The repercussions in higher education of the changes in the teaching and learning of mechanics in schools in England

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Additional Information:

- A Doctoral Thesis submitted in partial fulfilment of the requirements for the award of Doctor of Philosophy of Loughborough University.

Metadata Record: https://dspace.lboro.ac.uk/2134/15874

Publisher: © Stephen Lee

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The Repercussions in Higher Education of the Changes in the Teaching and Learning of Mechanics in Schools in England

By

Stephen Lee

A Doctoral Thesis

Submitted in partial fulfilment of the requirements for the award of Doctor of Philosophy of Loughborough University

September 2006

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Abstract

This thesis considered the repercussions in higher education of the changes in the teaching and learning of mechanics in schools/colleges in England. Within the last decade there has been an abundance of reports detailing concerns about the insufficient mathematical ability of students entering numerate degree programmes. In 2003, at an Engineering Professors Council meeting, Prof. Mike Savage indicated concern not only about students' knowledge of mathematics upon arrival, but also of mechanics. Thus, this thesis considered if there was now also a mechanics problem.

In this thesis, following a review of pre-university mathematics qualifications, three primary areas were considered: the schools' perspective; students' knowledge of mechanics upon arrival at university; and engineering academics' perspective. In addition, linear multiple regression models were created to predict students' first year performance.

In both 2004 and 2006 questionnaires were sent to 497 schools to determine the availability and uptake of specific modules in Mathematics A-levels. Changes detected in these undoubtedly have repercussions for higher education educators lecturing first year students.

Questionnaires, interviews and a mechanics diagnostic test were given to engineering students to establish the level to which they had studied mechanics prior to entry to university and to determine what knowledge of mechanics they had. Nearly a third of (1087) questionnaire replies gave indication that little or no mechanics had been studied, which has repercussions for those teaching a first year university module in mechanics.

Questionnaires and interviews were also used to gain engineering academics' perspective and one of the major issues was found to be a misalignment between expectation and reality. Finally, linear multiple regression models, created to predict students' first year performance, highlighted variables such as a student's mathematics diagnostic test result and whether they made use of the mathematics learning support centre as being important.
Acknowledgments

I am immensely grateful to my supervisors, Dr. Martin Harrison and Dr. Carol Robinson, for their support and guidance. They have provided insightful comments and constructive criticisms throughout my studies, which have been of tremendous benefit to me. My own personal development over the past three years also owes a lot to both Martin and Carol.

I would also like to thank all the staff in the Mathematics Education Centre and Department of Mathematical Sciences at Loughborough University who have assisted me throughout my time there, including my undergraduate years. Special thanks to Dr. Tony Croft and Dr. David Green who raised the funding that has enabled me to undertake this PhD.

Many thanks to all those who have participated in the studies that I have conducted, including both students and academics, as well as those who enabled me to conduct such studies. Without access to participants and the willingness of them to take part in such studies, it would have been virtually impossible to establish results such as those found.

Finally, my thanks go to those that have been close to me and endured me in recent years and especially to my family who have always given their love, support and encouragement for the past 25 years and undoubtedly forevermore.
Related Publications

The following papers were written prior to the submission of this thesis and report some of the work herein and other related activities.

Conference Contributions – Refereed:


Conference Contributions – Other:


**Edited Works: Contributions:**


**Journal Papers - Academic Journals:**


**Journal Papers - Professional Journals (non-refereed):**


**Journal Papers - Popular Journals (non-refereed):**


**Official Report:**

GLOSSARY:

ACME – Advisory Committee on Mathematical Education
ANOVA – Analysis of Variance
AQA – Assessment and Qualifications Alliance
CCEA – Northern Ireland Council for the Curriculum
CMS – Council for the Mathematical Sciences
DfES – Department for Education and Skills
ETB – Engineering and Technology Board
EU – European Union
GCE – General Certificate of Education
GCSE – General Certificate of Secondary Education
GNVQ – General National Vocational Qualification
HEA – Higher Education Academy
HEFCE – Higher Education Funding Council for England
ICE – Institute of Chemical Engineering
IChemE – Institution of Chemical Engineers
IEE – Institution of Electrical Engineers
IMechE – Institution of Mechanical Engineers
IMA – Institute of Mathematics and its Applications
JCQ – Joint Council for Qualifications
JMC – Joint Mathematical Council for the United Kingdom
LEA – Local Education Authority
LMS – London Mathematical Society
LTSN – Learning and Teaching Support Network
MEI – Mathematics in Education and Industry
MLSC – Mathematics Learning Support Centre (at Loughborough University)
NCETM – National Centre for Excellence in Teaching Mathematics
OCR – Oxford, Cambridge and the Royal Society of Arts Examinations
OFSTED – Office for Standards in Education
OMR – Optical Mark Reader
PGCE – Post Graduate Certificate in Education
QCA – Qualifications and Curriculum Authority
STEM – Science, Technology, Engineering and Mathematics
TLTP – Teaching and Learning Technology Programme
UCAS – Universites and Colleges Admissions Service
WJEC – Welsh Joint Education Committee
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1. Introduction

1.1. Background

Within the UK, concern has been expressed about the insufficient mathematical ability of students entering numerate undergraduate degrees. This has been labelled the 'mathematics problem'.

As reported by Professor D. Lawson (Coventry University) at his inaugural professional lecture 'A sideways look at the mathematics problem' in June 2006, there may have always been a mathematics problem, but not until the 1990s has such a problem been highly publicised in substantial reports. Indeed, there have been many such reports in the last decade, including:

- Tackling the mathematics problem, LMS (1995)
- The changing mathematical background of undergraduate engineers, Sutherland and Pozzi (1995)
- Engineering mathematics matters, IMA (1999)
- Mathematics in the university education of engineers, Kent and Noss (2003)

These reports detail many concerns surrounding the mathematics problem, including: "A long-standing worry about the numbers of prospective students in disciplines such as mathematics, science and engineering", LMS (1995:3) and "Evidence of a serious decline in students mastery of basic mathematics skills and level of preparation for mathematics-based degree courses", Hawkes and Savage (2000: 11). The other four reports demonstrated that the mathematics problem heavily impacts upon engineering degrees, primarily because of the considerable amount of mathematics contained within many of them.
There have also been a plethora of other reports from governing bodies and learned societies, which have reviewed various aspects of mathematics education post-14. These include:

- Teaching and learning algebra pre-19, Royal Society and JMC (1997)
- Mathematics education framework for progression from 16-19 to higher education, Sutherland and Dewhurst (1999)
- SET for success: the supply of people with science, technology and mathematics skills, Roberts (2002)
- Assessment in 14-19 mathematics, ACME (2005)

Many of these follow in response to the aforementioned reports and detail national strategies in mathematics, e.g. Smith (2004), national findings on the uptake of mathematics, e.g. QCA (2006) or recommendations to the government on the mathematical education of young people, e.g. Roberts (2002), ACME (2005). All reports, at least in part, detail how mathematical skills are key in much post-compulsory education (16+), as well as for future employment in many disciplines.

In addition, there have been several other government commissioned reports, which impinge upon university science, engineering and technology departments, including:

- 14-19 education and skills – implementation plan, DfES (2005)
The supply and demand for science, technology, engineering and mathematics skills in the UK economy, DfES (2006)

The first four of these focus upon the review and implementation of changes to pre-university qualifications; the final two detail analysis of recent trends in and the requirement to build up skills in science, technology, engineering and mathematics (STEM).

From the list of reports given in this section, it is evident that nationally much attention has been given to developments and issues with mathematics post-14. This obviously has implications for those teaching in higher education and especially at the further/ higher education interface. Detail of the changes in pre-university mathematics courses and discussion thereof will follow in Chapter 2. However, in the next subsection a more detailed review of the mathematics problem, along with evidence of an emerging issue with students' knowledge of mechanics will be given.

1.1.1. Further Detail of the Mathematics Problem

Over a decade ago in 1995 a Working Group on behalf of the London Mathematical Society, the Institute of Mathematics and Its Applications and the Royal Statistical Society produced 'Tackling the mathematics problem'. This was in order to 'identify the problems more clearly, and to suggest steps that might be taken to improve matters', LMS (1995: 4). Many further publications followed 'Tackling the mathematics problem' and it is now generally acknowledged that there is a mathematics problem. In the 2000 report 'Measuring the mathematics problem' Hawkes and Savage (2000) highlighted that:

There is strong evidence from diagnostic tests of a steady decline over the past decade of fluency in basic mathematical skills and of the level of mathematical preparation of students accepted onto degree courses.

Discussion into and research on the mathematical ability of students entering onto numerate undergraduate degrees has been widespread, see for example, Edwards (1997), Barry and Sutherland (1998) and Armstrong and Croft (1999). In each of the
papers findings from diagnostic tests were discussed and diagnostic tests were found to be useful tools in order to identify students' mathematical ability. In the papers by Edwards and Armstrong and Croft discussion into support mechanisms, e.g. support centres and support material, was also made.

More recently, Croft and Grove (2006) discussed what initiatives and resources have been developed in recent years. One example was the mathcentre project whose resource website in the last academic year averaged a quarter of a million hits a month. However, they also outlined a worrying trend that students' mathematical inadequacies are continuing beyond the transition to university:

We have drawn attention to the fact that the 'mathematics problem', well documented since the 1990s now has manifested beyond the transition to university. We have explained that the community has responded to transitional problems in many ways, but suggest that much more could be done to address issues emerging in later years.

In recent years (particularly in the past decade) there have been a number of changes made to the structure and content of A-levels in general and more specifically to A-level Mathematics. This has not aided the situation with respect to increasing the mathematical ability of students entering university, moreover the curriculum changes appear to have made the problem even more prominent, see James (2002), Mustoe (2004) and Nicholson and Belsom (2002), with James (2002: 145) concluding:

The continuing decline in the percentage of A-level candidates taking mathematics is an issue of widespread concern. The implications for undergraduate degree courses in engineering, as well as those in mathematics and other numerate disciplines, are indeed serious.

More recently, particular concern has been shown about one area of mathematics, namely mechanics. This topic plays a fundamental part in most undergraduate engineering degrees, with a compulsory module commonplace in the first year programme. An expectation of a minimal level of expertise in mechanics, primarily gained from studying it in A-level Mathematics courses, has generally been expected of students by university academics in England. Nevertheless, it was widely suspected
that the lack of mathematical knowledge, which students are entering university with, extends to a lack of knowledge in mechanics.

Indeed, this research project was motivated in part following a noticeable increase found in the number of students seeking help with their first year mechanics work in 2002. This support was sought in the Mathematics Learning Support Centre (MLSC) (a centre providing one-to-one help in mathematics) at Loughborough University. Discussions with such students led to it being established that some students had not studied mechanics in A-level Mathematics courses. In fact, some students reported that they had not had the opportunity to study mechanics modules; others commented that they had been advised not to study mechanics but to study, for example statistics, in order to gain a better mark. This painted a concerning picture and pointed towards a possible reason, changes in A-level Mathematics and the availability of modules to be studied therein, as to why such students were not entering university with the knowledge of mechanics that academics had traditionally expected of them. Indeed, the case for the continuing relevance of mechanics in A-level Mathematics had been outlined by Kitchen et al (1997). Subsequently, Kent and Noss (2003: 25) reported that 'It is quite common for students not to study any mechanics modules'. Furthermore, in 2003, at an Engineering Professors Council meeting, Professor Savage indicated concern not only about students' knowledge of mathematics upon arrival, but also of mechanics.

Hence, it was this evidence that culminated in this research being carried out, its primary aim being to determine the repercussions in higher education of the changes in the teaching and learning of mechanics in schools in England.

1.2. Outline of Thesis

Following the introduction, in Chapter 2, a comprehensive review of the changes in pre-university mathematics courses and specifically A-level Mathematics is undertaken. This focuses primarily on developments in the last 20 years and includes consideration of the uptake of A-level Mathematics along with issues that have affected it. A detailed review of the most recent changes to A-level Mathematics, in
2000 and 2004, then follows. Finally, the relevance of mechanics in the schools curriculum is discussed.

Following the discussion of the changes in pre-university mathematics courses in Chapter 2, an overview of general research methods used in this thesis will be given in Chapter 3. This will involve a summary of both questionnaires and interviews. In addition, ethical issues will also be reviewed.

This is used to inform the later implementation of such methods in the research. Although a general overview of the research methods used is given in Chapter 3, in the subsequent chapters details of the application of the specific research methods involved in each given chapter are then reviewed, i.e. the specific construction and administration of a questionnaire used in a chapter is detailed in that chapter.

After the introductory chapters (1, 2 and 3), there follows discussion and analysis of the research conducted for this thesis. For this thesis several areas were considered, which broadly fell into four categories: (where each perspective is with respect to the mechanics problem):

- Schools' perspective (Chapter 4)
- Students' knowledge of mechanics upon arrival at university (Chapters 5/6)
- Engineering academics' perspective (Chapter 7)
- Predicting students' first year university performance (Chapter 8)

Firstly, the schools' perspective with respect to the mechanics problem was reviewed (Chapter 4). The primary focus was to gain an understanding of the availability and uptake of mechanics in schools in England, in order that the repercussions in higher education could be ascertained. (It should be noted that when the term 'schools' is used in this context, it is referring to all school and colleges and other establishments where students study for 16-19 qualifications such as A-levels.) To that end a large scale survey of 497 schools (of the 2717 that offered A-levels) in England was conducted in January 2004. The construction and administration of this questionnaire is detailed along with analysis of the 243 replies. This not only involved obtaining
quantitative data on the availability and uptake of mechanics but also probed teachers as to the reasons why mechanics was not offered.

As will be seen in Chapter 2 (section 2.5) there was a change in the structure of A-level Mathematics courses in September 2004. Consequently, the questionnaire to schools administered in January 2004 was re-administrated in January 2006, to the same schools, specifically to review if this change in structure had had any effect on the availability and uptake of mechanics in schools in England. In Chapter 4, comparative analysis of the 225 replies, from the 2006 questionnaire, to the 243 replies, from the 2004 questionnaire, is detailed and the findings discussed.

A major area of interest was in actually establishing what knowledge of mechanics incoming university students had. This will be described in Chapters 5 and 6. Firstly, Chapter 5 builds upon the work done in Chapter 4 with consideration being given to how many mechanics modules, in A-level Mathematics courses, students had studied before embarking on their university (engineering, mathematics or physics) programme. Such data was collected via administering a questionnaire to several groups of students, which culminated in replies from 1087 engineering students from three universities. This also allowed for comments to be made as to whether the uptake of mechanics in schools matched the uptake of mechanics of those on relevant university programmes.

Continuing in Chapter 5, feedback and opinions on the prior mechanics knowledge, which is helpful for studying engineering at Loughborough University, were gathered from students. This entailed administering another questionnaire to a specific group of students and conducting follow-up interviews with a subset of the group. Analysis of this second questionnaire and follow-up interviews are detailed in Chapter 5. This allowed students' actual perspectives to be obtained rather than just gaining quantitative information on the number of modules of mechanics in A-level Mathematics they had studied. Having only information on how many mechanics modules students had studied did not necessarily translate into having an understanding of what their actual knowledge of mechanics was. Therefore, further research was conducted to establish what knowledge of mechanics students had, and
in Chapter 6 a mechanics diagnostic test created and administrated to engineering students is detailed.

At the start of Chapter 6, the structure and administration of the mechanics diagnostic test is outlined. Following this, analysis of the mechanics diagnostic test is conducted and reported upon. Initial analysis considers results from 450 students in four engineering departments. Thereafter one specific area of interest is considered. This concerns reviewing whether there was a relationship between the number of mechanics modules studied in A-level Mathematics and the mechanics diagnostic test result. This would give insight as to whether a student's prior knowledge of mechanics (as described by their mechanics diagnostic test result) relates to the number of mechanics modules they studied in A-level Mathematics. Several statistical measures, including correlation coefficients, line of best fit, analysis of variance (ANOVA), box-whisker plots and plots of confidence intervals were used to establish this. In addition, results of students who had not studied A-levels are also reviewed.

An analysis was conducted to establish which questions and topics in the mechanics diagnostic test were answered well and which not so well. This gives insight into which topics are more difficult and thus which topics students may have difficulty with when entering an engineering degree programme. Furthermore, as this was the first implementation of the mechanics diagnostic test, which was created by the author, item analysis was conducted on the test itself. This involved reviewing the difficulty of the questions to see whether the questions discriminated between good students and less well prepared students. In addition, comparative analysis between the mechanics diagnostic test and the mathematics diagnostic test was undertaken in order to identify if there was a link between performances in the two tests. For completeness item analysis was also conducted on the mathematics diagnostic test. Finally, the research into students' prior knowledge of mechanics, reported upon in Chapter 6, is summarised and discussed.

Chapter 7 details a different perspective to the schools' perspective reported upon in Chapter 4 and the responses gathered from students (Chapter 5); this is the engineering academics' perspective. A primary focus was to establish if academics are
aware of recent changes in pre-university qualifications and the implications thereof, for example that there could be a change in incoming students' prior knowledge. Furthermore, the focus was also on gathering information on what knowledge of mechanics academics assumed their incoming students had, along with gaining information on the current teaching practices in mechanics modules. To review this an online questionnaire was constructed and a number of follow-up interviews with academics were undertaken. Firstly, the responses to the questionnaires are examined. Analysis is carried out on the different sections of the questionnaire, which included: gaining an understanding of students' prior knowledge; the teaching of mechanics; mechanics materials and the monitoring of A-levels. The replies to the questionnaire give a good insight into the opinions of academics but follow-up interviews allow for a more in-depth discussion of the topics of interest. Finally, replies from both the questionnaire and follow-up interviews are summarised and allow for a discussion of the academics' perspective to be given.

Chapter 8 builds upon much of the work conducted in previous chapters. Following on from the change in pre-university qualifications discussed in Chapter 2 and the uptake of mechanics modules in A-level Mathematics detailed in Chapters 4 and 5, it would be extremely valuable to be able to predict how university students' may perform, so that those who could be in danger of failing could be offered suitable guidance and support. Simple linear regression models are initially created for 133 mechanical engineering students. These consider one variable, a student's mechanics diagnostic test mark, and try to use such a variable to predict both a student's overall first year performance and their performance in their first year university mechanics module. Subsequently, multiple linear regression models are created which consider 14 variables rather than just a single variable; this was to establish if a better model(s) could be produced. Such data is collected using a variety of methods, including questionnaires and diagnostic tests that will be detailed in Chapters 5 and 6. Discussion of the significant factors in the models will be given and comparisons are made to further models created for a group of 136 aeronautical and automotive engineering students.
Finally, Chapter 9 will draw together the research described in this thesis and address the issue of what repercussions, if any, there are in higher education following on from the changes in the teaching and learning of mechanics in schools in England. Discussion of the implications of the research along with suggestions for possible future work in the area will also be given.
2. Developments in Pre-University Mathematics Courses

2.1. Introduction

The rationale for this thesis was detailed in Chapter 1. A key issue of concern was that of incoming university students' abilities in mechanics. Consequently, it would be valuable to review developments in pre-university qualifications and this chapter will discuss this.

Firstly a brief synopsis of pre-university qualifications will be given. An overview of developments in pre-university mathematics courses and specifically A-levels then follows. A review of the uptake of A-level Mathematics in the last few decades is undertaken, including discussion of various issues that have affected the numbers studying the subject. A more detailed review of the two most recent changes in A-level Mathematics in 2000 and 2004 is then given. Finally, the place that mechanics has played in A-levels and its relevance to universities is outlined before a summary of the chapter is given.

2.2. Synopsis of Pre-University Qualifications

Within this section an overview of the types of course available prior to entry to university will be given. In addition, the relevant regulatory authorities and examining bodies will be outlined.

2.2.1. Types of Courses

In the English educational system there are several courses available to be studied prior to entry onto an undergraduate degree programme. These are generally encapsulated in the title of 'further education' and mostly concern the age band '16 to 19 years old', although there are students who do not fall into this age band and are classed as 'mature' students. Further education courses constitute the next step on from the compulsory schooling that everyone is required to study up to the age of 16,
where the assessment in nearly all schools is the General Certificate of Secondary Education (G.C.S.E.).

There are several types of course available to be studied in further education. These can be broken into two distinct categories 'general qualifications' and 'vocationally related qualifications'. Further information can be found on the 'key features of the main qualification groups' at web reference [1]. The majority of students follow the general qualifications route although in recent years more and more people are following the vocational route.

Vocational qualifications enable students to develop skills, knowledge and understanding in the vocational area that they are studying in. There are a number of these qualifications including General National Vocational Qualifications (GNVQs), and Vocational A-levels, although it should be noted that GNVQs are currently being withdrawn (by 2007).

Within the general qualifications structure are the qualifications of 'The Advanced General Certificate of Education' (known as GCE A-levels) and up to September 2000 'The General Certificate of Education Advanced Supplementary' (known as GCE AS-levels). After September 2000, as will be described in section 2.4, though still known as GCE AS-levels, such qualifications became entitled 'The General Certificate of Education Advanced Subsidiary'.

In 2000, Sutherland (2000: 82) spoke on the limitations of advanced GNVQs as preparation for engineering and science degree programmes:

> Over the last few years advanced vocational qualifications have been recognized as an alternative option for post-16 students. Unfortunately for students who want to progress to study engineering and science degrees, the Advanced GNVQ qualifications do not adequately prepare them for the mathematical aspects of science and engineering courses. One of the reasons for this is that many students are accepted on Advanced GNVQ courses with a very weak background in mathematics.
This aligns itself to the preconception that vocational qualifications have generally been seen as a precursor to employment, whereas A-levels have been seen as a precursor to higher education. Conversely, Dolton & Vignoles (2000: 55) showed concern with A-levels for those not going on to study in higher education:

A-Levels were initially developed as university entrance requirements. Thus, their narrow focus is partly the result of the specific purpose for which they were originally designed, i.e. to determine whether or not a student was competent to continue on to higher education. It has long been recognised that they may consequently not provide a suitable curriculum for students who do not go on to higher education.

However, in his inquiry into A-level standards in 2002, Tomlinson (2002: 7) talked about the place of A-levels as part of a more complete qualification, suitable for both entry to university and employment:

Ever since their introduction, A-levels have been associated with entry to higher education. This remains a valid and useful application. But over time they have also acquired a broader significance as a precursor to employment and as one strand in a qualifications framework which is designed to recognise the full range of advanced achievement of which young people are capable, ranging from the purely academic and theoretical learning through to the skills and knowledge associated with specific jobs.

This indicates that A-levels take on the role of not only preparing students for higher education, but also for entry to employment. This idea of preparing students for entry to university or for entry to a job was highlighted as one of the three key issues of major concern by Smith (2004) in 'Making mathematics count', specifically:

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.
Since such concerns were shown, a comprehensive review of the framework for qualifications of 14-19 year olds has been announced. There are specific reviews being undertaken into pathways of Mathematics 14-19 by two teams, one from the University of Leeds and one from King's College London/Edexcel, see web reference [2]. Incidentally, a further paper exploring an alternate pathways model has already been completed by Mathematics in Education and Industry, MEI (2005). The outcomes from the other two studies will be detailed in Summer 2006, when they will be 'making recommendations on the detailed mathematics curriculum and assessment framework'.

2.2.2. Regulating Authorities, Awarding Bodies and Related Organisations

The 1997 Education Act, web reference [3], set up a regulatory authority (QCA – the Qualifications and Curriculum Authority) in England to ensure the continuing availability of high quality qualifications that are fit for purpose, command public confidence and are understood by all concerned. The QCA maintains and develops the national curriculum and associated assessments, tests and examinations; and accredits and monitors qualifications in colleges and at work.

Within England there are three unitary awarding (examination) bodies. They are Assessment and Qualifications Alliance (AQA), Edexcel and Oxford, Cambridge and RSA Examinations (OCR). These were formed in 1997, 1996 and 1999 respectively from the merging of examining and awarding bodies, of which, prior to 1999 there were many. There are two other bodies, one for Wales, the Welsh Joint Education Committee (WJEC) and one for Northern Ireland, the Northern Ireland Council for the Curriculum (CCEA).

Each of the English bodies offers a number of different qualifications for various age groups, from 4-19 years. Each offers A-level qualifications including Mathematics A-levels. There is a further, independent curriculum development body, Mathematics in Education and Industry (MEI) whose specification is administered through OCR.

The Joint Council for Qualifications (JCQ) act as 'a single voice for the awarding bodies' and represent the full range of UK qualifications. They:
• Help awarding bodies to create common standards, regulations and guidance, but don't write them

• Help awarding bodies regulate themselves, but cannot ask individual awarding bodies to review their decisions

• Ensure exams are sat under consistent regulations, but do not get involved with individual candidates or papers

• Look at inconsistencies or policy issues, but they are not a regulator or arbitrator and do not hear appeals.

There is also the government education department, the Department for Education and Skills (DfES) who were established 'with the purpose of creating opportunity, releasing potential and achieving excellence for all', web reference [4]. In addition, the Office for Standards in Education, OFSTED, is a non-ministerial government department accountable to parliament who 'contribute to the provision of better education and care through effective inspection and regulation', web reference [5].

Finally, there are a number of other 'related organisations' who vest a specific interest in mathematics, including mathematics in schools and colleges. These include the Advisory Committee on Mathematics Education, ACME, web reference [6] and the Council for the Mathematical Sciences, CMS, web reference [7].

Following this overview of the various qualifications available to be studied prior to entry to university and the introduction to the regulatory authorities and examining bodies, in the next section developments specifically in pre-university mathematics courses will be outlined.

2.3. Insight into Developments in Pre-University Mathematics Courses

In the past 50 years, since the introduction of A-levels there have been many changes, with several of these occurring in the last 20 years. In this section the focus will be on
the changes that have occurred in qualifications perhaps most relevant for entry to higher education, A-levels and specifically A-level Mathematics courses

2.3.1. Pre-1996

A historical overview from the last century, including reference to the Education Act of 1944 can be seen in Howson (1996) and Gordon (2005), with Gordon (2005: 12) making the following comments on the 1960s and 1970s:

The 1960s are seen as a time where universities controlled A-level Mathematics, and designed A-levels mainly to meet their needs as an entrance measure. The 1970s saw change, with the widespread introduction of statistics, leading to more choice in mathematics courses.

