variation explained by this model is 31.9%, which is comparable to the Engineering student Multiple Regression models: which were approx. 36% for the 1st year models and 34% for the 2nd year model. The RMNat marks were approximately 14% higher in 2005 than in 2006 or 2007. Once again the confidence variable coefficient was approximately 5. This model predicts that a most confident student would achieve 18.3% higher marks than a least confident student, and likewise an A Mathematics GCSE grade student would achieve 19.6% more than one with grade D.

Second year Natural Science Students' Mark % = 39.723

+ 12.018 if 2005

+ 6.539 x GCSE Mathematics grade number

+ 4.568 x *Confidence in Statistics*

[R= 0.575 and R^2 = 33.0%, Adjusted R^2 = 31.9%,
All coefficients P<.001, Durbin Watson = 2.057, n=179]

5.3.3.2 2nd/3rd Year Social Science Statistics Regression Analysis

The following Linear regression model was produced to predict the social science students' marks and is based on the students' GCSE mathematics grade. This model only explained 16.6% of the variation in the students' marks. The low percentage explained indicates that most of the variation in marks is caused by other factors, although various other factors were tried in different models including: confidences, gender, motivation and time spent, none of these produced significant coefficients. So the large amount of unexplained variation must be the consequence of factors outside of this study. A second model was also produced for the overall Research Methods exam mark, however less variation was explained by this model, only 14.0%.

RMSS Statistics Questions Mark %

= 51.927 + 10.003 x GCSE Mathematics Grade number

[R= 0.407 and R^2 = 16.6%, all coefficients P<.001, Durbin Watson = 1.731, n=88]

RMSS Examination Questions Mark %

= 47.833 + 6.096 x GCSE Mathematics Grade number

[R= 0.374 and R^2 = 14.0%, all coefficients P<.001, Durbin Watson = 1.932, n=118]

The mean statistics question marks by GCSE mathematics grades are shown in Figure 5.11 below and the individual marks by GCSE mathematics grade are shown in Figure 5.12 below. A similar trend was found in the mean statistics question marks by whether students had studied A level mathematics, and this is shown in Figure 5.13 below.

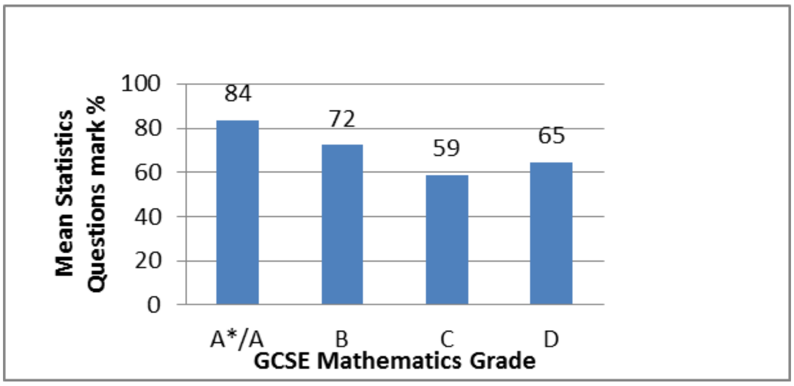

Figure 5.11 RMSS mean statistics question marks by GCSE mathematics grades

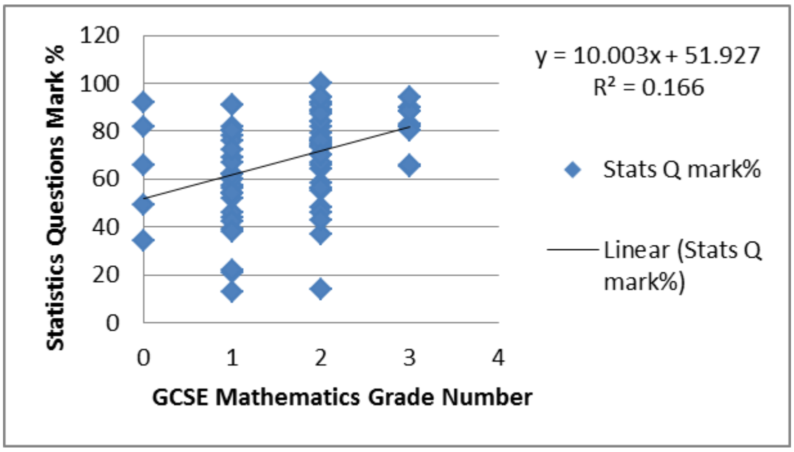

Figure 5.12 RMSS Individual Statistics Question Marks by GCSE Mathematics Grades with Linear Trend Line and Equation

Note: The GCSE Grade Numbers were allocated for grades as follows: A/A*=3, B=2, C=1 and D=0.

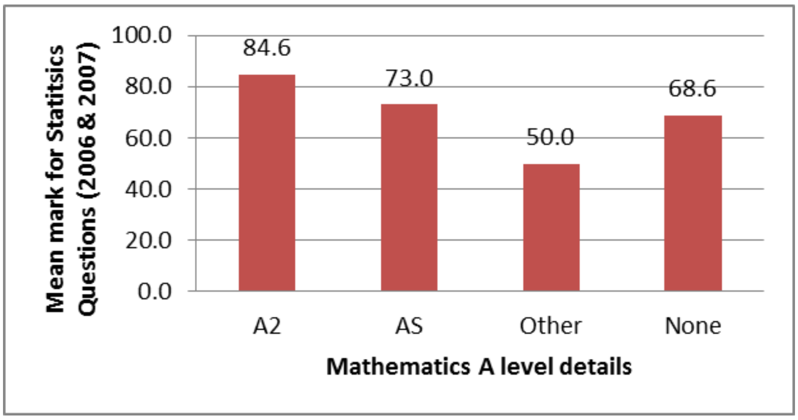

Figure 5.13 RMSS Mean Statistics Question Marks by A level Mathematics Type

This concludes the analysis of the second year natural science and social science students' closed question results.

5.3.4 2nd/3rd Year Natural Science Statistics Open Questions

Summaries of students' responses to a selection of open questions will be presented in this sub-section. Students' attitudes to learning statistics responses were categorised as positive, neutral or negative and the frequencies for these categories (and blanks) are shown in Figure 5.14 below.

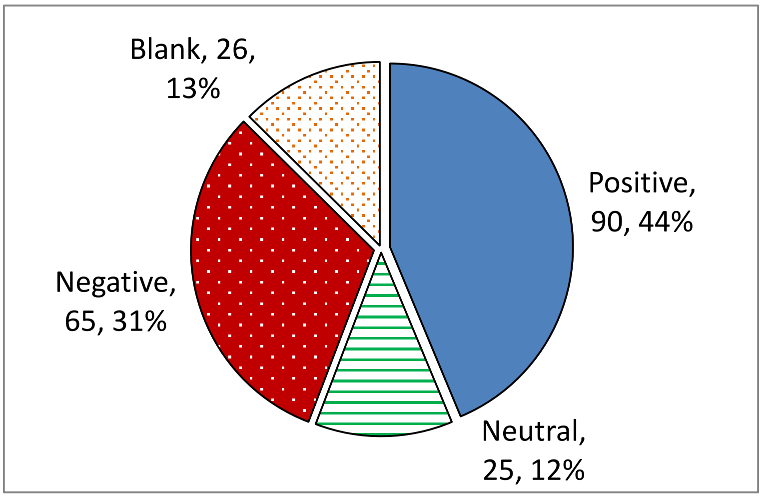

Figure 5.14 2nd Year Natural Science Students' Attitudes Summary

A summary of RMNat students' responses to ***'Which aspects of the module particularly helped your learning'*** is given in Table 5.39 below.

Table 5.39 2nd Year Natural Science Statistics Student Features of Module which Helped Learning

Response Type	Frequency	Example Response
Doing exercises	22	Practising doing the exercises
Tests	21	Tests each week act as a refresher
Genstat	16	The computers (Genstat) helped with process of the maths
Practical Computer exercises	16	Practical computer-based examples
All	7	All / Pretty much all of it.
Lecturer	7	A good lecturer, explains things well
Worked examples	7	Worked examples
Handouts	6	Notes given so can concentrate on what is being taught and less on writing the notes down
None	4	To be honest none of it particularly helped in fact it just made other subjects unnecessarily complex
Teaching	4	The teaching, very good standard
ANOVA	3	ANOVA / Using ANOVA weekly
Repetition of important things	3	Keep going over the important little things
Experiment design	2	Experiment design
Factorial experiments	2	Factorial experiments / Factorial for set-up of IP project
Lectures	2	Lectures well planned, structured and delivered
Not used for anything else	2	It only has relevance to this module so far / Not used any of it outside the classroom
Real data	2	Actually doing the calculations with real examples / Using realistic examples
Doesn’t make you feel stupid	1	Lecturer very thorough & will repeat if necessary. Doesn't make you feel stupid.
Interesting topics	1	Quite interesting topics - foot rot etc.
Learning how to analyse data for IP’s	1	Learning the way methods of analysis should be carried out for IP’s
Lecturer checking work	1	lecturer making sure they have been done correctly before we leave
Work broken down in smaller pieces	1	How it is all broken up into manageable classes
	24	Other varied singly occurring responses
Total	**155**	
Total excluding None	**151**	

A summary of RMNat students' responses to ***'Which aspects of the module particularly hindered your learning'*** is given in Table 5.40 below.

Table 5.40 2006 2nd Year Natural Science Statistics Student Features of Module which Hindered Learning

Response Type	Frequency	Example Response
None	24	None / Nothing really
Lecturer / Teacher	11	We have never had anything explained properly / just reads from handouts and students just fill in gaps / Boring tutor! / Being confused by lecturer
Difficulty using computers /Genstat	8	I'm not particularly skilled with computers / Not very good with computers / Genstat on computer takes time to get used to!
Confusion over terminology	6	Complicated jargon in explanations /Many different words which meant quite simple things
Difficult subject	5	Difficult principles to grasp / The complexity / Subject can be confusing as there is a lot of data to interpret at the same time
Too fast	5	The speed and intensity of information / Seems a bit rushed sometimes?
Timing	4	Lecture on a Friday afternoon, difficult to concentrate
Lecturer talking when working	2	Lecturer talking when trying to use genstat or formulae / Lecturer talking when you're trying to think
Maths	2	Mathematical aspects
Repetition	2	The lengthy labouring of points when they have already been clearly explained.
Test wording	2	Wording of test question
Too slow	3	Slow speed / Other class mates taking ages on questions.
Want open book exam	2	Non- open book exam - this stuff is complicated enough
2 hours too long	1	Straight 2 hours
Embarrassed to ask/answer questions	1	Class environment, embarrassed to try answering/ask questions.
Feeling less able than class mates	1	Other class members being great at it and me feeling very stupid when having to ask for help
Large class size	1	Classroom. Number of individuals within class
Wanted more notes, easier	1	Needed more notes. Found handbook difficult to follow
Various	28	25 various singly occurring responses, 3 don't know
Total	**110**	**Total (excluding None) = 86**

A summary of responses to ***'Can you suggest anything that would improve your confidence, attitudes or ability in mathematics?'*** is given in Table 5.41 below.

Table 5.41 2006 What would Improve Learning for 2nd Year Natural Science Statistics Students

Response Type	Frequency	Example Response
None	28	No, Not really, I feel they are high already
More practice	13	Doing it more! More practice
Apply to a work situation/real world	3	Put into practice in a work situation, Seeing its application to my life
More work outside of lectures	3	Doing more outside university / More time spent out of lectures on the subject
Use it more often	3	Using it more often, none of the other modules really use it./ If it was used more frequently. 2 hours a week used in complicated maths, its like never training but running 26 miles once a week
More computer work	2	More practice on the computer would increase my confidence. / Better having computer training earlier on
One to one help	2	Individual instruction from lecturers when they see you struggling
Pass module with good grade	2	Passing the module and getting good grade
Revision	2	Revise more / More revision for better understanding
Ask for Help	1	I could try approaching someone or teaching myself but I lack the time
Better motivation	1	My motivation to work at the subject
Better school teaching	1	Better teaching in schools
Better teaching	1	Different style of lecturing may aid learning
Better understanding of purpose	1	Understand why certain statistics are performed and what exactly they tell you
Do A level Maths before uni	1	Doing an A-level in maths
Genstat on own laptop	1	Able to put Genstat on my laptop would help me practise at home.
Glossary sheet	1	Having a glossary sheet of what different things test for and how
Handouts without gaps	1	Handouts with formula's & calculations in.
Integrate with other subjects	1	Integrate it more with the subject I am studying although was fairly well done anyway.
Revision material	1	Clear revision guides
Simpler explanations	1	Explanation in simple terms delivered at my level of understanding. Working through examples
Smaller groups / 1-1	1	More smaller groups, enabling 1 on 1s
Ability groups	1	More segregated into ability groups. Similar questions asked
Total	**88**	Includes 16 various other singly occurring responses

5.3.5 2nd/3rd Year Social Science Statistics Open Questions

A summary of responses to ***'How would you describe your attitude to learning statistics?'*** is shown in Table 5.42 below and summarised in Figure 5.15.

Table 5.42 2nd Year Social Science Statistics Students' Attitudes to Learning Statistics

Type	Frequency	Attitude
Average	8	Not the best. Once do it, it's not that bad but just seems bit tedious when start
Positive	8	positive
Disinterested	7	Does not interest me / I find it dull so put little effort in / No interest, easily bored - don't listen, no motivation
OK	7	OK / Open minded
Good	6	Fairly good as it should prove useful
Find difficult	5	Found it difficult to understand, still don't understand
Just got to get on with it	5	Just get on with it - you have to sit down and do it
Not enthusiastic	5	not good, not enthusiastic
Poor	5	Bad, I come to the lessons with the attitude that I'm going to hate it and I usually do!
Try	5	Not brilliant, I try but not understand really
Bored	4	Boring / Boring and overall tedious / Can get a bit bored as covered most of it in the past but some new methods incorporated have helped keep me interested
Reluctant	4	Don't think need to learn anymore
Can't see relevance	4	Not really something I will use in future / often wonder as to the relevance of statistics
Not motivated	3	Not very motivated
Too slow	3	It's explained in far too much detail, needs speeding up ; Taught too slowly
Useful subject	3	Useful for assignments - future dissertation
Willing	3	Willing
Defeated	2	Defeated ; Feel a little bit beaten before I start
Hate statistics	2	I hate stats and like other aspects of maths / I hate it, it is a waste of time, will never use statistics in the future
Negative	2	Negative. Reluctant to do so.
Not confident	2	Would like to learn to be confident with it, however, struggle to learn how to grasp it
Find hard but manage	2	I struggle a bit but am learning! / Often feel lost! But get there in the end - usually!
Improving	1	Can seem pointless sometimes, but the more I learn the better it gets
Very useful	1	Not really wanting to do it but it is very useful. You can prove anything with statistics!
Like when can do	1	I like it when I understand it but I'm easily put off
Various	**12**	12 various other singly occurring responses
Total	**113**	Including 3 which were *'?'*

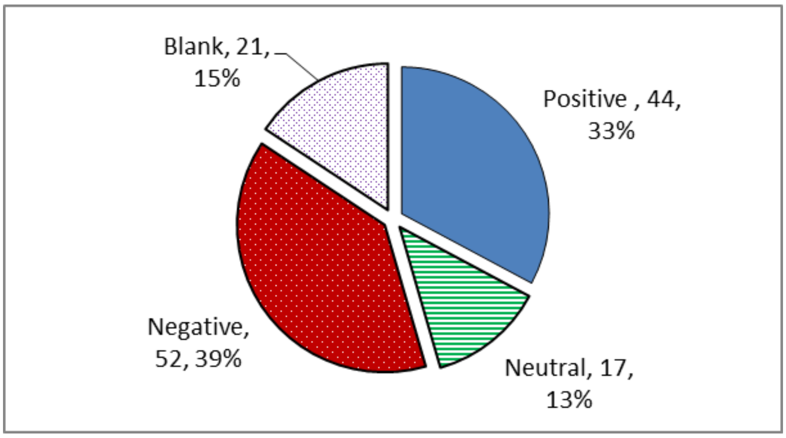

Figure 5.15 2nd Year Social Science Students' Attitudes Summary

Whilst the responses were mixed, there were unfortunately more negative responses than positive.

A summary of student responses to '**which aspects of the module helped their learning'** is shown in Table 5.43 below.

Table 5.43 2nd Year Social Science Statistics Student Features of Module which Helped Learning

Type	Frequency	Helped
Blank	41	
SPSS	18	SPSS / Think SPSS be useful for final year
Handouts	9	The handouts, they are clear and good to look back upon / Notes which are given out in class are helpful / The notes that were explanatory and then showed examples / Notes…fill in the 'blanks style'
Computer work	6	Computer work
Excel	5	Use of Excel / Excel work
None	5	None
Assignment	4	Assignments
Lecturer	4	Module tutor's trying to help me, but it is a shame I don't understand, Lecturer attitude and teaching methods / Lecturer makes this quick and clear /
Lectures	4	Lectures
Coping strategies	3	Coping strategies / Coping strategy sheets.
Examples	3	Examples given in lectures
Answers	2	Giving us the answer sheet helps
chi squared	2	T-tests and chi-squared
Clear examples	2	Clear examples / Having good examples to work from made it easier to follow step by step
Coloured paper	2	Coloured paper.
Correct application of formulae	2	Explaining of different methodologies etc. for dissertations & correct application of formulae
Doing work outside of class	2	Going over it on my own / Do homework, it makes you get your head around it, in a quieter environment
Proforma	2	Proforma, The revision sheet from XXXX showing the steps to take to answer questions
Research theories	2	Research theories
Revision	2	Revision
t tests	2	t tests
Tutorials	2	The tutorials are particularly helpful with the assistance of the lecturer
Worked examples	2	Worked examples
Various	35	35 various other singly occurring responses
Total	**161**	**Total Excluding blank = 120**

A summary of student responses to **which aspects of the module hindered their learning** is shown in Table 5.44 below.

Table 5.44 2nd Year Social Science Statistics Student Features of Module which Hindered Learning

Type	Frequency	Hindered
Blank	58	
None	12	None/ No aspect particularly hindered the learning
Computer exercises	9	Computer exercises / PC work / Computer session using SPSS / Didn't like the computer sessions. They were long and very boring
Statistics	6	Statistics
Formulae	5	All the formula / Equations / Very similar formulae / Formulae - certain aspects hard going
Difficult subject	3	It's just a difficult subject / Complex nature of the subject / All difficult, have tried.
Lack of motivation and interest	3	Lack of motivation and interest / Lack of enthusiasm
Teaching confusing	3	Did not find the way it was taught or explained very easy to understand / confusion in teaching / The teaching and the confusion from myself and my lecturer.
?	2	Don't know
Chi Squared	2	Chi squared
Long lectures	2	2 hour sessions / The length of lectures, sometimes lectures are too long
Not relevant to future job	2	Thought it seems irrelevant to our future job specification
Numbers	2	Numbers / too much numbers
Teaching poor	2	Poor lecturing / Poor teaching and explanations
Timing	2	I find it more difficult to concentrate on maths later in the day
Too fast	2	Lecturer going to fast when explaining formulas or points. / Rushing through it
Took time needed for other subjects	2	Occupied time needed for other more relevant subjects / The module hindered learning important things in other useful modules!
Write listen and learn at the same time	2	Having to write and listen and learn at the same time - not take things in / Copying down worksheets, with gaps to be filled in, whilst lecturer is discussing and drawing on other screen. Needed to focus on 1 or the other.
Overall knocked my confidence	1	Overall knocked my confidence
Sheets on H drive or Moodle not helpful if gaps not filled in	1	If miss lectures H-drive or Moodle sheets not helpful if gaps not filled in
Various	**28**	28 various other singly occurring responses
Total no. responses	**149**	**77 not blank / None / Don't know**

5.3.6 Second Year Students' Changes from the 1st Year to the 2nd Year

A comparison was made of the student id numbers in the 1st year and in the 2nd year, and it was found that 47 1st year natural science students' questionnaires could be matched with a 2nd year questionnaire, and likewise for 21 social science students. These students' marks and confidences were then compared and the results of these comparisons are shown in Table 5.45 below. It has already been shown in Table 5.1 and Table 5.30 that the second year marks were higher than the 1st year APD marks, however the mean mark values shown in Table 5.45 below differ slightly from the values in the earlier tables because these are the means of the matched students' details (only). When comparing the 2nd year mark to the 1st year mark there was a very clear increase in achievement by both the natural science and social science students: 36 out of 47 natural science students (77%) and 15 out of 21 social science students (75%) had an increase in mark. However, in contrast, there were some very clear

Table 5.45 Comparison of 1st Year and 2nd Year Marks and Responses for Natural Science and Social Science Students Matched by id Number

Student type	Mark %	Mark standard deviation	Confidence in mathematics	Confidence in statistics	Like mathematics	Like statistics	Motivation	Would choose to study statistics	
Natural Science (47 students)									
1st year APD	57.6	7.5	3.45	3.17	3.28	2.85	3.00	18	38.3%
2nd year RMNat	63.9	15.9	3.57	2.85	3.17	2.65	2.70	9	19.1%
Change	6.3	15.3	0.13	-0.32	-0.17	-0.26	-0.36	-9.0	-19.1%
Change Standard Deviation	15.3		0.64	0.72	0.81	0.86	0.89		
Social Science (21 students)									
1st year APD	60.7	11.0	2.81	2.48	2.71	2.14	2.86	1	4.8%
2nd year RMSS	71.6	18.8	2.90	2.24	2.57	2.24	2.71	2	9.5%
Change	10.7	19.6	0.10	-0.24	-0.14	0.10	-0.14	1	4.8%
Change Standard Deviation	19.6		0.87	0.81	0.77	1.06	1.46		

decreases in their ratings, in particular there was a decrease in *Confidence in Statistics*, *Liking of Mathematics*, *Liking of Statistics* (only for natural science students) and their Motivation. The largest decreases were for natural science students, however the lowest ratings (not changes) were still for the social science students all of whose 1st and 2nd year mean ratings were below 3, i.e. lacking confidence and motivation and disliking the subjects. These results are a further example of a clear disparity between the actual, very good marks, with an increase in achievement and students lacking confidence, having poor attitudes and low motivation. At the time of the survey the second year students had not taken their examinations, however once again it has been found that further reassurance from lecturers would be advisable to help to reassure students of their good chances of success based on the good performance of previous cohorts of students.

RMNat and RMSS students' responses to *'How do you consider that your confidence, attitudes or ability in mathematics have changed during this your second or third year? Can you describe in what ways and why?'* were analysed and summarised. Unfortunately just one question asked about three different attributes (although three separate questions would have been too repetitive) and not all students gave a clear response to all three attributes; however the responses which were obtained have been categorised and summarised. The number of students and respective proportions of student responses which indicated: improvements, no change; decrease; or no response are shown for students' confidences, attitudes and ability in Table 5.46 below.

Although the non-response portion is the largest for the 2nd year Social Science students', it can be seen that the greatest change reported was an improvement in confidence (28%), and the greatest decrease shown was that a large number of students reported having worse attitudes, which is consistent with the decreased rating for *Liking of Mathematics* (15%) which was reported in Table 5.30 (and surprisingly not such a large decrease in *Liking of Statistics*, because that was already very low in their first year, much lower than for mathematics). Interestingly Table 5.30 presents a more positive view of the students change from the 1st to their 2nd year than the changes in ratings presented in Table 5.46.

Table 5.46 Natural Science and Social Science Students' Confidence, Attitude and Ability Changes from the 1st to the 2nd Year

	Improved		No change		Decrease		No response	
	No.	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**
Natural Science								
Confidence	56	28%	44	22%	13	6%	88	44%
Attitude	31	15%	39	19%	7	4%	124	62%
Ability	43	21%	38	19%	3	2%	117	58%
Social Science								
Confidence	36	28%	24	18%	13	10%	58	44%
Attitude	26	20%	23	18%	20	15%	62	47%
Ability	30	23%	24	18%	8	6%	69	53%

A few examples of student responses are shown below.

- *'Yes I think confidence, attitudes and ability has improved. Statistics and their applications become more clear'*
- *'I have become more confident but I still struggle with maths and statistics as this is just one of my personal weaknesses*'
- *'Remained the same confidence, down in attitude, ability the same'*
- *'Haven't changed a lot, just still know I need to get a grip of it, just doing it and finding a strategy is hard'*
- *'Less confident because really struggle to understand it'*
- *'Decreased in all areas'*

This concludes the results of the second year students' open questions.

5.4 Conclusions from Questionnaires Completed by Natural and Social Science Students Learning Statistics

This chapter has reported on the findings from the questionnaires completed by 1st and 2nd year students studying statistics, who were on the Agriculture, Animal, Rural Affairs and Business courses (but not on Engineering Courses). These students achieved fairly well in their statistics assessments, especially the 2nd year students, but in contrast to that many of them were found to be lacking in confidence, and most of them did not like statistics and had low motivation to study statistics. The conclusions for this chapter are written in order of the Research Questions stated in the Introduction.

RQ I.a How can students' self-confidence in mathematics be defined and measured?

The three Mathematics Self-confidence Domains (*Overall Confidence*, *Topic Confidences* and *Applications Confidences*) were used in this chapter. The direct *Confidence in Mathematics* and *Confidence in Statistics* questions and three other Scale questions (in which students rated their agreement with the statement) were considered to be the most effective: *'I usually do well in mathematics; 'I do not have a mathematical mind';* and *'I have never felt myself able to learn mathematics'.* The *Topic Confidences* were also measured very effectively, with higher confidences being associated with easier or more familiar topics, as would be expected. The results of the *Applications Confidences* were similar to those of the engineering students, i.e. that some students would be more positive as they would have learnt and practiced more by then, whereas others felt they would be less confident due to having forgotten what they had learnt by then.

RQ I.b What effect does students' self-confidence in mathematics have upon their learning and performance?

It has been shown in this chapter that the students' *Confidence in Mathematics* and *Confidence in Statistics* are usually both significantly related to achievement (the only exception being 2nd year RMSS students for which only *Confidence in Mathematics* was significantly related). A linear regression model has been produced for each student group. The second year natural science students' Multiple Regression model was the most effective and explained 31.2% of the variation in marks, and was based on which year the questionnaire was completed, the students' GCSE grade and their *Confidence in Statistics*.

RQ I.c What contributes to forming students' self-confidence, both before and at university?

In the various tables of results of ANOVA and Kruskal Wallis tests in this chapter there have been clear relationships found between marks and: past qualifications; confidences; and attitudes, and also between the Overall *Confidence in Mathematics* and statistics and: past qualifications; confidences; and attitudes. There was also a Gender effect in the APD and RMNat data on *Confidence in Mathematics*, revealing that the females were less confident than males, but no Gender effect was found on achievement, females achieved equally as well as male students. There was no Gender effect in RMSS, it is suggested that this was due to the low confidence levels of all of the RMSS students, both male and female. As all the confidences were low, there was also little variation in the confidence levels, and so the amount of variation was possibly insufficient for a significant effect to be found. Other variables which have occasionally been found to have a significant effect on confidence included: Course, Award level (both of which are partly based on past qualifications and ability), the Importance of statistics, whether students Would choose to study statistics, Motivation, Whether motivation was the same as on other modules and Dyslexia (Dyslexia was found to have a significant effect on APD and RMSS students' *Confidence in Mathematics*, and never on achievement).

RQ I.d How does students' confidence in mathematics subsequently change from that on entry to university through university teaching?

The means for students own ratings for how their confidence had changed from the 1st year to the 2nd year were positive, and similarly a comparison of the year group means also indicated a positive change as at first glance the 1st years appeared to be less positive than second years in Table 5.1. The inclusion of HND students in the 1st year means shown in Table 5.1 produced a mean *Confidence in Mathematics* of 3.0, however exclusion of the HND students produced a mean APD BSc student mean *Confidence in Mathematics* of 3.2. However when the comparison was only made between equivalent groups of students (only BSc and only correct course groups, or using students whose id numbers have been matched), then a different picture emerged, which was that the students were generally less confident, and their attitudes and motivation were also reduced.

The results of the open question about the students' confidence, attitudes and abilities had changed from the first year to the second year, however, revealed more 'improved' than decreased' type responses (as was shown in Table 5.46). However these questions had a large non-response proportion. There was very possibly a positive bias in the responses in that those who were less confident were perhaps more reluctant to write that down, especially as this was question number 50.

RQ II.a What are the attitudes and views of students when and towards learning mathematics and statistics?

There was wide variation in the attitudes and views of the students surveyed. The closed questions which measured attitudes asked the students to rate their *Liking of*

Mathematics and *Liking of Statistics*. Many of the students disliked both mathematics and statistics, but they particularly disliked statistics (e.g. the mean value for 2nd year social science students' *Liking of Statistics* was only 2.3, for ratings 1 to 5, where 5=high). Although when asked to describe their attitudes in an open question there were more positive attitudes for APD students (40% of APD students gave positive responses compared to 30% negative responses), however there were more negative attitudes for 2nd year social science students (33% of APD students gave positive responses compared to 39% negative responses).

The students had more negative views about statistics than they did about mathematics, for example these are two student quotes: *'I don't mind mathematics, it's the statistics that I don't like'. 'I feel confident in all areas of maths except stats'.* Only 26% of the students completing questionnaires in their statistics lectures would have chosen to study the statistics if it had not been a compulsory part of their course. Gordon (2004) similarly reported that 73% of psychology students were unwilling to study statistics, and their reasons for this included: statistics not being interesting (80 responses, 29%), for example *'I generally find it dull, boring and tedious'*, or that statistics was not liked as a subject (37 responses, 13%).

Some students understood that the statistics skills and knowledge being taught to them would be relevant and useful to them for future studies and careers. The relevance and usefulness of the statistics being taught was better understood by the natural science students than by the social science students. It was known that the natural science lecturers were very effective at giving that message to their students. It is also possible, however, that the two student groups had different personal interests and that social science students were aspiring to different types of careers for which the statistics would really be less useful. It was understood to be a course entry requirement for the natural science students to have at least one science A level, and so these students were perhaps more naturally inclined toward scientific and logical methods than were the social science students, making them both more interested and also better qualified to learn statistics.

The natural science students were more positive than the social science students, and there are several possible explanations for this. It was shown that the social science students had significantly lower GCSE mathematics grade numbers for both 1st year and 2nd year students. There were more male students on the natural science courses than on the social science course, and males were found to be more positive than females overall. Social science students were examined on statistics calculations by hand, whereas the natural science students took a computer based examination in which the calculations were carried out by Genstat (statistical software programme), and possibly this difference in the assessment methods was also one of the root causes of the social science students being less confident and positive.

Some students reported that their enjoyment of these subjects came from being able to do it, and from understanding it.

RQ II.b How do the students' attitudes and views affect their learning of mathematics and statistics?

It was clear that some students did not see the point of learning statistics and this resulted in reduced effort. For example, one student wrote the following:

'*Don't see the point of doing work that is so hard – and not do anything with it ever again.*'

There were many significant relationships found between the students' achievement and their *Liking of Mathematics* and *Liking of Statistics*, which would suggest that these attitudes had an effect on the students' achievement. However these relationships were understood to be complex and these attitudes and views are one aspect of a larger picture in which a range of variables contribute to students working habits. This complex mix was also found by Brown *et al.* (2003b).

Motivation was found to be a significant independent variable in the two predictive models produced for APD assignment marks, however the percentage of variation explained by two APD models were each relatively low (22% and 20%).

RQ II.c What, in the students' opinions, are the characteristics of mathematics and statistics teaching which promote effective learning and improve self-confidence when learning mathematics and statistics?

Helpful features included use of computers (as in Christou and Dinov, 2010), the lecturer/good teaching, handouts, the opportunity for students to do exercises/practice in the classes, quizzes at the start to check knowledge learnt previously (RMNat students only). All of the methods of doing calculations (by hand; with a calculator; using Excel; and Using SPSS/Genstat) were rated highly (>4 out of 5) by all of the questionnaire groups. The most frequently occurring responses to the question asking what would improve their learning of statistics were: more practice; application to real life scenarios and future studies and careers, and more help / support from lecturers.

Being able to recognise what type of statistical test a question required was a need identified by students. It was also suggested by Garfield and Ben-Zvi (2007) that this was an important skill in statistical problem solving.

RQ II.d What differences can be identified for students with dyslexia, dyscalculia and/or other special needs when learning mathematics and statistics?

Dyslexic students described a range of effects on their learning, from none at all to quite negative effects, however no positive effects were stated. No significant effects of dyslexia were found by ANOVA tests on achievement in any student group. Kruskal Wallis tests, however, found a significant effect of dyslexia on students' *Confidence in Mathematics* in two student groups: 1st year APD students and 2nd year social science students (see Table 6.5). In the 1st year APD Factor Analysis, Dyslexia was found to be almost a separate Factor in its own right, it was only associated with gender (male students), and not with confidences, achievement or motivation. The responses to the open question about how students considered that dyslexia affected their learning were very varied. Some students considered that they had difficulties in remembering formulae, that it takes them longer to learn the statistics initially, and that they think they have to work harder at it than their non-dyslexic peers (see Table 5.22).

RQ II.e What evidence can be found for the effect of Mathematics Support on students' achievement and self-confidence in mathematics and statistics?

There were only questions about the mathematics support provision in the APD questionnaires, as larger numbers of 1st year students had used it than 2nd years (due to the support being aimed primarily at first years at that time). The mathematics support was rated highly by the 1st year APD students (all ratings at least 4 out of 5). Analysis of students' GCSE mathematics grades showed that the marks for equivalent GCSE grades were slightly higher for students who had received support although this difference in marks was not significant.

This concludes Chapter 5. Discussion and conclusions from this research will be presented in the next chapter, Chapter 6.

6 DISCUSSION AND CONCLUSIONS

6.1 Introduction to the Discussion and Conclusions Chapter

The findings of the research are summarised in this chapter with further comparisons of the results for different student groups that were presented in Chapters 4 and 5. A summary of the contribution to knowledge made by this thesis is given in Section 6.2. A summary of data analysis results for the different student groups is presented in Section 6.3 and in Section 6.4 the findings are listed by Research Question. Suggestions for future investigation and study are given in Section 6.5. Finally, some reflections and general summing up is provided in Section 6.6, which concludes the thesis.

6.2 Contribution to Knowledge Made by this Study

This sub-section summarises the contribution to knowledge made by this study. This thesis reports empirical and theoretical research from an original investigation into learning of mathematics and statistics by non-mathematics specialist students at an English University College. The primary investigation is into learners' self-confidence and its effect on achievement (by a deductive approach, as per Research Question I), combined with a broader investigation of their experiences learning mathematics and statistics (using an inductive approach, as per Research Question II). New perspectives and knowledge, including an original Three Mathematics Self-confidence Domains model, are presented which bring together a substantial range of literature and the empirical results of the new research.

6.2.1 Original Motivation for the Study

The original motivation for this study arose from the author's work, and substantial experience, gained over many years, as both the Mathematics Support Tutor and a Mathematics Lecturer, seeing students improve in their abilities and achievement as well as their self-confidence and attitudes. Student feedback (such as *'improved my confidence'*) spawned this author's desire to understand confidence better and find out what had caused the improved confidence and ability. Support for students learning statistics was also part of the author's role, and as the majority of students in this HEI were studying statistics rather than mathematics, due consideration was also given to statistics learning in this study. The primary focus of this study was to improve understanding from a mathematics education perspective, rather than validation of an instrument to measure confidence (as in, for example, Fogarty *et al.*, 2001 and Usher, 2007). Investigation of self-confidence, the effects of dyslexia, and recording the student viewpoint were all original aims of the study, and the effect of gender was included later after significant effects and interesting results were found.

6.2.2 Contribution to the Mathematics Problem and Mathematics Education

The contribution made by this thesis to the mathematics problem and to mathematics education in general is to highlight the effect of student self-confidence and other affective characteristics (such as liking the subject and motivation) on student learning of mathematics and statistics and their university experiences. This research was carried out at a time of widespread concern about mathematics education in English schools and higher education, which had become known as the 'Mathematics Problem'. Various reports and even a government inquiry into Mathematics Education (Making Mathematics Count, Smith, 2004) had been produced. Similar concerns were also reported internationally, for example in Australia (Frid *et al.*, 1997). Various reports also commented on the scarcity of research involving the learner viewpoint and also suggested the need for further research into learners' confidence and attitudes (Gal and Ginsburg, 1994, Frid *et al.,* 1997, Brown *et al.,* 2003b, Burton, 2004, QCA, 2006a, Cretchley, 2008). This author's substantial experience of working in this field led her to believe she was well-placed to make a timely and valuable contribution to addressing the 'Mathematics Problem'.