Following the changes in the 1970s, a four-year inquiry into the 'Teaching of mathematics in schools' began in 1978 and culminated in 'Mathematics counts' being published by Cockcroft (1982), often referred to as the Cockcroft Report. This report detailed many different aspects in the teaching of mathematics and contained a chapter on mathematics in the sixth form. There Cockcroft (1982: 170) highlighted that:

It is therefore essential that an A-level course in mathematics should not only provide a basis for further study but also provide a course which is balanced and coherent in its own right and which reaches suitable 'stopping points' for those who will, at least for the time being go no further.

It is interesting to note that some 20 years later the Smith Report, Smith (2004), as described earlier, highlighted the very same idea as still being a key issue of major concern. The changes that have occurred between these two comments will now be considered.

Following the Cockcroft Report a 'core' for mathematics was first agreed in 1983. As described by Easingwood (1997), the benefits attributed to subject cores included:
Providing a degree of commonality between A-level syllabuses

Helping to ensure comparable standards between the various examining boards

Enabling higher education and employers to have an idea of the scope and content of Advanced level studies

It is obvious that each of these points are positive in nature and were constructive to higher education establishments not only in allowing them to have an understanding of what had been studied, but also that different examining boards and syllabuses were comparable.

In 1989 the Advanced Supplementary (AS) level was introduced. Its material was designed to be of equal standard to that of the full A-level, but which would require only half of the study time. Subsequently, in 1993 the mathematics core was rewritten to accommodate AS-level, with such syllabuses being first examined in 1996. Discussion of the changes to the 1993 'subject core' from the previous 1983 'common core' can be seen in Porkess (1996) and Hirst (1996).

In 1990 MEI introduced the first A-level Mathematics modular course. When presenting at the Fifth IMA conference on 'Mathematical education of engineers' in April 2006, Roger Porkess, Chief Executive of MEI, highlighted issues with mechanics as one of the reasons why modular courses were introduced. Subsequently, Porkess (Private communication) commented that:

A figure that motivated me very considerably came from the scripts that I marked in 1986. This was the MEI A-Level paper two (applied mathematics), pre-modular of course in those days. There were a few short compulsory questions and then they had to choose some long questions with a free choice between those on mechanics and those on statistics. I marked just over 500 scripts and recorded the long questions answered by the candidates. They divided 93% statistics and 7% mechanics. That was what convinced me that mechanics would not survive in a non-modular syllabus. When, a few years later, we had modular exams, the division between Statistics 1 and Mechanics 1 candidates was about 4:3
This hinted towards issues with respect to the study of mechanics some 20 years ago. Also in 1996/1997, a number of researchers conducted studies into A-level scripts from the era. Bell (1997) considered A-level Mathematics scripts from one examination board and compared those in 1986 with those in 1995. He found that there had been an increase in the percentages of candidates obtaining high grades for the linear A-level Mathematics syllabuses. Conversely Tavemer (1996) compared examination boards in A-level Mathematics and how students performed. She concluded that:

The apparent difference in the final grade awarded to candidates may well be explained by the opportunity to re-sit modules if the candidate feels she or he has under achieved...However, teachers should be reassured that the boards appear to be comparable in their grading of papers in both Mathematics and Further Mathematics A-level.

The fact that the grading of papers between boards appeared to be comparable was very positive, as at the time there were still a large number of boards. In addition, there were also a large number of syllabuses and so some were favoured over others. Anderson (1999: 14) commented that:

The 1980s and 1990s have been characterized by a number of significant changes, in the style and content of school mathematics, at both GCSE and A-level. There has been a marked shift away from 'Double Maths'. (6286 entries in 1984 to 4180 entries in 1992). By 1992, there was apparent an equally significant shift towards syllabuses such as Pure-Mathematics-with-Statistics (7115 entries) and away from Pure-Mathematics-with-Mechanics (3859 entries).

The general figures for the numbers who studied A-level Mathematics will be commented upon further in section 2.4. But, the shift between courses involving pure mathematics with statistics and pure mathematics with mechanics noted here is of obvious interest. The comparative figures between statistics and mechanics given by Anderson agree, to a lesser extent, with the comments made by Porkess and further portray concerns over the stability of mechanics in A-level syllabuses.
2.3.2. 1996-2000

The choice to separate the period 1996-2000 was governed by the release of Sir Ron Dearing's 'Review of qualification for 16-19 year olds' in early 1996 and the implementation of his recommendations in the year 2000. Furthermore, this period coincided with the real emergence of documented evidence of the 'mathematics problem', as highlighted by reports such as 'Tackling the mathematics problem', LMS (1995).

Easingwood (1997) commented that:

In his review of qualifications for 16-19 year olds, Sir Ron Dearing acknowledged that the AS had not been as successful as had been hoped at its inception. Take-up has remained low (and indeed latterly has actually declined in Mathematics). The AS represents a sizeable part of the core of the A-level and it has generally been found to be relatively more demanding for many learners. Few schools offer more than two subjects at AS-level. It has therefore failed to achieve its main purpose of increasing breadth of study in post-16 education.

This highlighted many important points, specifically that AS-levels had been found to be more demanding than expected and that they had not increased the breadth of study of students. Thus, there was an obvious need to make improvements to the system and Easingwood (1997) went on to comment that:

Sir Ron's review found support for a reformulated AS which will be economic to teach, which should reduce student wastage rates and which will encourage breadth of study. Instead of covering half the A-level syllabus in the same depth, the new AS (re-named the Advanced Subsidiary) will cover the syllabus content in the breadth and depth 'appropriate to one year's study post-GCSE'.

As someone who studied A-levels at the end of this period, the change so that the new AS-levels would 'cover the syllabus content in the breadth and depth appropriate to one year's study post-GCSE' is the most crucial point. Seeing AS-levels as a first part to an A-level, in which you could continue on to study the 'second half' and gain an
A-level or not continue and obtain an AS qualification in itself, was fundamental in order to encourage a breadth of study.

The impending changes to be implemented in 2000 facilitated considerable discussion of 16-19 Mathematics. Indeed, a special edition of the IMA publication Teaching Mathematics and Its Applications on '16-19 Mathematics' was published in 1997. Included in this were papers entitled:

- Mathematics 16-19 - a view from the boundary, Glaister (1997)
- What can we expect from A-level Mathematics students? Lawson (1997)
- Improving mathematics provision for post-16 students, Wake (1997)

It is obvious from such publications that there was real concern over the subject itself, as well as the implications it had for others, i.e. university departments. However, it is also evident that there was a genuine desire to try and improve the situation. Subsequently, 'Measuring the mathematics problem' was published, Hawkes and Savage (2000). There, issues surrounding the mathematics problem at the school/university interface were outlined and recommendations given. The recommendations primarily surrounded diagnosing and supporting students once they entered higher education.

2.3.3. Post 2000

In the year 2000 there were major changes to the structure of all A-levels and subsequently further changes were made in A-level Mathematics in September 2004. The specific detail of the changes in A-level Mathematics, during this period, will be given in section 2.5. Here a brief overview will be given.

In September 2000 changes were made to the structure of A-levels, via the introduction of 'Curriculum 2000', in order that all A-level and AS qualifications
would become assessed completely by modules. An AS would consist of three modules and an A-level would consist of six modules. In most subjects the six modules for an A-level would be made up from three AS modules and three A2 modules (where A2 modules are modules that are generally taken in school year 13). In the structure adopted it was suggested that students would take at least four AS subjects (e.g. mathematics, physics, computing, physical education) in year 12, and then continue three (e.g. mathematics, physics and computing) onto full A-level status in year 13. These changes would encourage more students to obtain a greater breadth of study, i.e. to have studied four or five subjects to AS-level standard, before deciding which three or four of these to continue and 'specialise' in at full A-level standard. In general, prior to these changes students would enrol onto A-level courses from the outset rather then deciding to continue onto A-level standard at the end of their first year.

In the mathematics community there were many concerns raised following the implementation of Curriculum 2000. One of these related to the uptake of A-level Mathematics courses, particularly following a large failure rate of AS-level Mathematics candidates in summer 2001. This will be discussed further in section 2.4. Ultimately, these concerns led to a change in the specification for A-level Mathematics courses and this will be detailed in section 2.5.

Within this section an overview of the major changes, particularly in the last 20 years has been given. A review of the uptake over a similar period now follows.

2.4. Uptake of A-level Mathematics

The uptake of A-level Mathematics is obviously of great importance for higher education. Along with university mathematics departments, many engineering and physics departments have requirements for students to have studied A-level Mathematics (or its equivalent). Changes in the uptake of A-level Mathematics can not only impinge upon universities' first year programmes, for example by affecting students' knowledge when beginning a programme, but also the actual recruitment of
students can be affected as fewer students may have the necessary entrance qualifications.

Within this section a review of the uptake of A-level Mathematics will be detailed. An explanation for the large reduction in numbers in 2002 will then be detailed. Following this, specific issues that affect the uptake of A-level Mathematics, such as the image of mathematics, are discussed.

2.4.1. Numbers Studying A-level Mathematics

A review of the uptake of A-level Mathematics courses in recent years illustrates a very interesting but very concerning picture. Figure 2.1 depicts the uptake of A-level Mathematics since 1989 (originating source of data Porkess (2006: 4)).

An overall decline between 1989 and 2005 is evident, although there are several 'eras' of interest. Firstly, between 1989 and 1995 there was a large reduction in numbers from 84744 to 62188. Although an increase then followed until 1998 (to 70554), which was attributed to the fact that all A-level Mathematics courses went modular in 1995, a small fall followed until 2001 (to 66247). In 2002 there was a notably large drop of some 12307 candidates (or 19%) from the previous year and this will be discussed in the next subsection (2.4.2). Since 2002 a small increase has followed. However, it is important to note that, as detailed by Porkess (2006: 18):

Exact A-Level numbers are surprisingly difficult, perhaps impossible, to determine even for quite recent years... Until 2003, Further Mathematics was included with Mathematics and so some candidates were double-counted. The figures for 2004 and 2005 have been adapted so as to continue this practice on the grounds of comparability with the earlier data. Consequently recent figures are about 5000 too large.

Hence a large drop in the numbers taking A-level Mathematics courses over the past few decades has been seen. This is an obvious concern for those in higher education who need to recruit students with A-level Mathematics. However, this should also be placed in context with an increase in the total numbers studying A-levels.
Table 2.1 (originating source Porkess (2006: 4)) illustrates the total number of A-level candidates, the number of A-level Mathematics candidates and the respective mathematics percentage from 1989 to 2005. A plot of the total number of candidates can be seen in Figure 2.2.

![Figure 2.1 - Numbers studying A-level Mathematics 1989-2005.](image1)

![Figure 2.2 - Total numbers of A-level candidates 1989-2005.](image2)
The general trend in Figure 2.2 is an increase from year to year, apart from the period between 1998 and 2002 where there was a substantial decrease. It is apparent that this decline corresponds with the implementation of Curriculum 2000, but it is difficult to establish any direct link between them. Between 1989 and 2005 there has been an overall increase, although the peak number of 794262 candidates in 1998 has not been surpassed.

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Candidates</th>
<th>Mathematics Candidates</th>
<th>Mathematics Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1989</td>
<td>661 591</td>
<td>84744</td>
<td>12.8</td>
</tr>
<tr>
<td>1990</td>
<td>684 117</td>
<td>79747</td>
<td>11.7</td>
</tr>
<tr>
<td>1991</td>
<td>699 041</td>
<td>74972</td>
<td>10.7</td>
</tr>
<tr>
<td>1992</td>
<td>731 024</td>
<td>72384</td>
<td>9.9</td>
</tr>
<tr>
<td>1993</td>
<td>734 081</td>
<td>66340</td>
<td>9.0</td>
</tr>
<tr>
<td>1994</td>
<td>732 974</td>
<td>64919</td>
<td>8.9</td>
</tr>
<tr>
<td>1995</td>
<td>725 992</td>
<td>62188</td>
<td>8.6</td>
</tr>
<tr>
<td>1996</td>
<td>739 163</td>
<td>67442</td>
<td>9.1</td>
</tr>
<tr>
<td>1997</td>
<td>777 710</td>
<td>68880</td>
<td>8.9</td>
</tr>
<tr>
<td>1998</td>
<td>794 262</td>
<td>70554</td>
<td>8.9</td>
</tr>
<tr>
<td>1999</td>
<td>783 692</td>
<td>69945</td>
<td>8.9</td>
</tr>
<tr>
<td>2000</td>
<td>771 809</td>
<td>67036</td>
<td>8.7</td>
</tr>
<tr>
<td>2001</td>
<td>748 866</td>
<td>66247</td>
<td>8.8</td>
</tr>
<tr>
<td>2002</td>
<td>701 380</td>
<td>53940</td>
<td>7.7</td>
</tr>
<tr>
<td>2003</td>
<td>750 537</td>
<td>55917</td>
<td>7.5</td>
</tr>
<tr>
<td>2004</td>
<td>766 247</td>
<td>58508</td>
<td>7.6</td>
</tr>
<tr>
<td>2005</td>
<td>783 878</td>
<td>58830</td>
<td>7.5</td>
</tr>
</tbody>
</table>

Table 2.1 – Total A-level numbers and mathematics percentages

In the last column of Table 2.1, A-level Mathematics candidates as a percentage from the total number of A-level candidates are shown. Given the increase in total numbers of candidates and the decline in the number of mathematics candidates shown in Figures 2.1 and 2.2, it is no surprise that A-level Mathematics candidates as a percentage from the total number of A-level candidates has decreased steadily over this period. In addition to this, as stated by Matthews and Pepper (2006: 18)

Since 2001, and the introduction of Curriculum 2000, there has been a significant increase in the proportion of the national cohort taking A and AS qualifications rising from 38% in 2001 to 44% in 2004.
Thus, as a proportion of all students who are studying A-levels, (which as a proportion of the national cohort has been on the increase in recent years), fewer are studying A-level Mathematics courses. The Royal Academy of Engineering (2006: 3) highlighted a further issue:

Between 1994 and 2004, whilst the numbers entering university in the UK rose by almost 40%, the numbers opting for engineering degrees remained almost static, at 24500 - dropping proportionately from 11% to less then 8% of entrants.

There are many reasons why such a proportionate drop may have occurred, but ultimately fewer candidates studying A-level Mathematics has not aided the situation; as pointed out in section 1.1, the requirement from the majority of engineering courses for candidates to have studied A-level Mathematics (or its equivalent) means fewer candidates are in a position to offer such a qualification.

2.4.2. Explanations for the Large Reduction in Numbers Studying A-level Mathematics in 2002

As highlighted in Figure 2.1 and detailed earlier there was a considerable drop in the uptake of A-level Mathematics in 2002. There are several explanations for this and these will now be reviewed.

Curriculum 2000 was introduced in 2000 and thus the first cohort of students who completed AS-level Mathematics from this specification was in 2001. Subsequently, the first cohort of students who completed the full A-level in Mathematics from this specification was in 2002. When considering the pass rates for AS-level Mathematics some interesting statistics can be seen.

<table>
<thead>
<tr>
<th>Mathematics</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS-level</td>
<td>66.6</td>
<td>81.7</td>
<td>82.7</td>
<td>84.6</td>
</tr>
</tbody>
</table>

Table 2.2 – Percentage of AS-level Mathematics entry gaining grades A-E
Table 2.2 details the percentage of AS-level Mathematics students who gained a grade of A-E, under the Curriculum 2000 specification (original data source, Matthews and Pepper (2006: 23)). What is striking from Table 2.2 is the much lower pass rate in 2001 than for subsequent years. This corresponds to the high failure rates in AS Mathematics that were well publicised at the time, namely that one in three students failed. However, as described by Matthews and Pepper (2006: 23):

The AS results (in Table 2.2) are for certificated AS qualification only, and thus exclude those students who declined their certification. This may have had an effect of emphasising the failure rate. It is possible that good students who performed less well than they expected decided not to accept their AS and continued the A-level, hoping to improve through re-taking, whereas those with poor results, including failures, may have decided not to continue with the full award and therefore may have accepted their certification.

This may occur in most years, but it was particularly evident in 2001. This explanation is supported by the fact that there was, as shown in Figure 2.1, a decrease of some 12307 students (or a 19% reduction) who completed the full A-level in Mathematics in 2002 when compared to 2001. It is further supported when the percentage of A-level Mathematics students who gained a grade of A-E or A-C are considered, see Table 2.3.

<table>
<thead>
<tr>
<th>Grade</th>
<th>Year</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-E</td>
<td></td>
<td>90.2</td>
<td>95.4</td>
<td>95.7</td>
<td>96.4</td>
</tr>
<tr>
<td>A-C</td>
<td></td>
<td>65.5</td>
<td>75.8</td>
<td>76.8</td>
<td>78.2</td>
</tr>
</tbody>
</table>

Table 2.3 – Percentage of A-level Mathematics entry gaining grades A-E/A-C

Table 2.3 details the percentage of A-level Mathematics students who gained a grade of A-E or A-C under the Curriculum 2000 specification (original data source, Matthews and Pepper (2006: 23)). It should be noted that the figures for 2001 are from the pre-Curriculum 2000 specification, but are there for comparison. In 2002, a larger percentage of students studying A-level Mathematics obtained a pass grade of A-E than did in 2001, 95.4% versus 90.2%. In addition, in 2002 a larger percentage of
students studying A-level Mathematics obtained a high grade of A-C than did in 2001, 75.8% versus 65.5%. This indicates that those who did continue to study the full A-level in Mathematics, despite the high failure rates for AS-level Mathematics in 2001, did do well.

Thus, one reason why there was a reduction in numbers studying A-level Mathematics in 2002 has been seen. At least two more reasons have been attributed to the fall in numbers studying A-level Mathematics in 2002. The first of these is the constraints of Curriculum 2000, which meant that students had to study three modules in their first year. The specifics of this will be clearly seen in section 2.5.1, when the Curriculum 2000 specifications for A-level Mathematics are discussed. However, to give a brief insight, the issue surrounds the fact that in A-level Mathematics students had generally only taken two examinations in their first year and four in their second year when they had developed their mathematical skills. The requirement to study three under the Curriculum 2000 specifications meant this was an obvious change.

The second is the total number of modules in all A-levels that students were required to study following the implementation of Curriculum 2000. As detailed earlier (section 2.3.3) following the implementation of Curriculum 2000 students were required to study three modules for each AS-level they studied and then a further three modules for each subject which they continued to study a full A-level in. This meant that for an average student who studied four AS-levels they would undertake 12 (4x3) modules and consequently 12 examinations in their first year. Prior to Curriculum 2000 nearly all A-level courses were linear, except mathematics, which had been modular since 1995. This meant students would have enrolled onto A-level courses from the outset and would study one (or possibly more) examination at the end of their two-year course. Thus, the only (external) examinations students would study in their first year would be their mathematics ones, although students would likely have undertaken internal examinations for other subjects at the end of their first year. Consequently, this large increase in external examinations which students were required to undertake could also be seen as a factor for the high failure rate in AS-level Mathematics when first certified in 2001.
ACME (2005: 3), who are an independent committee that acts as a single voice for the mathematical community and who advises Government on issues such as the curriculum, assessment and the supply and training of mathematics teachers, commented upon the number of examinations in Curriculum 2000:

The modular assessment structure associated with the introduction of Curriculum 2000 is a particular concern. Students take six modules in mathematics (and in all other A2 subjects), and may retake them as many times as they wish. The total volume and the frequency of assessment have become excessive, and, across the totality of their studies, students are quite simply confronted by too many external assessments.

As reported earlier this year by Rebecca Smithers, Education Guardian (2006), by September 2008 QCA plans to reduce the number of modules studied in many A-levels from six modules to four modules. As yet it is unclear if mathematics will be changed, with OCR currently trialing the possibilities. However, MEI (2005b) outlined difficulties that could be faced if change was made to the mathematics specifications, including issues with having too many changes in recent years and issues with a loss of coherence of material when splitting into four modules.

This concern over the large number of examinations that students study has led to many discussions about students being 'taught for the exam'. Indeed in 2002, on the BBC News website, BBC (2002), David Rendel the Liberal Democrat higher education spokesman said, "As it stands, children are being taught to pass exams." Furthermore, in the 2006 OFSTED report 'Evaluating mathematics provision for 14-19 year olds' one of the factors which 'acted against effective achievement, motivation and participation' was, OFSTED (2006: 3):

A narrow focus on meeting examination requirements by 'teaching to the test', so that although students are able to pass the examinations they are not able to apply their knowledge independently to new contexts, and they are not well prepared for further study.

It is evident that there is concern that students are being taught to the test, not only in
A-level Mathematics, but also in many other subjects.

2.4.3. Specific Issues Related to the Uptake of A-level Mathematics

An overview of the uptake of A-level Mathematics has already been seen, along with a discussion of why there was a large drop in those studying A-level Mathematics in 2002. However, there are several other issues that impinge upon the uptake of A-level Mathematics and an overview of some of these will now be given.

*i Careers advice and an associated wage premium*

Prior to starting A-levels, students may not be aware of the usefulness of studying A-level Mathematics and thus may not consider studying it. This is both in terms of what careers are available to those who have studied mathematics as well as the associated pay premium. In their paper 'The pay-off to mathematics A-level', Dolton and Vignoles (2000: 52) summarised that: "The main conclusion from our research is that there is a high wage premium associated with having a Mathematics A-level." Subsequently, if there is not an 'awareness' of such benefits then who should make suitable students aware? Dolton and Vignoles (2000: 63) indicated that:

If students are unaware of the wage premium associated with mathematics A-Level, then teachers and careers services, who may themselves be unaware of the pay-offs to mathematics A-Level, should be advising students of the benefits of this qualification, and perhaps encouraging more who are capable of studying advanced mathematics to take this subject. However, it is unlikely that encouragement alone would increase the take up of mathematics A-Level.

More specifically the Engineering and Technology Board, ETB (2005: 8) indicated that:

Teachers were unclear about pathways open to their pupils to enter engineering careers, and what qualifications were best suited to this. Teachers also saw engineering as a dirty, old-fashioned and predominately male orientated career.
Thus, highlighting that teachers and careers services are in a position to advise students. But it may be that such people may themselves be unfamiliar with suitable careers and associated wage premiums. However, in recent years there has been some effort to rectify this with the creation of the website, www.mathscareers.org.uk. This site was produced by the three learned and professional societies, the London Mathematical Society, the Royal Statistical Society and the Institute of Mathematics and its Applications. Collectively, under the title of the Council for the Mathematical Sciences, they are currently running a number of projects under the banner of 'mathematics careers', aimed at informing students from aged 11 upwards on the opportunities available to students of mathematics and statistics. They indicated that these subjects "improve students' employment prospects and open up many fascinating careers, but they suffer from an image problem and are seen as unpopular and difficult."

The comment citing that there is an image problem and that the subject is unpopular and difficult will be discussed next. However, it is worth pointing out that there may be a subset to this problem of awareness. In this thesis the specific focus surrounds mechanics. Therefore, within A-level Mathematics awareness of the benefits of having studied mechanics modules for those wishing to study engineering should be highlighted. However, in reality many of those advising students may not be aware of the benefits themselves. This is something that is inherently more difficult to deal with than a general issue of a lack of knowledge on careers and thus would invariably be extremely difficult to resolve.

**ii An image problem and a shortage of mathematics teachers**

As hinted at previously, an issue with mathematics is that it has an 'image problem'. In a paper entitled 'Your students' images of mathematicians and mathematics', Picker and Berry (2001), asked middle school children to 'draw a mathematician at work'. They commented that "The images indicate that for these children, mathematicians and the work they do are invisible and media images have filled the void." Thus, indicating that the 'real' work that a mathematician does is in essence unknown and consequently media images, which may not portray a true picture, are taken to be 'reality'. If such images are obtained from middle-school children and if there is
nothing to change their viewpoint, then such beliefs may continue through to adulthood.

It has already been alluded to that mathematics teachers can play an important part in making students aware of the possible career paths and the usefulness of studying mathematics post GCSE. However, there have been documented concerns over the shortage of mathematically trained teachers teaching mathematics. Tikly and Wolf (2000: 1) highlighted the fact that:

> We cannot recruit or retain the mathematics teachers we need, so that, already, large numbers of our pupils are in classes without a mathematically qualified teacher.

Indeed, this is not a recent phenomenon and Cockcroft (1982: 174) highlighted that "There are some teachers who find difficulty in teaching mechanics." Expectation is that given the recent interest in studying statistics and discrete mathematics (see Chapter 4) that those going on to teach mathematics may not have the necessary background in mechanics to be competent and confident enough to teach mechanics at A-level.

OFSTED (2006: 2) highlighted factors that acted against effective achievement, motivation and participation in mathematics as:

> Teaching which presents mathematics as a collection of arbitrary rules and procedures, allied to a narrow range of learning activities in lessons which do not engage students in real mathematical thinking.

It is likely that when mathematics teachers are not suitably qualified but are required to teach the subject then such actions may take place.

The 'Post-14 Mathematics Inquiry', Smith (2004), identified three key issues of major concern, two of these were:

- The shortage of specialist mathematics teachers, particularly in England and Wales
• The lack of resources, infrastructure and a sustained continuing professional development culture to support and nurture all teachers of mathematics.

Thus, in recent years there has been an appreciation of the problem of recruiting and retaining mathematics teachers. Consequently, several initiatives have been implemented. These have included giving a training bursary of £9000 (up from £7000 in 2005) for those specialising in a mathematics PGCE and giving a £5000 'golden hello' (up from £4000 in 2005) to mathematics teachers after their first year in a mathematics teaching post. Subsequently, following the Smith report in 2004 and recommendations from ACME, a National Centre for Excellence in Teaching Mathematics (NCETM) funded by the DfES, has been created and was launched in June 2006. The NCETM will 'support and promote professional development in the teaching of mathematics'. Having more specialist and suitably trained mathematics teachers will undoubtedly benefit those studying A-level Mathematics. The creation of the NCETM will also give much needed publicity to the subject.