The mathematics problem in Higher Education was mainly viewed as a lack of prior knowledge and skills which made new entrants inadequately prepared for the mathematics content in a wide range of university courses (for example, Hawkes and Savage, 2000). This thesis raises awareness of previously neglected issues regarding negative student beliefs (particularly lack of self-confidence) and attitudes towards mathematics. This is achieved by presenting a substantial range of literature on the various theoretical standpoints and past research (including self-efficacy and self-concept), which is combined with a novel simplification of self-confidence terminology as applied to mathematics learning in the form of the proposed Three Mathematics Self-confidence Domains model as will be shown in Figure 6.1 (see also section 2.7.6 and Parsons, 2006a and 2006b, and Parsons *et al.*, 2009 and 2011). *Confidence* was defined as a person's belief of their capability, in this case in mathematics. This thesis is believed to be the first research on *Overall Confidence in Mathematics* (as defined in

Section 2.7.6) of UK university students. The novel three Mathematics Self-confidence Domains model was validated by comparison with literature and by the results and analyses of new empirical data collected from a range of different student types over three academic years (2005-7). Comparison of different student groups was another novel aspect of this research. *Self-confidence in Mathematics* (and other beliefs, such as viewing mathematics as difficult or statistics as irrelevant) and students attitudes (such as *Liking of Mathematics*) have been shown in this thesis to be problematic, especially for students with less mathematical backgrounds, and especially for the learning of statistics. Not only is improving student self-confidence in their abilities in mathematics a worthwhile aim, but the clear links found between self-confidence and achievement (both past and future) demonstrate that improving self-confidence will also promote improved achievement.

6.2.3 Past Literature and Theoretical Foundations

The new empirical research reported in this thesis builds on literature which also found links between confidence and achievement. This was mostly in studies of US students and school children (e.g. Pajares and Miller, 1994, Tapia and Marsh, 2004a, and Usher, 2007), and also Australian students (e.g. Frid *et al.*, 1997, Fogarty *et al.,* 2001, Gordon, 2004, and Wilson and MacGillivray, 2007). Much of the past research has been correlational, and as Cretchley (2008, p.152) states *'few studies have taken on the difficult task of quantifying and monitoring key affective factors and assessing their role in mathematics learning'*. This thesis has explicitly endeavoured to achieve the task of *'quantifying and monitoring key affective factors and assessing their role in mathematics learning'* and is believed to be the first research on UK university students to do this. A range of predictive regression models and exploratory factor analyses have produced approximate effect sizes and percentage variance explained for a range of different student groups, enabling both an appreciation of the approximate effect size for self-confidence and other affective variables, and also enabling comparison of the effects on different student types. In general, past qualifications were found to have the greatest effect on university achievement, but the effect of these subjective, and potentially modifiable, affective variables was also measurable and worth paying attention to. Details of statistical analysis results are summarised later in this section and in Section 6.3 along with a detailed comparison with results from past literature, including: Shaw and Shaw (1997 and 1999), Fogarty *et al.* (2001), Tapia and Marsh (2004a), Wilson and MacGillivray (2007), Liston and O'Donoghue (2009a), Ferla *et al.* (2009), and Liu and Koirala (2009).

The theoretical foundation adopted for this study was based on the following standpoints:

- Fishbein and Ajzen's (1975) Causal Chain of beliefs, attitudes, intention and behaviour, which usefully separated beliefs and attitudes (see Figure 2.2);
- McLeod (1992) and Pehkonen and Pietilä's (2004) classification of mathematics Affect into beliefs, attitudes and emotions, which are described as *"cold*", *"cool*" and *"hot"* (respectively) to reflect the increasing intensity and speed of formation, and decreasing stability and level of cognitive processing of these constructs. The focus in this thesis was on certain beliefs and attitudes, rather than emotions;
- Bandura's (1997) social cognitive theory which defined self-efficacy as an individual's perceived ability to perform a given task in a particular set of circumstances, and specified four sources of self-efficacy (enactive mastery experiences, vicarious experiences, verbal persuasion, and physiological and affective states) and four mediating processes (cognitive processes, motivational processes, selective processes and affective states);
- Ernest (2000) described positive and negative learning cycles in mathematics; and
- Pajares and Miller (1994), Bong and Skaalvik (2003) and Ferla *et al.* (2009) all distinguished between the more global mathematics self-concept and task specific mathematics self-efficacy, whilst acknowledging the centrality of perceived competence in both self-efficacy and self-concept; and
- Dweck's (2000) Theories of Intelligence as '*malleable*' or *fixed'*.

6.2.4 Three Mathematics Self-Confidence Domains

Three Mathematics Self-confidence Domains were designed and proposed by the author at the outset of this research (Parsons, 2006a and 2006b, and Parsons *et al.*, 2009 and 2011): *Overall Confidence*, *Topic Confidences* and *Applications Confidence*. The relationships between the three Mathematics Self-confidence Domains are portrayed in Figure 6.1 below. The terms *Confidence* and *Self-confidence* were preferred in this study to *Self-efficacy'* and '*Self-concept'* (whilst these and their intended equivalence was explained in sections 2.7.4, 2.7.5 and 2.7.6) as these were easily understood by the English survey respondents, thus producing an example of 'accessible terminology and research instrument' as deemed necessary by Cretchley (2008, p.152).

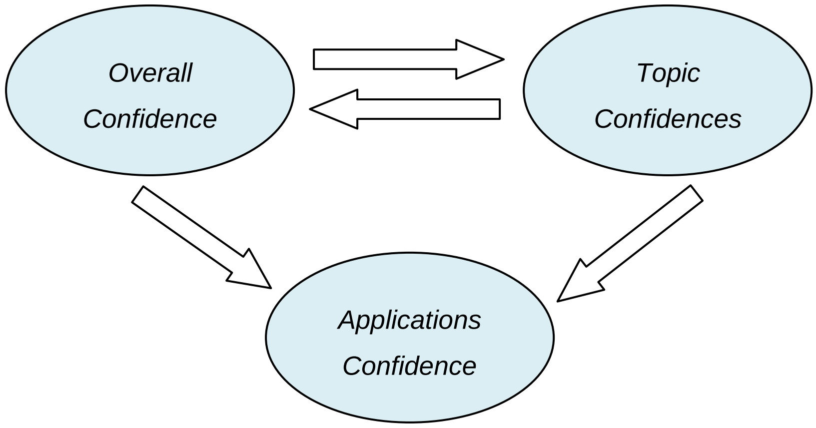

Figure 6.1 Mathematics Self-confidence Domains (Author's own, 2014)

Overall Confidence in Mathematics was defined as a person's self-judgement or belief about their overall ability in mathematics. This is similar to Pajares and Miller's (1994) and Ferla *et al.'s* (2009) mathematics self-concept, and Bandura's (1997) *operative capability* self-efficacy. A separate *Topic Confidence* is formed for different mathematics topics or tasks, dependent upon the nature of the topic, level of difficulty, familiarity, and other circumstances of the task. It was proposed that a person would have one single *Overall Confidence in Mathematics*, but many *Topic Confidences*, as many as the number of topics being considered. One difference between these two Self-confidence Domains, is that the *Overall Confidence* is a more stable attribute which is harder, and takes longer, to form and change (as referred to by Kent and Noss, 2003 and Ferla *et al.,* 2009) and is similar to self-concept which is stable (McLeod, 1992 and Pehkonen and Pietilä, 2004), compared to a *Topic Confidence* which could change during the duration of one class, or as the result of one helpful explanation from the teacher or mathematics support tutor, or due to successfully (or unsuccessfully) completing a task, particularly a difficult task. Ferla *et al.* (2009) found that self-efficacy and self-concept influenced each other reciprocally, which is consistent with the reciprocal relationship between *Overall Confidence* and *Topic Confidences* shown in Figure 6.1 above. *Applications Confidence* is a person's confidence that they will be capable of the mathematics required of them in the future, in practical and real life situations, in a job or further studies (for example, as referred to by ACME, 2011). For students who were surveyed on statistics modules their *Overall Confidence in Statistics* was also collected, and the *Topic Confidences* and *Applications Confidence(s)* questions were for a mixture of mathematics and statistics tasks.

This research is believed to be the first to investigate *Overall Confidence in Mathematics* of UK university students (Parsons, 2006a and 2006b, and Parsons *et al.,* 2009 and 2011). Warwick's (2008a) study in 2006 of 16 computing student interviews about mathematics self-efficacy and engagement in learning overlapped with the data collection for this thesis. Earlier studies had investigated *Topic Confidences* in the UK, including: Armstrong and Croft (1999) and Shaw and Shaw (1997), and, as already stated, much of earlier research was based in the US (e.g. Pajares and Miller, 1994) and Australia (e.g. Frid *et al.,* 1997).

6.2.5 Methodology and Analysis

Student surveys were carried out by the author and other lecturers in the summer terms of 2005, 2006 and 2007 (n=701) using an instrument designed by the author and drawing on earlier work, particularly: Shaw and Shaw, 1997 and 1999, Armstrong and Croft, 1999, Fogarty *et al.*, 2001, and Gordon, 2004 (see Table 2.1). Seven different student groups were surveyed which included first and second year undergraduate engineering, natural science and social science students. The data was combined for the three years for most of the student groups (where appropriate). The three Mathematics Self-confidence Domains (*Overall Confidence, Topic Confidences* and *Applications Confidence)* were successfully operationalised (converted to variables and questions). Data was collected comprising demographic details, confidences (beliefs), attitudes, motivation, experiences of learning before and at university, etc. The study did not focus solely on self-confidence, but evaluated self-confidence in the context of other characteristics (such as motivation) in order to compare effects (as per Research Question II), including comparison against secondary data of students' university achievement (i.e. mathematics and statistics examination and assignment marks). For survey results and student mark data, totals and percentages were calculated, and means were shown in tables and graphs. Potential issues associated with the use of means for the Likert scale data (regarding the assumption of interval data characteristics) were discussed (referring back to Stevens, 1946) with a discussion on the validity and reliability of single-item and multi-item Likert Scales. ANOVA and Kruskal Wallis tests were used to determine which factors had had significant effects on marks and confidences (respectively). Correlation analyses found that almost all of the affective variables were inter-correlated and many correlated significantly with student marks. Regression analyses produced predictive models for student marks for the different students groups giving approximate effect sizes for previous achievement (particularly a coded GCSE Mathematics Grade) and *Overall Confidence in Mathematics* or *Overall Confidence in Statistics* (as appropriate for the student group).

Exploratory Factor Analyses were used to group variables into fewer latent factors, whilst Cluster Analysis grouped students into clusters with similar characteristics.

This work is also unique in terms of the University College setting, which itself was unique. One benefit of conducting this research part-time was the inclusion of data spread over a longer time period than is possible in a standard full-time three year PhD, also the researcher's role as a member of staff enabled access to data such as student marks which would otherwise probably not have been possible.

Whilst the methodology and findings are not totally generalisable due to the a-typical nature of the HEI in which this study was carried out (e.g. smaller class sizes), the Methodology was reproducible and could be adopted by other researchers to explore the confidences of their student cohorts.

6.2.6 Findings Related to the Three Mathematics Self-Confidence Domains

Findings related to the three Mathematics Self-confidence Domains both validated the proposed model and produced insights into student confidences. Survey respondents were readily able to self-rate their confidences for the three domains, which produced meaningful data. In their open question responses, many students indicated that their *Overall Confidence in Mathematics* had been formed a long time ago (consistent with McLeod, 1992, and Pehkonen and Pietilä, 2004, who described beliefs as 'cold', i.e. stable), whilst for other students it had changed during that academic year, indicating that change was possible under certain favourable conditions. *Topic Confidences* were rated for a range of topics studied in the modules (between 1 and 5, where 5 = high confidence), and were found to be very variable (e.g. mean values from 2.7 to 4.3 for the various 2006 APD topics). From these the mean *Topic Confidence* was also calculated. Students could feel confident to do a particular task, but still be lacking in confidence overall. *Applications Confidences* were found to be slightly lower (than the *Overall Confidence in Mathematics* and the mean *Topic Confidences*) which was understandable considering the uncertainty surrounding future requirements of mathematics which would make most people less confident that they would be able to do what was required of them. In general, it was found that a person's Mean *Topic Confidence* was greater than their *Overall Confidence in Mathematics,* which was greater than their *Applications Confidence* (as will be shown in Tables 6.1 and 6.2, and Figure 6.2). This difference in values for the three Mathematics Self-confidence Domains and the greater variability of the *Topic Confidences* supported the theoretical differences between the three Mathematics Self-confidence Domains and was part of the validation of the proposed model.

In general *Overall Confidence in Mathematics* was often found to be slightly higher than *Liking of Mathematics. Confidence in Mathematics* and *Liking of Mathematics* were both usually found to be higher than the equivalent *Confidence in Statistics* and *Liking of Statistics* (for example, for the second year social science students the mean values were 3.0, 2.8, 2.5 and 2.3 respectively, whilst for second year BEng/MEng engineering students the mean values were 3.7, 3.6, 3.1, 2.5 respectively). So overall, across all surveyed student groups, mathematics was generally preferred to statistics, and there was unfortunately a general dislike for statistics. Students' *Confidence in Life* was almost always found to be higher than all the mathematics and statistics confidences (students who had studied A level mathematics usually being the exception), thus indicating the potential for improvement in students' mathematics and statistics confidences. Students' dislike of statistics was also apparent from the low percentages of students who would have chosen to study the statistics modules (e.g. 23%) if it was not compulsory, compared to the higher percentages of engineering students who would have chosen to study mathematics (e.g. 88%). Whilst the primary focus in this thesis was on beliefs and attitudes and not on emotions, it was unfortunately apparent that there was also generally a lack of enjoyment of mathematics by students, based on the very few responses to the question asking when students had last enjoyed mathematics.

In order to compare the single-item *Overall Confidence in Mathematics* with a multi-item scale, an 11-item scale for Mathematics Confidence (based on Fogarty *et al.*, 2001) was included in the 2006 surveys, and then replaced by a reduced version (5 items) in the 2007 surveys. Shaw and Shaw (1999) also used single-item 5 point Likert Scale questions to measure their attitude variables. According to McLeod's (1992) definition of Affect the Fogarty *et al.* (2001) multi-item scale comprised a mixture of cognitive and emotional items (perhaps due to the influence of Marsh, who Ferla *et al.,* 2009, noted was known to define Self-concept as multi-dimensional including emotional components). In this thesis, however, *Overall Confidence in Mathematics* was considered entirely cognitive and a uni-dimensional construct (consistent with other researchers, e.g. Ferla *et al.,* 2009, and Pampaka *et al.*, 2011). A significant difference was found between the paired responses between a Fogarty *et al.* (2001) confidence item and an emotion item, thus giving an example of an empirical distinction between a confidence (belief, cognitive) component and an emotional component (which Bong and Skaalvik, 2003, suggested might be impossible to find). This suggests that the 11-item scale, whilst it had high internal reliability (Cronbach's Alpha=0.89), had less validity for measuring the type of *Confidence in Mathematics* as was defined in this thesis (i.e. as a belief, purely cognitive and uni-dimensional in nature). Further work could usefully be carried out to design and validate a short multi-item scale of purely cognitive confidence items.

Data from the operationalised Mathematics Self-confidence Domains was analysed to find and quantify the effects of self-confidence on performance. Regression models were produced for achievement for all the student groups. One interesting model for first year engineering students explained approximately 36% of the variation in university mathematics marks using students' past mathematics achievement (their mark increased approximately 12% for each increased GCSE Mathematics grade) and *Confidence in Mathematics* (their mark increased approximately 5% for each increased confidence self-rating). This predicted that a very confident student could potentially achieve approximately 20% higher marks than one lacking confidence. These models were novel, and were not intended to be deterministic (i.e. an exact prediction), and also could not prove causal relationships, but provided supporting evidence for the heuristic that *'confidence contributes to student achievement'*. Summarised results of the statistical analyses are given in Section 6.3, with a detailed comparison with literature, showing that confidences and attitudes are significantly affected by past attainment and that past attainment, confidences and attitudes also significantly affected university attainment. Correlation and regression analyses were also reported by studies in other countries: Australia (Wilson and MacGillivray, 2007), Eire (Liston and O'Donoghue, 2009a), and US (Liu and Koirala, 2009). Factor Analyses in Australia (Fogarty *et al.,* 2001) and the US (Tapia and Marsh, 2004a, and Liu and Koirala, 2009) produced valid, and generally comparable, self-confidence and self-efficacy factors. Shaw and Shaw's (1997 and 1999) UK engineering student Factor and Cluster analyses considered experiences and difficulty rather than confidences. Using Path Analysis Pajares and Miller (1994) and Bandura (1997) in the US found that Self-efficacy mediated the effect of gender and prior experience on performance, and Ferla *et al.* (2009) in Belgium produced slightly different results. As Path Analysis was not carried out in this thesis, the results cannot be directly compared, however, the higher relative strength of the effect of self-efficacy compared to past attainment in Pajares and Miller (1994) and Ferla *et al.* (2009) was not found in this thesis. All of these studies found relationships between beliefs, attitudes and attainment, even if the details sometimes differed, as did the definitions of confidence (Burton, 2004). Overall these relationships were considered complex (as similarly concluded by Burton, 2004, and Brown *et al*., 2003b).

6.2.7 Findings Related to the Different Student Types

Comparison of the different groups revealed that, in general, engineering students were more confident in mathematics than natural science students, who were more confident than social science students. MEng and BEng engineering students were more confident than the BSc and FdSc students. Engineering students also liked mathematics more than the non-engineering students liked statistics, who also exhibited more reluctance and avoidance. Table 6.1 in the next section contains the means and percentages of key confidence, liking, and motivation variables, and student achievement for all the different student groups. Closed and open question responses were generally consistent. Studying and comparing these different student groups was also a novel aspect of this thesis.

Special consideration also needs to be given to ensuring students acquire understanding as well as skills in order to build confidence. Students' view of intelligence was also highlighted as important; a *'malleable'* (also called *'incremental')* rather than *'fixed'* (also called 'entity') theory of intelligence (Bandura, 1997 and Dweck, 2000) was advantageous in promoting effort, thus contributing to creating a Positive Mathematics Learning Cycle (Ernest, 2000 adapted).

ANOVA and Kruskal Wallis tests identified factors which significantly affected university marks or overall confidences (and those which did not). Past qualifications significantly affected university marks and also significantly affected confidences. Confidences very often also significantly affected university marks, producing reciprocal determinism (i.e. confidences and achievement each influenced each other). Higher achievement at university was associated with higher confidence at university and higher achievement pre-university. Factors which did not usually affect either university marks or confidences included: age, motivation, time spent, and year of survey (except for second year natural science assessments which changed each year and were accounted for). Summaries of the ANOVA and Kruskal Wallis test results will be presented in Tables 6.2 to 6.5 in Section 6.3.2.

A serious deficit in female self-confidence (compared to males) was found in two mixed gender groups, whilst female achievement was not significantly different from males' in any group surveyed. In the third mixed gender group (second year social science) most students, both male and female, were lacking confidence (see Tables 6.4 and 6.5). Females being less confident was also a finding of the Cluster Analysis for the first year APD statistics module which produced a lacking confidence cluster of students who were predominantly female with slightly above average achievement (i.e. their confidence was disproportionately low compared to their achievement), and also produced an A Level Mathematics cluster of predominantly male students who were generally the most high achieving and most confident. The other two clusters found were more as would be expected: grouping moderately successful students into a cluster and a lower achievement student cluster. Summarised results of the Factor Analyses and Cluster Analyses are given in Section 6.3.4, and full details were in Section 5.2.4. Similar gender effects were also found by Betz and Hackett (1983), McLeod (1992), Sax (1994), Skaalvik and Skaalvik (2004), Hyde *et al.* (2006), Pierce *et al.* (2007), Nunes *et al.* (2009a and b), Ferla *et al.* (2009), and OECD, 2013.

Dyslexic students were also found to be less confident in some student groups, whilst their achievement did not differ significantly (possibly due to mitigating effects of exam arrangements and extra support), although dyslexia was associated with lower achievement in factor analysis results for first year engineering students (see Tables 6.4 and 6.5). Dyslexic students perceived that they learned more slowly.

This concludes the section summarising the original contribution to knowledge made by this thesis. Further conclusions and summaries of results now follow in the proceeding sections.

6.3 Further Results and Discussion

6.3.1 Summary of Means for the Different Student Groups

Summaries of means and percentages for the key confidence, attitude and motivation variables and student university marks for the different student groups have been combined and are shown in Table 6.1 below. These details were previously presented separately in the results chapters, 4 and 5.

Of particular note were the first and second year BEng and MEng (and also BSc) engineering students who had the highest confidences, liking and motivation ratings and also highest pre-university achievement and university achievement. The least confident were the second year social science students. This variation in confidences

Table 6.1 Summary of Students' Confidences, Attitudes, Motivation and Marks by Student Group

		Confidence				Attitude			Motivation		Marks	
Student Group and Year	No. Students	Confidence in Mathematics	Confidence in Statistics	Confidence in Life	More Confident?	Like Mathematics	Like Statistics	Like Subject More After Module	Motivation Rating	% Would Choose to Study Module	Overall Mean Mark %	Statistics Q's Mean Mark %
1st Year BEng / MEng Engineering Students learning Mathematics												
2005	6	3.3	3.0	3.7	4.2	4.0	3.0	4.0	4.0	83	85.3	
2006	17	3.9	3.1	3.9	3.8	3.5	2.5	3.4	3.4	88	77.3	
2007	15	3.3	3.1	3.5	4.1	3.5	2.9	3.6	3.5	87	77.0	
Total	38	3.6	3.1	3.7	4.0	3.6	2.7	3.6	3.6	87	78.4	
1st Year BSc Engineering Students learning Mathematics												
2005	15	3.2	2.7	3.9	4.1	3.3	2.6	3.7	3.4	100	65.9	
2006	20	3.6	3.1	3.6	4.3	3.6	2.8	3.8	3.4	70	69.5	
2007	15	3.6	3.0	3.8	4.5	4.0	3.1	4.0	3.6	60	72.3	
Total	50	3.5	2.9	3.7	4.3	3.6	2.8	3.8	3.4	76	69.3	
1st Year FdSc/HND Engineering Students learning Mathematics												
2005	8	3.4	3.0	3.8	3.9	3.4	2.9	3.3	3.4	50	47.9	
2006	13	3.3	2.9	4.0	3.7	3.1	2.4	3.2	3.3	31	41.5	
2007	2	2.0	2.0	4.5	3.0	2.0	2.0	2.5	2.5	0	38.5	
Total	23	3.2	2.9	4.0	3.7	3.1	2.5	3.1	3.3	35	43.5	
2nd Year BEng / MEng Engineering Students learning Mathematics												
2005	17	3.8	3.3	4.1	-	3.5	2.7	3.4	3.6	88	59.1	
2006	8	4.1	3.3	4.0	-	3.9	2.4	4.0	3.9	88	69.9	
2007	20	3.5	2.8	4.0	-	3.5	2.4	3.7	3.3	70	61.9	
Total	45	3.7	3.1	4.0	-	3.6	2.5	3.6	3.5	78	62.4	
1st Year APD Statistics with Excel												
2005	118	3.1	2.8	3.6	3.3	3.0	2.5	2.8	2.7	31	51.4	
2006	83	3.0	2.7	3.9	3.5	3.0	2.6	3.1	2.9	19	50.8	
Total	201	3.0	2.7	3.7	3.4	3.0	2.5	2.9	2.8	26	51.2	
2nd and 3rd Year Natural Science Students' Statistics with Genstat (RMNat)												
2005	52	3.3	3	3.7	3.3	3.0	2.8	3	2.9	44	71.3	
2006	102	3.3	2.7	3.8	3.1	3.0	2.5	2.7	2.7	23	60.9	
2007	52	3.1	2.7	3.9	3.8	3.2	2.6	3.1	2.7	25	57.7	
Total	206	3.3	2.8	3.8	3.3	3.1	2.6	2.9	2.7	29	62.6	
2nd and 3rd Year Social Science Students' Statistics with SPSS (RMSS)												
2005	29	3.2	2.8	3.7	3.3	2.9	2.4	2.9	2.9	34	59.3	N/A
2006	47	2.7	2.4	3.8	3.2	2.6	2.3	2.9	2.9	33	56.0	68.4
2007	55	3.2	2.5	3.9	3.1	2.9	2.2	2.5	2.5	9	59.8	69.2
Total	131	3.0	2.5	3.8	3.2	2.8	2.3	2.7	2.7	23	58.3	68.8

and achievement is consistent with higher confidence being associated with higher achievement, both before and at university, and supports the notion that '*success boosts confidence, and confidence boosts success.'*

There were generally high percentages of engineering students who would choose to study mathematics (up to 100%), with the exception of the FdSc/HND students, who generally understood that mathematics was necessary for engineering. These were contrasted with the generally low percentages of students on statistics modules (mean percentages in the twenties) who would have chosen to study statistics if it had not been compulsory. This was understood to be a problem which originated before university, which made it harder for lecturers to teach and motivate students. Emphasising practical applications, and the usefulness and importance of statistics for future studies and careers was identified as helpful for improving student motivation and attitudes, which for example the second year natural sciences statistics lecturers had managed very well. Other helpful features overall included: students doing the work themselves; provision of handouts; being given worked examples; mathematics support; and teaching at an appropriate speed and level of difficulty. Further comparisons of the different student groups were given in Section 6.2.7.

6.3.2 Summary of ANOVA and Kruskal Wallis Test Results

The results of ANOVA and Kruskal Wallis tests to determine whether there were significant relationships between students' marks, overall *Confidence in mathematics* and *Confidence in Statistics* and other variables are shown as P values in Tables 6.2, 6.3, 6.4 and 6.5 below. P values of less than, or equal to, 0.05 indicate a significant relationship. The non-significant probabilities, greater than 0.05, have been shown in cells with grey shading.

In Table 6.2 below, it can be seen that for all student types the students' GCSE Mathematics Grade and whether the students had taken A Level Mathematics variables were almost always significantly related to both achievement and confidences. The only exception was APD, for which only a minority of students would have taken A Level Mathematics, and the second year engineering students whose *Confidences in Mathematics* were not very varied (being 78% either 3 or 4).

Table 6.2 Summary of P Values for ANOVA and Kruskal Wallis Tests for GCSE Mathematics Grade and Whether Students had Studied A level Mathematics

Student Type	Year	Student Marks ANOVA P Values		Confidence in Mathematics KW P Values		Confidence in Statistics KW P Values	
		GCSE Grade	A level	GCSE Grade	A level	GCSE Grade	A level
1st Year Engineering	2005-7	<0.001	<0.001	<0.001	0.005	-	-
1st Year APD	2005-6	<0.001	0.203	<0.001	<0.001	<0.001	<0.001
2nd Year Engineering	2005-7	0.028	0.017	0.066	0.088	-	-
2nd Year RMNat	2005-7*	<0.001	<0.001	-	-	-	-
2nd Year RMNat	2006 only	<0.001	0.014	<0.001	<0.001	0.003	0.009
2nd Year RMSS	2005-7	<0.001	0.036	<0.001	<0.001	<0.001	<0.001

* RMNat 2005-7 2-way ANOVA carried out with Questionnaire Year as second factor

In Table 6.3 below it is shown that the students' *Confidence in Mathematics* and *Confidence in Statistics* were usually both significantly related to achievement. In the three cases where one of these was not significantly related to achievement, the other one was. There were no significant relationships with Confidence in Life. *Liking of Mathematics* and *Liking of Statistics* were also more often significantly related to achievement than not, but the links can be seen to be less strong than for the overall *Confidence in Mathematics* and *Confidence in Statistics*.

Table 6.3 Summary of P Values for ANOVA and Kruskal Wallis Tests for Student Marks by Overall Confidence in Mathematics and Statistics and Liking of Mathematics and Statistics

Student Type	Year	Student Marks (ANOVA P Values)				
		Confidence in Mathematics	Confidence in Statistics	Confidence in Life	Liking of Mathematics	Liking of Statistics
1st year Engineering	2005-7	<0.001	0.045	0.211	<0.001	0.169
1st Year APD	2005-6	0.02	0.019	0.707	0.071	0.148
2nd Year Engineering	2005-7	0.007	0.138	0.801	0.016	0.161
2nd Year RMNat	2005-7*	<0.001	<0.001	0.324	<0.001	<0.001
2nd Year RMNat	2006 only	0.137	0.004	0.708	0.081	0.028
2nd Year RMSS	2005-7	0.028	0.149	0.632	0.150	0.234

* RMNat 2005-7 2-way ANOVA carried out with Questionnaire Year as second factor

In Table 6.4 below it is shown that almost none of the students' Age, Dyslexia, Gender and Amount of Time Spent Working Outside Lectures were significantly related to achievement. Students' motivation rating, however, did have significant relations with achievement for three of the student groups.

Table 6.4 Summary of P Values for ANOVA Tests for Student Marks by Age, Dyslexia, Gender, Motivation and Amount of Time Spent Working Outside Lectures.

Student Type	Year	Student Marks (ANOVA P Values)				
		Age	Dyslexia	Gender	Motivation	Time Spent
1st year Engineering	2005-7	0.731	0.151	All male	0.005	0.616
1st Year APD	2005-6	0.076	0.329	0.461	<0.001	0.714
2nd Year Engineering	2005-7	0.328	0.340	All male	0.589**	-
2nd Year RMNat	2005-7*	0.730	0.087	0.120	0.005	0.935
2nd Year RMNat	2006 only	0.055	0.632	0.301	0.543	0.679
2nd Year RMSS	2005-7	0.091	0.159	0.401	0.330	0.940

* RMNat 2005-7 2-way ANOVA carried out with Questionnaire Year as second factor
** Although Motivation was not significantly related to 2nd year Engineering mathematics marks, 'Whether or not motivation was the same as for other modules' was significantly related to marks (P=0.048)

It can be seen in Table 6.5 below that neither the students' age nor amount of time spent working outside lectures were significantly related to *Confidence in Mathematics*.

Table 6.5 Summary of P Values for Kruskal Wallis Tests for Confidence in Mathematics by Age, Dyslexia, Gender, Motivation and Amount of Time Spent Working Outside Lectures.

Student Type	Year	Confidence in Mathematics (Kruskal Wallis P Values)				
		Age	Dyslexia	Gender	Motivation	Time Spent
1st year Engineering	2005-7	0.369	0.084	All male	<0.001	0.424
1st Year APD	2005-6	0.732	0.029	0.003	<0.001	0.861
2nd Year Engineering	2005-7	0.164	0.515	All male	0.072	-
2nd Year RMNat	2006 only	0.099	0.575	0.002	0.098	0.159
2nd Year RMSS	2005-7	0.901	0.011	0.175	0.728	0.373

However, there were significant effects of dyslexia and gender on *Confidence in Mathematics* in Table 6.5 above. Students with dyslexia were found to be less confident in mathematics in two student groups. Females were found to be significantly less confident in mathematics than males in two student groups, and the low P values for this gender effect (P=0.003 and P=0.002) indicated a marked difference. However, for both dyslexia and gender, no significant effect was found on achievement.

RMNat 2005-7 three years' combined data has been excluded from Table 6.5 and the Kruskal Wallis analysis for confidences was only carried out on the single year 2006 data set. As Kruskal Wallis is the non-parametric equivalent to a one-way ANOVA it was not possible to also take into account the effect of the Questionnaire Year.

Solomon (2006 and 2007) found that female students especially aimed for more dual goals: e.g. '*speed and understanding'* (Solomon, 2007, p.14). One student surveyed for this thesis wrote *'If I don't understand something, I really can't do it!'* It is suggested that girls needing to understand the subject more than boys is part of the explanation for why some girls felt less confident in mathematics in this thesis. It was interesting that no gender differences, however, were found for *Confidence for Statistics*.

6.3.3 Summary of Multiple Regression Models

Predictive regression models for university marks were produced giving approximate effect sizes for past qualifications and affective variables, especially *Confidence in Mathematics* and *Confidence in Statistics.* Producing such approximate effect sizes from multiple regression models was a particularly novel contribution to knowledge by this thesis. The purpose of such models in this thesis was to demonstrate that it was possible to measure the effect of confidence (approximately) and that the effect was sufficiently large that educators would be advised to give due consideration to confidence and other affective variables as well as to teaching skills and knowledge. It must be remembered, though, that the models produced depend greatly on the choice of the independent variables (e.g. the number, combination and proximity of such variables to the dependent variable) and that due to high multi-collinearity between variables there were interesting combinations which it was not possible to produce significant models for. As Berry (1993) explains empirical analysis can only test and confirm theoretical models, and in this case the intention was to test the relationships between marks, past achievement and confidences or other affective variables, and significant regression models were produced for university marks for the each student group.

The first model shown for the first year engineering student marks was one of the most effective and explained 35.8% (Adjusted R^2) of the variation in student marks (Parsons *et al.,* 2009). The second year BEng and MEng engineering student Multiple Regression model using first year marks was the most effective and explained 58.2% of the variation in marks, and the natural science student Multiple Regression model both also explained a relatively high proportion (31.2%) of the variation in marks. In all of the multiple linear regression models given below students' past achievement had the highest effect on achievement at university. For all but one student type, it was possible to produce a valid multiple regression model which also included confidence or other affective variables.

Several significant models were produced for the 1st year engineering students. In three models there is a baseline mark of approximately 30% for the students with low GCSE mathematics grade and low Confidence or Liking or Motivation. All independent variables were recoded to start from zero and GCSE mathematics grades were coded as follows: A*/A = 3, B=2, C=1, D/E=0, unless otherwise stated. Each higher GCSE mathematics grade was predicted to add approximately 12-13% to the mark, and each higher confidence, liking or motivation adds approximately 5-6% to the mark. All three models were similar in explaining approximately 36% of the variation in student marks. The Adjusted R^2 values represent the percentage variation explained.

1st year Engineering students' mark %

= 31.9 + 12.3 x GCSE Grade + 5.2 x *Confidence in Mathematics*

[Adjusted R^2 = 35.8%, n=107]

1st year Engineering students' mark %

= 30.5 + 12.6 x GCSE Grade + 5.5 x *Liking of Mathematics*

[Adjusted R^2 = 36.8%, n=107]

1st year Engineering students' mark %

= 28.2 + 13.6 x GCSE Grade + 5.7 x Motivation

[Adjusted R^2 = 36.0%, n=107]

A model was also produced for first year BEng and MEng students with an A2 mathematics grade (i.e. a subset of the first year engineering students) as follows, which predicted that students with the highest possible A2 Grade (A) would achieve a 19.5% higher mark than ones with the lowest grade. The A2 grades were coded as follows: Grade A=5, B=4, etc.

1st year Engineering BEng and MEng students' mark %

= 71.8 + 3.893 x A Level Grade Code [Adjusted R^2 = 42.6%, n=19]

The following models were produced for 2nd year BEng/MEng engineering students' mathematics examination marks. The first model based on A level type code (recoded to A2=3, AS=2, Other=1 and none=0) and *Overall Confidence in Mathematics* shows a baseline mark of approximately 26% with increased marks for increased confidence and for full A2 A level compared with less post-16 mathematics learning.

2nd Year Engineering students' Mathematics Mark %

= 25.72 + 5.61 * A Level Type Code + 9.43 * *Confidence in Mathematics*

[Adjusted R^2 = 34.3%, n= 40]

Or, alternatively

= -29.8 + 1.174 * First Year Mathematics Mark

[Adjusted R^2 = 58.2%, n=33]

The second model, based on the first year marks, shows a drop in marks (although not as great as the constant value shown) and an exaggeration of the differences in marks achieved in the first year. The above two models demonstrate how using different levels of proximity for the explanatory variables can provide different insights into the relationships in the data.

Models were also produced for the subset of second year BEng and MEng students with an A2 mathematics grade. These models predicted that a student with the highest possible A2 Grade (A) would achieve a 36% higher mark than one with the lowest grade, whilst a most confident student would achieve 38% higher marks than a least confidence student.

2nd year Engineering BEng and MEng students' mark %

= 48.037 + 7.282 * A level Grade Code [Adjusted R^2=40.2%, n=22]

Alternatively

= 42.972 + 9.495 * Confidence in Mathematics [Adjusted R^2=18.1%, n=24]

A further model was produced for the drop in students' mathematics marks from the first year to the second year and those students without A Level mathematics were predicted to drop their mark by the most. The following predictive equation was produced based on the students' A Level mathematics grades, which predicted that students without any A Level mathematics would drop 25% in their marks in the second year mathematics compared to their first year mark, compared to an 8% drop for students with grade A at A2 Level mathematics. Where A Level Type Codes were as follows: A2 A grade = 0, A2 other grades =1, AS =2, Other =4, None =4)

Drop in 2nd Year Mathematics marks = 8.14 + 4.18 x A Level Type Code

[Adjusted R^2 = 18.7%, n= 30]

Two significant models were produced for 1st year APD students, which used the following independent variables: GCSE Mathematics Grade number (grades were recoded: A*/A=3, B=2, C=1, D/E=0), Motivation (recoded as 0-4) and Response to '*I have never felt myself able to learn mathematics'* (which was also re-coded to 0-4, where 4= strongly agree), which as a negatively phrased item has a negative coefficient. The two models are listed below.