Furthermore, in summer 2006 the Higher Education Funding Council for England (HEFCE) awarded £3.3 million of funding to a project entitled 'Increasing the supply of mathematical sciences graduates'. The underlying aim of the project is to establish sustainable methods of increasing the supply of mathematical sciences graduates.

2.4.4. Universities' Reliance on Students Having Studied A-level Mathematics

As indicated at the beginning of this section, many university departments, i.e. engineering, physics and obviously mathematics, require students entering their degree programmes to have studied A-level Mathematics (or its equivalent). Evidently, the overall decrease in numbers, highlighted in section 2.4.1, has implications for universities. This is not only the fact that there has been a reduction in numbers studying the subject, but that those studying the subject are 'less well prepared' upon entry to university.

Sutherland (2000: 101) highlighted that

More and more young people in the UK are progressing to university. The disjunction between school mathematics and the mathematical demands of a
wide range of university courses is increasingly becoming a barrier to the progress of knowledge.

This type of remark again refers to the 'mathematics problem' and looking back a decade, in Sir Ron Dearing's Report on the 'Review of qualifications for 16-19 year olds', Dearing (1996: 9) he stated that:

There is strong support for maintaining the rigour of A-levels. A particular point of concern is the standard in mathematics among those presenting themselves for degree courses in the subject, and in the physical sciences.

Subsequently, Mustoe (2002: 69) indicated a lack of response, to a continually changing student intake, from universities over the years.

There is a fundamental mismatch between what is expected of students and what they can realistically achieve, even some of the most able students find difficulty with concepts that would have been mastered by their counterparts ten years ago. Mathematics requires time in order to develop a body of useful techniques, and omission of important foundations causes problems later. Above all there are no 'quick-fix' solutions.

Here, Mustoe highlights that nowadays even some of the most able students have problems. In addition, he cites the fact that when there are gaps in knowledge it is very difficult to 'fix' the problem and that learning ideas and concepts over a longer period of time, i.e. during an A-level, is what is required.

In Britain it is not compulsory for students to study any mathematics post-GCSE. This differs from many other countries, particularly in Europe. Wolf (2000: 134) indicated that:

The contrast with recent European and, indeed, worldwide trends is astonishing. As described above, other countries have been increasing the mathematics requirements of both academic and vocational programmes in recent years... it remains a possibility that the rest of the world has got it wrong and the British have got it right... however, one must conclude that the evidence is otherwise.
Indeed, following the publication of the '14-19 curriculum and qualifications reform', Tomlinson (2004), there was the opportunity for the government to introduce comparable qualifications to those seen across Europe, for example in the style of the International Baccalaureate. However, less then a year later when the '14-19 education and skills – implementation plan', DfES (2005), was published the decision was to run new 'diplomas' alongside A-levels rather than to replace them. Many saw this as a missed opportunity, but inevitably if the new measures once implemented (the first diplomas will be available from 2008) do succeed, then there will still be those who will argue the case that a total change should have been made.

2.4.5. Summary

Within this section there has been a discussion of the uptake of A-level Mathematics. This was in the context that many university departments require students to have studied A-level Mathematics. An overview of the numbers who have studied the subject in recent years was depicted, with evidence of an overall decline in the past 20 years. A review of why there was a large decrease in the numbers in 2002 was undertaken. Following this specific issues were considered, this included having appropriate careers advice, overturning an image problem and increasing the supply of appropriately qualified mathematics teachers. Finally there was a brief discussion of many university departments reliance on students having studied mathematics pre-university, particularly A-level.

It is widely hoped that in the coming years there will be a rise in the number of students studying A-level Mathematics. The changes to the syllabi in September 2004, which are discussed in the next section, along with an increasing number of government funded projects, such as those discussed in 2.4.3, could contribute to such a rise.

2.5. Detailed Review of A-level Mathematics Syllabus Changes in 2000 and September 2004

As was detailed in section 2.3 there have been many changes made to pre-university qualifications. These have included A-level Mathematics courses and thus there will
now follow a detailed review of the changes that have taken place in recent years. This will focus on the changes made to all A-level qualifications under Curriculum 2000 and the subsequent changes made, in A-level Mathematics, in September 2004. Such changes have had an affect on students entering universities during the time that research in this thesis has been carried out. Changes implemented in 2000 will be detailed first. The changes made to A-level Mathematics courses, in September 2004, will then follow.

2.5.1. Curriculum 2000

As was described in section 2.3.3 there were major changes to the structure of all A-levels in the year 2000, so that each A-level became examined by six modules. When the specifications were introduced for first teaching from September 2000 in mathematics all examination bodies offered their own array of modules. The modules available to be studied in A-level Mathematics courses are outlined in Table 2.4. It should be noted that the exemplar A-level structure used throughout this thesis is the OCR specification. Hence, other examination boards may have small differences to OCRs.

<table>
<thead>
<tr>
<th>Pure</th>
<th>AS</th>
<th>A2</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td></td>
<td>P2-P6</td>
</tr>
<tr>
<td>Mechanics</td>
<td>M1</td>
<td>M2-M4</td>
</tr>
<tr>
<td>Statistics</td>
<td>S1</td>
<td>S2-S4</td>
</tr>
<tr>
<td>Discrete</td>
<td>D1</td>
<td>D2</td>
</tr>
</tbody>
</table>

Table 2.4 – Modules available in Curriculum 2000

In general there will be, Table 2.4, six modules in pure mathematics [P1 (AS-level module), P2-P6 (A2-level modules)], along with a selection of 'applied' modules, which would consist of at least the following:

- Mechanics [M1 (AS-level module), M2-M4 (A2-level modules)]
- Statistics [S1 (AS-level module), S2-S4 (A2-level modules)]
- Discrete [D1 (AS-level module), D2 (A2-level module)]
However, a few other modules were available from certain examination boards, e.g. Numerical Methods.

As in other A-levels, mathematics modules were classified as AS or A2. However, in other courses, students studied three AS modules in Year 12 and three A2 modules in Year 13. This was not the case in mathematics. With the introduction of 'Curriculum 2000, for AS-level certification in mathematics, AS-level Mathematics candidates were required to study two compulsory 'common core' modules (P1, P2) and an applied module and thus were required to incorporate a compulsory A2 module in their programme (as P2 is an A2-level module). This raised the issue as to whether AS-level Mathematics was harder than other subjects. Porkess (2000 and 2000b) discusses several issues, which may indicate that it is indeed the case.

For certification in A-level Mathematics, students were required to study three compulsory 'common core' modules (P1, P2, P3) and three other modules (at most two of which are classified as AS). Thus, for certification in A-level Mathematics, students studied either three AS and three A2 modules or two AS, and four A2 modules. Examples of possible combinations can be seen in Table 2.5, where the AS modules are in italics and A2 modules are in bold.

<table>
<thead>
<tr>
<th>P1</th>
<th>M1</th>
<th>S1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>M1</td>
<td>S1</td>
<td>P2</td>
<td>P3</td>
<td>M2</td>
</tr>
<tr>
<td>P1</td>
<td>M1</td>
<td>P2</td>
<td>P3</td>
<td>P4</td>
<td>M2</td>
</tr>
<tr>
<td>P1</td>
<td>M1</td>
<td>P2</td>
<td>P3</td>
<td>M2</td>
<td>M3</td>
</tr>
</tbody>
</table>

Table 2.5 – Possible module combinations for A-level Mathematics

Thus A-level Mathematics, unlike any other A-level, could consist of a combination of two AS and four A2 modules and hence potentially be harder than other A-levels. In particular, if a potential engineering student studied three modules of mechanics, they would take four A2 modules, whereas taking the first module of statistics (S1) together with one or two mechanics modules and pure modules would result in a
combination of three AS modules and three A2 modules. One can see why teachers, endeavoring to ensure that their students obtain the highest possible grades, may have been tempted to advise students to study the latter combinations.

The various examination boards could specify the 'common core' modules differently but all needed to include certain topics and were therefore very similar across the boards. However, with reference to the mechanics modules M1-M4, there was more scope for differentiation between the boards (due to the fact that these were not 'core' modules). An example of the content of the four mechanics modules offered by the examination board OCR is in Appendix A. In reality, similar content was found in the early mechanics modules of all examination boards, although in later modules greater differences between the boards became evident.

2.5.2. Curriculum Changes in September 2004

Following the introduction of Curriculum 2000, as reported in section 2.4.1, the numbers taking A-level Mathematics fell dramatically in 2002. This, along with other concerns, including those over the time pressures schools faced in trying to cover all the required material, Graham (2002), have been factors in causing changes to the specifications which were approved in October 2003. The changes were implemented for first teaching in September 2004 and thus the first cohort of A-level students' results will be available this summer (2006). The changes involved restructuring module content and consequently certification for A-level Mathematics courses changed again.

Table 2.6 gives a summary of the modules available to be studied from the specification that was first taught from September 2004. There were four 'core' units (units as opposed to modules) labelled C1, C2 (AS-level units), C3 and C4 (A2-level units). These replaced the old common core of P1-P3 and so the content of the three old modules was essentially spread across the four new units. This implies that A-level Mathematics may become easier. Students then chose two applied units to add to the four core units to create a Mathematics A-level. This was a fundamental change, as the maximum number of applied units, which a student could study for a Mathematics A-level, reduced from three to two. This was a significant change and
implications of this change on the uptake of and availability of applied modules in schools can be seen in Chapter 4.

<table>
<thead>
<tr>
<th></th>
<th>AS</th>
<th>A2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pure</td>
<td>C1, C2</td>
<td>C3, C4</td>
</tr>
<tr>
<td>Mechanics</td>
<td>M1</td>
<td>M2-M4</td>
</tr>
<tr>
<td>Statistics</td>
<td>S1</td>
<td>S2-S4</td>
</tr>
<tr>
<td>Discrete</td>
<td>D1</td>
<td>D2</td>
</tr>
</tbody>
</table>

Table 2.6 – Modules available from September 2004

Another consequence of the changes meant that it was possible for A-level Mathematics students to have studied four AS units and two A2 units e.g. C1, C2, C3, C4, M1, S1. This differed from the Curriculum 2000 specification, where, as has been commented upon earlier, students could have taken four A2 modules and two AS modules or three AS and three A2 modules. Again this may lead to the A-level being easier.

In the recent report on an 'Evaluation of participation in A-level Mathematics', Pepper & Matthews (2006: 190) indicated that:

For many students studying the new syllabus, C1 was generally found to be less demanding and the time in examinations more manageable. A few students were pleased about not having to do three application units, however this was the opposite for another group of students, particularly for those studying engineering.

This highlights that spreading the material from the three pure modules in the Curriculum 2000 specification into four modules in the later specification (taught from September 2004), may have eased the issue of time pressures cited earlier. However, the changes also mean that in essence the new specification only covers five-sixths of that of the Curriculum 2000 specification. The will obviously have consequences for universities and Porkess (2003: 16) commented that:
There is already no lack of complaints from universities about the poor mathematics of their entrants. How will these reforms help the situation? The 'official' answer is that by allowing students more time to do the pure mathematics, they will be better at it and so better generally. I am sure this will be true for many of the weaker students, but I am sceptical of the argument when it comes to the more able. However, the good news is that the new arrangements for Further Mathematics should make it possible for able (and reasonably able) students to end up knowing more mathematics.

Currently, it is not yet possible to say if this viewpoint is true, as students from the new specifications will only enter universities in September 2006. It should be noted that it might have been the case that some students who entered university in September 2005 could have taken all the modules from the new specification in a single year. However, the expectation is that such numbers are very small.

2.5.3. Revolutionary Changes in Further Mathematics

The final point highlighted by Porkess (2006: 5), regarding new arrangements in Further Mathematics, is noteworthy:

Over the last twenty five years Further Mathematics numbers have fallen, proportionately, even more than those for single A-level Mathematics, from about 15000 to 5000...The reduction in the uptake of Further Mathematics during the 1980s and 1990s was undoubtedly another factor in the perception among university mathematics departments that standards were falling. It was not just that new undergraduates were arriving knowing less mathematics but that they had spent much less time doing it, and so were less fluent.

Such a decline in numbers studying A-level Further Mathematics was an obvious concern and the fact that there was no apparent reason why any reversal in numbers should take place meant that the numbers could have continued to decrease further. However, in the last few years there have been two key reasons why a turnaround may be a distinct possibility. The first of which is a change in specification for AS/ A-level Further Mathematics in 2004, and an increase in the availability of the subject
through the Further Mathematics Network. An overview of each of these will now be given.

Firstly, major changes were made to A-level Further Mathematics in 2004. Full details can be seen in Stripp (2004). In the Curriculum 2000 specification students were required to study the module Pure 4 plus two other modules for certification in AS Further Mathematics. Not only was Pure 4 an A2 module (and not an AS module), but also students were required to have studied the three previous pure modules (P1, P2 and P3) before they could study Pure 4. Stripp (2004: 15) highlighted that:

This meant the old AS-level Further Mathematics was actually harder than A-level Mathematics and was extremely awkward for most schools to timetable alongside A-level Mathematics.

It was not only difficult for schools to timetable the subject but it may not have been a financially viable option to run a very small Further Mathematics class. Also, it may have been the case that the teacher shortages discussed earlier meant that a school did not have staff able to teach it. It was for such reasons that Further Mathematics has been on the decline. Further Mathematics was not really equivalent to any other AS/A-level. However, the opportunity arose to change the structure of Further Mathematics alongside the changes in the single Mathematics courses that were taught from September 2004.

The changes meant that AS Further Mathematics would be able to comprise of three AS units. One of these was compulsory and called Further Pure 1 (FP1), with a free choice of the two other AS units (although the choices still had to conform to examination boards' criteria, i.e. the same unit could not form part of both AS Mathematics and AS Further Mathematics qualifications). As commented upon by Stripp (2004: 16):

The new AS will be more a 'broadening' than a 'deepening' option. This means that AS-Level Further Mathematics is no longer an 'elite' qualification, suitable only for A-level Mathematics high-fliers. It will be a very useful qualification for any student who plans to do a strongly mathematics-related degree, such as engineering or
science, as well as Mathematics itself. Such students will benefit not only from the new mathematics they will learn but also simply from doing more mathematics, which will have a positive effect on their mathematical fluency and confidence.

Conversely, an A-level in Further Mathematics (where a further compulsory unit was required to be studied alongside two other A2 units) would act to deepen a student's understanding. This would still challenge and enthuse the more able students as it had before. Therefore, some parity was reached between the relative difficulty of AS Further Mathematics and other AS subjects. However, it would not necessarily follow that the subject would be available for students to study. This is why the second key reason, the creation of a national Further Mathematics Network, was crucial

Full information on the Further Mathematics Network can be obtained from their website (http://www.fmnetwork.org.uk) or alternatively from Porkess (2006: 14-17).

In summary (from their website):

The Further Mathematics Network is a DfES-funded initiative to establish 40-50 regional Further Mathematics Centres across England. The primary functions of these Centres are to set up and provide teaching and tutoring of Further Mathematics AS/A-level to students in schools and colleges that couldn't otherwise offer it and to support students and teachers in schools and colleges that do teach Further Mathematics. Each Centre also has a role in promoting Mathematics in general by organising initiatives to help attract more students into post-16 Mathematics, and a responsibility to support the CPD (Continued Professional Development) of teachers, to help them teach Further Mathematics in their own schools and colleges.

Thus, the change in specification and the availability for any student to study the qualification is revolutionary for the subject and there is a real possibility of an increase in the number of students studying it. Indeed, in the figures that have been released for 2006, BBC (2006), AS Further Mathematics numbers showed a 24.5% increase in the past year and have increased by an encouraging 58% over the past two years. Furthermore, A-level Further Mathematics numbers showed a 22.5% increase, showing that the increase in AS numbers from last year is being translated into increased A-level numbers this year. As outlined previously, this will undoubtedly be of benefit to university departments who will recruit such students.
In summary, within this section the recent changes that have taken place in A-level Mathematics courses have been outlined. These focussed upon Curriculum 2000 changes and those that followed in September 2004. In addition, the positive changes to Further Mathematics were also outlined. The next section will specifically focus upon mechanics and the school curriculum.

2.6. Schools Curriculum and the Mechanics Problem

Within this chapter developments in pre-university mathematics courses have been outlined. Here there will be a specific focus on issues surrounding mechanics as part of such courses.

Historically, since the origins of A-level qualifications at the beginning of the 1950s, mechanics has been traditionally included as indicated by Cockcroft (1982: 172): "Thirty years ago no problem arose. The applied element of both single- and double-subject mathematics courses was almost always Newtonian mechanics". However, with the widespread introduction of statistics in the 1970s this was not the case. In the Cockcroft report in 1982 there was much discussion involving what material should be a compulsory part of A-level Mathematics. Cockcroft (1982: 172) concluded that:

There are strong arguments that, in an ideal situation, all who study mathematics at A-level should have the opportunity to gain some knowledge of Newtonian mechanics as well as of probability and statistics...We have considered whether we should recommend the study of one area of application rather than another but have decided that it is not possible to do this because of the diversity of students' future needs and interests.

Thus, there was no recommendation to include mechanics as a compulsory part of an A-level Mathematics course because it was in effect 'not needed' by everyone, e.g. social scientists who would benefit more from having studied statistics.

Recently, Porkess (Private communication) discussed a situation that occurred a few years after the Cockcroft Report. As detailed in section 2.3.1, Porkess indicated that
the numbers who chose to answer optional mechanics questions in scripts he marked in 1986 were extremely small compared to those who answered the optional statistics questions. He concluded from this that mechanics would not survive in the linear course that was around and hence this acted as one reason why he endeavoured to bring in modular courses.

A decade later when mathematics courses were all modular and at a time when the construction of Curriculum 2000 was being discussed, Kitchin et al (1997: 166) outlined the continuing relevance of mechanics in A-level Mathematics, indicating that:

This paper argues for the design of a pre-university Mathematics A-level course which includes a substantial amount of mechanics in which students' skills in using and applying algebra and calculus can be developed. This proposal is counter to the trends of recent decades, in which applications of mathematics have been introduced which make fewer demands on such important pure mathematical content.

They highlighted several key aspects as to why mechanics should be incorporated, these included:

• Mechanics provides opportunities for students to practice and become technically fluent in the use of algebra, trigonometry and calculus

• An essential role of applied mathematics in modelling. The discipline and skills of mathematical modelling are central to science and engineering

• Applied mathematics, especially mechanics, offers ample scope to motivate and inspire students by allowing them to experience interesting and intellectually challenging mathematical applications

• Mechanics should encourage and prepare students to further study science, applied science and engineering
As can be seen from such points there are many benefits to studying mechanics, particularly for those going on to university to study engineering degree programmes, which usually require students to have studied both A-level Mathematics and A-level Physics (or their equivalent). Although a detailed historical review of the content of A-level Physics has not been undertaken, 20 years ago Cockcroft (1982: 173) commented that:

Some of the greatest pressure for the inclusion of mechanics in mathematics syllabuses comes from those in higher education who are responsible for courses in engineering...However, for very many years most of those entering engineering degree courses have studied mechanics as part both of mathematics and of physics. In consequence, teaching for degree courses in engineering is based on the expectation of the level of competence in mechanics which this double study provides.

Since Curriculum 2000 there has certainly been compulsory mechanics within A-level Physics. Thus students entering university offering A-level Physics will have studied some mechanics and hence within this research study exposure to this mechanics will be taken as a common level (as the vast majority of engineering students will have studied A-level Physics). However, those who studied A-level Mathematics may well not have studied mechanics (as will be discussed in Chapters 4 and 5). One reason for students not having studied mechanics could have been the modular structure adopted since Curriculum 2000.

However, before this is discussed it is worth pointing out as Cockcroft (1982: 174) did, that:

As far as we are aware, there is no European country outside the British Isles in which mechanics forms part of school courses in mathematics; it is considered to be part of physics. However, there are also considerable differences in the time required to complete first degree courses in these countries and in the structure of the examinations which are taken by students in preparation for university entrance.

Recently, ACME (2005: 5) portrayed some of the positive aspects of modular courses:
Modular assessment can have benefits for many students, especially those requiring encouragement and reinforcement. A further positive feature of modular courses is that they require good syllabus coverage, and the nature of assessment means that it is difficult to avoid significant chunks of the specification. Furthermore, it reduces what, for many students, is the significant stress of the single end-of-course examination.

However, it could be argued that the stress involved in undertaking six exams, i.e. under the structure of Curriculum 2000, is greater than for one or two exams as would have been the case in a two year linear course. Perhaps more significantly though, although modular courses allow for good syllabus coverage, in some instances they also allow for certain topics or indeed whole strands, i.e. mechanics, to be omitted.

Kent and Noss (2003: 25) reported that:

The mathematics problem of students arriving at a university to study numerate degree courses falls into several areas. One is the 'patchiness' of A-level topics studied, due to the modularised curriculum - so that some students in a class will have studied, say, vectors whilst others have not.

This would be the case if students had not studied a given module, for example vectors may be in say FP1 and students may not have studied that module. Conversely they also reported that "It is quite common for students not to study any mechanics modules" thus supporting the fact that whole strands like mechanics could be omitted.

Consequently, it would be beneficial to review just how many students had studied mechanics modules in recent years to detect if there had been any changes. However, as reported by Porkess (2006: 18): "Exact A-Level numbers are surprisingly difficult, perhaps impossible, to determine even for quite recent years." The same could be said for obtaining detailed information on the numbers studying specific modules. Such information was sought from the examination bodies as well as the Joint Council and the QCA. Data that was obtained for all modules can be seen in Appendix B. Table 2.7 shows the data collated for mechanics modules.
The data obtained is incomplete and patchy. Most data was able to be collected from the examination board AQA, who until the changes in September 2004 offered two specifications. Data for these two specifications from 2002 - 2004 actually shows that numbers studying M1 has seen a quite small increase for the January sessions and has

<table>
<thead>
<tr>
<th>Exam Board</th>
<th>Exam Session</th>
<th>Number studying module</th>
</tr>
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<tbody>
<tr>
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Table 2.7 – Numbers studying mechanics modules 2001-2006
been oscillating for the June sessions. Numbers who studied higher modules (M3, M4, etc.) oscillated from year to year. Indicating actual numbers, from adding the figures for both AQA A and AQA B, M1 numbers for January 2004 (1595 + 232 = 1827) were up 225 from January 2003 (1440 + 162 = 1602), which were up 86 from January 2002 (1306 + 210 = 1516). Although 4893 students studied M1 under the new specification in the June 2005 session, this was actually (184) less than the combined number from AQA A and B specifications (3420 + 1657 = 5077) from the June 2004 session. This followed combined numbers from specifications A and B, for M1 in the June sessions, oscillating around the 4900 mark (2004 - 5077, 2003 - 4814, 2002 - 4924).

Only having data from the other examination boards for one session made it difficult to determine whether there are any similar patterns. It would have been particularly useful to have obtained figures for Edexcel as they examine the most candidates each year. A considerable effort was made to obtain all data from all examination boards, but when contacted most examination boards were not clear if such information was held, and if it was, then where it could be found in their records.

It may well be that recent reports of a substantial increase in numbers studying AS/A-level Further Mathematics in the past few years, BBC (2006), could have meant more students have the opportunity to study M1 in AS Further Mathematics, see Lee et al (In Press). However, this does not seem to be backed-up by this patchy data obtained from examination boards.

It could also be noted (see Appendix B) that there were proportionately more students who had studied statistics than mechanics. This was in the ratio 5:3. Little more can be deduced from such incomplete data. It should also be mentioned that it is not clear how many of those listed for each session for each examination board, were actually students who were re-sitting a module.

With the changes to A-level Mathematics courses that have occurred in recent years anecdotal evidence suggests that more and more students may be re-sitting modules, primarily to obtain a better mark. There is little documented evidence of such
practice, but a review from a solitary examination board (OCR) in 2004 was detailed in Matthews and Pepper (2006: 34). Table 2.8 shows the distribution found on the number of times each module was taken.

<table>
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<td>Three times</td>
<td>Four times</td>
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<tr>
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</table>

Table 2.8 – Number of times each module was taken.

The table shows each module offered in A-level Mathematics as well as the number of times a candidate sat each module. For example 314 students sat P2 three times. Interestingly, there were several modules that had a significant percentage of students retaking, including nearly half of those who studied P1, slightly more than half who studied P2 and approximately 30% of those who studied M1 and S1. Matthews and Pepper (2006: 34) went on to say that "The large retake units are all AS units, and it is likely that they are retaken by a large number of candidates to improve grades" and that there were several reasons for this, including:

- They are the units taken in the first year of the course - so there is more opportunity for re-sitting

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• They are the units that are taken in the first year of the course when the students' development is most limited - so there is more room for improvement

• They are the easier units - so that a really good result is more likely

Indeed, some 20 years ago Cockcroft (1982: 172) noted that:

It is the experience of many teachers that the early stages of both mechanics and probability and statistics need to be taught slowly and with great care, allowing ample time for discussion and for the underlying ideas to sink in and develop.

Thus, this is in agreement with the notion that students need time to develop and learn the underlying principles and concepts of a topic. It is for this exact reason that there can be real problems when students enter university engineering programmes, with little or no knowledge of mechanics, as will be seen later.

2.7. Summary

Within this chapter a varied and wide-ranging discussion of pre-university mathematics courses has been held. This began with an overview of the various qualifications available to be studied prior to entry to university, as well as an introduction to the regulatory authorities and examining bodies associated with such qualifications. Following this a brief overview of developments in mathematics courses was given. There it was highlighted that there have been several major changes over the last 20 years to both the content and structure of pre-university mathematics courses.