APD Students' Assignment Mark % = 34.451

+ 6.887 x GCSE Mathematics Grade number + 3.052 x Motivation

[R^2 = 22.4%, n= 182]

APD Students' Assignment Mark % = 47.717

+ 5.432 x Motivation

- 4.900 x '*I have never felt myself able to learn mathematics'*

[R^2 = 20.6%, n=74, only 2006 data]

The following Multiple Regression model was produced to predict the natural science students' marks and is based on the Questionnaire year, GCSE mathematics grade and *Confidence in Statistics.* The percentage variation explained by this model is 31.9%, which is comparable to the Engineering student Multiple Regression models. This model predicts that the RMNat marks were approximately 12% higher in 2005 than in 2007 or 2006. Once again the confidence variable coefficient was approximately 5. This model predicts that a most confident student would achieve 18.3% higher marks than a least confident student, and likewise an A Mathematics GCSE grade student would achieve 19.6% more than one with grade D.

Second year Natural Science Students' Mark % = 39.723

+ 12.018 if 2005

+ 6.539 x GCSE Mathematics grade number

+ 4.568 x *Confidence in Statistics*

[Adjusted R^2 = 31.9%, n=179]

The following Linear Regression models were produced to predict the 2nd/3rd year Social Science students' marks which were based on the students' GCSE mathematics grade. The first model only explained 16.6% of the variation in the students' statistics question marks. Most of the variation in marks was caused by other factors outside of this study. A similar model was also produced for the overall Research Methods examination mark for which even less variation was explained. It was not possible to model second year social science marks on confidences, the suggested reason for this was that the confidences were all low and lacked sufficient variation to be used to explain the marks.

Second year Social Science Students' Statistics Questions Mark % = 51.927

+ 10.003 x GCSE Mathematics Grade number [R^2 = 16.6%, n=88]

Second year Social Science Students' Whole Examination Mark % = 47.833

+ 6.096 x GCSE Mathematics Grade number [R^2 = 14.0%, n=118]

A range of different regression models (shown above) explained achievement in terms of past qualification grades, confidences and other affective variables. Often the confidences (and other affective variables) had a regression coefficient of approximately 5, which when comparing a most confident student with a least confident student produces a difference in marks of approximately 20%. We can see that the first and second year engineering mathematics marks models had higher percentage variation explained (R^2) than for the statistics marks (both for examinations and assignments). In the above models the effect of Mathematics GCSE grade was more often greater than the effect of confidence

Previous work which found similar relationships are now listed, however none of these were with UK students. In the US, Reyes (1984, cited in McLeod, 1992) found correlations greater than 0.40 between confidence and achievement in secondary mathematics; Wood and Bandura (1989, in Bandura, 1997, p.122) found a direct effect of self-efficacy on performance (=0.55); and Pajares and Miller (1994) found that Self-efficacy was a stronger predictor of attainment (direct effect = 0.545) than perceived usefulness of Maths, Maths anxiety, maths self-concept (direct effect = 0.163), and prior experience (direct effect = 0.099), and that Maths self-efficacy was found to mediate the effects of gender and prior experience. Wilson and MacGillivray (2007) produced a regression model using six performance indicators (Maths qualifications, whether a maths student at university, Gender, Whether had done higher maths pre-university, Self-efficacy and survey year) which explained 29.4% of variation in Australian student mathematics skill scores. Liu and Koirala (2009) found a significant correlation (R=0.362) between mathematics self-efficacy and student performance (IRT scores) of 11726 US high school sophomores, and Regression analysis produced the following model: IRT score = 25.543 + 5.091 x Self-efficacy (R^2 = 12.9%). Liston and O'Donoghue (2009a) found a positive (but weak) correlation between Irish first semester university mathematics marks and Mathematics Self-concept (R=0.22).

All regression models depend greatly on the choice of independent variables used. The models produced in this thesis were not intended to be deterministic (i.e. not for exact predictions), but provide supporting evidence for the heuristic that *'Confidence contributes to student achievement'* or *'Confidence boosts success'*. Past qualifications were fixed before university, however, student confidence and motivation can be influenced during university teaching and so teaching staff should also give consideration to improving students' confidence and motivation.

The Factor Analysis and Cluster Analysis results for the different student groups will now be summarised in the next subsection.

6.3.4 Summary of Cluster and Factor Analysis Results

Factor and Cluster Analyses were carried out to provide an increased understanding of factors affecting learning and attainment and different student types (similar to Shaw and Shaw, 1997 and 1999).

Factor analysis results for first year APD students produced six underlying factors, which explained 68.8% of the variance. These six factors and their constituents (with percentage variation explained and Cronbach's Alpha values) were as follows:
Confident in and likes mathematics (23.3%, Alpha =0.951) – High *Confidence in Mathematics* and *Liking of Mathematics* (but not statistics), and all of the 11 Mathematics Confidence Scale Questions (adapted from Fogarty *et al.*, 2001);
Confident in and likes statistics (16.9%, Alpha =0.914) – High *Confidence in*

Statistics and *Liking of Statistics*, and to a lesser extent also *Confidence in Mathematics* and *Liking of Mathematics*; **High university achievement** (8.3%, Alpha =0.701) – high university achievement in statistics, and to a lesser extent high GCSE mathematics grade; **Spends lots of time** (7.9%, Alpha =0.397) – Older students, doing mathematics support, longer time spent outside of lectures, and those who would choose the module; **A level Mathematics** (7.4%, Alpha =0.692) – Had A level mathematics and high GCSE mathematics grades, predominantly male, *Liking of Mathematics* and excited about maths; and **Dyslexia** (5.0%, Alpha =0.271) – Dyslexia, and, to a lesser extent, male students (Alpha was low as these two items represented different characteristics). The interesting features of the APD factors are that: achievement was separated from confidences and attitudes (Likings), and that past achievement (A level Maths) was separated from university achievement (although GCSE mathematics grade appeared in both factors); Mathematics confidences (and liking) were separated from those for statistics; having A level mathematics was associated with being male and with being excited about mathematics; and dyslexia almost stood alone, except for the high correlation with male gender.

Four clusters were produced by hierarchical Cluster Analysis for first year APD students studying statistics: **A Level Mathematics cluster** (21 students, 11%) who were mainly male; **Fairly Confident cluster** (76 students, 38%) of students without A level maths; **Lacking Confidence cluster** (36 students, 18%) who were predominantly female and had slightly better than average achievement; and a **Lower Achievement cluster** (37 students, 18%), plus excluded cases (31 students, 15%). Once again we see that having A Level mathematics was associated with being male. The Fairly Confident factor represented the majority of students who were managing alright. Particularly notable, though, was the Lacking Confidence factor who were predominantly female, for whom there was a disparity between slightly above average achievement and their very low confidences, and this was definitely an area which merited attention to address this lack of confidence.

Factor Analysis results for first year engineering students produced four underlying factors which explained 62.3% of the variance, as follows: **High Achievement in Mathematics** (20.9%, Alpha =0.736) – Had A level mathematics, high GCSE Grade, were on the MEng or BEng course, high mathematics module mark and not dyslexic; **Confident in Statistics and Mathematics** (16.3%, Alpha =0.752) – high *Confidence in Statistics*, *Liking of Statistics* and *Confidence in Mathematics*; **Motivated and Like Mathematics (**16.1%, Alpha =0.605) – high motivation, high *Liking of Mathematics*, choosing to study mathematics, and older students; and **Time spent outside of lectures** (9.0%, Alpha =0.012) **–** worked longer outside of lectures, but also younger (alpha is low as these are two different characteristics). Whilst the APD exploratory factor analysis separated mathematics from statistics, the engineering student factor analysis has separated *Confidence in Mathematics* from *Liking in Mathematics,* providing an empirical distinction between confidence and liking (an attitude).

Four clusters were produced by hierarchical Cluster Analysis for first year engineering students: **High Achievement cluster** (19 students, 17%, mean mark 92%), **Good Achievement cluster** (42 students, 38%, mean mark 74%)**, Medium Achievement cluster** (25 students, 23%, mean mark 50%), and **Students in Difficulty cluster** (6 students, 5%, mean mark = fail), plus excluded cases (19 students, 17%). Whilst these clusters appear reasonable, the engineering student clusters are less interesting than those for the APD students, which was probably caused by the engineering students being a more homogenous, all male cohort compared to the more diverse, mixed gender APD students.

Examples of Factor Analyses and Cluster Analyses were described in the Literature Review (Chapter 2) and are summarised below for comparison. It can be seen that the results found in this thesis are different from existing work, but are comparable (or good) in terms of percentage variation explained and Cronbach's Alpha values. Shaw and Shaw (1997 and 1999) produced five student clusters, which were listed in Section 2.2, and were also able to reduce their 8 attitude variables into three factors (positive university experience, perception of difficulty and workload, and positive pre-university experience), which explained 64.5% of the variation in data. Fogarty *et al.* (2001) produced a three factor model which explained 48% of variance and a seven factor solution which explained 61%. Their Mathematics Confidence factor (11-item scale) had high internal reliability (Cronbach's Alpha= 0.89), and explained 14.42% of the variation. However, the equivalent APD 'Confident In and Likes Mathematics' factor and the equivalent factor 'Confident In and Likes Statistics' had higher Alpha values (0.951 and 0.914), and higher variance explained (23.3% and 16.9% respectively). Tapia and Marsh's (2004a) Attitude Towards Mathematics Inventory (ATMI) explained 55% of the variance, and comprised four factors: Self-confidence (Alpha = 0.95), Value of mathematics (Alpha = 0.89), Enjoyment of mathematics (Alpha = 0.89), and motivation (Alpha = 0.88). Liu and Koirala's (2009) Exploratory Factor Analysis one factor model of five self-efficacy items for US high school sophomores explained 73.6% of variation, with Alpha =0.933. Factor Analyses for the APD and first year engineering students explained 68.8% and 62.3% of variability, which can be seen to compare favourably with the results from these other studies.

As for the Regression analyses, the variables put into these analyses were chosen carefully, based on the research question and consistent with other understanding of the research context. This completes the summary of results from the various statistical tests.

6.4 Research Findings by Research Question

In this section the quantitative and qualitative findings which answer the Research Questions and sub-questions are explained, and reference is also made to relevant literature. Research Question I was about students' self-confidence in mathematics, and Research Question II was a broader enquiry, with a more inductive approach, intended to identify and investigate the range of different factors which contributed to determining students' experiences and levels of achievement in mathematics and statistics at the University College (as were listed in the Introduction, Chapter 1).

6.4.1 RQ.I What is the effect of students' self-confidence in mathematics on their learning of mathematics and statistics?

RQ I.a How can students' self-confidence in mathematics be defined and measured?

It was found that Self-confidence was defined differently in the literature by different researchers and study participants (Burton, 2004 and Cretchley, 2008), with varying terminology, including the terms self-efficacy (Bandura, 1997) and self-concept (Pajares and Miller, 1994). There were various reports which had aimed to compare and reconcile the terminology and definitions (e.g. Bong and Clark, 1999, and Bong and Skaalvik, 2003, and Chamberlin, 2010). In this thesis the definition of confidence adopted was as a persons' belief in their ability to learn and do mathematics. A distinction was made between beliefs (including confidences), attitudes, emotions and motivation, as has already been explained in the Contribution Section, 6.2. One positive aspect of this study was that the definition of confidence was made at an early stage.

The new three Mathematics Self-confidence Domains model was proposed in this research (see also Parsons, 2006a and 2006b, and Parsons *et al.*, 2009 and 2011), which comprised: *Overall Confidence in Mathematics, Topic Confidences and Applications Confidence* and the relationships between these, which have already been explained in the Contribution Section 6.2 (See Figure 6.1) and Section 2.7.6. The three domains were compared with Albert Bandura's self-efficacy theory (1997). Bandura would class all three domains as self-efficacy, but would differentiate between an operative capability self-efficacy (equivalent to *Overall Confidence*) and a sub-skill self-efficacy (equivalent to *Topic Confidence*). Frank Pajares (1996) would describe *Overall Confidence* as Self-concept in mathematics (although this is a more wide-ranging construct and includes values of personal worth), and would use the term self-efficacy for the *Topic Confidences*.

In the surveys two questions were posed which asked students to rate their (Overall) *Confidence in Mathematics* and *Confidence in Statistics*, these were present in every version of the questionnaires. These two single rating questions were supplemented by 11 Scale questions (based on Fogarty *et al.,* 2001) for first year students in 2006, and by 5 Scale questions in the three first year questionnaires and the two 2007 statistics modules' second year questionnaires. The single rating *Overall Confidence in Mathematics* and *Confidence in Statistics* questions and three other Scale questions (in which students rated their agreement with the statement) were evaluated to be the most effective questions as these were found to be the most highly related to marks by ANOVA tests and correlation and regression analysis. Four such Scale questions were: *'I usually do well in mathematics'; 'I find maths confusing'; 'I do not have a mathematical mind';* and *'I have never felt myself able to learn mathematics'.*

The *Topic Confidences* were also measured very effectively, with higher confidences being associated with easier or more familiar topics, as would be expected. However this wide variation in each student's *Topic Confidences* made the *Topic Confidences* less useful than the *Overall Confidences*, unless one's interest was in a specific topic.

The *Applications Confidences* were considered the least usable of the three domains, but still considered important. ACME (2011) wanted young people to have learnt more mathematics than they would need at work so that they would be more confident to apply the maths in unfamiliar settings at work. 11 separate questions were asked in the 2004/5 questionnaires which yielded responses very similar to the *Topic Confidences*, but were usually slightly lower. These were simplified in 2006 and 2007

to a single rating for how their confidence would change in the future and an open question to explain why, which yielded more useful results. The results of the *Applications Confidences* were generally that some students would be more confident in the future as they would have learnt and practised more, whereas others felt they would be less confident due to having forgotten what they had learnt by then.
The mean *Confidence in Mathematics* and *Confidence in Statistics* values given in Table 6.1 in Section 6.3 revealed that the different student groups had different levels of *Confidence in Mathematics* and *Confidence in Statistics*. As was expected, the BEng and MEng engineering students were the most confident in mathematics as these students had generally studied A Level mathematics and were more mathematically inclined than the 2nd and 3rd year Social science students who had the lowest confidences. The most common pattern of overall confidences was that students' Overall confidence in Life in general was greater than their *Overall Confidence in Mathematics*, which was greater than their *Overall Confidence in Statistics.* A comparison of the different student groups was given in Section 6.2.7.

Figure 6.2 below shows mean values for the second year BEng and MEng students' self-confidences in mathematics, showing *Overall Confidence in Mathematics* (dotted), *Topic Confidences* (solid) with the mean *Topic Confidence* value (outline) and the mean *Applications Confidence* (striped), this was previously shown as Figure 4.21. The variation in the *Topic Confidences* is evident and ranged from 4.4 to 2.5, out of a range of 1 (low) to 5 (high). All the different students groups surveyed had *Topic Confidences* which covered a similarly wide range.

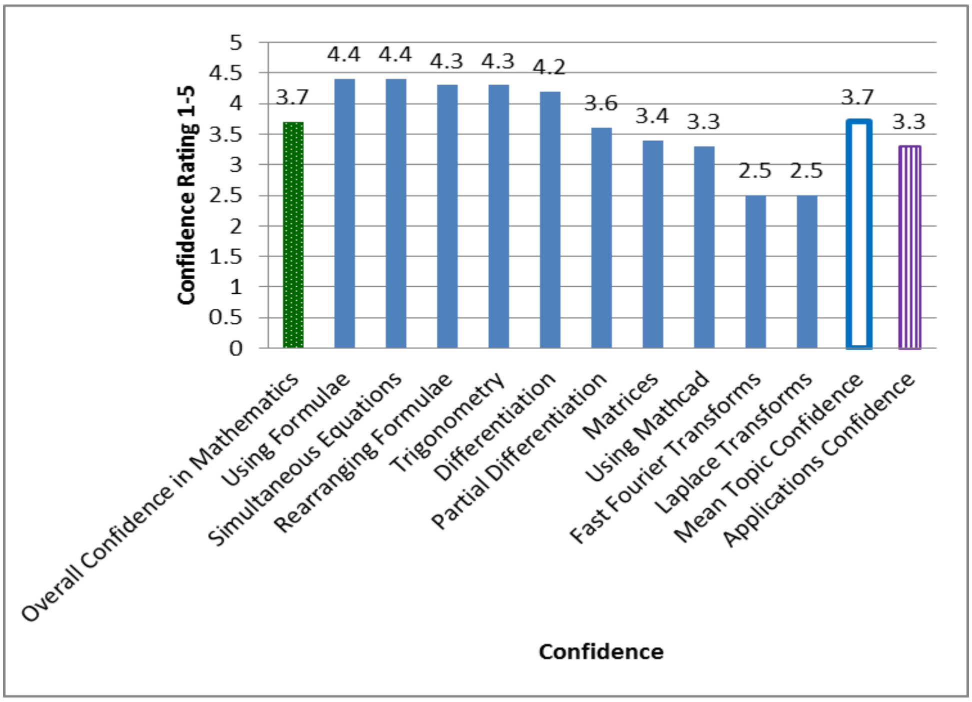

Figure 6.2 Second Year BEng and MEng Student Confidence Mean Values 2005-7

All the student groups exhibited a similar pattern of Mean *Topic Confidences* being higher than (or equal to) *Overall Confidence in Mathematics*, which was higher than the *Applications Confidence,* as shown in Table 6.6 below for the engineering students.

Table 6.6 Mean Engineering Student Confidences for the Three Mathematics Self-confidence Domains 2005-2007 (Ratings 1 to 5, where 5=high)

	Overall Confidence	Mean Topic Confidence	Applications Confidence
First Year BSc and FdSc	3.4	3.6	3.3
First year BEng and MEng	3.6	3.8	3.4
Second year BEng and MEng	3.7	3.7	3.3

RQ I.b What effect does students' self-confidence in mathematics have upon their learning and performance?

The student marks were obtained for all of the modules surveyed with permission from the module leaders, and matched with the survey data by means of the student id numbers from the questionnaires. Students' *Confidence in Mathematics* was significantly related to achievement in 5 student groups tested (i.e. every group except for the single year 2006 natural science student data), and *Confidence in Statistics* was also significantly related to achievement in 4 of the 5 student groups tested (all except the second year social science students who generally all had very low confidences, i.e. with insufficient variability for significance). The details are provided in Section 6.3 in Table 6.3.

ANOVA tests, Regression models and Factor and Cluster Analyses found relationships between achievement and confidence, which have already been described in Sections 6.2.6 and 6.3. Quantification of the effect of *Confidence in Mathematics* (and statistics) on attainment was done predominantly by regression models predicting student marks. A pattern which was found repeated in several models and for different student groups, was that past achievement had the greatest effect on current achievement, but that confidences (and other affective variables) had an effect approximately half the size of that due to past achievement.