A review of the uptake of A-level Mathematics was then detailed. It was seen that in the last 20 years there has been a substantial reduction in the numbers studying the subject. Explanations for the exceptionally large reduction in numbers in 2002 were also given, these included issues with the number of examinations and the way the A-level course had to be structured, i.e. three modules in the first year and three in the second year. In addition, specific issues that could affect the uptake of A-level
Mathematics were outlined and these included problems with the image of mathematics and a shortage of qualified mathematics teachers to name but two. Universities' reliance on such qualifications were also given.

The recent changes that took place in A-level Mathematics courses were outlined. These focused upon Curriculum 2000 changes and those that followed in September 2004. In addition, the positive changes to Further Mathematics, including the change in specification and the formation of a national Further Mathematics Network were discussed.

Finally, the relevance of mechanics in the schools' curriculum was detailed. This included the many benefits, especially for prospective engineering students, as well as to others, of having studied mechanics prior to entering university.

Hence, this chapter has stood to give an insight into the many developments and associated issues surrounding pre-university mathematics courses, which are obviously of great importance to universities. Furthermore focus was given to the position of mechanics within such courses.
3. Research Methods

3.1. Introduction

All research projects are underpinned by the research methods used within them. Consequently, it is fundamental that a researcher has an understanding of both the research methods that could be used and of those actually used in a project. This chapter acts as an introduction to some of the general research methods used in educational research projects.

Within this chapter an overview of educational research methods and research design will be introduced. A discussion on the categories of quantitative and qualitative research methods will then be given. The notion of sampling will then be examined. Following this some specific research methods, those of questionnaires and interviews, the main methods used in this thesis, are reviewed. Also some other methods, namely focus groups and case studies, are reviewed. Ethical issues, particularly with respect to the two principal research methods used (questionnaires and interviews) are then discussed, before a summary of the chapter is given.

3.2. Educational Research Methods

Wiersma (1991: 2) stated that "Research is essentially an activity, or process, and certain characteristics help define its nature." The general characteristics indicated were that research is empirical, research can take a variety of forms and that it should be valid, reliable and systematic. This indicates the imprecise manner in which research is often described. Further investigation of the literature gives insight into an overview of techniques that could be used for a given research project.

In the framework of planning and conducting research, although many types of guidelines exist and need to be adhered to, for example ethical issues, Cohen et al (2000: 73) stated that:
There is no single blueprint for planning research. Research design is governed by the notion of 'fitness for purpose'. The purposes of the research determine the methodology and design of the research.

This highlights that the development of appropriate research methodologies for a given research project is motivated by its rationale. It follows that different components of a research project could involve different research methods as appropriate for the objective of a given component. For example, in this thesis (section 7.2), an online questionnaire is used to gather data from a large group of academics, but in section 7.3, interviews are used to focus on responses from a small number of academics.

Focussing specifically on research methodology in the context of educational research, Cohen et al (2000: 44) stated that:

By research methods we mean that range of approaches used in educational research to gather data which are to be used as a basis for inference and interpretation, for explanation and prediction.

This description encapsulates the use of research methods that are depicted in this research project; that is to say various methodologies are used to gain an indication of the repercussions in higher education of the changes in the teaching and learning of mechanics in schools in England. In this thesis the research methods of questionnaires, interviews and testing are used, but others such as focus groups and case studies, to name but two can be used. An expanded list of research methods can be seen in Cohen et al (2000: 77).

There are obviously many different research methods available to be used in a project, but it is important to identify the different components. That is to say that a given instrument, i.e. interview, questionnaire, test, should be used for some given research.

Considering further the notion of research design, which underpins any research project, Cohen et al (2000: 38) described the need to address principles of research design, including:
(i) Formulating operational questions
(ii) Deciding appropriate methodologies
(iii) Deciding which instruments to use for the data collection
(iv) Addressing reliability and validity in the investigation and instrumentation
(v) Addressing ethical issues in conducting the investigation
(vi) Deciding on the sample for the investigation
(vii) Deciding on data analysis techniques
(viii) Deciding on reporting and interpretation of results.

This encapsulates many ideas, each of which will require a judgement from the researcher(s) in their research project. Many of these ideas will be discussed further in this chapter.

3.3. Quantitative and Qualitative Research Methods

Wiersma (1991: 3) stated that "Educational research is quantitative and qualitative and can take on any number of specific forms depending on the phenomenon under investigation." This reiterates the idea of fitness for purpose; is a quantitative method suitable or is a qualitative method more suitable? In reality as discussed by Wiersma (1991: 15) "Qualitative and quantitative research (methods) have their own characteristics, but as applied to educational research the distinction is more on a continuum than a dichotomy." Thus, indicating that a given research method is likely to contain elements of both qualitative and quantitative nature and not exclusively one.

Probing further the idea of research design, Wiersma (1991: 96) detailed that:

In qualitative research, design is more flexible and to some extent emerges as the research is conducted. Quantitative research typically has a more structured design from the outset and there is little, if any, deviation from the design during the study.

An example of a qualitative research method would be an interview and an example of a quantitative research method would be a multiple-choice questionnaire. However,
as just stated both of these examples are likely to contain at least some elements of both quantitative and qualitative nature, i.e. not exclusively at either end of the qualitative-quantitative continuum.

The transient nature of qualitative research as something that evolves was highlighted by Hatch (2002: 20):

It could be said that there are as many kinds of qualitative research as there are qualitative researchers. Each qualitative study has its own unique character that develops and often changes as studies are implemented.

That is not to say that a quantitative method cannot evolve. For example, an interview (qualitative) could be modified, from a scheduled outline, during the interview whereas a questionnaire (quantitative) once administered cannot be changed, but a subsequent re-administration could be modified and improved upon.

Considering the type of data that is collected from quantitative and qualitative research, Wiersma (1991: 14) stated that "Quantitative research relies heavily on statistical results represented with numbers; qualitative research relies heavily on narrative description." This collection of data obviously impacts upon both the storage and analysis of the information. Specifics of this will be detailed later, with respect to given research methods, i.e. questionnaire (3.5.2) and interviews (3.5.3). However, in general as stated by Hatch (2002: 147), "(qualitative) Data analysis is portrayed as messy, cumbersome, inductive, creative, challenging, subjective, non-linear, labour-intensive, exhilarating, and time-consuming." Wiersma (1991: 85) denoted that "Qualitative data analysis requires organization of information and data reduction." Thus, as will be seen later (when considering interviews), an important part of qualitative research is the collection, encoding and storage of data prior to being able to complete suitable analysis.

The situation with regard to analysis, specifically of qualitative data, is depicted by Hatch (2002: 149):
It is not an exaggeration to say that no qualitative analysis is ever complete. There are always more data than can be adequately processed, more levels of understanding than can be explored, and more stories than can be told. Data analysis is like teaching - there is always more you could do. Knowing when to stop data analysis is a judgement call that can be as perplexing as deciding how to start.

Thus, there is an obvious inherent level of complexity with analysing qualitative data, which should not be underestimated.

There can be a plethora of reasons for conducting research and there is usually a specific reason why a particular research method would be used, i.e. Wiersma (1991: 14), "Quantitative research is done to determine relationships, effect, and causes." Or Bell (1999: 13) "The aim of a survey is to obtain information which can be analysed and patterns extracted and comparisons made" which would likely be predominantly quantitative. In general, Ebel and Fnsbie (1991: 23) stated "The purpose of evaluation is to make a judgement about the quality or worth of something."

Thus, an introduction to the concepts of quantitative and qualitative research has been given. This will now be built upon by considering the issue of sampling.

3.4. Sampling

Cohen et al (2000: 92) stated that "The quality of a piece of research not only stands or falls by the appropriateness of methodology and instrumentation but also by the suitability of the sampling strategy that has been adopted." This clearly highlights the importance of sampling and indicates the need to give careful consideration to it.

There are many issues that arise when discussing sampling, two of the most prevalent are:

i. Establishing a representative sample from the total population
ii. Determining the size and selection of the sample

In a research project it is important to consider both of these points. However, it is obviously essential to contextualise each, as stated by Bell (1999: 126):
In very large surveys, like the census, sampling techniques will be employed to produce a sample which is, as far as possible, representative of the population as a whole... it will probably be difficult for an individual researcher working on a small-scale project to achieve a true random sample... However, even in a small study, efforts should be made to select as representative a sample as possible.

Thus, although every effort should be made to construct a representative sample, the limitations of a given research project should be recognised. This matter can also impose restrictions on the second point, primarily determining the size of the sample

As stated by Cohen et al (2000: 93):

A question that often plagues novice researchers is just how large their samples for the research should be. There is no clear-cut answer, for the correct sample size depends on the purpose of the study and the nature of the population under scrutiny.

For example, if surveying a group of 150 students, as in Chapter 5, all students would be asked to complete it and thus the sample would be the total population. Whereas, if a survey was to be conducted on schools teaching A-levels, as in Chapter 4, a sample of 500 from a population of over 2700 would be suitable (as will be justified later).

There are two outlining types of sampling, described as probability sampling (e.g. simple random sampling, systematic sampling, stratified sampling, cluster sampling, stage sampling and multi-purpose sampling) and non-probability sampling (e.g. convenience sampling, quota sampling, purposive sampling, dimensional sampling and snowball sampling), see for example Cohen et al (2000: 99-104), Wiersma (1991: 247-269) for further information.

Within probability sampling each member of the population has a known non-zero probability of being selected, whereas in non-probability sampling members are selected in some non-random way. The primary advantage of probability sampling is that the sampling error can be calculated. Although, Cohen et al (2000 96) noted that
"Sampling error is not necessarily the result of mistakes made in sampling procedures. Rather, variations may occur due to the chance selection of different individuals."

Although, as previously mentioned, it is often difficult to provide a specific value for the size of a given sample, Krejcie and Morgan (1970: 610) produced a table (see Table 3.1), which used mathematical techniques to compute values for the size of a random sample, n, that should be taken from a given population size, N. For example, for a population of 200 a random sample of 132 should be taken, conversely for a population of 2000 a random sample of 322 should be taken. This is for a sample with a 95% confidence error, i.e. 5% sampling error. It is key to note that these values are for a random sample and in reality very few samples are actually truly random.

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<td>750 - 254</td>
<td>2600 - 335</td>
<td>100000 - 384</td>
</tr>
</tbody>
</table>

Table 3.1 – Sample size required from population

From Table 3.1 it can be seen that the smaller the population size, the larger the percentage from such a population needs to be taken. Krejcie and Morgan (1970: 610) noted "As the population increases the sample size increases at a diminishing rate and remains constant at slightly more than 380 cases."
In this section an overview of sampling has been discussed. A synopsis on sampling as given by Cohen et al (2000: 104) was:

Every element of the research should not be arbitrary but planned and deliberate, and that, as before, the criterion of planning must be fitness for purpose. The selection of a sampling strategy must be governed by the criterion of suitability. The choice of which strategy to adopt must be mindful of the purposes of the research, the time scales and constraints on the research, the methods of data collection, and the methodology of the research.

Thus highlights prevalent points and reiterates the need to relate a sampling strategy to the criterion of a given research project. For example, as will be seen in Chapter 7, an online questionnaire was produced and an email forwarded to a large number of academics and support staff on a relevant mailing list, so as to obtain as good a response rate as possible, in a short time period and for little cost.

3.5. Specific Methodologies

Within this chapter various concepts concerning research methodologies have been discussed. These included qualitative and quantitative research methods and sampling. Within this section the specific research methods of questionnaires and interviews, will be discussed further. These are the primary research methods that are used in this thesis. It should be noted that discussion of the precise detail, such as the piloting strategy for a given questionnaire, will be given in the applicable chapter and not in the following section.

3.5.1. Questionnaires

Within many fields of research a tool that continues to be both appropriate and valuable is that of a questionnaire. It has vast applications, primarily due to the versatility and adaptability available in its design. The widespread use of questionnaires is somewhat reflected in the large amount of literature on the subject, as stated by Bell (1999. 133) "Most books dealing with research methods will have a chapter on the design of questionnaires."
Within questionnaire design there is a great deal of flexibility available. Hence, it is inherently difficult to say what works best for a given situation, as several good options may be possible. Therefore, it is perhaps more beneficial to give consideration to certain areas, which can then be duly applied in a given research project.

Within this subsection a number of areas, concerned with questionnaires will be discussed, these include:

i. Question wording
ii. Types of questions
iii. Layout
iv. Administration procedures and analysing the data

\textit{i Question wording}

Firstly, considering the question wording, Bell (1999: 121-124), highlighted several different styles that should be avoided:

- Hypothetical questions, e.g. If you fail your first year mechanics module, will this be down to your prior knowledge upon entry to university?
- Double questions, e.g. Do you go to mathematics and mechanics lectures?
- Leading questions, e.g. Do you agree that all students should be able to obtain mathematics support?
- Presuming questions, e.g. Does the university make adequate provision for mathematics support?

There can also be issues with the way that questions are asked and the responses that they require. These can include:

- Ambiguity, imprecision and assumption
- Memory
- Knowledge
- Offensive and sensitive questions
These all involve how the question is worded so that a response, which is a true reflection of a participant's actual thoughts, can be obtained. The first group of four points are self-explanatory in their meaning, from the exemplar questions. However, the second group of four are not so obvious and so shall be discussed further.

The need to eliminate ambiguity, imprecision and assumption in questions as far as possible is self-evident but it can be somewhat difficult at times to be aware that this type of error has occurred. One such example that highlights this is when a question asks for a quantitative answer that is open to one's own interpretation. For example, 'How often do you attend tutorials? Always, Often, Not often, Never.' This is very much dependent on what the individual regards as often. If tutorials are held every week, is often once every two weeks, once every three weeks? In such a case the participant may feel either confused and miss the question or put in an answer given from their own interpretation. In both cases this is not the desired outcome for the researcher. Hence, if an answer is given then the researcher may take everyone's interpretation to mean the same thing, which is unlikely to be the case.

Issues with regard to memory can play an important role in how good the gathered information is. The concern here is with respect to what constitutes an appropriate time scale to recall information. For example, a 17 year old may easily recall exam results that they obtained when they were 16, but someone who did the exams twenty years previous may not find it as easy. Conversely, it may be difficult for many people to recall what they ate only one week ago. Therefore, it is obvious from these two examples that care needs to be given in allowing for questions to be asked on relevant and appropriate time scales.

Another factor that may be important in obtaining representative answers is respondent's knowledge. There is a need to give attention to questions that require the respondent to complete something that they may need to do further work to get information on. For example, if you asked how many people used the library in a given time scale, then an individual is unlikely to know this information and it may take a substantial amount of effort to acquire such data. In this type of situation the individual may skip the question thinking they will come back to it later and yet they may not. If this is a common theme throughout a questionnaire, it may be found that
there are several gaps or that the respondent may just leave the whole thing. Again this is not a desirable outcome for the researcher.

It is obvious that offensive questions should not be used unless absolutely crucial to a study. Also extra care and attention needs to be given when sensitive questions must be asked. This is relevant to many topics, some which may seem as trivial as age, to stronger issues like social behaviour. A useful approach to these questions is to review such questions as if you were the respondent, so that it can be understood what is expected of a participant. This is not only useful for sensitive questions but also for the questionnaire as a whole.

**ii Types of Question**

The wording of questions is important but also of significance are the two interlinked areas of question types and layout of the questionnaire. The question type for instance will have a bearing on how the questionnaire can be laid out as certain types have restrictions or work best when done in specific ways. For example, the Likert scale, which presents a set of attitude statements, is used to ask subjects to express their agreement or disagreement on a five-point scale, see web reference [8]. Common question types found in questionnaires include:

- Multiple-choice questions
- Dichotomous questions, e.g. Yes/No, Male/Female
- Rank ordering, e.g. (a, b, c) may be ranked 1-b, 2-a, 3-c
- Rating scales; e.g. 1, 2, 3, 4, 5

As expected there is a great deal of information available in this area and so further investigation as to the relative merits of each should be sought before one is chosen. For example, Ebel and Frisbie (1991: 154-179) detail a chapter on multiple-choice questions.

Bell (1999: 120) commented that it is expected that once researchers are familiar with each of these styles then they should easily be able to select and use whichever is appropriate for the given research project.
Another classification of question type is whether a question is open or closed. Again the relative merits of each are very much dependent on the type of research being carried out. It was suggested by Cohen et al (2000: 247), that:

The larger the size of the sample, the more structured, closed and numerical the questionnaire may have to be, and the smaller the size of the sample, the less structured, more open and word-based the questionnaire may be.

That is to say for a small sample size, a questionnaire that has lots of open-ended questions is feasible because it would be possible to conduct qualitative analysis on a small sample. However, for larger samples qualitative analysis becomes increasingly more difficult and time consuming and so more quantitative orientated questions are generally appropriate.

iii Layout of the questionnaire

A key element of a questionnaire is its appearance. In essence it does not matter how good the questions are if the questionnaire looks uninviting, boring and difficult, as a good response-rate is less likely. Therefore, it is critical that significant effort and consideration is given to the layout. However, this is often one of the most difficult areas to get right, as a layout that looks good to one person may not necessarily look good to another person. This is one reason why it is key to pilot a questionnaire (as discussed shortly in iv Administration procedures)

Connected to the layout of a questionnaire is how it is structured. A common sequence of a questionnaire as suggested by Cohen et al (2000: 257) is:

i. To commence with unthreatening factual questions;
ii. To move to closed questions about given statements or questions, eliciting responses that require opinions, attitudes, perceptions, and views;
iii. To move to more open-ended questions that seek responses on opinions, attitudes, perceptions, and views together with reasons for these responses.
Although this does portray a rather simplistic model, in reality there will be many factors that will impinge on this.

*iv Administration procedures and analysing the data*

There are many key points to acquiring and analysing data successfully. These include:

- Planning, i.e. procedure for distribution, sorting and recording
- Cover letters and follow-up letters (for subsequent administrations)
- Piloting
- Data collection, storage and analysis

The first of these points can sometimes be overlooked or somewhat rushed in order that a questionnaire can be sent out and subsequently returned as quickly as possible. However it must be pointed out that the planning stage is perhaps the most important because it is at this stage that the structure of both the questionnaire and its distribution should be in place, along with plans for any problems that may arise, such as a low return rate.

When using a questionnaire, it is vital that both the timing and medium for administration are considered. For example, issues may arise if a questionnaire is mailed out in mid-December when there is obviously a considerable amount of Christmas mail in the postal system. However, if a questionnaire was to be given to a group of students then administrating it by hand in mid-December may be appropriate to get information before they leave for their Christmas break.

Also concerned within the administration process are cost issues. It is vital that this component of the project is considered at the beginning of the process. Again, it is very much dependent on an individual research project as to which process and the associated cost could and should be used. For example, the costs of administrating and mailing a questionnaire, as used in Chapter 4, were significantly more than setting-up an online questionnaire, which respondents can log onto and complete, as used in Chapter 7 (although if expertise in creating online questionnaires was not
freely available this may be a significant cost). One reason why, in Chapter 4, a mailed questionnaire was chosen in preference to an online questionnaire was because a suitable list of contact email addresses for schools was not readily available.

With reference to the second point, cover and follow-up letters, again there are several texts that provide a useful list of things that should or should not be included, e.g. Streiner and Norman (1995: 153) and Wiersma (1991: 178-179). Cohen et al (2000: 249), detailed how effective follow-up letters can be:

The Government Social Survey (now the Office of Population Censuses and Surveys) recommends the use of three reminders which, they say, can increase the original return by as much as 30 per cent in surveys of the general public.

The third point, piloting, is very important and is one that should not be dismissed or rushed. It is significantly easier to change the wording of a questionnaire if only a small sample has been sent (the sample here is referring to the number of questionnaires used in the pilot) as opposed to several hundred. Furthermore, as stated by Oppenheim, (1992: 48) "A pilot has several functions, principally to increase the reliability, validity and practicability of the questionnaire." A feature that is paramount to the pilot stage is that everything should be as it will be in the finished product, i.e. this includes such particulars as paper type, question wording and accompanying letter.

The fourth point concerned data collection, storage and analysis. In questionnaires there will generally be a mixture of question types, as discussed earlier. This will mean that different types of data will have been collected and stored. It is critical that due care and attention is given to how this data is stored so that subsequent analysis can be completed. Furthermore, the concept of having data in appropriate form to analyse relates right back to the construction of the questionnaire. For example, it is often important to consider what type of analysis is to be conducted so that appropriate questions (and their structure) can be created.

Simple numerical data collected for quantitative analysis is considerably easier to store and review than passages of data, on which qualitative data analysis could be
conducted. As discussed in 3.3, there are inherent difficulties when conducting qualitative analysis. When conducting qualitative analysis Hatch (2002: 181) advises, "read the data for a sense of the whole." For instance it is pointless transcribing every qualitative comment received in a questionnaire if there are one or two common themes in the replies, as this would be inefficient.

The analysis that is conducted on the data collected can vary tremendously, but will be intrinsically related to the desired outcome of the research, which obviously differs for each project conducted. Within quantitative analysis there is invariably the opportunity to conduct statistical analysis and the literature on conducting such is vast; see for example Mosteller and Tukey, (1977), Streiner and Norman (1995) and Rawlings (1988) In addition, literature is available on qualitative analysis; see for example Hatch (2002). Analysis conducted on the research methods carried out in this thesis will be given in detail in the appropriate chapters.

Within this subsection an overview of several key areas concerning the research method of a questionnaire have been outlined. This focussed on topics such as the question wording, the types of questions, the layout and the administration procedures and analysis. In this thesis a number of questionnaires have been produced. This review of the methodology of questionnaires, in all but one case (the reason which is explained in the relevant text, 4.2), informed the process in each.

### 3.5.2. Interviews

Another method that is commonly used when conducting educational research is an interview. Within this project interviews were used in two separate cases, although both were on a small scale (eight participants or less). As with the research method of a questionnaire there is a large amount of literature on conducting interviews, e.g. Hatch (2002: 91-116), Cohen et al (2000: 266-292), Bell (1999: 135-146) and Wiersma (1991: 190-196).

It is useful to consider the different aspects of interviews and within this section the following will be discussed:
1. Reasons for using interviews

ii. Types of interviews

iii. Administration procedures

iv. Transcribing and analysing

**i Reasons for using interviews**

As described by Cohen et al (2000:267) an interview is "An exchange of views between two or more people on a topic of mutual interest." This highlights one of the main reasons for conducting interviews; the opportunity to have a discussion about a topic of interest (certainly to the researcher and most likely to the participant too). The adaptability of 'a discussion' is one of the primary reasons why interviews are used as a research tool

Many of the advantages of an interview, particularly over a questionnaire, were highlighted by Bell (1999: 135):

> A skilful interviewer can follow up ideas, probe responses and investigate motives and feeling, which the questionnaire can never do... Questionnaire responses have to be taken at face value, but a response in an interview can be developed and clarified

It is worthwhile re-iterating that interviewing is a 'skill' and some researchers are more confident in conducting them than others. An option available is to employ a trained interviewer or interviewers. This may be a desirable option if a researcher is extremely busy or inexperienced. However, the factor of cost would also play a part if such an exercise were an option. This highlights one of the negative aspects, that of cost, as noted by Wiersma (1981: 190), "Interviews are costly in terms of time and effort." Indeed, the quantity of work involved in conducting an interview, not to mention a series of interviews is vast. The effort required to complete administration procedures and then transcribe and analyse interviews will be discussed shortly.

Another possible negative aspect to interviews is the aspect of bias. There may be several ways in which this could happen, Borg (1981: 87) detailed that:
Eagerness of the respondent to please the interviewer, a vague antagonism that sometimes arises between interviewer and respondent, or the tendency of the interviewer to seek out the answers that support his preconceived notions are but a few of the factors that may contribute to blasing of data obtained from the interview. These factors are called *response effect* by survey researchers.

However, the apparent difficulties with respect to bias mean that, as stated by Bell (1999: 129) "It is easier to acknowledge the fact that bias can creep in than to eliminate it altogether." Thus, the decision to use an interview has to be very much aligned to the goals of the research.

**ii Types of interviews**

Once it has been decided that an interview is the most appropriate research method it needs to be established what type and structure should be used. Options can include one to one interviews, telephone interviews or group interviews. With respect to the structure, very much like the qualitative-quantitative continuum described earlier, a continuum can be constructed, with structured interviews at one end and unstructured interviews at the other. Structured interviews follow a pre-determined list of questions as rigidly as possible and are particularly useful for use by inexperienced interviewers. Unstructured interviews are exactly as the name suggests and as Bell (1999: 138) advocates:

Unstructured interviews centred around a topic may, and in skilled hands do, produce a wealth of valuable data, but such interviews require a great deal of expertise to control and a great deal of time to analyse.

The use of one type over another and of one structure over another is very much dependent on the research project and the objectives for which the method is being used.
iii Administration procedures

As already hinted at, when using interviews as a research method there are many issues which need to be considered. Bell (1999: 143) gave a checklist for conducting interviews as well as 'a few words of warning'. These included:

Interviews are very time-consuming. If you allow one hour for the actual interview, there is also travelling time and time lost through any one of numerous mishaps. Your original project plan should take account of the time required for planning and conducting interviews, for coping with cancelled arrangements, second visits and finding replacements for people who drop out.

This gives a good overview of the issues inherent with interviews. It therefore stands to reason that adequate administration procedures need to be in place.

Hatch (2002: 115) gave a summary of tips for successful interviews, which incorporated details of administration procedures. These included:

- Follow the rules of polite conversation
- Interview in a comfortable place
- Plan well before the interview begins
- Learn how to listen
- Explore informants' understandings
- Invite informants to help you be a better researcher by giving feedback.
- Transcribe your interviews right away

These points re-iterate how valuable it is to be organised and to have planned the administration of interviews. The final point regarding transcribing the interviews will now be discussed further.

vi Transcribing and analysing

In essence the transcribing of interviews is a vital component of the overall interviewing procedure. If the events and discussions that occurred in the interviews
are not appropriately recorded then there will be difficulty in producing analysis. It is very much dependent on the type and structure of the interviews as to how best to transcribe them. In a very structured interview there may be a considerable amount of numerical data, whereas in an unstructured interview there may be scattered written notes. However, if possible and where appropriate, technology can be used to good effect.