Theoretically, Bandura's Social Cognitive Theory (1997) specifies four mediating processes through which self-efficacy beliefs take effect. These were: cognitive, motivational, affective and selective processes (Bandura, 1997, p.116), This thesis would concur with these four types of processes as having an effect on students learning, and supporting evidence for this has been presented in the results in Chapters 4 and 5 and Parsons *et al.* (2011). Other literature which was found to support the effect of self-confidence on learning included Zimmerman *et al.* (1992), Warwick (2008a). Liu and Koirala (2009) concluded that it was more important to promote self-efficacy in order to improve achievement in mathematics than to promote [positive] students' attitude towards mathematics, whilst Pajares (2000) states that *'Students who have a strong sense of self-efficacy are well equipped to educate themselves when they have to rely on their own initiative.'*

RQ I.c What contributes to forming students' self-confidence, both before and at university?

Prior success in mathematics was found to be the most powerful determinant of student self-confidence, and a range of other variables (including gender) were also found to have significant effects on confidence. The relationships between confidence and the various variables were investigated using ANOVA tests, Kruskal Wallis tests, correlation and regression analyses. Many statistically significant relationships were found, and this would suggest, but does not prove, causality. The positive and negative mathematics learning cycles proposed by Ernest (2000) were considered to have held true, which actually makes confidence more important as it feeds into what is either a positive or negative cycle. Whereas past achievement is fixed, improving a students' confidence is possible and is something that lecturers should aim to do.

The results of ANOVA and Kruskal Wallis tests which were presented in the results chapters (4 and 5) have been drawn together and are summarised in Section 6.3.2. Clear relationships were found between marks and: past qualifications; confidences; attitudes; and motivation, and also between the *Overall Confidences in Mathematics* and *Confidences in Statistics* and: past qualifications; confidences; and attitudes. There was also a Gender effect in the APD and RMNat data on *Confidence in Mathematics*, revealing that the females were less confident than males, but no Gender effect was found on achievement, females achieved equally as well as male students. Dyslexia was also found to have a significant effect on *Confidence in Mathematics* in some instances, where dyslexic students were less confident than their non-dyslexic peers. Dyslexia was also not found to affect achievement, but perhaps the effects were mitigated by the extra time allowed in examinations and the support provided. Other variables which have occasionally been found to have a significant effect on confidence included: Course, Award level (both of which are partly based on past qualifications and ability), the Importance of statistics, whether students Would choose to study statistics, Motivation and Whether motivation was the same as on other modules. Age never had a significant effect on confidence.

It was shown in Section 4.5 and in Parsons *et al.'s* (2011) comparison with final year engineering student interview responses that Bandura's sources of self-efficacy (1997) could be effectively applied to Engineering students learning mathematics, and it can also be seen that these also apply to the other student groups who were learning statistics.

Bandura's four principal sources of self-efficacy were investigated as sources of self-confidence, which were as follows: Enactive mastery experiences, Vicarious experiences, Verbal persuasion, Physiological and affective states (Bandura, 1997, p.79), which require cognitive processing and reflection to take effect. Overall these sources were verified by the empirical results. However, one limitation of Bandura's enactive mastery experiences found in this thesis was that it did not distinguish between competence and understanding, the differentiation of which is important in mathematics. Some lack of clarity was also found as Physiological and affective states were defined and found to be both a source and a mediating process for the effects of self-efficacy. Overall this thesis would support Bandura's *Social cognitive theory*, and provides further empirical and theoretical data to support this, as did Britner and Pajares (2006).

Interestingly, findings for Mathematics anxiety (Trew, 2005) bear great resemblance to findings for *Confidence in Mathematics*. Those with high mathematics anxiety: avoid mathematics by taking fewer elective mathematics courses, hold faulty beliefs and negative attitudes towards general problem solving and demonstrate lower achievement in mathematics. Suggestions for reducing mathematics anxiety included: to dispel common misconceptions: mathematics is not a male domain; and ability is not a fixed quantity but is modifiable (Bandura, 1997, Dweck, 2000), and to change classroom environments by emphasising challenge, effort and enjoyment rather than talent or innate ability (Trew, 2005). Thus it can be seen that these recommendations to help reduce mathematics anxiety would also help to build student C*onfidence in Mathematics*.

RQ I.d How does students' confidence in mathematics subsequently change from that on entry to university through university teaching?

There were very diverse experiences and confidence ratings provided by different students in the different student types surveyed. Many students had positive experiences at the University College, especially the first year engineering students, and stated that their confidence had improved (from responses in questionnaires and in final year engineering student interview responses, Parsons *et al.,* 2011). However, there were some students who felt less confident. As the level of difficulty of the material being learnt in the second and final years was (as would be expected) harder than the first year, it is not surprising that many students felt less confident, however there were certainly instances where the lack of confidence could have been reduced by more supportive teaching styles. The change in their average *Overall Confidence* self-ratings from the first year to the second year was actually small (±0.1 out of 4), indicating only a slight increase for BEng and MEng engineering students and social science students; and a very slight decrease for second year natural science students (See Tables 6.1 and 5.30).

It was, however, often found that students' level of self-confidence stemmed from a long time ago in the past and was not quick or easy to change, which was consistent with Kent and Noss (2003), and Pehkonen and Pietilä (2004). For example, one lacking confidence student wrote *'I think my lack of confidence stems from way back and will be difficult to rectify'* and Garfield and Ben-Zvi (2007) similarly found that attitudes were little changed after a course on statistics. This contributes to validating the distinction between the *Overall Confidence* (which is slower and harder to change) and *Topic Confidences* (which are quicker and more easily changed).

6.4.2 RQ.II What different factors can be identified which affect students' learning of mathematics and statistics?

RQ II.a What are the attitudes and views of students when and towards learning mathematics and statistics?

There was wide variation in the attitudes and views of the students surveyed. The closed questions which measured attitudes asked the students to rate their *Liking of Mathematics* and *Liking of Statistics*. The mean values for *Liking of Mathematics* and *Liking of Statistics* for the different student groups can be seen in Table 6.1. Details of student views were summarised in the many open question summary tables (especially Tables 4.22, 5.21 and 5.42), and the views of seven of the interviewed engineering students can be found in Parsons *et al.* (2011).

Some students understood that the skills and knowledge being taught to them would be relevant and useful to them for future studies and careers. The relevance and usefulness of the subjects were better understood by the engineering students and the natural science students than for the social science students. Overall the students unfortunately had more negative views about statistics than they did about mathematics, for example these are two student quotes: *'I don't mind mathematics, it's the statistics that I don't like'* and *'I feel confident in all areas of maths except stats'.* Some students reported that their enjoyment of these subjects came from being able to do it, and from understanding it.

Whilst there were many instances where students had positive attitudes and were interested and motivated to learn mathematics and statistics, the findings of this study indicate that more could be done to improve student attitudes, and suggests that practical ways to do this would be to include more practical real-world applications of the subjects and also to try to make lectures as interesting and enjoyable as possible.

RQ II.b How do the students' attitudes and views affect their learning of mathematics and statistics?

Engineering students were generally more positive about learning engineering mathematics than many of the other students groups were about learning statistics, and this was also reflected in the levels of motivation for the different student groups. The four engineering students groups shown in Table 6.1 all had good mean motivation ratings (above 3 out of 5, e.g. 3.6) whereas the three groups surveyed in their statistics modules lacked motivation and had mean motivation values below 3 (e.g. 2.7) out of 5. It was clear that some students did not see the point of learning statistics and this resulted in reduced effort. It was also possible though for some students to not like the subjects but to still achieve well. The results of ANOVA tests for the effect of liking the subjects on achievement are shown in Table 6.3 in Section 6.3.2. The second year Research Methods module for natural science students is worthy of note, because the message was made very clearly that the statistics being taught were necessary to help the students with their final year research project. Similarly the engineering students had a good appreciation that the mathematics they were learning was necessary for engineering. Low confidence sometimes resulted in reduced student effort, particularly for learning statistics.

It is helpful for lecturers to promote the view of intelligence as incremental, rather than fixed entity (Carmichael and Taylor, 2005, Bandura, 1997, Dweck, 2000, and Warwick, 2008a). It is not a *"you either have or you don't"* characteristic. If students know that they can improve their intelligence by learning new things and through effort, it gives them hope and motivation.

RQ II.c What, in the students' opinions, are the characteristics of mathematics and statistics teaching which promote effective learning and improve self-confidence when learning mathematics and statistics?

Helpful features indicated by students included use of computers, the lecturer/good teaching, handouts, the opportunity for students to do exercises/practice in the classes, quizzes at the start to check knowledge learnt previously (RMNat students only). All of the methods of doing calculations were rated highly (above 4 out of 5) by all of the questionnaire groups. The most frequently occurring responses to the three questions asking what had helped, not hindered or would their improve learning of statistics were:

good teaching; more practice; handouts; application to real life scenarios and future studies and careers; worked examples; mathematics support; appropriate speed and level of difficulty; and more help. A summary of the category of responses to the three questions is given below in Table 6.7.

Table 6.7 Summary of Entity Type for What Helped (not) Hindered or Would Improve Learning for All Survey Respondents

Entity	No. Responses	Description
Student	197	Work, understanding, confidence, motivation, interest, etc.
Module	189	Organisation, resources, handouts, room/time, etc.
Teaching	171	Person, speed, helpfulness, explanations, etc.
Computers	166	Use of computers particularly helped learning statistics
Subject	124	Difficulty, need to know previous work, relevance, etc.
Help	55	Maths Support, lecturer help, one to one help, wanted more

It is good that the students really understood that they needed to work themselves, but this also implied that the lecturers need to provide work for students to do, i.e. to provide opportunities for mastery experiences (Bandura, 1997). Students would prefer to understand and enjoy their lectures, this was also referred to in (Robinson *et al.*, 2010) who quote a positive student '*I feel that the tutors and students work as a team aiming for one goal and that is the students' understanding and enjoyment of the subject.'*

Real world and practical applications featured high on the students' preferences, and this was consistent with Norris (2012) and ACME (2011) who both stressed teaching the applications of mathematics. ACME (2011) also recommended for the study of mathematics post-16 to include familiarisation with mathematical models and experience of computerised computation.

The author would agree with Burton (2004) who concluded that identifying which pupils were confident was much easier than creating classroom conditions which helped confidence to flourish. It has been more difficult to propose means to raise student confidence than to define, measure and analyse student levels of self-confidence. Additional work was carried out to produce practical guidelines, however, whilst some useful recommendations were identified, further research would be required to fully validate these, and for this reason these guidelines have not been included in the final write-up of this thesis.

RQ II.d What differences can be identified for students with dyslexia, dyscalculia and/or other special needs when learning mathematics and statistics?

Dyslexic students described a range of effects on their learning, from none at all to quite negative effects, however no positive effects were stated. The results of the ANOVA and Kruskal Wallis tests found that dyslexia did not have a significant effect on achievement for any of the five student types analysed, but there was a significant effect on confidence, dyslexia was significantly associated with lower *Confidence in Mathematics* for two student types (second year social science students and first year APD students). There was extra time allowed in examinations and student support provision for the dyslexic students at the college which may have mitigated against the effects of dyslexia on achievement. In the First year APD Factor Analysis, Dyslexia was found to be almost a separate factor in its own right, it was only associated with gender (male students), and not with confidences, attitudes, achievement or motivation. Analysis of the open question responses revealed a range of effects including experiencing difficulties in remembering formulae, that it took the student longer than their peers to learn the statistics initially, and that they thought they had to work harder at it. Additional work was carried out investigating the effects of dyslexia and dyscalculia which has not been included in the final write-up of this thesis, which was omitted in favour of the main narrative on self-confidence.

RQ II.e What evidence can be found for the effect of Mathematics Support on students' achievement and self-confidence in mathematics and statistics?

There were questions about the mathematics support provision in first year student questionnaires. The mathematics support was rated highly for helpfulness, clear teaching, relevance for students' needs and arrangements/timings (all were rated above 4 out of 5). The mathematics support was the second most helpful feature for the first year engineering students, and it was seventh overall for all surveyed students (from combined responses to what had helped, not hindered or would improve their learning), and was also listed in Table 6.7 above. Analysis of the first year students learning APD statistics' GCSE mathematics grades showed that the marks for equivalent GCSE grades were slightly higher for students who had received support, although this difference in marks was not significant (which was possibly due to the wide variation in marks achieved by supported students). Whilst this support was not a major focus of the research (partly for ethical reasons as the author was the

Mathematics Support tutor) overall positive feedback was obtained about the mathematics support provision. Where the provision could be improved was in the availability and timing; many students wrote that what would improve their learning would be more help and more one to one help (although this could also be from their lecturer in the classes).

6.5 Suggestions for Future Work

The following areas were suggested for further work:

- Survey and interview teaching staff for their perspectives
- Structured Equation modelling on *Confidence in Mathematics* and other data.
- Design a multi-item scale solely comprising cognitive belief items;
- Further research to identify teaching characteristics which improve student confidence and attitudes;
- Further investigation of the effects of dyslexia and dyscalculia and other Specific Learning difficulties;
- Investigate the three Mathematics Self-Confidence Domains in other universities.

The author would suggest that while more investigation into students' self-confidence and attitudes towards learning mathematics and statistics has been carried out since Frid *et al.* (1997) and Chamberlin (2010) both recommended further research, and since Carmichael and Taylor (2005) wrote that further clarification of the interrelations between affective constructs was needed, this remains an area which has still not yet been fully explored. At the time of writing there existed a much larger body of literature than in 2004 at the start of this study, including: Chamberlin (2010), ACME (2011), Vorderman *et al.* (2011), GB. Parliament (2012), TISME (2013) and OECD (2013). This demonstrates the on-going worldwide interest in Mathematics education and self-confidence and self-efficacy.

6.6 Closing Remarks – A Message of Hope

As this thesis is completed, we are nationally at a time of more major changes in many areas of compulsory and post-16 education mathematics education: new primary national curriculum, concern over GCSE mathematics not being fit for purpose (Vorderman *et al.*, 2011) resulting in the production of new GCSE Mathematics specifications (Gove, 2013), Post-16 mathematics becoming compulsory for all 16+ year olds, and redesign of A levels (Sparks, 2012, Gove 2013). Also at this time the government had made far reaching Higher Education Reforms in terms of university recruitment and funding. Despite these far reaching changes, educators must ensure that their primary objective remains the effective learning of the individuals in our classrooms, as Carol Vorderman describes it: we should aim to provide *‘A world-class mathematics education for all our young people’* (Vorderman, 2011).

It is hoped that this thesis has presented the *’student viewpoint’* of their experiences learning mathematics and statistics, and that from this educators can understand better how students view learning these subjects and can adopt approaches to teaching to move closer to meeting students’ needs and expectations. Some students described very positive experiences and were confident and successful, whilst others admitted with honesty to having struggled and having felt unable to do what they perceived as difficult and sometimes boring and irrelevant material.

The diversity of learners and educators has been apparent throughout this thesis, and it is clearly a great challenge to simultaneously satisfy such diverse student needs, interests and expectations, through a diverse group of lecturing staff, to prepare students for a diverse range of careers and futures. Certain themes have emerged throughout; no experiences have stood in isolation, but in accordance with socio-constructionist learning theories, each student arrives in a university classroom with a history of past successes or failures, which will as much influence their learning, confidence, attitudes, effort and motivation as the sets of skills and knowledge that they acquired from those endeavours. Often the more successful, higher achieving students had more experience of success, whilst those who previously struggled and lacked confidence were most likely to continue at university in a similar manner. However, there were large numbers of students, especially girls and dyslexic students, for whom their ability was better than their confidence and attitudes, for whom it would be a very worthwhile objective of teaching staff to seek to address this lack of confidence and poor attitudes with as much attention as is currently given to helping students to acquire new knowledge and skills, even if this is harder, takes longer and is more difficult to measure (McLeod, 1992, Kent and Noss, 2003, and Pehkonen and Pietilä, 2004). It does at least extend the armoury that a lecturer can work with. Mathematics and statistics educators are, by nature of their own competence and interest in these subject areas, not likely to have experienced the difficulties that so many of these students have described. It is an unfortunate feature of English society today that negative beliefs and attitudes about mathematics and statistics appear to be common in many of our non-specialist learners. Staff are asked to remember that many students have genuine difficulties and also lack the hope that they can become successful enough to succeed in these subjects for their chosen studies and careers. Students did understand that their own effort was required and was one of the main keys to success. In this study there was wide-scale evidence that students can achieve beyond their expectations given the right classroom conditions, sufficient help and effort on their own part.

It is helpful for lecturers to promote the view of intelligence as incremental, rather than a fixed entity (Carmichael and Taylor, 2005, Bandura, 1997, Dweck, 2000, and Warwick, 2008a). If students know that they can improve their intelligence by learning new things and through effort, it gives them hope and motivation. Creating collaborative and supportive learning environments, with a discursive approach, to explain well and not to rush (Burton, 2004), helps to raise students' confidence. Interestingly, the approaches used for teaching research methods at this HEI have since successfully moved increasingly towards the use of student projects and away from hand calculations for learning statistics, as was recommended in the literature. In this study many student responses indicated appreciation for their lecturers' good teaching, they valued doing work themselves, handouts, practical applications of mathematics, the mathematics support and all help they were given. However, the wide scale lack of confidence, of otherwise successful students, indicates that still more could be done.

So in closing, if one was to ask 'What is the Golden Nugget in this thesis?' the reply has to be that "*student self-confidence in maths matters*". Evidence has been presented for clear links between students' self-confidence and attitudes and their achievement in mathematics and statistics. Whilst students arrive at university with backgrounds and past achievement that is fixed, educators can influence their university experience and should seek to encourage their students to believe that they have the potential to succeed, and try to provide some enjoyment of these vital subjects along the way. So not only should educators seek to convey knowledge and skills to their learners, they should also aim to create confident learners who will approach new problems with the belief that, given the right support and effort, *'I can learn the mathematics and statistics that I need to do - I can do it!'* Finally, this thesis has provided supporting evidence for the notion that '*success boosts confidence, and confidence boosts success!'*

‘Concern for man himself and his fate must always form the chief interest of all technical endeavours … in order that the creations of our minds shall be a blessing and not a curse. Never forget this in the midst of your diagrams and equations.’

(Einstein, 1931, in Bynum and Porter, 2006, p.198)

‘Most of the fundamental ideas of science are essentially simple, and may, as a rule, be expressed in a language comprehensible to everyone.’

(Einstein and Infeld, 1938, in Bynum and Porter, 2006, p.201)

‘But blessed is the man who trusts in the LORD, whose confidence is in him’

Jeremiah 17 v. 7

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APPENDICES

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Note: The questionnaires samples in these Appendices have been adjusted to fit onto the pages of the thesis document (allowing for larger left margin) which has required the line spacing to be reduced and the spaces for students to write responses to open questions have also been reduced.