Technology such as video recorders or voice recorders can be used to capture all the discussion (as well as body language if using a video camera) from an interview. This can then be reviewed post-interview and used for transcribing purposes. However, there is always difficulty when transferring information from one media to another. For example, when taking information from a recording device (be it video or voice) and transcribing to written text, in many cases there will be a reduction in data, as noted by Cohen et al (2000: 282): "We are not arguing against transcriptions, rather, we are cautioning against the researcher believing that they tell everything that took place in the interview." Both computer hardware and software is continually being developed which can be used to aid the data collection and analysis process. Examples include software such as Nvivo or ATLAS/ti, designed specifically for qualitative analysis, as well as hardware that transcribes spoken English directly into text in a piece of software. But, even if every word from an interview was taken and put in written form, in the analysing stage much of the detail will be lost. Cohen et al (2000: 282) noted that:

In qualitative data the data analysis here is almost always inevitably interpretive, hence the data analysis is a less completely accurate representation (as in numerical, positivist tradition) but more of a reflexive, reactive interaction between the researcher and the decontextualised data that are already interpretations of a social encounter.

Consequently, the limitations of compiling detailed analysis from interviews should be noted. However, the enhancement an interview can have to a researcher's understanding of a given phenomenon should not be undervalued. Within a single interview, a single idea could be discussed which may inspire a new project.
3.5.3. Other Related Methods

Within this section there has been discussion of two primary research methods, questionnaires and interviews. Encapsulated in the discussion were mailed questionnaires, online questionnaires and individual interviews. An additional research method, focus groups, which are inherently related to group interviews, will also now be commented upon as a useful research method.

i Focus groups

Hatch (2002: 132) detailed that "focus groups are more than just interviewers asking questions of informants in a group setting. Focus group interviews rely on the interactions that take place among participants in the group to generate data." Indeed there is a considerable amount of literature on the subject, see Berg (1998) and Morgan (1997).

It was highlighted that focus groups (Krueger, (1994), Morgan, (1997)) are useful for:

- Orientation to a particular field of focus
- Generating hypotheses that derive from the insights and data from the group
- Generating and evaluating data from different sub-groups of a population
- Gathering feedback from previous studies
- Developing themes, topics, and schedules for subsequent interviews and/or questionnaires

This final bullet point is one that is particularly relevant in an educational context, as noted by Hatch (2002: 131):

While it is possible to apply focus group methods developed in sociology and marketing to self-contained studies in education settings, many qualitative researchers adopt focus group techniques as supplemental sources of data

This comment that focus groups have been used predominantly as a secondary source of information (in an educational context) for example, as supplementary to a
questionnaire, does not mean that they cannot be used as a sole primary source of analysis. Cohen et al (2000: 288) noted that "the use of focus groups is growing in educational research, albeit more slowly than, for instance, in business and political circles."

Within this research study focus groups were not used. As previously mentioned there were two instances where individual interviews were used. In one case somewhat sensitive data on individual's backgrounds were discussed and in a focus group situation this may have affected the replies from the participants (see 5.6). In the second instance it would have been extremely difficult to gather the participants together in one place at one time (or all available at one time where the possibility of a video conference could have taken place), (see 7 3) in order to conduct a focus group.

**ii Case studies**

A further research method that is commonly used in educational research is a case study. A case study is defined in the Oxford English Dictionary as "a detailed study of the development of a particular person, group, or situation over a period of time." However, within the context of research as noted by Hatch (2002: 31), "Case study is a term that has become a catch-all for identifying qualitative studies of various types."

Many methods can be and are used within the context of a case study, e.g. a questionnaire followed by a series of interviews or meetings, see for example Cohen et al (2000: 181-190). It is more the act of conducting a detailed study on, for example, an individual, than what specific methods are used. Therefore, it is clear that a thorough understanding of a given individual can be obtained through conducting a case study. Thus, it stands to reason that if within a research project such information needed to be obtained, then conducting a case study would be valuable to the research. Within the context of this research study no case studies were conducted because one of the primary objectives was to gain a picture of the whole, rather than to follow individuals. However, as an extension to the research and findings in this research study, the tracking of individuals could be worthwhile.
3.6. Ethical Issues

In the context of educational research, as in any other discipline, there is the requirement for a researcher to be ethical and adhere to ethical guidelines. The literature on the subject is vast. Within research methods books it is usual to find a chapter or considerable passages on ethics, e.g. Cohen et al (2000), Bell (1999) and Hart and Bond (1995). Here, it is appropriate to consider ethical issues in the two key research methods used, that of questionnaires and interviews. Such discussion now follows.

i Questionnaires

There are inherently ethical issues surrounding the implementation of a questionnaire. As suggested by Cohen et al (2000: 246):

The questionnaire will always be an intrusion into the life of the respondent, be it in terms of time taken to complete the questionnaire, the level of threat or sensitivity of the questions, or the possible invasion of privacy.

This gives an insight into some of the ethical issues that can be faced when conducting a questionnaire. Several ethical issues emerge when considering the administration procedure of a questionnaire. Depending on the situation, informed consent may be required preceding administration, e.g. if administering a questionnaire to university students in another university or department then consent is required from the staff, department and university before even being able to administrate the questionnaire to the students. This protocol is fundamental in allowing the research to be carried out.

In the example given, there is also a secondary requirement for consent, from the students themselves. Once access has been granted, students need to be made fully aware of what participation in the research would entail, as well as making clear their right not to participate. Invariably, in such situations it is the responsibility of the researcher to highlight both the benefits of the research, i.e. for the participants and for others, as well as the possible negative aspects, i.e. that participants may need to
give personal information. Moreover, such guarantees as to confidentiality, anonymity and non-traceability are essential and can be an important factor in the mind of a possible participant, when considering whether they wish to participate in the research.

Cohen et al (2000: 246) commented that:

Respondents cannot be coerced into completing a questionnaire. They might be strongly encouraged, but the decision whether to become involved and when to withdraw from the research is entirely theirs.

In a situation where a questionnaire is sent unsolicited, a covering letter is usually used to explain such ethical practice. Furthermore, when a participant from such a survey replies, the researcher can only assume that the participant has understood and has given their consent to be part of the study.

Some of the outlying ethical issues when administering a questionnaire have been discussed, but it is also a factor when designing a questionnaire. For example, concern over intrusive or sensitive questions. Consideration of the reaction that a participant could feel from completing a questionnaire with such questions in should be examined at an early stage and could be picked up by obtaining comprehensive feedback from those who complete a pilot.

*ii Interviews*

Many of the ethical issues discussed with respect to questionnaires apply when conducting interviews, e.g. guarantees as to confidentiality, anonymity and non-traceability. However, the intrusive nature of interviews, particularly the interpersonal interaction in face-to-face interviews, means that serious consideration has to be given to ethics.

Cohen et al (2000: 292) indicated that:
It is difficult to lay down hard and fast ethical rules, as, by definition, ethical matters are contestable. Nevertheless, it is possible to raise some ethical questions to which answers need to be given before the interviews commence.

Following this a list of 17 questions, such as "What has been done to ensure that the interview is conducted in an appropriate, non-stressful, non-threatening manner?" are outlined. It was re-iterated that the list was not exhaustive, but gave an indication of the issues that should be reviewed before carrying out any interviews.

Finally, a very important point was raised by Bell (1999: 145), "Don't queer the pitch for other researchers by disenchanting respondents with the whole notion of research participation." That is to say the researcher should not think solely about a respondent's participation in a current project, but also consider the wider implications of how the work conducted could affect involvement of the participant in future research (not necessarily by the same researcher).

3.7. Summary

Within this chapter an overview of educational research methods has been given. It was seen that the idea of research and specifically research design is governed by the nature of a given project and the ensuing requirement of 'fitness for purpose'.

A discussion on the wide-ranging categories of quantitative and qualitative research methods was also given. This considered quantitative and qualitative methods on a continuum, as well as introducing the types of methods and analysis appropriate for each. It was established that quantitative and qualitative research methods are of particular use in given circumstances, i.e. quantitative in large scale numerical data gathering and qualitative in more small scale narrative data gathering. Furthermore, the difficulties that are often experienced with analysing qualitative data were highlighted, that is to say the often large amounts of narrative data obtained.

A short discussion was held on sampling, including establishing a representative sample from the total population and determining the size and selection of the sample. Once again it was highlighted that the situation for a given research project plays a
fundamental part in what is appropriate and suitable in terms of the selection of a sample.

Thereafter followed an overview of two of the most frequently used research methods, questionnaires and interviews. A considerable amount of discussion was given into the specifics of these methods, including discussion of the structure and administration procedures as well as data collection and analysis thereof. Two other research methods were described, that of focus groups and case studies. These illustrated methods that are continually being used more often in educational research.

The two methods of questionnaires and interviews were focal to the collection of appropriate data within this project. Before using a specific method it was key to ask the question - 'is this the best method of obtaining the information for this component of this project?' As mentioned previously it is usually the case that a variety of methods are suitable to collect some given data and inevitably a combination of methods can prove to be the best solution.

Finally the issues surrounding ethics, particularly with respect to the two principal research methods used (questionnaires and interviews) were discussed. Here awareness of such protocol was shown.

Hence, within this chapter an overview of research methodology in an educational context has been given. This has stood to inform the use of appropriate methods within this thesis, with the chapters following this reporting on the implementation of such methods.
4. Schools' Perspective

4.1. Introduction

In order to establish the repercussions in higher education of the changes in the teaching and learning of mechanics in schools, it is essential that an understanding of recent and current trends in schools are reviewed and then placed in context with what is happening in universities.

Through anecdotal evidence it had become apparent that some students, who were seeking help with mechanics in the MLSC at Loughborough University, had been unable to study mechanics within A-level Mathematics at school or were advised against it. Students offered different reasons for this and therefore in order to gain a better understanding of why students were or were not offered mechanics modules in A-level Mathematics courses in schools or why students chose not to study mechanics modules, a study of the availability and uptake of mechanics modules (in schools) was conducted. This is reviewed in this chapter.

The construction, trialling and administration of a questionnaire, which was posted to 500 schools in January 2004 is described. Detailed analysis of the questionnaire replies is undertaken. However, as seen in Chapter 2, there were changes to the structure of A-level Mathematics in September 2004. Therefore, the questionnaire was modified and administrated in January 2006 to assess what effect the September 2004 changes had had, on the availability and uptake of mechanics modules in schools. Comparisons are made between the results obtained in 2004 and 2006. The implications from the findings of these two questionnaires are also given.

4.2. 2004 Schools Questionnaire

A questionnaire was chosen over other research methods to collect the required data, as it was most appropriate to obtain the information required from a large number of schools. A questionnaire would be more economic than telephoning schools or conducting interviews. It is imperative that due care and attention is given to both the
construction and administration of questionnaires, as discussed in Chapter 3 on research methods. In this section these procedures will be considered and reviewed in the context of the questionnaire(s) produced.

4.2.1. Questionnaire Construction

A short questionnaire that was both easy and quick to complete was produced (see Appendix C for the final version of the 2004 questionnaire) in the hope that as many recipients as possible would complete and return it. The questionnaire was two pages in length, i.e. one double-sided A4 sheet, and consisted mainly of boxes to be ticked or for numbers to be inserted into boxes. There were also some open parts to questions that allowed for comments and written responses, where appropriate. It would have been possible to create a questionnaire that was longer and contained more questions, however, good practice recommends, e.g. Bell (1999) that producing a questionnaire which gathered all the required data with as few questions as possible would be most effective.

During its construction the questionnaire was produced to adhere to ethical guidelines, such as the requirement of consent. Here, if teachers returned the questionnaire then this would indicate that they would be giving their consent to use the information they provided. Guarantees of confidentiality, anonymity and non-traceability were given in the accompanying letter (which can be seen in Appendix D), in order to both reassure teachers and encourage them to participate.

4.2.2. Questionnaire Administration

Here three elements are considered:

1) The sample selection
2) The piloting scheme
3) The time and cost of administration
i) The Sample Selection

An important task was to obtain a representative selection of schools to mail the questionnaire to.

Throughout England there are some 2717 'schools' that teach A-levels (this is any A-level and would not necessarily include A-level Mathematics). These schools are detailed in the education tables on the BBC News website (www.bbc.co.uk/news). Each school can be found under its relevant Local Education Authority (LEA), with there being 149 LEAs in total. In England there are six types of LEA, which are (including the number of LEAs and schools in each type):

- Administrative Counties (34 LEAs, 1411 schools)
- Unitary Authorities - Administrative Counties (40 LEAs, 344 schools)
- Unitary Authorities - Metropolitan District (36 LEAs, 511 schools)
- Unitary Authorities - Non-Metropolitan Authorities (6 LEAs, 73 schools)
- London - Inner (14 LEAs, 108 schools)
- London - Outer (19 LEAs, 270 schools)

A selection of 500 schools, i.e. 18% of the total number of schools in England teaching A-levels, was taken to be the sample. This offered a good compromise between the need to have a reasonable sample size for subsequent statistical analysis and to keep the administration time and costs to a reasonable level.

In order to keep the sample representative of the total (schools) population a proportion of schools for each type of LEA was taken. So, for instance the number of schools that were taken from the Administrative Counties' group was calculated as:

$$500 \times \frac{1411}{2717} = 260 \text{ schools}$$

A cyclic pattern of the LEAs within a LEA type was then taken. The same cyclic method of selection was applied to each of the other groups.
<table>
<thead>
<tr>
<th>LEA Type</th>
<th>No of Schools Required</th>
<th>No of LEAs Taken</th>
<th>No of Schools Taken in Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Administrative Counties</td>
<td>260</td>
<td>8</td>
<td>260</td>
</tr>
<tr>
<td>UA - Admin. Counties</td>
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<td>7</td>
<td>62</td>
</tr>
<tr>
<td>UA - Met. District</td>
<td>94</td>
<td>6</td>
<td>90</td>
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<tr>
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<td>16</td>
</tr>
<tr>
<td>London - Inner</td>
<td>50</td>
<td>4</td>
<td>50</td>
</tr>
<tr>
<td>London - Outer</td>
<td>20</td>
<td>4</td>
<td>19</td>
</tr>
</tbody>
</table>

Table 4.1 - Number of schools from each LEA in sample

Table 4.1 shows information on the outcome of the selection of the schools. This includes the number of schools required, determined by the proportion of schools in the LEA type compared to all schools; the number of LEAs taken in each LEA type and the number of schools actually taken. It should be noted that because there are a specific number of schools in each LEA the overall total could not be exactly 500, consequently 497 schools were taken.

**ii) The Piloting Scheme**

There was an awareness of inherent problems associated with mailing questionnaires, such as having relatively high administration costs and generally receiving a low response rate. Therefore, inline with guidelines, Cohen et al. (2000: 260), a piloting scheme was set-up. Details of the piloting scheme now follow.

The questionnaire sent out in the pilot can be seen as Appendix E. The revamped version sent out in the actual study can be seen as Appendix C.

An essential stage of producing a questionnaire is the piloting, with previous research showing that it is both an important and necessary stage, Cohen et al. (2000: 260). Reasons for this, as seen in Chapter 3, include:
• To establish that it collects the required data
• To check for ambiguities

Within the pilot, the complete questionnaire package was incorporated. This included the cover letter and the questionnaire, which were both in the style that the expected final version would look. Also included in the pilot stage was a memo (see Appendix F) that detailed the piloting procedure and asked for comments on different aspects of the questionnaire, cover letter and return procedure.

A group of 10 people (coded P1-P10) were selected for the piloting. These were made up of people who were known to staff in the Mathematics Education Centre at Loughborough University. They were mathematics teachers, heads of (school) mathematics (departments) or ex-teachers. A short profile of each can be seen as Appendix G.

Of the pilot group, responses were received from eight out of the ten participants. By reviewing each participant's completed questionnaire and their comments in the memo, a summary of the pilot responses was constructed and now follows. In addition, any action taken as a consequence of the comments received also follows.

Feedback on the layout and appearance was good, with it being described as 'fine', 'very good' and 'clear'. One comment suggested that the 'headings appear cramped at the beginning'. However, due to the space constraints any alterations would be difficult to administrate. It was decided that in order to try and highlight the title more it would be underlined.

With respect to the cover letter, comments were received saying that it was 'fine', 'clear' and 'concise'. A couple of suggestions were made that in the letter it should be further highlighted that the questionnaire is about applied module options. This was useful and an alteration was made to the final cover letter to include this.

Overall it was felt that the questionnaire was easy to complete with both the yes/no responses and tick/number boxes being particularly liked. In the cover letter it was
stated that the questionnaire should take only five minutes to complete and most participants in the pilot said that this was the case. However, this was only if they did not have to search for numbers for questions seven and eight (see Figure 4.1), which asked for the number of students studying each mathematics course (question seven) and how many students were studying any type of A-level course (question eight). If the numbers for questions seven and eight had to be sourced, it was suggested that a completion time of more like ten minutes was required. To that end, of the eight replies, three participants estimated the numbers given in questions seven and eight, two participants had to look them up and three already knew them.

<table>
<thead>
<tr>
<th>Course</th>
<th>Number of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS Mathematics</td>
<td></td>
</tr>
<tr>
<td>A2 Mathematics</td>
<td></td>
</tr>
<tr>
<td>AS Further Mathematics</td>
<td></td>
</tr>
<tr>
<td>A2 Further Mathematics</td>
<td></td>
</tr>
</tbody>
</table>

7. Could you please indicate the number of students studying each Mathematics course in 2003-2004. (If any other courses are available please insert into spaces)

8. Could you please indicate the total number of students, within your establishment, studying all A-Levels in 2003-04.

Figure 4.1 - 2004 pilot schools' questionnaire, questions seven and eight

In reviewing the question structure and wording along with any other comments made, some remarks were made on question three (see Figure 4.2), where participants were asked to insert the number of mathematics modules they offer and how many students study each module. Many raised concern over 'deleting yes/no as appropriate' with several people actually circling them regardless of this instruction. In the final version for 2004 the instruction delete was changed to circle. Concerns were also mentioned regarding the listing of all modules, for example six mechanics modules, suggesting that not many boards offer the full number and that perhaps having the later ones (M5, M6, S4, etc.) as another option with 'select if offered by your board' would be more appropriate. However, it was thought that this would complicate things too much and it would not be a serious problem if people had to circle 'no' if they don't offer the module.
In the responses to the pilot questionnaire, several people wrote N/A for question four and question five (see Figure 4.3), which asked why they did not offer all statistics and mechanics modules. They then answered 'no' for question six, which asked if guidance on module choice was offered to students. This meant that not a lot of information was gathered. If people did complete question four and question five then the 'other' section was favoured and information on the module choice (or lack of module choice) was given. This is the kind of information that was being sought in question six but which was not given. The useful information was only obtained through the memo. In the final version for 2004 it was decided to alter question six to include an opportunity to comment on the 'no' option as well as the 'yes' option.

In the final version for 2004 there were also slight alterations to question seven and question eight, which asked for the total number of students who studied each mathematics course, so that it was made clear which figures were required. It was evident that some people had been confused over what the 'total' should be, that of just mathematics students or that of all students in sixth form, or students in sixth form doing A-Levels.
Two people suggested a possible inclusion of a question on the options (expected) to be taken from the syllabus being taught from September 2004. However, in this instance, a short (maximum two page) questionnaire was to be created to discover the situation in schools with regard to applied module options before the changes in 2004. The questionnaire would then be re-administrated in January 2006 to review what affect, if any, the new syllabi had had. Thus this suggestion was not adopted.

Overall, feedback from the piloting scheme was very encouraging with the questionnaire seemingly well received. The response was certainly satisfactory for the purpose and goals of the scheme and instilled confidence that the final sample of 497 schools would enable the required data to be obtained. In preparation for logging the replies from the questionnaires received back from the 497 sent, each of the pilot responses was inputted into a spreadsheet. This enabled the best way of logging the replies to be found. This was important, as there would be several hundred questionnaires to log manually, which would involve many hours of data input.
iii) The Time and Cost of Administration

In reviewing the administration of the questionnaire there was a considerable amount of time and cost incurred in producing the mail-out to 497 schools. These are important factors that need to be considered when deciding whether to use such a research method.

For the mail-out of the questionnaire in 2004, there was approximately 30 hours of administration effort required. This included preparing and printing the questionnaires and letters, as well as sorting them into envelopes. In addition, costs for the postage and materials were approximately £300. As will be discussed in the next section, after the first reply date had passed there had been some 184 replies, which represented a 37% return rate. However, in line with good practice (Cohen et al (2000: 263)) a second mail-out, to those who had not replied, was undertaken. The primary reason for this was not only to try and increase the return rate but also to eliminate some sample bias, in the sense that those who reply initially, may reply because they have a particular opinion on the subject. This re-administration again incurred extra time and costs. However, after the second reply date had passed there were in total 243 replies, which represented a 49% return rate. Cohen et al (2000: 262) stated that researchers should "be satisfied if you receive a 50 percent response to the questionnaire."

It was found that there were approximately the same costs with respect to materials for the two mail-outs in 2006. However, a few hours worth of administration time were saved. This was because the same schools were used and consequently all their addresses did not have to be re-sourced.

4.3. Analysis of 2004 Questionnaire

This section details analysis that has been carried out on the replies from the 'A-level mathematics questionnaire' in January 2004, referred to as the '2004 Schools Questionnaire'. Firstly, the replies received back from the second mail-out of the questionnaire (to the non-respondents) will be compared to the replies from those who initially replied. Following this, the replies will be compared to check if replies are
representative of the original sample of 497 schools. Finally, details of the uptake and availability of mechanics in schools are given, along with analysis of the other questions on the questionnaire.

4.3.1. Consistency of the Two Waves of Replies

The questionnaire was mailed in January 2004, and there were 184 replies received back by the end of January. At the beginning of February 2004 those who had not replied were re-mailed the questionnaire and a further 59 replies were received, thus bringing the total number of replies to 243.

If analysis is to be done in terms of the total number of replies, i.e. the 243, then it needs to be checked that the first wave of 184 replies is similar to the second wave of 59 replies, in the area of interest. The comparison reviewed the percentage of schools in each wave who offered a given number of mechanics modules, see Table 4.2.

<table>
<thead>
<tr>
<th>Number of mechanics modules offered</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wave 1 184 Replies</td>
<td>4.35</td>
<td>19.57</td>
<td>39.13</td>
<td>20.11</td>
<td>9.78</td>
<td>4.35</td>
<td>2.72</td>
</tr>
<tr>
<td>Wave 2 59 Replies</td>
<td>8.47</td>
<td>25.42</td>
<td>25.42</td>
<td>28.81</td>
<td>6.78</td>
<td>3.39</td>
<td>1.69</td>
</tr>
</tbody>
</table>

Table 4.2 - Percentage of schools that offer N (N = 0-6) mechanics modules

Table 4.2 shows the percentage of schools that offered a given number of mechanics modules (from zero to six). For example, in the first wave of replies it can be seen that 19.57% of schools offered only one module of mechanics, whereas in the second wave 25.42% of schools offered only one module of mechanics.

In order to see if there were any statistically significant differences in the percentage of schools that offered a given number of mechanics modules, between the two waves, a $\chi^2$ test was used. To undertake this test a null hypothesis needed to be stated.
Null hypothesis 1: There are no differences between the first and second sample (wave) of replies, in the number of mechanics modules offered.

This test was done using a statistical software package SPSS (see http://www.spss.com). Calculating \( \chi^2 \) gave a value of 6.75 and \( P(\chi^2 > 6.75) = 0.34 \), i.e. the probability of \( \chi^2 \) exceeding 6.75 is 0.34, which is labelled \( p \). If the probability, \( p \), was less than 0.05, i.e. a 1 in 20 chance of occurring, then it could have been said that there was a significant difference between the samples. Therefore, with a probability of 0.34, there was no real evidence that the responses in terms of mechanics modules offered are different between the samples. Thus, the null hypothesis was accepted and hence, in the area of interest, there was assumed to be no difference between the two waves of replies. Subsequent analysis could and was conducted on all 243 replies in total.

Given that the replies were going to be taken as a whole, it needed to be established if the 243 replies were representative of the initial sample of 497 schools, which were taken as being representative of the population of 2717 schools as a whole. Some specific areas were reviewed, including:

- Total number of students on roll
- Total number of students in the sixth form (years 12 + 13)
- The type of school (e.g. Comprehensive, Independent)
- Which type of LEA the school belongs to
- What the predominant gender is in the school (e.g. Male only, female only or mixed)
- If the school is taking part in the Excellence Challenge programme (explained shortly)

It should be noted that the original 497 schools were only representative of the 2717 schools in terms of LEAs, and not (necessarily) representative in terms of all the areas above.
These areas were considered as this type of data was accessible and available for nearly all schools in the country (the data was available from Loughborough University's Central Administration), except data on the Excellence Challenge programme, which was acquired from the Department for Education and Skills (DfES). (The Excellence Challenge programme was established by the DfES in 2001, with the aim of increasing the number of young people from disadvantaged backgrounds who had the qualifications and aspirations necessary to enter higher education.) This allowed for data to be matched up for those schools that replied to the questionnaire, although this did require a large amount of reorganisation of data in various spreadsheets. These six areas could then be reviewed in relation to answers from the questionnaire, for example a chart showing what percentage of students in the different types of school had studied each mechanics module could be produced.

It should be pointed out that other measures of comparing schools are available, for example school league table position. However, the six measures used were taken as suitable for the purpose of being representative of each school.