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Appendix I Mathematics Learning Questionnaire for 1st Year BEng and MEng Engineering Students 2005

This survey is intended to find out your (the students') experiences and attitudes to learning mathematics and statistics, i.e. to create a general 'student voice'. The results will be used to provide a general understanding of feelings and issues.

Survey participation is entirely voluntary. Answering any question is also voluntary. No individual students will be identified in the reporting of any results. Responses to this questionnaire will not have any effect on your module marks.

Please tick the appropriate boxes or write details in the space provided.

Please use the last page to continue if there is insufficient space for any answers.

1. **Award level** MEng ☐ BEng ☐ BSc ☐ HND ☐ FdSc ☐

2. **Course Name** ____

3. **Gender** Male ☐ Female ☐

4. **Age** ________

5. **Are you Dyslexic?** Yes ☐ No ☐ Don't know ☐

6. **Are you Dyscalculic?** Yes ☐ No ☐ Don't know ☐

7. **Student id no.** ____________________________________

8. **Mathematics GCSE:** Grade _____ Date ______ No. times taken _____
   Tier: Higher ☐ Intermediate ☐ Foundation ☐

9. **A level maths or other maths qualifications:** A2 ☐ AS ☐ Other ☐
   Details (grades, dates, modules, etc.):

---

10. **Given a choice would you have chosen to study this module?**

    Yes ☐ No ☐

How confident would you describe yourself overall?
Please tick one box per question

	Very confident				Not confident
11. **in mathematics?**	☐	☐	☐	☐	☐
12. **in statistics?**	☐	☐	☐	☐	☐
13. **in life in general?**	☐	☐	☐	☐	☐

14. **For how long have you held this opinion of your self-confidence in mathematics?**

15. **How do you think that your experiences of mathematics *before* coming to university have affected your confidence or liking of the subject?**

(Please describe your experiences if possible)

16. **Has this module helped you to feel more confident than previously?**

More confident				Less confident
☐	☐	☐	☐	☐

Do you like the subject?

	Really Like				Detest
17. **Like Mathematics?**	☐	☐	☐	☐	☐
18. **Like Statistics?**	☐	☐	☐	☐	☐

19. **Has this module helped you to *like* the subject more?**

More				Less
☐	☐	☐	☐	☐

20. **How would you describe your *attitude* to learning mathematics?**

21. **How would you rate your *motivation* in this area?**

Really motivated				Not motivated
☐	☐	☐	☐	☐

22. **Is this more or less motivation than for your other modules overall?**

More ☐ Less ☐ The same ☐

23. **How much time have you spent outside lectures working on this module on average in hours per week?** (tick one box)

0 ☐ 1 hour ☐ 2 hours ☐ 3 hours ☐ 4+ hours ☐

How would you describe your ability to do *(or confidence in doing)* the following topics in the module? (Please tick one box per topic)

		Very able Can Do				Not Able Can't Do
24.	**Using equations and formulae**	☐	☐	☐	☐	☐
25.	**Rearranging equations & formulae**	☐	☐	☐	☐	☐
26.	**Simultaneous equations**	☐	☐	☐	☐	☐
27.	**Trigonometry (Sin, Cos, Pythagoras)**	☐	☐	☐	☐	☐
28.	**Partial fractions**	☐	☐	☐	☐	☐
29.	**Differentiation (basic)**	☐	☐	☐	☐	☐
30.	**Differentiation of products, quotients**	☐	☐	☐	☐	☐
31.	**Integration**	☐	☐	☐	☐	☐
32.	**Complex numbers**	☐	☐	☐	☐	☐
33.	**Matrices**	☐	☐	☐	☐	☐
34.	**Differential equations**	☐	☐	☐	☐	☐

How confident do you feel about *applying* these in the future, for example to analyse your project/dissertation data or at work? (Please tick one box per topic)

APPLYING MATHS		Very confident				Not confident
35.	**Using equations and formulae**	☐	☐	☐	☐	☐
36.	**Rearranging equations & formulae**	☐	☐	☐	☐	☐
37.	**Simultaneous equations**	☐	☐	☐	☐	☐
38.	**Trigonometry (Sin, Cos, Pythagoras)**	☐	☐	☐	☐	☐
39.	**Partial fractions**	☐	☐	☐	☐	☐
40.	**Differentiation (basic)**	☐	☐	☐	☐	☐
41.	**Differentiation of products, quotients**	☐	☐	☐	☐	☐
42.	**Integration**	☐	☐	☐	☐	☐
43.	**Complex numbers**	☐	☐	☐	☐	☐
44.	**Matrices**	☐	☐	☐	☐	☐
45.	**Differential equations**	☐	☐	☐	☐	☐

46. **What effect has your dyslexia or dyscalculia had?**

Please skip to the next question if not applicable.

47. **Which aspects of the module particularly *helped* your learning?**

48. **Which aspects of the module particularly *hindered* your learning?**

49. **Have you experienced an occasion when a topic suddenly became a lot clearer than before (e.g. like a light switching on)?**

Yes ☐ No ☐
Details:

50. **Have you had any support from other sources?**

Lecturer	☐	Friends	☐	Family	☐	Mathematics support	☐
Books	☐	Web-sites	☐	Other	☐	None	☐

Details:

If Mathematics support was used then please answer the questions below. Otherwise please continue on the next page.

51. **Was the Mathematics support for group or individual help?**

Group ☐ Individual ☐ Both ☐

How would you rate the Mathematics support ?

	Good				Poor
52. **Helpfulness of support**	☐	☐	☐	☐	☐
53. **Clear teaching**	☐	☐	☐	☐	☐
54. **Relevance to your needs**	☐	☐	☐	☐	☐
55. **Arrangements / Timing**	☐	☐	☐	☐	☐

56. **Other comments on the mathematics support (e.g. suggestions)**

57. **When did you last enjoy doing something in maths?** (please give details)

58. **Can you suggest anything that would improve your confidence, attitudes or ability in mathematics?**

59. **Any other comments**

Thank you very much for completing this questionnaire.

You are welcome to contact me if you would like to discuss anything.

S J Parsons, Learning Support Tutor, sjparsons@harper-adams.ac.uk

Appendix II Mathematics Learning Questionnaire for Research Design and Analysis Second Year Students 2005

This survey is intended to find out your (the students') experiences and attitudes to learning mathematics and statistics, i.e. to create a general 'student voice'. The results will be used to provide a general understanding of feelings and issues. Survey participation is entirely voluntary. Answering any question is also voluntary. No individual students will be identified in the reporting of any results. Responses to this questionnaire will not have any effect on your module marks.

Please tick the appropriate boxes or write details in the space provided.
Please use the last page to continue if there is insufficient space for any answers.

1. **Award level** BSc ☐

2. **Course Name** ____

3. **Gender** Male ☐ Female ☐

4. **Age** ________

5. **Are you Dyslexic?** Yes ☐ No ☐ Don't know ☐

6. **Are you Dyscalculic?** Yes ☐ No ☐ Don't know ☐

7. **Student id no.** ____

8. **Mathematics GCSE:** Grade _____ Date ______ No. times taken _____
   Tier: Higher ☐ Intermediate ☐ Foundation ☐

9. **A level maths or other maths qualifications:** A2 ☐ AS ☐ Other ☐
   Details (grades, dates, modules, etc.):

---

10. **Given a choice would you have chosen to study this module?**

Yes ☐ No ☐

How confident would you describe yourself overall?
Please tick one box per question

Very confident		Not confident				
11.	**in mathematics?**	☐	☐	☐	☐	☐
12.	**in statistics?**	☐	☐	☐	☐	☐
13.	**in life in general?**	☐	☐	☐	☐	☐

14. **When did you form your opinion of your general self-confidence in maths?**

Age 5-7 ☐ 7-11 ☐ 11-14 ☐ 14-16 ☐ 16-18 ☐ 18+ ☐

Comments:

15. **How do you think that your experiences of mathematics *before* coming to university have affected your confidence or liking of the subject?**

(Please describe your experiences if possible)

16. **Has this module helped you to feel more confident than previously?**

More confident ☐ ☐ ☐ ☐ ☐ Less confident

Do you like the subject?

		Really Like				Detest
17.	**Like Mathematics?**	☐	☐	☐	☐	☐
18.	**Like Statistics?**	☐	☐	☐	☐	☐

19. **Has this module helped you to *like* the subject more?**

More ☐ ☐ ☐ ☐ ☐ Less

20. **How would you describe your *attitude* to learning statistics?**

21. **How would you rate your motivation in this area?**

Really motivated ☐ ☐ ☐ ☐ ☐ Not motivated

22. **Is this more or less motivation than for your other modules overall?**

More ☐ Less ☐ The same ☐

23. **How much time have you spent outside lectures working on this module on average in hours per week?** (tick one box)

0 ☐ 1 hour ☐ 2 hours ☐ 3 hours ☐ 4+ hours ☐

How would you describe your ability to do *(or confidence in doing)* the following topics (Please tick one box per topic)

		Very able/ Can Do				Not Able Can't Do
24.	**Percentages**	☐	☐	☐	☐	☐
25.	**Use formulae**	☐	☐	☐	☐	☐
26.	**Calculate the Mean**	☐	☐	☐	☐	☐
27.	**Calculate number of replicates**	☐	☐	☐	☐	☐
28.	**Skeleton ANOVA degrees of freedom**	☐	☐	☐	☐	☐
29.	**Factorial ANOVAs**	☐	☐	☐	☐	☐
30.	**t – tests**	☐	☐	☐	☐	☐
31.	**Interpret a C.V. %**	☐	☐	☐	☐	☐
32.	**Use of Genstat**	☐	☐	☐	☐	☐
33.	**Plot dose response result graphs**	☐	☐	☐	☐	☐
34.	**Interpret an F Prob value**	☐	☐	☐	☐	☐

How confident do you feel about *applying* these in the future, for example to analyse your project/dissertation data or at work? (Please tick one box per topic)

APPLYING MATHS		Very confident				Not confident
35.	**Percentages**	☐	☐	☐	☐	☐
36.	**Use formulae**	☐	☐	☐	☐	☐
37.	**Calculate the Mean**	☐	☐	☐	☐	☐
38.	**Calculate number of replicates**	☐	☐	☐	☐	☐
39.	**Skeleton ANOVA degrees of freedom**	☐	☐	☐	☐	☐
40.	**Factorial ANOVAs**	☐	☐	☐	☐	☐
41.	**t – tests**	☐	☐	☐	☐	☐
42.	**Interpret a C.V. %**	☐	☐	☐	☐	☐
43.	**Use of Genstat**	☐	☐	☐	☐	☐
44.	**Plot dose response result graphs**	☐	☐	☐	☐	☐
45.	**Interpret an F Prob value**	☐	☐	☐	☐	☐

46. **What effect has your dyslexia or dyscalculia had?** (If applicable)

47. **Which aspects of the module particularly *helped* your learning?**

48. **Which aspects of the module particularly *hindered* your learning?**

How would you rate these methods/tools for learning and doing statistics?

	Helpful/Good				Unhelpful/Poor
49. **Calculations by hand**	☐	☐	☐	☐	☐
50. **Using a calculator**	☐	☐	☐	☐	☐
51. **Using Excel**	☐	☐	☐	☐	☐
52. **Using Genstat**	☐	☐	☐	☐	☐

53. **Have you experienced an occasion when a topic suddenly became a lot clearer than before (e.g. like a light switching on)?**

Yes ☐ No ☐ Details:

54. **Have you had any support from other sources?**

Module Lecturer ☐ Other Lecturer ☐ Family ☐ Mathematics support ☐

2nd Yr students ☐ 4th Yr Students ☐ Books ☐ Web-sites ☐

Other ☐ None ☐

Details/Comments:

Have you used what you learnt in the first year IRM module for this module?

		Definitely Used				Not Used
55.	**From memory**	☐	☐	☐	☐	☐
56.	**From IRM notes**	☐	☐	☐	☐	☐

57. **How important do you consider learning statistics is?**

Definitely Important				Not Important
☐	☐	☐	☐	☐

58. **How do you consider that your confidence, attitudes or ability in mathematics have changed during this your second year?**

Can you describe in what ways and why?

59. **Can you suggest anything that would improve your confidence, attitudes or ability in mathematics?**

60. **Any other comments**

Thank you very much for completing this questionnaire.

You are welcome to contact me if you would like to discuss anything.

S J Parsons, Learning Support Tutor, sjparsons@harper-adams.ac.uk

Appendix III Mathematics Learning Questionnaire for APD Statistics 2006

This survey is intended to find out your (the students') experiences and attitudes to learning mathematics and statistics, i.e. to create a general 'student voice'. The results will be used to provide a general understanding of feelings and issues.

Survey participation is entirely voluntary. Answering any question is also voluntary. No individual students will be identified in the reporting of any results. Responses to this questionnaire will not have any effect on your module marks.

Please tick the appropriate boxes or write details in the space provided.
Please use the last page to continue if there is insufficient space for any answers.

1. **Award level** BSc ☐ HND ☐ FdSc ☐

2. **Course Name** ____

3. **Gender** Male ☐ Female ☐

4. **Age** ________

5. **Are you Dyslexic?** Yes ☐ No ☐ Don't know ☐

6. **Are you Dyscalculic?** Yes ☐ No ☐ Don't know ☐

7. **Student id no.** ____

8. **Mathematics GCSE:** Grade _____ Date ______ No. times taken _____
   Tier: Higher ☐ Intermediate ☐ Foundation ☐

9. **A level maths or other maths qualifications:** A2 ☐ AS ☐ Other ☐
   Details (grades, dates, modules, etc.):

---

10. **Given a choice would you have chosen to study the statistics in this module?** Yes ☐ No ☐

How confident would you describe yourself overall?

Please tick one box per question

	Very confident				Not confident
11. **in mathematics?**	☐	☐	☐	☐	☐
12. **in statistics?**	☐	☐	☐	☐	☐
13. **in life in general?**	☐	☐	☐	☐	☐

14. **For how long have you held this opinion of your self-confidence in mathematics?**

15. **How do you think that your experiences of mathematics *before* coming to university have affected your confidence or liking of the subject?**

(Please describe your experiences if possible)

16. **Has this module helped you to feel more confident than previously?**

More confident				Less confident
☐	☐	☐	☐	☐

Do you like the subject?

	Really Like				Detest
17. **Like Mathematics?**	☐	☐	☐	☐	☐
18. **Like Statistics?**	☐	☐	☐	☐	☐

19. **Has this module helped you to *like* the subject more?**

More				Less
☐	☐	☐	☐	☐

20. **How would you describe your *attitude* to learning statistics?**

21. **How would you rate your motivation in this area?**

Really motivated				Not motivated
☐	☐	☐	☐	☐

22. **Is this more or less motivation than for your other modules overall?**

More ☐ Less ☐ The same ☐

23. **How much time have you spent outside lectures working on the statistics in this module on average in hours per week?** (tick one box)

0 ☐ 1 hour ☐ 2 hours ☐ 3 hours ☐ 4+ hours ☐

How would you describe your ability to do *(or confidence in doing)* the following topics in the module? (Please tick one box per topic)

	Very able Can Do				Not Able Can't Do
24. **Percentages**	☐	☐	☐	☐	☐
25. **Using formulae**	☐	☐	☐	☐	☐
26. **Mean, Median, Mode**	☐	☐	☐	☐	☐
27. **Standard Deviation, Variance**	☐	☐	☐	☐	☐
28. **Correlation**	☐	☐	☐	☐	☐
29. **Linear Regression**	☐	☐	☐	☐	☐
30. **t – tests**	☐	☐	☐	☐	☐
31. **Use of Excel for calculations**	☐	☐	☐	☐	☐
32. **Use of Excel for data analysis**	☐	☐	☐	☐	☐
33. **Presenting data in Excel** (e.g. graphs)	☐	☐	☐	☐	☐
34. **Explaining results**	☐	☐	☐	☐	☐

35. **When you need to use or apply some of these topics in the future, to your research project, dissertation or at work, how would you expect your confidence in these topics to have changed?**

More confident		unchanged		Less confident
☐	☐	☐	☐	☐

Can you explain why?

36. **Which aspects of the module particularly *helped* your learning?**

37. **Which aspects of the module particularly *hindered* your learning?**

38. **What effect has your dyslexia or dyscalculia had?** (if applicable)

39. **Have you experienced an occasion when a topic suddenly became a lot clearer than before (e.g. like a light switching on)?**

Yes ☐ No ☐ Details:

Please rate whether you agree or disagree with the following statements

		Strongly agree		neutral		strongly disagree
40.	**I have less trouble learning maths than other subjects**	☐	☐	☐	☐	☐
41.	**When I meet a new mathematics problem I know I can handle it**	☐	☐	☐	☐	☐
42.	**I do not have a mathematical mind**	☐	☐	☐	☐	☐
43.	**It takes me longer to understand mathematics than the average person**	☐	☐	☐	☐	☐
44.	**I have never felt myself able to learn mathematics**	☐	☐	☐	☐	☐
45.	**I enjoy trying to solve new mathematics problems**	☐	☐	☐	☐	☐
46.	**I find mathematics frightening**	☐	☐	☐	☐	☐
47.	**I find many mathematics problems interesting and challenging**	☐	☐	☐	☐	☐
48.	**I don't understand how some people seem to enjoy mathematics problems**	☐	☐	☐	☐	☐
49.	**I have never been very excited about maths**	☐	☐	☐	☐	☐
50.	**I find maths confusing**	☐	☐	☐	☐	☐

51. **When did you last enjoy doing something in maths?** (please give details)

52. **Have you had any support from other sources?**

Lecturer	☐	Friends	☐	Family	☐	Mathematics support	☐
Books	☐	Web-sites	☐	Other	☐	None	☐

Details:

If you used mathematics support then please answer the questions below. Otherwise please continue from question 59.

53. **Was the Mathematics support for group or individual help?**

Group ☐ Individual ☐ Both ☐

How would you rate the Mathematics support ?

		Good				Poor
54.	**Helpfulness of support**	☐	☐	☐	☐	☐
55.	**Clear teaching**	☐	☐	☐	☐	☐
56.	**Relevance to your needs**	☐	☐	☐	☐	☐
57.	**Arrangements / Timing**	☐	☐	☐	☐	☐

58. **Other comments on the mathematics support (e.g. suggestions)**

59. **Can you suggest anything that would improve your confidence, attitudes or ability in mathematics?**

60. **Any other comments**

Thank you very much for completing this questionnaire.

You are welcome to contact me if you would like to discuss anything.

S J Parsons, Learning Support Tutor, sjparsons@harper-adams.ac.uk

Appendix IV Mathematics Learning Questionnaire for 1st Year BSc and FdSc/HND Engineering Students 2007

This survey is intended to find out your (the students') experiences and attitudes towards learning mathematics and statistics, i.e. to create a general 'student voice'. The results will be used to provide a general understanding of feelings and issues.