Charts comparing the percentage of schools of a given type in each of the six areas for the original 497 schools and the subsequent (243) replies can be seen in Figures 4.4 - 4.9. Specific comments on trends observed in these charts, can be seen in Appendix H. Here the interest is solely in determining whether the (243) replies are representative of the original 497 schools.
Comparisons of Replies to Questionnaire with Initial 497 Schools - School Size

Figure 4.4 - Total number of students on roll

Comparisons of Replies to Questionnaire with Initial 500 Schools - Numbers in Years 12 + 13

Figure 4.5 - Total number of students in years 12 and 13
Figure 4.6 - Comparison of the type of school (e.g. comprehensive, independent)

Figure 4.7 - Comparisons of to which type of LEA schools belong
Figure 4.8 - Comparison of what the predominant gender is in the schools

Figure 4.9 - Comparing if schools are taking part in the Excellence Challenge Programme
These charts show little difference between the schools that replied and the original sample of 497 schools. However, it is not clear statistically if there is no significant difference. Therefore, a $\chi^2$ test was conducted for each set of data. For example the percentage of schools in each LEA of the original sample of 497 schools was compared with the 243 replies. The corresponding p value found in each $\chi^2$ test is given in Table 4.3.

<table>
<thead>
<tr>
<th>Figure</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.4 No. on Roll</td>
<td>0.73</td>
</tr>
<tr>
<td>4.5 Year 12+13 Size</td>
<td>0.79</td>
</tr>
<tr>
<td>4.6 Type of School</td>
<td>0.31</td>
</tr>
<tr>
<td>4.7 Type of LEA</td>
<td>0.38</td>
</tr>
<tr>
<td>4.8 Gender</td>
<td>0.65</td>
</tr>
<tr>
<td>4.9 EC</td>
<td>0.77</td>
</tr>
</tbody>
</table>

Table 4.3 - Results from $\chi^2$ Test

Table 4.3 shows several different p values (varying from 0.31 - 0.79) for the different areas considered. There would be a significant difference, at the 5% level, between two variables if the p value was below 0.05. Therefore, all show that there is no significant difference between the initial sample of 497 schools and the 243 replies received back. This indicates that the replies are representative of the original sample, which was taken to be representative (in terms of LEAs) of the population of 2717 schools. Hence, analysis can be undertaken of the replies with confidence that the replies are a representative sample of the original 497 schools and of all 2717 schools.

If data was easily available for all 2717 schools in each of the areas, then it would be possible to analyse if the original 500 schools and subsequently the (243) replies were representative of all 2717 schools in all areas considered, rather than LEA type only. However, this would take a considerable amount of time and require a great deal of administration and hence was not undertaken in the scope of this project.

4.3.2. Availability of Mechanics in Schools in January 2004

With the 243 replies having been shown to be representative of the sample, analysis of specific areas of interest can now be undertaken. As described in the introduction
to this chapter, areas of interest include gaining an understanding of just what the availability and uptake of mechanics modules are in schools. These will now be considered.

Within the 243 schools that completed the questionnaire, there were some 13,754 students studying either AS-level or A-level Mathematics courses. Firstly the results on the availability or non-availability of 'applied' modules are presented.

<table>
<thead>
<tr>
<th>No Modules Offered</th>
<th>% of Students</th>
<th>% of Schools</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanics</td>
<td>2.62</td>
<td>5.35</td>
</tr>
<tr>
<td>Statistics</td>
<td>1.36</td>
<td>2.06</td>
</tr>
<tr>
<td>Discrete</td>
<td>43.40</td>
<td>46.09</td>
</tr>
</tbody>
</table>

Table 4.4 - Availability of modules (No modules offered) - 2004

Table 4.4 shows the percentage of schools that did not offer any modules for each of the three applied strands and the percentage of students in the 13,754 student sample who studied AS-level or A-level Mathematics in one of these schools. It can be seen that approximately 5% of schools in the sample do not offer any mechanics. Thus potential engineering students attending one of these schools have no opportunity to study mechanics modules within AS-level or A-level Mathematics. Very few schools do not offer any statistics modules (approximately 2%). The figures are much greater for discrete modules; this is presumably because discrete mathematics is still relatively new at A-level.

<table>
<thead>
<tr>
<th>No, or at most 1, Module Offered</th>
<th>% of Students</th>
<th>% of Schools</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanics</td>
<td>15.83</td>
<td>26.34</td>
</tr>
<tr>
<td>Statistics</td>
<td>14.14</td>
<td>21.81</td>
</tr>
<tr>
<td>Discrete</td>
<td>79.10</td>
<td>79.01</td>
</tr>
</tbody>
</table>

Table 4.5 - Availability of modules (No modules or at most 1 module offered) - 2004
Table 4.5 shows the percentage of schools which did not offer any, or offered at most one module, for each of the three applied strands, and the percentage of students in the 13,754 student sample who studied AS-level or A-level Mathematics in one of these schools. Thus students at these schools were unable to study two or more modules of a given strand. It can be seen that over a quarter (26.34%) of schools in the sample offer at most one module of mechanics. Over 15% of students in our sample are unable to study mechanics beyond M1. Similar numbers of students are unable to study statistics beyond S1 and again it can be noted that the availability of discrete modules is low.

In this thesis interest lies in the availability of mechanics modules. As can be seen from the content of the first four mechanics modules, given in Appendix A, and from specimen examination papers, web reference [9], the material presented in M1 is an introduction to mechanics and at a very basic level. Not until students study M2 do they start to encounter more demanding material. (Traditionally, material equivalent to that in M1 and M2 would have been commonly studied in Mathematics A-levels, see Cockcroft (1982: 173)). Thus these results on the availability of mechanics modules show that a significant number of students (over 15%) are unable to study mechanics to a level that was once commonplace within Mathematics A-level syllabuses. Moreover, as shall be discussed later in Chapter 7, some lecturers of mechanics at university assume a prior knowledge of M1 and M2. Students from schools where mechanics is not offered beyond M1 are thus at a distinct disadvantage in these universities, if they choose to study mechanics.

4.3.3. Uptake of Mechanics in Schools in January 2004

The analysis has until now focused upon the availability of applied modules. However, even if mechanics modules are available, students may not choose or may be advised not to study them. Hence, a review of the uptake of applied modules in schools will now be considered.

In Figure 4.10 the percentage of school students, who are studying each of the individual modules, is displayed. For example, it can be seen that approximately 43% of students are studying M1, compared to 51% studying S1. The percentage of
students who studied M2 or S2 are similar to each other, at 18%. Few students study the higher level modules. More specifically, in total, 8% study M3, M4, M5 or M6. Consequently at most 26% of students study more than a basic mechanics module (M1).

![Percentage of school students studying each applied module](image)

Figure 4.10 - Percentage of school students studying each applied module

These results demonstrate that a significant proportion of school students still study mechanics, at least until M1 level. However, it gives no indication of whether the students who chose to study mechanics are those students who will proceed to study engineering. It is possible that some potential engineering students may not be among the 43% of students who study mechanics. This will be addressed in Chapter 5 when findings from questionnaires to first year engineering, mathematics and physics students are presented.

**i Availability of mechanics modules within different LEAs**

In addition to reviewing the uptake and availability of mechanics in schools it was also possible to look further at the specific areas that had been previously introduced, e.g. which type of LEA schools were from, to establish if there were any obvious trends. To that end, two further components of analysis were carried out. The first involved reviewing what percentage of schools had offered a given number of
mechanics modules to be studied, in each of the six areas given previously. Table 4.6 shows the percentage of schools in each LEA type that offer a given number of mechanics modules. So for example, 30.71% of the 127 schools in the Administrative Counties offered two modules of mechanics.

<table>
<thead>
<tr>
<th>LEA</th>
<th>No. of Schools</th>
<th>No. of mechanics modules offered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Admin Counties</td>
<td>127</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.15</td>
</tr>
<tr>
<td>UA - Met Districts</td>
<td>42</td>
<td>7.14</td>
</tr>
<tr>
<td>UA - Non Met Districts</td>
<td>11</td>
<td>0.00</td>
</tr>
<tr>
<td>Outer London</td>
<td>28</td>
<td>3.57</td>
</tr>
<tr>
<td>Inner London</td>
<td>4</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>243</td>
<td>5.35</td>
</tr>
</tbody>
</table>

Table 4.6 - Percentage of schools in each LEA type that offer N (N=0-6) mechanics modules

Tables for the other areas can be seen in Appendix I. In addition, $\chi^2$ tests were completed for each area to observe if there was a significant difference between the number of mechanics modules offered by schools in each area reviewed. For example, in Table 4.6 the area of 'type of LEA' that schools come from is reviewed and the $\chi^2$ test considers if there is a significant difference in the number of mechanics modules offered by schools in the six different types of LEAs. The results in Table 4.7 show the corresponding p value obtained, for the $\chi^2$ tests conducted.
### Table 4.7 - Results from $\chi^2$ test

<table>
<thead>
<tr>
<th>Area of interest</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>LEA</td>
<td>0.008</td>
</tr>
<tr>
<td>EC</td>
<td>0.2114</td>
</tr>
<tr>
<td>Gender</td>
<td>9.5E-05</td>
</tr>
<tr>
<td>Type of School</td>
<td>0.0007</td>
</tr>
<tr>
<td>No. on Roll</td>
<td>0.0374</td>
</tr>
<tr>
<td>Year 12+13 Size</td>
<td>0.0198</td>
</tr>
</tbody>
</table>

As can be seen from Table 4.7 all but one of the $p$ values are below 0.05, which would indicate that there is some significant difference between the number of mechanics modules studied and the specific area of interest. For example, between the number of mechanics modules studied and the type of LEA or between the number of mechanics modules studied and the year 12+13 size. Further comments on why this was not considered further will be made after point ii has been discussed.

#### ii Average number of mechanics modules offered by different schools

The second component of further analysis involved considering the average number of mechanics modules offered by schools. The statistical method of one-way Analysis of Variance (ANOVA) was used to compare the means in each area of interest. For example, in the area of 'type of LEA' the average number of mechanics modules offered by schools in each type of LEA was calculated and then ANOVA was used to see if there were any significant differences between the average number of mechanics modules offered in the six LEAs. Here there were no significant differences and in fact there were only significant differences in two cases, when considering the gender of the school and the type of school.

It should be noted that ANOVA was used here rather than $\chi^2$ because in this situation the data could be classed as continuous, i.e. the average number of mechanics modules offered could take any value not just discrete values of 1, 2, 3. However this also brings in a separate issue, that averaging the number of mechanics modules could in effect 'mask' results. Thus this type of analysis may not be as useful when looking to draw conclusions.
Firstly, there was a significant difference between the average number of mechanics modules offered by single sex (male) schools and the average number of mechanics modules offered by mixed sex schools. This indicates that single sex (male) schools offer significantly more mechanics modules than mixed sex schools. Secondly, there was a significant difference between the average number of mechanics modules offered by independent schools and the average number of mechanics modules offered by other schools (including comprehensive). The underlying data indicates that independent schools offer significantly more mechanics modules than other schools.

It would be possible to review the given data further, particularly in terms of the six specific areas. However, in this thesis one of the primary aims is to consider what knowledge of mechanics students entering onto engineering degrees have and therefore further analysis of (i) and (ii) will not be pursued here.

4.3.4. Further Analysis of 2004 Schools Questionnaire

In section 4.3.2 analysis was conducted into the uptake and availability of mechanics modules in schools, using data collected from questions three, seven and eight of the questionnaire to schools. Obviously there was a large amount of data collected from the other questions, with some interesting findings emerging. Hence, analysis from the other five questions will be given here.

The first two questions on the questionnaire to schools (see Figure 4.10) asked what examination board each school used for their GCE A-level Mathematics course and if they had changed examination board in the past five years.
In Figure 4.11 the percentage of schools who used a particular examination board are displayed. It is evident that the most popular board used by the schools that replied to the questionnaire was Edexcel, with nearly 45% of schools using them. Approximately 17% and 14% of schools used OCR and AQA A respectively, with slightly fewer using OCR (MEI) and AQA B. As this questionnaire was only sent to schools in England it was not expected that many, if any, schools would be using the Irish (CCEA) or Welsh (WJEC) examination boards and this proved to be the case.

The response to question two, which asked if each school had changed the examination board they used, showed that 81% had not changed. This meant that with
the changes made to A-levels in the year 2000, through Curriculum 2000, a very large proportion of schools in the sample had not changed the examination board they used. This may have been expected as, in mathematics, there was not a dramatic change to the structure or syllabus, as discussed in Chapter 3.

In the sample, 19% of schools had changed examination board in the past five years and when reviewing the year of change, it emerged that 90% of these schools had changed in 2000-2001, i.e. at the time of the introduction of Curriculum 2000. Reasons for changing examination board included:

- The new board was better organised (in terms of administration) than the old one
- The new board's scheme of work fitted in better with the teaching at the school
- The old board's examinations were more difficult than the new board's

Therefore, reviewing these reasons it would appear that Curriculum 2000 was not a basis for schools to change examination board, as the factors mentioned were not directly linked to Curriculum 2000 and were more to do with the content and administration of courses from each examination board.

**i Reasons why applied modules were not offered**

![Figure 4.12 - 2004 final version, schools' questionnaire, questions four and five](image)

Of the three other questions contained within the questionnaire to schools, two questions (four and five), see Figure 4.12, built upon data collected in question three.
In question three, information was obtained on which applied modules schools offered and how many students studied each of them, as analysed in section 4.3.2. In questions four and five clarification was sought as to why some or all mechanics (question four) and statistics (question five) modules were not offered. There were four options offered for schools to choose from, as well as an 'other' option. The results can be seen in Figure 4.13.

Figure 4.13 shows the percentage of schools that offered each reason as to why they didn't offer all mechanics and statistics modules to their students. Schools were free to choose more than one options and so the total percentages do not add to 100%. It should be noted that not all schools completed the two questions; 58 completed question four and 33 schools completed question five. Considering the relative sizes of the bars between each of the reasons, it is evident that the two most common responses were 'Timetable Constraints' and 'Other', and so the reason why schools did not offer students all mechanics (or statistics) modules was because of timetable constraints or another reason. When reviewing just what the 'other' reasons were, nearly all contained some version of the expression "Because all are not needed" and that they "Need to offer some mechanics and statistics" not just all modules of one strand. This was as expected, as it was anticipated that few schools would offer all modules of a strand.

Figure 4.13 - Reasons why schools don't offer all applied modules
A second perspective for analysis of the replies is to review each pair of bars, i.e. each reason, with respect to mechanics and statistics. In considering the percentage of schools that offered each reason for mechanics and statistics, in three cases the difference is less than 2.5%, see Table 4.8. There was a difference of 6.01%, for the reason that financial constraints meant that all modules were not offered. Interestingly the largest difference (10.50%) was for the reason of a lack of pupil interest. Referring back to Figure 4.13, it is evident that a higher percentage of schools cited 'lack of pupil interest' for statistics then did for mechanics. Although this is interesting it is difficult to offer any firm explanation why this may be the case.

<table>
<thead>
<tr>
<th>Question Response</th>
<th>Difference Between Mechanics and Statistics (%) [i.e. Mechanics - statistics]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Financial Constraints</td>
<td>6.01</td>
</tr>
<tr>
<td>Teacher Skills Shortage</td>
<td>-1.78</td>
</tr>
<tr>
<td>Lack of Pupil Interest</td>
<td>-10.50</td>
</tr>
<tr>
<td>Timetable Constraints</td>
<td>-2.35</td>
</tr>
<tr>
<td>Other</td>
<td>2.41</td>
</tr>
</tbody>
</table>

Table 4.8 - Difference between responses for mechanics and statistics

In the analysis of questions four and five it is very difficult to give any further explanation into the reasons offered by the respondents without any further investigation. From a philosophical viewpoint, in the mixture of quantitative and qualitative responses to the two questions, does the fact that more teachers selected 'timetable constraints' make it a more significant issue than financial constraints? In terms of quantitative analysis it would suggest this, however in qualitative analysis it may be that financial constraints are more significant. This is because financial constraints may be more easily rectifiable than timetable constraints, and thus more students would have been able to study more of the applied modules.
Guidance given on applied module choice

The final question to be reviewed from the questionnaire to schools was question six. This aimed to gather information on whether students received any guidance on which (applied) modules to study, see Figure 4.14. A simple choice of yes or no was given and then space to explain why the option ticked had been chosen. Figure 4.15 shows which option staff in schools ticked.

From Figure 4.15 it can be seen that in 54% of schools, advice was given to students, whereas in 43% of schools no advice was given and there was no response to the question from only 3% of the schools. It should be pointed out that advice may not have been needed if, for example no module choice was available.

Figure 4.15 - Indication as to whether guidance was given to students on which applied modules to study
Considering first those schools that replied 'no' to question six and reviewing the explanations given, it can be seen that in all but a few cases the reason was that 'no module choice was available', i.e. the staff chose which modules students should study. In addition, some schools offered a second reason why no module choice was given and this was that their school was small. In relation to the uptake of mechanics it is extremely difficult to suggest whether students having no module choice is a good or a bad thing. This is because it is not implicit what schools do actually offer, to which students, when they do not offer their students any choice. One school stated that they are "Not able to offer choices, here we do a general course, with some mechanics and some statistics." This scenario may well be more widespread, but again more evidence would be required to support this, as the questionnaire produced was not able to detect this. It would be possible to review the response to question six from schools, with their response to question three, which asked which modules were available and how many students studied them. However, this is not straightforward because it is unknown whether modules are available to all students, or perhaps solely to those studying Further Mathematics. So again it would be difficult to give an accurate explanation of the situation.

In reviewing replies from the 54% of schools who said that they do offer guidance on which applied modules to study, there was again one answer that was more common than any other. The advice given was that if students were studying physics or engineering type courses alongside their mathematics course then they should study mechanics modules; other students and in particular those studying business or sociology or psychology type courses should study statistics modules. This is an interesting finding and in many ways it is a positive one. However, as has been seen in the analysis of questions four and five there are many difficulties in actually offering the different modules to students, in particular timetable constraints. Therefore, it is not simple to assess just how widely implemented these positive comments are.

Other explanations given, included that students should study modules based on:

- Which they enjoy most, i.e. if they have studied a first module (M1/ S1/ D1) and were choosing a second module (M2/ S2/ D2)
• Their future study plans and ambitions, i.e. prospective university courses

Such advice does appear to be appropriate but again it is extremely difficult to assess to what extent such guidance is given.

In this section replies from a questionnaire mailed to 497 schools have been reviewed and analysed. A summary of the main findings will be presented in section 4.5.1 after a follow-up questionnaire is reported upon in the next section.

4.4. 2006 Schools Questionnaire

The questionnaire constructed in January 2004 was modified and administered in January 2006. This was to establish what affect, if any, the changes in the A-level Mathematics structure and syllabi (first taught in September 2004) had on the uptake and availability of mechanics in schools. Firstly the re-administration process will be reviewed before results of the questionnaire and comparative analysis with the results from 2004 are conducted.

4.4.1. Construction, Pilot and Administration 2006

In the January 2006 questionnaire, it was established that by and large the same data that was collected in January 2004 needed to be obtained. It should be noted that the 2004 questionnaire had been successful as a tool to gather data. This was one of the reasons why relatively few changes were considered. These were only in areas where more clarity to a question could be made or where additional data was required, i.e. where improvements could be made to the previous questionnaire. There were several minor alterations, for example adding an extra option in questions five and six, which asked why certain modules were not available. There was one larger change that is worthy of further discussion. This involved the question on which applied modules schools offered and which students studied them.

In the responses to the 2004 questionnaire it was noted that it could not be distinguished if modules offered by schools and studied by students were in A-level
Mathematics or A-level Further Mathematics. Given that students studying A-level Further Mathematics study more modules than those studying A-level Mathematics it may be the case that certain modules are only available to and studied by students on these A-level Further Mathematics courses. Consequently, in the 2006 questionnaire the question which asked which (applied) modules schools offered and how many students they had studying them was altered so that there was a distinction between the modules available in A-level Mathematics and those in A-level Further Mathematics. The original question can be seen in Figure 4.16 and the altered question for 2006 can be seen in Figure 4.17.

Figure 4.16 - 2004 pilot schools' questionnaire, question three

Figure 4.17 - 2006 version 1, schools' questionnaire, question three
Version 1 of the 2006 questionnaire can be seen in Appendix J (this can easily be compared with the 2004 questionnaire in Appendix C). Because changes had been made to the questionnaire administrated in January 2004 it was decided that it would be appropriate to pilot this new version. The pilot involved forwarding the 2006 questionnaire to 10 suitable people who were current or ex-teachers in school mathematics departments. Replies were received back from six of the 10 people. Feedback was predominantly positive and a useful suggestion was made on one of the questions that had been changed. It was suggested that question three, discussed in the last paragraph, was modified slightly so that it was clearer to understand and complete. The changed question (from that seen in Figure 4.17) can be seen in Figure 4.18.

3 Please indicate which of these APPLIED modules you offer in AS/A-level Mathematics and approximately how many students are studying them in 2005 - 2006:

(Please circle Yes/No as appropriate and write the number of students studying the module in the box)

<table>
<thead>
<tr>
<th>Module</th>
<th>Status</th>
<th>Number of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>Yes/No</td>
<td>S1</td>
</tr>
<tr>
<td>M2</td>
<td>Yes/No</td>
<td>S2</td>
</tr>
<tr>
<td>D1</td>
<td>Yes/No</td>
<td></td>
</tr>
</tbody>
</table>

4 Please indicate which of these APPLIED modules you offer in AS/A-level Further Maths and approximately how many students are studying them in 2005 - 2006:

(Please circle Yes/No as appropriate and write the number of students studying the module in the box. If you do not offer Further Mathematics tick here)

<table>
<thead>
<tr>
<th>Module</th>
<th>Status</th>
<th>Number of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>Yes/No</td>
<td>D1</td>
</tr>
<tr>
<td>D2</td>
<td>Yes/No</td>
<td>S2</td>
</tr>
<tr>
<td>M5</td>
<td>Yes/No</td>
<td>S3</td>
</tr>
<tr>
<td>M6</td>
<td>Yes/No</td>
<td>S4</td>
</tr>
</tbody>
</table>

(If you offer any others, which are not listed above [excluding any pure modules], please insert below)

Figure 4.18 - 2006 final version, schools' questionnaire, questions three and four

It was thought that this made the distinction between the modules studied by those on A-level Mathematics courses and those on A-level Further Mathematics courses clear. The final version of the 2006 questionnaire can be seen in Appendix K.

The 2006 questionnaire was administrated to the same 497 schools that received the 2004 questionnaire. There are several reasons for this. Firstly, it would save a considerable amount of administration time, for example on sourcing and sorting relevant school addresses. Secondly, re-administrating the questionnaire to the same
schools would allow feedback from the analysis in 2004 to be sent with the questionnaire. It was hoped that this feedback, an outline of results from the 2004 questionnaire, would interest teachers and perhaps encourage more to reply. In addition, in analysis of the 2004 questionnaire, the 497 schools had been shown to be representative of all schools with respect to their LEA and a near 50% response rate had been achieved from the 497 schools.

4.4.2. Consistency of the Two Waves of Replies

The questionnaire was mailed in January 2006, and there were 163 replies received back by the end of January. At the beginning of February 2006 those who had not replied were re-mailed the questionnaire and a further 62 replies were received, thus bringing the total number of replies to 225 (a response rate of 45%). The questionnaire was sent out twice for the same reasons as described with the 2004 questionnaire in section 4.3.1.

Furthermore, the same analysis that was carried out on replies to the 2004 questionnaire detailed in section 4.3.1, was carried out on the replies to the 2006 questionnaire, namely if there was a difference between the two waves of replies (in 2006) and if there was a difference between the replies and the original sample of 497 schools.

Table 4.9 shows the percentage of schools in each wave who offered a given number of mechanics modules.

<table>
<thead>
<tr>
<th>Number of mechanics modules</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wave 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>163 Replies</td>
<td>6.75</td>
<td>30.67</td>
<td>40.49</td>
<td>17.18</td>
<td>3.68</td>
<td>1.23</td>
</tr>
<tr>
<td>Wave 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>62 Replies</td>
<td>12.90</td>
<td>33.87</td>
<td>30.65</td>
<td>14.52</td>
<td>8.06</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Table 4.9 - Percentage of schools that offer N (N=0-6) mechanics modules
As in section 4.3.1, a $\chi^2$ test was used to establish if there was a significant difference between the two waves. A $\chi^2$ value of 0.3 was found and therefore (at the 95% significance level) there is no real evidence that the responses in terms of mechanics modules offered are different between the samples. Hence, in the area of interest, there is assumed to be no difference between the two waves of replies and subsequent analysis can and will be conducted on all 225 replies, in total.

As in the analysis of the 2004 questionnaire it needed to be established if the 225 replies were representative of the initial sample of 497 schools, which were taken to be representative of the whole population (with respect to LEAs). $\chi^2$ tests were used to determine if there was any significant difference between the replies and the original sample and the corresponding p value found in each $\chi^2$ test is given in Table 4.10.

<table>
<thead>
<tr>
<th></th>
<th>2006</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. on Roll</td>
<td>0.96</td>
</tr>
<tr>
<td>Year 12+13 Size</td>
<td>0.70</td>
</tr>
<tr>
<td>Type</td>
<td>0.63</td>
</tr>
<tr>
<td>LEA</td>
<td>0.84</td>
</tr>
<tr>
<td>Gender</td>
<td>0.16</td>
</tr>
<tr>
<td>EC</td>
<td>0.83</td>
</tr>
</tbody>
</table>

Table 4.10 - Results from $\chi^2$ tests in 2004 and 2006

Table 4.10 shows several different p values (varying from 0.16 to 0.96) for the different areas considered, in 2006. All show that there is no significant difference between the initial sample of 497 schools and the 225 replies received back and so analysis can be undertaken on the replies with confidence that the replies are a representative sample of the original 497 schools.

4.4.3. Availability of Mechanics in Schools 2006

With the changes in the syllabi that were first taught in September 2004 it would be very useful to compare results from the 2006 questionnaire with those obtained for the 2004 questionnaire.
In 2004 there were responses from 243 schools that had 13754 students studying Mathematics A-levels. In 2006 there were responses from 225 schools that had 13673 students studying Mathematics A-levels. Results of what percentage of schools did not give students the opportunity to study particular applied modules, i.e. mechanics, statistics or discrete, can be seen in Table 4.11.

<table>
<thead>
<tr>
<th>No Modules Offered</th>
<th>% of Students 2004</th>
<th>% of Students 2006</th>
<th>% of Schools 2004</th>
<th>% of Schools 2006</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanics</td>
<td>2.62</td>
<td>2.04</td>
<td>5.35</td>
<td>8.44</td>
</tr>
<tr>
<td>Statistics</td>
<td>1.36</td>
<td>1.57</td>
<td>2.06</td>
<td>7.11</td>
</tr>
<tr>
<td>Discrete</td>
<td>43.40</td>
<td>23.22</td>
<td>46.09</td>
<td>34.67</td>
</tr>
</tbody>
</table>

Table 4.11 - Availability of modules (no modules offered) 2004/2006

There are two things to consider here, firstly the size of the percentages for each year and secondly how these percentages changed between the two years. In this instance there is a particular interest in the availability of mechanics, due to the implications for engineering students. Considering first the percentage of schools, it is evident that a little over 5% of schools in 2004 and a little over 8% of schools in 2006 did not offer any mechanics modules to their students. This increase is concerning as in 2006 in 1 in 12 schools in the sample, students did not have the opportunity to study mechanics. However, Table 4.11 also shows that there was a reduction in the percentage of students that could not study any mechanics. This coupled with the increase in the percentage of schools not offering any mechanics may imply that it is schools with a low number of students that are not offering mechanics.

A more pronounced increase in the percentage of schools that did not offer any statistics, compared to mechanics, is also seen. A decrease in the figures for discrete modules was noted, which implies more schools are offering it.

Reviewing the percentage of students that were not able to study any modules of a given strand, it can be seen that there is a decrease for mechanics, which means more students can study mechanics, which is a positive finding. An even larger decrease
was seen in discrete mathematics, where in 2006 23% of students could not study any discrete compared to 43% in 2004.

Also of importance are those students who can only study at most one module of a strand, especially in mechanics, due to the implications for engineering students highlighted previously. Several interesting figures emerged, as seen in Table 4.12.

<table>
<thead>
<tr>
<th>Module Offered</th>
<th>% of Students</th>
<th>% of Schools</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanics</td>
<td>15.83</td>
<td>29.66</td>
</tr>
<tr>
<td>Statistics</td>
<td>14.14</td>
<td>25.03</td>
</tr>
<tr>
<td>Discrete</td>
<td>79.10</td>
<td>70.83</td>
</tr>
</tbody>
</table>

Table 4.12 - Availability of modules (no modules or at most one module offered) 2004/2006

Firstly, in 2004 there were a reasonably high percentage of schools (26%) that offered at most one module of mechanics. However, this increased significantly in 2006 to 40% of schools. This means that in 40% of the schools in the 2006 sample, students could not study more than M1 and thus could not study mechanics up to a level (comparative to the current content of Mechanics 1 (M1) and Mechanics 2 (M2) modules) that was once commonplace within A-level Mathematics. Thus, in 2004 74% of schools offered two or more mechanics modules, whereas in 2006 only 60% of schools offered two or modules of mechanics. This is worrying, but the situation may in fact be worse. These figures include schools offering modules to students who study A-level Further Mathematics. It may actually be the case that some modules, like M1 the first mechanics module, is only available to students on Further Mathematics courses. In 2004 the questionnaire could not distinguish if this was so, however in 2006 the questionnaire was modified slightly, so that it could be established which modules were studied in A-level Mathematics and which were studied in A-level Further Mathematics. The results solely for the availability of at most one module of a strand for students studying A-level Mathematics can be seen in Table 4.13.
<table>
<thead>
<tr>
<th>% of Schools (2006)</th>
<th>0 modules offered</th>
<th>1 module offered</th>
<th>At most 1 module offered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanics</td>
<td>16.00</td>
<td>46.22</td>
<td>62.22</td>
</tr>
<tr>
<td>Statistics</td>
<td>10.67</td>
<td>52.44</td>
<td>63.11</td>
</tr>
<tr>
<td>Discrete</td>
<td>64.00</td>
<td>27.56</td>
<td>91.56</td>
</tr>
</tbody>
</table>

Table 4.13 - Availability of modules (no modules or at most one module offered) for A-level mathematics students

As can be clearly seen in Table 4.13 the figures have increased considerably from those in Tables 4.11 and 4.12, which included those schools offering modules to A-level Further Mathematics students. Thus, in 62% of schools, students who embark on an A-level in Mathematics cannot study more than the first (basic) module of mechanics. A similar percentage cannot study more than one statistics module. Relating this to the changes that have occurred in A-level Mathematics indicates that in A-level Mathematics a large percentage of schools (62% for mechanics and 63% for statistics) are only offering students at most the first module of a strand, i.e. 38% of schools in the sample are offering M2 to students. These findings highlight the worth of A-level Further Mathematics as a subject, not only to deepen a student's knowledge, but also to widen a student's knowledge, i.e. by having the opportunity to study more first level modules.

Incidentally, in the sample a sizeable increase in the number of students studying AS-level Further Mathematics from 942 in 2004 to 1412 in 2006 was seen, although the numbers studying A-level Further Mathematics remained static at approximately 800. This may be showing the affect that the change in AS-level Further Mathematics courses, studied from September 2004, which were described in 2.5.3, has had on uptake.
4.4.4. Uptake of Mechanics in Schools 2006

As in the analysis carried out on the 2004 questionnaire it would be informative to not only consider the availability of applied modules in schools, but also the uptake of applied modules. Therefore, analysis will now be conducted into the uptake of applied modules.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanics</td>
<td>41.67</td>
<td>41.72</td>
<td>18.02</td>
<td>12.59</td>
</tr>
<tr>
<td>Statistics</td>
<td>50.84</td>
<td>52.29</td>
<td>18.86</td>
<td>12.27</td>
</tr>
<tr>
<td>Discrete</td>
<td>16.57</td>
<td>18.73</td>
<td>2.89</td>
<td>2.91</td>
</tr>
</tbody>
</table>

Table 4.14 - Percentage of school students studying each of the first two applied modules

Firstly considering the percentage of students who studied the first module of a strand then it can be seen that there is very little difference between the figures, in Table 4.14, for 2004 and 2006. Approximately 42% of the students had studied M1, which is an encouraging number. However, when reviewing what percentage of students actually studied the second module (M2) there were considerably less, with 18% of students studying the module in 2004. Furthermore, comparing these with the 2006 figures, there are fewer students (13%). The same fall in numbers is evident in the percentage studying S2. From this it could be inferred that the changes in A-level Mathematics in September 2004 may have contributed to this decline in the numbers studying the second module of both mechanics and statistics. Also, the fact that the number of applied modules able to be studied in A-level Mathematics was reduced from three to two means less applied modules will be studied in total.

A response was received from a Head of Mathematics to the questionnaire in 2004, which stated 'It would be ludicrous for us to offer M1 and M2 when M1 and S1 are much easier' when considering what to offer after the changes in September 2004. It looks as though this view may have been widespread when reviewing the figures for 2006 in Table 4.14. In essence, this is the type of response that could be expected from schools, given one of their prime objectives is to help students gain the best possible mark in their A-levels, which obviously not only benefits the students but
also the school. However, for universities there may be disappointment that students cannot and are not studying the higher-level modules.

In 4.3.2 analysis was conducted into some specific areas, for example into the availability of mechanics modules within different LEAs. However, this was exploratory analysis and as described in 4.3.2 did not align itself to the primary aims of this thesis and so such analysis was not conducted for the 2006 questionnaire.

4.4.5. Further Analysis of 2006 Schools Questionnaire

In the previous sections analysis was conducted into the availability and uptake of mechanics modules in schools using data collected from questions three, four, eight and nine of the 2006 questionnaire to schools. However, as reported upon for the 2004 questionnaire (in section 4.3.3) there were several other questions which teachers were asked to complete in the questionnaire. The questions allowed for valuable information on other topics to be obtained and further analysis of these questions now follows.

1 Which examination board(s) are you using for your 2005-2006 GCE Mathematics courses?

- AQA
- OCR
- CCEA (Northern Irish)
- Other
- Edexcel
- OCR (WJEC)
- WJEC
- OCR (MEI)
- Other

2 If you have changed examination board for Mathematics courses in the previous six years please complete the following:

   (If you have changed more than once, please state so but only complete for last change)

- More than one change? Yes / No
- Previous Board
- Year of last change
- How many changes?
- Reason(s) for change

Figure 4.19 - 2006 final version, schools' questionnaire, questions one and two

As in 2004 the first two questions on the questionnaire to schools (see Figure 4.19) asked what examination board each school used for their GCE A-level Mathematics course and if they had changed examination board in the past six years. There was only a minor change in question one from the same question asked in 2004. From the
changes to the mathematics specifications for first teaching in September 2004, there
was only one A-level Mathematics syllabi offered by AQA, as opposed to two
previously (although they do offer an A-level Statistics specification). Question two
also had minor changes, which involved asking if there had been more than one
change of examination board in the previous six (as opposed to five) years in order to
include the year 2000.

<table>
<thead>
<tr>
<th></th>
<th>AQA</th>
<th>EdExcel</th>
<th>OCR</th>
<th>MEI</th>
<th>CCEA</th>
<th>WJEC</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>24.58</td>
<td>44.17</td>
<td>17.08</td>
<td>14.17</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2006</td>
<td>23.61</td>
<td>49.07</td>
<td>13.89</td>
<td>13.43</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 4.15 - Comparison of which examination board schools used in 2004 and 2006

In Table 4.15 the percentage of schools, in both 2004 and 2006, that used a particular
examination board are shown. It is evident that Edexcel was the most popular
examination board to study from in both years. Similar figures were also seen for the
other examination boards, with approximately 24% of schools using AQA (note the
figure in 2004 in Table 4.15 is a combined total of AQA A and AQA B syllabi, so
that a comparison could be made to 2006). As stated for the 2004 questionnaire, in
2006 the questionnaire was only sent to schools in England. Consequently, it was not
expected that many, if any, schools would be using the Irish (CCEA) or Welsh
(WJEC) examination boards and again this proved to be the case.

Question two, which considered if a school had changed examination board in the
previous six years produced interesting results, as seen in Table 4.16.

<table>
<thead>
<tr>
<th></th>
<th>Had changed</th>
<th>Had not changed</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>18.26</td>
<td>81.74</td>
</tr>
<tr>
<td>2006</td>
<td>7.11</td>
<td>92.89</td>
</tr>
</tbody>
</table>

Table 4.16 - Percentage of schools that had changed examination board

Firstly, it is evident that relatively few schools in the 2006 questionnaire, 7.11%, had
changed examination board. All of the schools that said that they had changed
examination board said that they had only changed once in the previous six years.
However, a third of those that had changed examination board had done so in 2004.
and cited the change in specification as the primary reason for the change. This still means that the vast majority, about 97%, of the 225 schools who replied in 2006 had not changed examination board at the time of the change in specification. Thus, in the sample, the change in specification in September 2004 was not seen as a basis for schools to change examination board. Incidentally, the findings from the 2004 survey indicated that Curriculum 2000 had not been a basis for change either.

**i Reasons why applied modules were not offered**

Questions five and six (see Figure 4.20) in the 2006 questionnaire built upon question three, where information was obtained on which applied modules were offered in A-level Mathematics. In these questions clarification was sought as to why a school did not offer all mechanics modules (question five) and all statistics modules (question six) that were available in A-level Mathematics, i.e. M1 and M2 or S1 and S2. These two questions were very similar to those that were asked in the questionnaire in January 2004, i.e. with there being a selection of options and an 'other' option. In the 2006 questionnaire one additional option was inserted, this asked if both modules of mechanics were not offered because mechanics was the most difficult of applied modules (question five) and similarly for statistics (question six). Results for the two questions can be seen in Table 4.17.

![Figure 4.20](image)

**5 If you do not offer M1 and/or M2 in A-level Mathematics is this due to:**

(Please tick all that apply)

- Financial Constraints
- Teacher Skills Shortage
- Lack of Pupil Interest
- Timetable Constraints
- Mechanics being most difficult of applied modules

Other: __________________________________________________________

**6 If you do not offer S1 and/or S2 in A-level Mathematics is this due to:**

(Please tick all that apply)

- Financial Constraints
- Teacher Skills Shortage
- Lack of Pupil Interest
- Timetable Constraints
- Statistics being most difficult of applied modules

Other: __________________________________________________________
Firstly, it should be noted that not all schools completed the two questions. The number of schools that did reply, for each question, in both 2004 and 2006 is in brackets in the second row of Table 4.17, i.e. 51 schools completed question five on mechanics in 2006. In addition, schools were able to choose more than one option so the total percentages will not add up to 100%.

<table>
<thead>
<tr>
<th>Question Response</th>
<th>Mechanics (%)</th>
<th>Statistics (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2004 (58)</td>
<td>2006 (51)</td>
</tr>
<tr>
<td>Financial Constraints</td>
<td>12.07</td>
<td>7.84</td>
</tr>
<tr>
<td>Teacher Skills Shortage</td>
<td>10.34</td>
<td>5.88</td>
</tr>
<tr>
<td>Lack of Pupil Interest</td>
<td>25.86</td>
<td>19.61</td>
</tr>
<tr>
<td>Timetable Constraints</td>
<td>43.10</td>
<td>31.37</td>
</tr>
<tr>
<td>Strand being the most difficult of the applied modules</td>
<td>n/a</td>
<td>35.29</td>
</tr>
<tr>
<td>Other</td>
<td>44.83</td>
<td>35.29</td>
</tr>
</tbody>
</table>

Table 4.17 - Reasons why first two modules of an applied strand were not offered in A-level Mathematics

If results from 2004 and 2006 are reviewed then there are some interesting findings. One of the most common reasons for not offering both modules of a strand, given in 2004, was due to timetable constraints and this was also one of the most common responses in 2006. The same could also be said for the category of 'other', which was the most popular answer in both questionnaires. Various comments were contained in this 'other' category, but the most common were that 'both modules were not needed' and that they 'need to offer some mechanics and statistics' and not just one strand. However, in 2006 the questionnaire was modified to ask whether the strand (i.e. mechanics or statistics depending on which question) was the most difficult of the applied modules. A striking difference was seen between (a) the percentage of schools that responded to say that they did not offer both S1 and S2 for students to study, because it was the most difficult of the applied modules (3%) and (b) those that said
that they did not offer M1 and M2 because it was the most difficult of the applied modules (35%). This agrees with anecdotal evidence that mechanics was perceived to be the most difficult of the applied strands.

**ii Guidance given on applied module choice**

![Figure 4.21 - 2006 final version, schools' questionnaire, question seven](image)

The final question to report upon is question seven, which asked if schools offered guidance on module choice in A-level Mathematics to their students. The question can be seen in Figure 4.21.

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
<th>No Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>53.91</td>
<td>42.80</td>
<td>3.70</td>
</tr>
<tr>
<td>2006</td>
<td>48.89</td>
<td>41.78</td>
<td>9.33</td>
</tr>
</tbody>
</table>

*Table 4.18 - Percentage of schools that offered guidance on module choice in A-level Mathematics*

The results to question seven are shown in Table 4.18. Firstly, in the final column, an increase in those not answering the question can be seen. Those that did not offer guidance, approximately 42% in each year, were, in all but a few cases, the schools that did not give students a choice of which modules to study and hence the need for advice was redundant. It was noticeable that 54% of schools who replied to the questionnaire in 2004 offered guidance, whereas only 49% of schools who replied in 2006 offered guidance. However, the advice given by schools, in both 2004 and 2006, was very similar in nature. The advice generally incorporated the following: if students were studying physics or engineering type A-levels alongside their Mathematics A-level then they should study mechanics modules, whereas other students, and in particular those studying business or sociology or psychology type A-
levels, should study statistics modules. As described earlier in this chapter when the results from the 2004 questionnaire were analysed, this is an interesting finding and in many ways it is a positive one. However, as has been seen in the analysis in Table 4.17 there are many difficulties in actually offering the different modules to students, one being timetable constraints. Therefore, it is not simple to assess just how widely implemented these positive comments are. In addition, some other responses were also received to the question. These included, for example that students should consider studying modules depending on their future study and career plans, and those which they enjoyed the most.

4.5. Summary and Discussion

Within this chapter, two surveys of schools, using questionnaires, have been described and their results analysed. In this section a summary of each of the questionnaires and the associated results will be given. Following this, conclusions will be drawn from the questionnaires.

4.5.1. Summary of 2004 Schools Questionnaire

A survey of schools was carried out in January 2004 with a primary aim of gaining an understanding of the availability and uptake of mechanics in schools. Replies received from the two administrations of the questionnaire were found not to be statistically different and so analysis was conducted on all 243 replies.

From the analysis it was found that mechanics modules were not as widely available as statistics modules within AS/ A-level Mathematics. In over a quarter of schools in the sample, no more than one module of mechanics was offered. Thus there are a significant proportion of school students, some of whom may wish to go on to university to study engineering, who are unable to study mechanics beyond M1, which is at a very basic level. In addition, the number of students studying mechanics modules is less than the number studying statistics modules, though 43% of students did study mechanics to M1 level. However, potential engineering students may not have been among this group. For some of these students, mechanics may not even
have been available at their school. Others decided, or were advised, not to study mechanics.

Several interesting observations were made from data collected from the questions that asked why some or all modules of a strand were not available for students to study. The main two reasons were found to be timetable constraints and that staff did not feel that there was a need for all modules of a strand to be available.

It was also reviewed if schools offered their students guidance on module choice. All but a few of the 43% of schools that did not offer guidance to students cited that they did not offer any module choice. In the 54% of schools that said that guidance was given, again one reply was more common. The advice given was that if students were studying physics or engineering type courses alongside their mathematics course then they should study mechanics modules; for other students, particular those studying business or sociology or psychology style courses then the advice was that they should study statistics modules. This type of guidance is certainly positive, but it is difficult to assess just how widely implemented it is, due to reasons seen in question four, e.g. modules of a specific strand could not be offered because of timetable constraints.

4.5.2. Summary of 2006 Schools Questionnaire

A similar survey of schools to that conducted in January 2004 was carried out in January 2006. A primary aim was to see what effect a change in structure and syllabi (in September 2004) had had on the availability and uptake of mechanics in schools. The key difference in the syllabi was that under the new syllabi students were only able (and required) to study two applied modules in A-level Mathematics.

The questionnaire administered in January 2004 was modified and improved upon. Replies received from two administrations of the questionnaire were found not to be statistically different and so analysis was conducted on all 225 replies. As the purpose of this second survey was to discover if the changes in structure and syllabi in September 2004 had affected the availability and uptake of mechanics in schools, comparative analysis to that carried out on the questionnaire in 2004 was undertaken.
From the analysis of the 225 schools who replied in 2006 it was found that mechanics modules, specifically M1 and M2, were not as widely available as before the changes to the syllabi in September 2004. Furthermore, as detailed in Table 4.13 of section 4.4.3, if the availability of modules is reviewed for students who only study A-level Mathematics (thus excluding those studying A-level Further Mathematics) then the lack of availability is even more striking, i.e. 62% of schools offer at most one module of mechanics. Thus there are a significant proportion of school students, some of whom may wish to go on to study engineering at university, who are unable to study mechanics beyond M1, if only studying A-level Mathematics, which is at a very basic level. With respect to the uptake of mechanics modules it was evident that approximately the same percentage 42% of students (note there was approximately the same number of students studying A-level Mathematics courses in both of the responses samples, i.e. 2004 and 2006) were studying M1. However, a noticeable reduction was seen in the percentage of students studying M2.

Again, as seen in the analysis of the 2004 questionnaire, the other questions on the 2006 questionnaire were also analysed. In reviewing the responses to questions on why all mechanics and statistics modules were not offered in A-level Mathematics and if any advice was given on module choice, in general, similar responses to those received in 2004 were seen in 2006.

4.5.3. Discussion

The motivation for this chapter has been to gain an understanding of recent trends in schools so that they can be placed in context with what is happening in universities. More specifically, interest has been in establishing just what the availability and uptake of mechanics in A-level Mathematics courses was in schools. One particular research method from those detailed in Chapter 3 was seen to be appropriate for such a study; this was a questionnaire. As detailed in the chapter careful consideration was given to the construction, piloting and administration of each questionnaire so that a high-quality research tool was produced. The good response rate to these mailed questionnaires indicated that this was the case and thus allowed for suitable analysis to be undertaken.
Comparative analysis of the availability and uptake of mechanics in schools, prior to and post changes to the A-level Mathematics syllabi in September 2004, was produced. From this comparative analysis it was highlighted that there was a changing picture with respect to the availability and uptake of mechanics modules (in fact a changing picture was also seen for the other strands). However, the changes seen were more of a concern than of an improving situation. The fact that the availability of mechanics, in the schools in the samples, had reduced from 74% of schools offering two or more modules of mechanics in 2004 to 60% offering two or more modules of mechanics in 2006 has to be of interest. Furthermore, additional information sought in the 2006 questionnaire enabled it to be seen that the situation may in fact be worse. This was because those students who had been studying AS/ A-level Further Mathematics had been included in the analysis of the availability of modules. Even if a school offered the first mechanics module (M1), which is in essence an AS-level Mathematics module, but which could also be included in AS-level Further Mathematics, it may have only been available to those on AS/ A-level Further Mathematics courses. Results from the 2006 questionnaire indicated that only 38% of schools offered both mechanics modules (M1 and M2) to students studying A-level Mathematics. This is noteworthy given the general low number of students who, in recent years, have been studying A-level Further Mathematics. Although the change in syllabi in 2004, as well as the creation of a national Further Mathematics Network which has made Further Mathematics available to any student studying in a school or college in England, have both already contributed to an increase in numbers studying AS/A-level Further Mathematics, see BBC (2006).

The main findings with respect to the uptake of mechanics modules were also stark. Given that there were approximately the same number of students studying AS/ A-level Mathematics courses in both the 2004 (13754) and 2006 (13673) samples, the noticeable reduction in students who were studying second level modules, particularly M2 and S2, should be highlighted. This would imply that following the change in syllabi in September 2004 students were choosing or made to study two first level modules. As discussed in section 4.4.3, this may enable students to gain the best possible mark in their A-levels, which not only benefits the students but also the school. In the report published on an evaluation of participation in A-level
Mathematics by Matthews and Pepper (2006: 69) of the QCA, which was discussed in Chapter 2, reference was made to choice of applied units in A-level Mathematics:

Of the (19) case study centres, nine offered no choice of applied units. The most common offer - M1 and S1 only - gives students no choice of units (6 centres). No centres offered only M1 then M2.

This supports the results detailed in the comparative analysis of the questionnaires discussed in this chapter. They also commented upon what part the change in syllabi in September 2004 had had on this:

There was a feeling in nine of the centres in both February and July that it is difficult, perhaps increasingly so, to offer students a choice of application units (notably mechanics and statistics). In some cases, this was attributed to a lack of staff or students' interest. In other cases it seemed to be a new issue for 2004/05, related to the new A-level. Now that it is possible to gain the A-level with 4 AS units (C1, C2 and two units from D1/M1/S1) and 2 A2 units (C3 and C4) some centres may have sought to maximise their results by not offering students any of the A2 applications. Indeed, this was easily the most common combination of units offered by the respondent centres.

Furthermore, the comments received back from the questionnaires in 2004 and 2006 concur with comments that Matthews and Pepper (2006: 69) received from teachers who completed their study:

Most students will choose 2 application units from M1, S1 and D1. Students who do not do 2 units from M1, S1 and D1 will be penalised. For example, good physics students may want to do M1 and M2, as M2 is harder they may get a lower grade. Similarly some biology students may want to do S1 and S2.

It is worth pointing out that this assumes that second modules are harder than first modules. It may in fact prove easier to make a progression from a first module to a second then to study two first modules in unrelated areas, i.e. S1 to S2 may be easier than S1 to M1.
Thus, in conclusion, in this chapter research into the availability and uptake of mechanics in schools in recent years has been reported upon. A natural progression for this research is to establish what the relationship is between the situation in schools, particularly with respect to the uptake of mechanics, and the knowledge of mechanics students enter university with. In the next Chapter, 5, both surveys of and interviews with students reviewing this will be reported upon.
5. Loughborough University Undergraduates' Knowledge of Mechanics

5.1. Introduction

One of the motivating reasons for this work, as discussed in the introduction, was due to a concern over incoming engineering students' lack of knowledge of mechanics, which had become evident through students visiting the MLSC at Loughborough University. Following on from discussion in Chapter 2, of the changes that have taken place in A-levels in recent years, analysis was carried out into the uptake and availability of applied modules and specifically mechanics modules, in schools (Chapter 4). Research into incoming students' knowledge of mechanics upon arrival to university is of interest and is a natural progression from the research already reported upon. This is considered in this chapter.

In this instance students' prior knowledge of mechanics is discussed with respect to the number of mechanics modules they had studied in their A-level Mathematics courses. In Chapter 6 a more in-depth study of students' prior knowledge of mechanics is discussed through the findings of a mechanics diagnostic test. In this chapter the primary method of gaining an understanding of which mechanics modules students had studied is by administering a questionnaire. The structure and administration of the questionnaire to Loughborough University students will be described, along with a discussion of the results. In addition, results from the administration of the questionnaire to students at other universities will be given.

After this the students' perspective on what prior knowledge of mechanics is useful for studying an engineering degree is detailed. Students' opinions were initially gathered through administration of a second questionnaire and subsequently through follow-up interviews. Results from both these methods will be discussed.

Finally, a discussion will be given of the implications of the findings of the study into students' opinions and their prior knowledge of mechanics.
5.1.1. Who Studies Mechanics at Loughborough University?