Survey participation is entirely voluntary. Answering any question is also voluntary. No individual students will be identified in the reporting of any results.
Responses to this questionnaire will not have any effect on your module marks.

Please tick the appropriate boxes or write details in the space provided.
Please use the last page to continue if there is insufficient space for any answers.

1. **Award level** BSc ☐ HND ☐ FdSc ☐

2. **Course Name** ____

3. **Gender** Male ☐ Female ☐

4. **Age** ________

5. **Are you Dyslexic?** Yes ☐ No ☐ Don't know ☐

6. **Are you Dyscalculic?** Yes ☐ No ☐ Don't know ☐

7. **Student id no.** ____

8. **Mathematics GCSE:** Grade _____ Date ______ No. times taken _____

   Tier: Higher ☐ Intermediate ☐ Foundation ☐

9. **A level maths or other maths qualifications:** A2 ☐ AS ☐ Other ☐

   Details (grades, dates, modules, etc.):

---

10. **Given a choice would you have chosen to study this mathematics module?**
    Yes ☐ No ☐

11. **How would you describe your *attitude* to learning mathematics?**

12. **Which aspects of the module particularly *helped* your learning?**

13. **Which aspects of the module particularly *hindered* your learning?**

14. **If applicable, what effect has your dyslexia or dyscalculia had on learning mathematics?**

How confident would you describe yourself overall?
Please tick one box per question

	Very confident				Not confident
15. **in mathematics?**	☐	☐	☐	☐	☐
16. **in statistics?**	☐	☐	☐	☐	☐
17. **in life in general?**	☐	☐	☐	☐	☐

18. **For how long have you held this opinion of your self-confidence in mathematics?**

19. **How do you think that your experiences of mathematics *before* coming to university have affected your confidence or liking of the subject?**

(Please describe your experiences if possible)

20. **Has this module helped you to feel more confident than previously?**

More confident				Less confident
☐	☐	☐	☐	☐

How would you describe your ability to do *(or confidence in doing)* the following topics in the module? (Please tick one box per topic)

		Very able Can Do				Not Able Can't Do
21.	**Using equations and formulae**	☐	☐	☐	☐	☐
22.	**Rearranging equations & formulae**	☐	☐	☐	☐	☐
23.	**Simultaneous equations**	☐	☐	☐	☐	☐
24.	**Trigonometry (Sin, Cos, Pythagoras)**	☐	☐	☐	☐	☐
25.	**Exponential functions and logs**	☐	☐	☐	☐	☐
26.	**Differentiation (basic)**	☐	☐	☐	☐	☐
27.	**Differentiation of products, quotients**	☐	☐	☐	☐	☐
28.	**Integration**	☐	☐	☐	☐	☐
29.	**Complex numbers**	☐	☐	☐	☐	☐
30.	**Matrices**	☐	☐	☐	☐	☐
31.	**Differential equations**	☐	☐	☐	☐	☐

`

32. **When you need to use or apply some of these topics in the future, to your research project, dissertation or at work, how would you expect your confidence in these topics to have changed?**

More confident		unchanged		Less confident
☐	☐	☐	☐	☐

Can you explain why?

Please rate whether you agree or disagree with the following statements

		Strongly agree		neutral		strongly disagree
33.	**I usually do well in mathematics**	☐	☐	☐	☐	☐
34.	**I do not have a mathematical mind**	☐	☐	☐	☐	☐
35.	**It takes me longer to understand mathematics than the average person**	☐	☐	☐	☐	☐
36.	**I have never felt myself able to learn mathematics**	☐	☐	☐	☐	☐
37.	**I enjoy trying to solve new mathematics problems**	☐	☐	☐	☐	☐
38.	**Mathematics is useful**	☐	☐	☐	☐	☐

Do you like the subject?

		Really Like				Detest
39.	**Like Mathematics?**	☐	☐	☐	☐	☐
40.	**Like Statistics?**	☐	☐	☐	☐	☐

41. **Has this module helped you to *like* the subject more?**

More ☐ ☐ ☐ ☐ ☐ Less

42. **How would you rate your *motivation* in this area?**

Really motivated ☐ ☐ ☐ ☐ ☐ Not motivated

43. **Is this more or less motivation than for your other modules overall?**

More ☐ Less ☐ The same ☐

44. **How much time have you spent outside lectures working on this module on average in hours per week?** (tick one box)

0 ☐ 1 hour ☐ 2 hours ☐ 3 hours ☐ 4+ hours ☐

45. **Have you had any support from other sources?**

Lecturer ☐ Friends ☐ Family ☐ Mathematics support ☐
Books ☐ Web-sites ☐ Other ☐ None ☐
Details:

If you used mathematics support then please answer the questions below. Otherwise please continue from question 52.

46. **Was the Mathematics support for group or individual help?**

Group ☐ Individual ☐ Both ☐

How would you rate the Mathematics support ?

		Good				Poor
47.	**Helpfulness of support**	☐	☐	☐	☐	☐
48.	**Clear teaching**	☐	☐	☐	☐	☐
49.	**Relevance to your needs**	☐	☐	☐	☐	☐
50.	**Arrangements / Timing**	☐	☐	☐	☐	☐

51. **Other comments on the mathematics support (e.g. suggestions)**

52. **Can you suggest anything that would improve your confidence, attitudes or ability in mathematics?**

53. **Any other comments**

Thank you very much for completing this questionnaire.

You are welcome to contact me if you would like to discuss anything.

S J Parsons, Learning Support Tutor, sjparsons@harper-adams.ac.uk

Appendix V Mathematics Learning Questionnaire for Research Methods Second Year Social Science Students 2007

This survey is intended to find out your (the students') experiences and attitudes towards learning mathematics and statistics, i.e. to create a general 'student voice'. The results will be used to provide a general understanding of feelings and issues.

Survey participation is entirely voluntary. Answering any question is also voluntary. No individual students will be identified in the reporting of any results. Responses to this questionnaire will not have any effect on your module marks.

Please tick the appropriate boxes or write details in the space provided.
Please use the last page to continue if there is insufficient space for any answers.

1. **Award level** BSc ☐

2. **Course Name** ______________________________________

3. **Gender** Male ☐ Female ☐

4. **Age** ________

5. **Are you Dyslexic?** Yes ☐ No ☐ Don't know ☐

6. **Are you Dyscalculic?** Yes ☐ No ☐ Don't know ☐

7. **Student id no.** ______________________________________

8. **Mathematics GCSE:** Grade _____ Date ______ No. times taken _____

   Tier: Higher ☐ Intermediate ☐ Foundation ☐

9. **A level maths or other maths qualifications:** A2 ☐ AS ☐ Other ☐

   Details (e.g. If A level maths taken please state which modules and grades):

---

10. **Given a choice would you have chosen to study the statistics in this module?** Yes ☐ No ☐

How confident would you describe yourself overall in the following?

Please tick one box per question

		Very confident				Not confident
11.	**in mathematics?**	☐	☐	☐	☐	☐
12.	**in statistics?**	☐	☐	☐	☐	☐
13.	**in life in general?**	☐	☐	☐	☐	☐

14. **How would you describe your *attitude* to learning statistics?**

How would you describe your ability to do *(or confidence in doing)* the following topics (Please tick one box per topic)

		Very able Confident				Not able Not confident
15.	**Percentages**	☐	☐	☐	☐	☐
16.	**Using formulae**	☐	☐	☐	☐	☐
17.	**Mean, Median, Mode**	☐	☐	☐	☐	☐
18.	**Standard Deviation, Variance**	☐	☐	☐	☐	☐
19.	**Deciding which type of test to use**	☐	☐	☐	☐	☐
20.	**Correlation and Regression**	☐	☐	☐	☐	☐
21.	**t – tests**	☐	☐	☐	☐	☐
22.	**Chi Squared tests**	☐	☐	☐	☐	☐
23.	**Multiple Regression**	☐	☐	☐	☐	☐
24.	**Use of SPSS**	☐	☐	☐	☐	☐
25.	**Presenting data in Excel** (e.g. graphs)	☐	☐	☐	☐	☐
26.	**Explaining results**	☐	☐	☐	☐	☐

27. **When you need to *apply* some of these topics in the future, to your research project or at work, how would you expect your confidence to have changed?**

More confident		unchanged		Less confident
☐	☐	☐	☐	☐

Can you explain why?

28. **Which aspects of the module particularly *helped* your learning?**

29. **Which aspects of the module particularly *hindered* your learning?**

30. **What effect has your dyslexia or dyscalculia had on studying the statistics and SPSS in this module ?** (If applicable)

How would you rate these methods/tools for learning and doing statistics?

	Helpful/Good				Unhelpful/Poor
31. **Calculations by hand**	☐	☐	☐	☐	☐
32. **Using a calculator**	☐	☐	☐	☐	☐
33. **Using Excel**	☐	☐	☐	☐	☐
34. **Using SPSS**	☐	☐	☐	☐	☐

35. **Have you experienced an occasion when a topic suddenly became a lot clearer than before (e.g. like a light switching on)?**

Yes ☐ No ☐ Please give details:

36. **Have you had any support from other sources?**

Lecturer	☐	Friends	☐	Family	☐	Mathematics support	☐
Books	☐	Web-sites	☐	Other	☐	None	☐

Please give details or comments:

Please rate whether you agree or disagree with the following statements

		Strongly agree		neutral		strongly disagree
37.	**I usually do well in mathematics**	☐	☐	☐	☐	☐
38.	**I do not have a mathematical mind**	☐	☐	☐	☐	☐
39.	**It takes me longer to understand mathematics than the average person**	☐	☐	☐	☐	☐
40.	**I have never felt myself able to learn mathematics**	☐	☐	☐	☐	☐
41.	**I enjoy trying to solve new mathematics problems**	☐	☐	☐	☐	☐

42. **Has this module helped you to feel more confident in statistics than previously?**

More confident				Less confident
☐	☐	☐	☐	☐

Do you like the subject?

		Really Like				Detest
43.	**Like Mathematics?**	☐	☐	☐	☐	☐
44.	**Like Statistics?**	☐	☐	☐	☐	☐

45. **Has this module helped you to *like* statistics more?**

More				Less
☐	☐	☐	☐	☐

46. **How would you rate your motivation in this area?**

Really motivated				Not motivated
☐	☐	☐	☐	☐

47. **Is this more or less motivation than for your other modules overall?**

More ☐ Less ☐ The same ☐

48. **How much time have you spent outside lectures working on this module on average in hours per week?** (tick one box)

0 ☐ 1 hour ☐ 2 hours ☐ 3 hours ☐ 4+ hours ☐

49. **How important do you consider learning statistics is?**

Definitely Important ☐ ☐ ☐ ☐ ☐ Not Important

50. **How do you consider that your confidence, attitudes or ability in mathematics have changed during this your second or third year?**

Can you describe in what ways and why?

51. **Can you suggest anything that would improve your confidence, attitudes or ability in mathematics?**

52. **Any other comments**

Thank you very much for completing this questionnaire.

You are welcome to contact me if you would like to discuss anything.

S J Parsons, Learning Support Tutor, sjparsons@harper-adams.ac.uk

Appendix VI APD Statistics Mathematics Learning Questionnaires 2006 - Guidelines for Lecturers

Thank you for administering the attached questionnaires in your APD lecture. Please would you read or paraphrase the introduction section (copied below) to the students.

Introduction from Student questionnaire
This survey is intended to find out your (the students') experiences and attitudes to learning mathematics and statistics, i.e. to create a general 'student voice'.
The results will be used to provide a general understanding of feelings and issues.

Survey participation is entirely voluntary.
Answering any question is also voluntary.
No individual students will be identified in the reporting of any results.
Responses to this questionnaire will not have any effect on your module marks.

Please also emphasise to students that

- we are grateful to them for filling the questionnaires in
- we value honest responses
- particularly to complete all tick box questions
- there are no consequences for their module marks
- only to read their own responses.

The student id no. is being requested so that the responses to this questionnaire can be linked to other data, not to students' names. I can honestly say that students have not been individually identified from questionnaire data obtained to date.

The time taken to complete the questionnaire is 10-15 minutes, depending on how much the students want to write.

Please can you collect the completed questionnaires in during the lecture and thank them for participating, and then return the questionnaires to me after completion.

(Don't announce this part to the students.) - Please don't feel that negative attitudes are necessarily a bad reflection on your teaching - last year's results showed that many students had underlying negative attitudes to the subjects of mathematics and statistics, often resulting from past experiences, but their responses about the module and the teaching were more often positive, and were especially positive about the use of computers.

Thank you again.

[Contact details]

Appendix VII   Final Year Student Semi-Structured Interview Questions 2009

<u>Introduction – before recording the interview</u>

Thank you for volunteering and giving up your time to be interviewed. You do get a £10 WH Smith's voucher in appreciation of you doing this.

Just to explain why we are doing this. There are two main purposes:
One being to understand better how students experience learning mathematics and statistics, and it is also counting towards research for a PhD which I am doing with the Maths Education Department at Loughborough University.

To give you a broad idea of what I am hoping we can talk about, here is an outline of the main areas for discussion: [show student a piece of paper with the following on]

- How confident you feel in doing maths or statistics
- Experience before Harper Adams (anything that stands out, rather than detailed history).
- Experience at Harper Adams
- Experience out on placement
- Experience doing Honours Project / dissertation / final year
- Expected use of mathematics / statistics in the future
- Other comments, e.g. suggestions

[Explain the recording equipment.]

[Explain that the content of the interview will be used anonymously, regarding both the student's identifying details and any references to other individuals e.g. staff. But make a note of the students' name, course and Student id no. for my records and disk no. used.]

If that's all OK I'll switch this on and we'll start.

Start of Interview Questions

Which course are you taking? (course name and award BSc, BEng, HND, FdSc etc.)

Are you in your final year?

When did you start at Harper?

[Check that the student is in their final year and that they started in 2004 for degree or 2005 for HND courses]

Confidence in general

Would you describe yourself as confident at learning and doing mathematics?

Could you please rate yourself for each of the following statements?

[Give student a piece of paper with the statements below]

Please rate whether you agree or disagree with the following statements

	Strongly agree		neutral		strongly disagree
I usually do well in mathematics	☐	☐	☐	☐	☐
I usually do well in statistics	☐	☐	☐	☐	☐
I do not have a mathematical mind	☐	☐	☐	☐	☐
It takes me longer to understand mathematics than the average person	☐	☐	☐	☐	☐
I have never felt myself able to learn mathematics	☐	☐	☐	☐	☐
I enjoy trying to solve new mathematics problems	☐	☐	☐	☐	☐
Mathematics is useful	☐	☐	☐	☐	☐
Statistics is useful	☐	☐	☐	☐	☐

[Discuss their responses as appropriate]

[Explore any differences between responses to mathematics and statistics]

Experiences before Harper Adams

Is there anything that stands out, or that you would like to talk about, from your experiences at school or college before you came to Harper Adams?

Mathematics & Statistics Learning at Harper Adams

Now it would be useful if we could talk about what maths and stats you have learnt or needed here and how you got on with it.

Which mathematics or statistics modules did you study here?

[I will probably know anyway from their course, but check and also with which lecturer/group]

For each module:

How did you get on with (module name)?

Were there aspects of the module which you found helpful? Or not helpful?

Do you remember how your confidence in your ability was affected? What caused that?

What are the characteristics of a classroom environment which help to build confidence?

What are the characteristics which reduce it?

(ditto for characteristics of teaching staff)

Can you see the purpose of what you were taught?

Do you think anything could have been improved?

[I am considering having a list of features on paper for students to rate importance (1-5?) e.g. handouts, speed of teaching, work to do, OHPs/PowerPoint/ Use of whiteboard, group size etc.]

Dyslexia/Other Special Needs

I am also interested to understand how students with dyslexia or dyscalculia have experienced these modules.

Has that affected you? [If yes continue with questions below, otherwise skip to Placement]

How do you think it affected you?

Did you get help from the learner support team?

[Explore further according to responses given – particularly follow up any mention of longer time to do work and ask for examples/evidence.]

Use of Mathematics Support

[Let students make comments and follow up carefully – take care not to fish for comments]

Did you use the maths support (or Extra Maths)?

Tell me a bit about when you used it (which stage of your studies) and why?

Do you think provision like this is better focussed on helping first year students build a strong foundation, or would resource be better used elsewhere? Where? Why?

Placement Experiences

You spent a year out on placement last year, perhaps we could talk a bit about that now.
Where did you spend your placement?
How did it go overall?
Did you need to use any maths or statistics? Were you able to do it alright?
Did what you learnt here or at school prepare you for that?
[Follow up any comments / other areas of interest.]

Dissertation / Honours Project / Work based project

You are just completing your final year,
Have you needed to use Mathematics or statistics during this year?
How did it go?

Future Use of Mathematics / Statistics

After you leave Harper do you expect to use maths or stats?
How do you expect you will get on?
[Any other brief discussion as seems useful.]

If you think back over your years here, what was the highlight of your learning experiences?

End

Explain that it is the end. Switch off the recording.
Thank the student for their time & give voucher.
Explain that the transcript of their interview will be typed up in due course, which will probably be after they have left. Ask whether they would like to be sent a copy? If yes, ask them to provide contact details, make a note if contact details given on the spot (e.g. home e-mail address).
Wish them well for exams / future!

Appendix VIII Analysis of Student Marks and Overall Confidence in Mathematics by Questionnaire Year

Appendix VIIIa – Student Marks by Questionnaire Year – ANOVA Tests by Student Group

Student Mark Type	P-Value	CV%	df	Mean 2005	Mean 2006	Mean 2007
1st Year Engineering	0.259	31.2	104	65.0	65.1	72.4
2nd Year Engineering	0.443	31.0	40	59.1	69.9	61.9
1st Year APD	0.811	30.6	185	51.4	50.8	-
RMNat	<0.001	26.1	189	71.3	60.9	57.7
RMSS - Total	0.344	22.1	116	59.3	56.0	59.8
RMSS- Stats Q	0.859	28.8	87	-	68.4	69.2
RMSS - Stats Q^2	0.548	48.2	87	-	5276	4960

Appendix VIIIb – Overall *Confidence in Mathematics* by Questionnaire Year – Kruskal Wallis Tests by Student Group

Student Type	P-Value	H Value	df	Student no.	Mean 2005	Mean 2006	Mean 2007
1st Year Engineering	0.167	3.138	2	111	3.3	3.6	3.4
2nd Year Engineering	0.098	4.042	2	45	3.8	4.1	3.5
1st Year APD	0.979	0.001	1	201	3.1	3.0	-
RMNat	0.728	0.569	2	205	3.3	3.3	3.1
RMSS	0.157	3.383	2	131	3.2	2.7	3.2