Firstly, it is appropriate to detail which students at Loughborough University study mechanics. Programmes in which mechanics is studied include Mathematics, Physics and Engineering. The Mathematical Sciences department, each year, teaches approximately 200 first year students who are studying a Mathematics or joint honours Mathematics degree. However, not all these students are required to study a significant amount of mechanics within their degree. The Physics department has an undergraduate intake of approximately 50 students who are required to study mechanics as part of their first year programme. Finally, there are five engineering departments:

- Aeronautical and Automotive Engineering
- Chemical Engineering
- Civil and Building Engineering
- Electronic and Electrical Engineering
- Wolfson School of Mechanical and Manufacturing Engineering

These have a combined intake of approximately 700 undergraduate students each year. With the exception of Chemical Engineering (which has the least number of students) all students study compulsory modules in mechanics. Consequently, with the changes in A-level Mathematics that were discussed in Chapter 2 and the declining numbers who are studying later mechanics modules (in A-level Mathematics) as discussed in Chapter 4, it is possible that there will be a change in the students' ability to be successful in their mechanics modules. Consequently, it was decided to determine just what modules in A-level Mathematics students had studied.

Within universities there is a lot of data held on a student's record. This data predominantly comes from the UCAS application that a student completes to gain entry. However, data such as what A-level modules a student studied in each of their A-levels is not usually readily available. Therefore, such data would have to be obtained via some other means. A suitable method, which was implemented, involved a simple questionnaire.
It should be noted that early in 2006 it emerged that such information will become available to universities, via UCAS, for students entering university in Autumn 2006. It is believed that this information will not go directly to departments but to the university centrally and thus departments would need to request such information.

5.2. Structure and Administration of Prior Knowledge Questionnaire

It is important that consideration is given to the construction of a questionnaire. However, it is also important to look at how it is administered. Even if a questionnaire is well constructed, if it is not administered well, then there may be difficulties in collating the results and producing findings. In this chapter it will be seen that a significant improvement was made to the return rate of a questionnaire in the second year of administration due to a change in the way that it was administered.

5.2.1. 2003-2004 Questionnaire

This first version of the questionnaire was produced in October 2003. Previous experience of constructing questionnaires from a final year degree dissertation, Lee (2003: 69-70) was drawn upon to construct the questionnaire. The previous experience pointed towards creating a simple questionnaire that was quick and relatively easy to complete. Such a questionnaire was created and entitled 'prior learning in mathematics' and can be seen in Appendix L.

The most viable option of administration was to present the questionnaire to students at the start of a lecture (or tutorial session), in the first few weeks of semester one of the academic year 2003-2004. A second method of administration was also considered and trialled. This entailed attaching the questionnaire to an email and sending it to the student's university email address. The smallest engineering department, Chemical Engineering, who have approximately 50 first year students, were the group chosen to trial this method. The response rate achieved was very disappointing with only 10% of the questionnaires being returned. Consequently, it was decided not to extend this method to any of the other departments.
The questionnaire contained questions posed on the mathematics qualifications gained during further education. Questions were focused upon those students who had taken Mathematics A-level(s). For them data was gained on the examination board involved and also what modules and respective grades the student had achieved. If a student had studied any other mathematics qualification in the further education age band, either instead of, or alongside A-level Mathematics then this could also be entered.

Mid-way through administering the first version of the questionnaire to the students the questionnaire was reviewed by Mr Godfrey Pell, a research fellow to the Mathematics Education Centre at Loughborough University. He gave some advice concerning the second question that asked the students for their student ID number, which had 'optional' written next to it. The advice was to simply remove 'optional'. He advised that whilst optional was there students would tend not to complete this, as they would recognise that it was not vital for the study, otherwise it would have been compulsory in the first place. By requesting the ID of each student, the few that may actually object would simply not fill it in. This piece of advice proved correct with a significant increase in students who inserted their IDs after the optional statement was taken away. It was important to obtain each student's ID because this would allow for this data to be collated with other student information that was subsequently collected, such as their diagnostic test results.

The questionnaire was administered during a lecture part way through semester one in the academic year 2003-2004 to students on undergraduate mathematics, physics and engineering programmes. Unfortunately, there was a low attendance and consequently a low response rate; all those that were present in the lecture completed a questionnaire. The total number of completed replies was 457 out of a possible 854 on these programmes. The data was separated into two categories, firstly those that had completed the questionnaire correctly and had studied Mathematics A-level(s) and secondly those that had studied 'other' qualifications or had not completed the questionnaire correctly. There were some 389 students in the first group and the results from these students along with those collected in 2004-2005 will be looked at in section 5.3.
5.2.2. 2004-2005 Questionnaire

The questionnaire was re-administrated in the academic year 2004-2005 to monitor the intake for that year and to establish if there were any recurring trends. After reviewing the first version of the questionnaire, i.e. the one administrated in 2003-2004, it was decided that a more focussed questionnaire could be just as successful. The second version, which was A5 size compared to the previous years A4 size can be seen in Appendix M. In particular it was decided that the data collected on what grades each student had achieved in each module was not needed. It not only led to a significant amount of extra administration, in terms of manually inputting values in a spreadsheet, but also caused some confusion for students. This usually occurred when students could not recall the grades they achieved in each module, which in turn led to them taking longer to complete the questionnaire.

There was also a major development in the second year of administrating the 'prior learning in mathematics' questionnaire. A new mechanics diagnostic test had been developed by the author to be administrated to a large proportion of the engineering students in the academic year 2004-2005 (details of which can be seen later in Chapter 6). As the 'prior learning in mathematics' questionnaire was also to be administrated to engineering students, it was decided to incorporate as much of the questionnaire as possible into the mechanics diagnostic test. There are several reasons for this; one such reason is that the students would not have to complete two separate forms, i.e. the questionnaire and the mechanics diagnostic test. A second reason was that the mechanics diagnostic test was to be marked electronically by an Optical Mark Reader (OMR). If the questionnaire and diagnostic test were combined this would save on a huge amount of administration because the data collected from the questionnaire had to be manually input into a spreadsheet. However, due to the fact that the mechanics diagnostic test was to be optically marked, it meant that certain criteria had to be met, i.e. only five options could be given for each question. Therefore, the questionnaire, as far as possible, was copied into the start of the mechanics diagnostic test. The mechanics diagnostic test, with the equivalent 'prior learning in mathematics' questionnaire on page two can be seen as Appendix N. The question on qualifications, other than A-level Mathematics could not be put into a
format suitable to be optically marked because so many different types of qualification could have been studied. Therefore it would be inappropriate to select only five to be put into the test as the possible options.

The mechanics diagnostic test (that included the questionnaire at the start) was given to the aeronautical and automotive, electrical and electronic, manufacturing and mechanical engineering students. It was also decided to give the questionnaire, without the mechanics diagnostic test, to the civil and building engineering students so that a comparison could be made with the previous year's results. However, as the chemical engineering students do not study a mechanics module and as there was such a small number to compare from the previous year, this group of students were not given the questionnaire. The physics students also sat the mechanics diagnostic test and so completed the questionnaire. The mathematics students completed the questionnaire, although they did not sit the mechanics diagnostic test.

The questionnaire was administrated at the beginning of semester one in the academic year 2004-2005 to students on undergraduate Mathematics, Physics and Engineering programmes. As described in the previous paragraph this was either through the questionnaire itself or by completing the questionnaire as part of the mechanics diagnostic test. The total number of completed replies that were of direct interest, i.e. those that had studied A-level Mathematics, and had completed the questionnaire correctly totalled 703. This was nearly double the number of corresponding replies from the 2003-2004 intake. This increase could have been for several reasons: Firstly, because of the change to administrate it in week one; Secondly because it was combined with a diagnostic test that students were required to complete.

5.3. Results - Prior Knowledge Questionnaire

The focus of the questionnaire was to gather information on which applied modules in A-level Mathematics students had studied. To that end, results for the replies collected from students in the academic year 2003-2004 can be seen in Figure 5.1. This shows the percentage of students who had studied a certain number of modules. There are four separate bars to represent the different types of module, i.e. mechanics,
pure, statistics and discrete. There were a few other types of module available but the number of students studying them was very small and these are ignored.

![A-Level Modules taken](image)

**Figure 5.1 – Results of 'prior learning in mathematics' questionnaire**

From Figure 5.1 comparisons can be made between the percentages of students who study the same number of modules in a different strand. For example it is seen that 23% of students had studied one module of mechanics compared to 45% of students who had studied one module of statistics. Specifically reviewing mechanics modules, it can be seen that over 45% of students had studied two modules of mechanics. This is useful because studying two mechanics modules stands to provide the students with a realistic basic amount of knowledge to build upon when starting a first university module in mechanics. It can also be seen that around 37% of students had studied at most one module of mechanics. This is a little more concerning as those students will not have studied a significant amount of mechanics and they may have difficulties when starting a first university module in mechanics.

One reason for this separation between students who have only studied zero or one module and those who had studied more, as commented upon in 4.4.2, is that the material covered in the first mechanics module is an introduction to topics in mechanics. Hence, the module is essentially set at an elementary level, with topics such as 'force as a vector', 'equilibrium of a particle' and 'Newton's Laws of motion'
(for constant acceleration) being covered. Therefore, although students who have studied M1 will have been exposed to some useful material, it is unclear how much help this will have been to them as preparation for studying an engineering degree. This will be considered in section 5.5 where results of an additional questionnaire entitled 'What prior mechanics knowledge is helpful for studying engineering at Loughborough University' are discussed. In addition, details of interviews with students that were a follow-up to the questionnaire will be given (section 5.6).

5.3.1. Year on Year Comparisons

A similar chart to that in Figure 5.1 could be produced from the results of students entering in 2004-2005. With there being a particular interest in what mechanics students had studied, a comparison between the percentage of students that had studied a given number of mechanics modules in the two intake years gave an insight into year on year trends. This can be seen in Figure 5.2.

![Comparison of A-level Mathematics mechanics modules studied 03/04-04/05](image)

In Figure 5.2, the percentage of students that had studied a certain number of mechanics modules for each of the two intake years is given. For example, from the
2003-2004 intake 24.42% of students had studied one module of mechanics and from the 2004-2005 intake 26.37% had studied one module of mechanics. It can be seen that the data for the two intake years are very similar. It is worth reiterating that the number of replies for the 2004-2005 intake was larger than the 2003-2004 intake.

In Figure 5.1 the overall picture, with respect to all the different strands, was reviewed. In Figure 5.2 the review only incorporated mechanics modules. The focus will now continue on the mechanics modules studied, with differences between the engineering departments being considered. This can be seen in Figure 5.3.

![Percentage of students from different departments who studied two or more modules of mechanics](image)

Figure 5.3 – Mechanics modules studied by department comparison 03/04-04/05

As has been mentioned earlier there is interest in those students who had studied at most one module of mechanics and conversely those that had studied two or more modules of mechanics. Figure 5.3 shows details of the percentage of students for each department who had studied two or more modules of mechanics. For example, in the 2003-2004 intake approximately 65% of mechanical engineering students had studied two or more modules of mechanics, whereas in the 2004-2005 intake approximately 70% had studied two or more modules of mechanics. Thus, for mechanical engineering students there was an increase in the percentage of students who had studied two or more modules of mechanics.
It can be seen that there is some variation both between departments and within the same department for the two intake years. There are several possible explanations for this. One is to do with the type of students who would be expected to embark on such a programme. It would be anticipated that students who want to study engineering at university would recognise the relevance of studying mechanics modules at A-level although, as has been seen in Chapter 4, not all students necessarily had a choice.

Considering the students in the Mathematical Sciences department, a large number, approximately 28% for the 2003-2004 intake and approximately 47% for the 2004-2005 intake, entered having studied two modules of mechanics. A second explanation may be down to the entrance requirements, particularly for engineering, where not all of the departments have the same entrance requirements. Consequently, it may not be surprising that the Aeronautical and Automotive engineering department, who have the highest entrance requirements, for engineering, have the highest percentage of students who have studied two or more modules of mechanics. It can be seen that all but one of the percentages, for each department, in the 2004-2005 intake are higher than the corresponding percentages for the 2003-2004 intake. One explanation for this could be down to the difference in sample size between the two intakes. This will be discussed further in the next section (5.3.2).

The overall average percentage for engineering, mathematics and physics students that have studied at most one module of mechanics for the two intake years was very similar. Therefore, it was important that the breakdown of departments was reviewed in order to see the specific differences, i.e. the lower figures for students in the mathematics department and the higher figures for the aeronautical and automotive engineering students. This gives an indication of the number of students that may well find they need some kind of support or help with their first university mechanics module. For example, 30% of the Mechanical engineering students have studied at most one module of mechanics in A-level Mathematics and this equates to nearly 45 students. Therefore, this is a large number of students that are starting from a low level of prior knowledge.
5.3.2. Review of Response Rates

When reviewing both the responses and the response rate of this questionnaire, the circumstances under which it was administrated have to be taken into consideration. The response rate of around 50% for the 2003-2004 intake would appear to be slightly disappointing. However, this was remedied by making some changes for 2004-2005. Firstly, the majority of students received the questionnaire with the mechanics diagnostic test. This produced a much higher response rate, in the region of 90%, for the 2004-2005 intake. Secondly, where the questionnaire was not administrated with the mechanics diagnostic test there was still an increase in the number of replies because it was given to students very early in the academic year. For example, total replies from Civil and Building engineering students increased from 36% in the 2003-2004 intake to 76% in the 2004-2005 intake, similarly the total replies from the students in the Mathematical Sciences department increased from 24% in the 2003-2004 intake to 92% in the 2004-2005 intake. It is worth noting that the significant increase from the mathematics students was primarily because the questionnaire was administrated in a mandatory session where the students sat a mathematics diagnostic test.

In reviewing the number of respondents it is also worth commenting on those who did not respond, particularly for the 2003-2004 intake; these were the non-attendees. This leads to the question, 'what could be expected from those who did not attend?' One expectation may be that they could be those that have lower qualifications or who need extra support and it is feasible that they would perhaps decrease the percentage that have studied two or more modules of mechanics. Alternatively, it could be the able students who did not attend tutorials. Thus, in 2003-2004 the percentages of those that had studied two or more modules of mechanics may have been larger. Therefore, because either of these permutations or a combination of them could be found means that it is particularly difficult to draw out an accurate reason.
5.4. Extending Prior Knowledge Questionnaire to Other Universities

The research would be better informed if samples from other universities were also taken. Therefore, local universities were asked if the 'prior learning in mathematics' questionnaire could be administered to their students. Both Leicester University and Nottingham University responded positively and allowed the questionnaire to be administered to their first year engineering students.

5.4.1. Analysis of Replies from Three Universities

The number of students studying engineering at the two universities differed considerably. At Leicester University there were in total around 80 students studying engineering, compared to over 400 students at Nottingham University and over 700 from Loughborough University. The number of replies from Leicester University and Nottingham University was 41 and 255 respectively. This equated to over 50% of students in each case, which reflected the attendance on the day of administration. In both universities the questionnaire was administered in a lecture in the final few weeks of semester two in the 2004-2005 academic year. This may in part explain why the attendance for the lectures was low and there would almost certainly have been a higher response rate if administered in the first week of semester one.

It was decided to focus on engineering students and not necessarily look at mathematics and physics students as was done at Loughborough University. Results from Nottingham University and Leicester University were collated and a chart showing the percentage of students that had studied a particular number of mechanics modules, along with those for Loughborough University, can be seen in Figure 5.4.
Figure 5.4 – Comparison of number of mechanics modules studied by students in three universities.

From Figure 5.4 it can be seen that the results from Loughborough University and Nottingham University are very similar, particularly for the students who have not studied much mechanics. For example, 10% of engineering students at Loughborough University and 7% of engineering students at Nottingham University have studied no mechanics modules. The comparable figures for those who have studied one module of mechanics are 24% and 19% respectively. The results from Leicester University are distributed rather differently. There are a higher percentage of students, when compared to the other two universities, who have studied either no mechanics modules or one module of mechanics. Also, there are a lower percentage of students who have studied two or more modules of mechanics. Thus, the sample of engineering students at Leicester University have less prior knowledge of mechanics than those at Loughborough and Nottingham Universities. In considering why this should be, a more in-depth look at the requirements for students at the two universities was considered. This showed that the entrance requirements for studying engineering at Nottingham University are in line with those at Loughborough University, which are both slightly higher than at Leicester University. However, with there being many different engineering programmes available, particularly at Loughborough University and Nottingham University, there was also a variation in
entrance requirements between the programmes. Therefore, this does not give a clear indication why Leicester University students should have studied fewer modules of mechanics in A-level Mathematics. Consequently, the fact that there is a large difference in the number of replies may be of interest.

A $\chi^2$ test can be used to test if there is a statistically significant difference between the universities in the number of mechanics modules offered. Incorporated within this test is the number of replies from each university. A null hypothesis is that there is no difference between the three universities in the number of mechanics modules students have studied. Here the $\chi^2$ result was 0.003. A $\chi^2$ result of below 0.05 indicates that there is a statistical difference between the universities in the number of mechanics modules that their engineering students have studied. However, this does not give any insight into why this might be and further investigation would be needed if a specific reason for the difference were sought.

5.4.2. Cumulative Analysis from Three Universities

As discussed in the previous three sections a questionnaire was administrated to engineering students at Loughborough University in the academic year 2003-04 and was extended to include two other universities (Nottingham University and Leicester University) in the academic year 2004-05. It is worthwhile constructing a cumulative total for the three universities from these two years so an overall picture can be seen.

In total there were 1087 engineering students who completed the questionnaire and who had studied A-level Mathematics. Figure 5.5 shows the percentage of these students who had studied a given number of mechanics modules.

It was heartening to see that approximately 68% of engineering students had studied two or more modules of mechanics. This is considerably more than those in schools in 2004 as seen in section 4.4.3 where, at most, 26% of students had studied two or more mechanics modules. However, results from the 2006 questionnaire to schools showed that at most 17% of students had studied two or more mechanics modules. Consequently, it seems likely that the percentage of engineering students who had studied two or more modules may now be lower (than the 68% in 2004). Thus, there
may be a further overall decline in the prior mechanics knowledge of incoming engineering students. This is something that should concern engineering educators. Administrating the questionnaire to first year students at the beginning of the next academic year (September/ October 2006) may help establish if this is the case or not.

Indeed recently, Prof. Clements at Bristol University conducted a similar study on the number of mechanics modules studied by engineering students. Clements (in press) indicated that:

Robinson et al discovered that amongst engineering students across the three universities surveyed, 9% had studied no mechanics modules and 23% had studied one module only. The equivalent figures for Bristol University are 11% and 17%.

Thus signifying that the similar findings to those detailed in this chapter can also be found in other universities.

Figure 5.5 – Chart showing number of mechanics modules studied in A-level Mathematics/ Further Mathematics by 1st year engineering students
5.5. Second Prior Knowledge Questionnaire

The first questionnaire, which had two versions, was designed to gain information on students' prior knowledge in mathematics. It was administrated to relevant students at Loughborough University and had served to give a useful indication of what modules students had studied in A-level Mathematics. In addition, administrating the questionnaire to students at other universities had been constructive in establishing that the concerning results found are not confined to only Loughborough University. Information on the number of modules of mechanics that students had studied had been collected, but no opinions had been obtained from students. It was therefore thought that gaining information on 'what prior mechanics knowledge is helpful for studying engineering (at Loughborough University)' would allow for a more specific understanding of what mechanics would be useful for studying engineering, including obtaining the students' perspective.

5.5.1. Methodology for Gaining Students' Opinions

It was decided to target one department, mechanical engineering. This department was large in size and contained around 150 first year students. Due to the number of students it meant that certain methods for data collection would be more appropriate than others. It was decided that a questionnaire would be appropriate to gain an overall picture of the students' opinions.

A questionnaire entitled 'what prior mechanics knowledge is helpful for studying engineering at Loughborough University' was produced. This consisted of 13 questions on two sides of A4. Many questions had a range of options to be ticked as well as space for comments. The questionnaire was broken into two sections. Students who completed the questionnaire were all required to complete the first section, which consisted of eight questions. This included questions on how much of the mechanics in their first year module they had met before, as well as how much prior knowledge of mechanics they thought was required and what level they thought the lecturer assumed. Only students who had studied A-level Mathematics were then asked to complete the rest of the questions. These focussed upon why or why not their school had offered certain modules in A-level Mathematics as well as how useful the
modules they had studied had been. The second section was indicated by a change in the background shading, although the question numbers continued from the previous section. The questionnaire can be seen in Appendix O.

In line with recommendations (Cohen et al (2000: 260)) a pilot of the questionnaire was undertaken. A group of 10 aeronautical engineering students trialled the questionnaire in a tutorial session. The trialists completed the questionnaire without any difficulties and gave positive comments on both the layout and ease of completion. In light of this it was decided that the questionnaire was fit for purpose and would not be changed, although the technique of analysing the replies was reviewed after inputting the replies from the trialists. This basically involved changing how certain questions were encoded so that analysis could be done more easily.

5.5.2. Results of Second Prior Knowledge Questionnaire

The questionnaire was administered to mechanical engineering students at the end of a lecture period in week nine of semester two in the academic year 2004-2005. There are 152 registered mechanical engineering students and so with 78 replies there was a response rate of 51%. Not all 152 students were present in the lecture, but all of the students that were in the lecture did complete the questionnaire.

A copy of the questionnaire containing the percentages of the replies for each of the questions from the 78 respondents can be seen in Appendix P. Only 68 students had studied A-level Mathematics and hence completed the second section. Therefore, the percentages for question 9 to 13 are out of 68. A review of the responses received will now follow.

Question one asked for the students' IDs and as commented upon in 5.2.1 this was made a compulsory question, as opposed to being optional. This resulted in all but one of the students completing it, which is useful because data for the students from the other surveys (and diagnostic tests) can easily be collated via student IDs.
Question two asked what degree programme students were studying. The 78 students were all studying mechanical engineering programmes, with 68% studying for a BEng in the subject and 32% studying for a MEng in the subject. These figures were similar to those for all (152) students on the course, where 75% study for the BEng and 25% study for the MEng.

Question three asked if students enjoyed studying mechanics. Interestingly there was a near divide, with 51% saying they did and 49% saying they didn't. Upon reviewing the responses perhaps the questionnaire could have benefited by the insertion of a text box here so that students could have explained why they did/ didn't enjoy studying mechanics.

<table>
<thead>
<tr>
<th>0% - 5%</th>
<th>6% - 25%</th>
<th>25% - 49%</th>
<th>50% - 100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>26%</td>
<td>49%</td>
<td>22%</td>
<td>3%</td>
</tr>
</tbody>
</table>

Figure 5.6 – Second questionnaire question four

Question four, see Figure 5.6, looked to ascertain what percentage of the material in the Engineering Mechanics module, students had met prior to coming to university. There were four intervals offered and it was expected that the majority of students would have completed the boxes with the lower intervals. This proved to be the case with 26% saying they had studied 0% - 5% of the material and a further 49% saying they had studied 6% - 25%, i.e. 75% of students had previously met less than one quarter of the material from the Engineering Mechanics module. Unsurprisingly only 3% had felt that they had previously met 50%-100% of the material. This translated into only two students. Further investigation showed that these students had both studied A-level Further Mathematics and had studied four mechanics modules within this. Perhaps, it may have been beneficial to have had an option of only 0% rather than incorporating it into the interval 0%-5%, so that it could clearly be seen how many students had not actually met any material contained within the Engineering Mechanics module.
Analysis of question five will be looked at shortly, after the result from question eight has been discussed.

Question six asked if the lecturer assumed that students had more, the correct amount or less prior knowledge of mechanics than they actually had. The largest group, 46% thought that lecturers assumed more. 42% of students thought the lecturer assumed the correct amount of prior knowledge and only 13% thought the lecturer assumed less. Again further analysis meant that these could be tied in with how much prior knowledge students actually had. If they had studied three or four mechanics modules then students said the lecturer assumed less. The results for the assumption that the lecturer had assumed more and the correct amount generally equated to the groups who had studied little mechanics, i.e. zero or one module and those that had studied two modules respectively.

Question seven asked if students had studied A-level Mathematics or not. As previously mentioned 68 out of the 78 students (87%) had studied A-level Mathematics, which meant that 10 students (13%) had not. These students had studied a number of different qualifications; four had studied BTECs, one had studied a HNC, four had studied no mathematics qualifications since GCSE Mathematics and one did not put any comment.

Question eight, see Figure 5.7, asked if students had studied a foundation year. There were 11 students (14%) who indicated that they had studied a foundation year, although these were not necessarily those that had studied other qualifications. All of these students had studied a foundation year at Loughborough University, which was identified by their different ID number. These students will have been exposed to some mechanics, as there is a mechanics module in the foundation year course.
Figure 5.7 – Second questionnaire question eight

In the second part of question eight, see Figure 5.7, data was collected on which modules, in A-level Mathematics, students had studied. Details of the results can be seen in Table 5.2.

<table>
<thead>
<tr>
<th>No of Mechanics Modules</th>
<th>No of Students</th>
<th>% of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>8</td>
<td>11.76</td>
</tr>
<tr>
<td>1</td>
<td>13</td>
<td>19.12</td>
</tr>
<tr>
<td>2</td>
<td>35</td>
<td>51.47</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
<td>11.77</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>5.88</td>
</tr>
</tbody>
</table>

Table 5.1 – Percentage of students who had studied a certain number of mechanics modules

Table 5.1 shows the number and percentage of mechanical engineering students who had studied a certain number of mechanics modules in A-level Mathematics. For example, of the 68 students who had studied A-level Mathematics 13 had studied one module of mechanics, which equated to 19.12% of the students who replied. Considering the percentage of students who studied the various number of mechanics modules, these numbers are similar to those in Figure 5.2, which showed the percentages for all 703 students.
It is now appropriate to refer back to Question five, which asked if students thought other students had previously studied more, the same or less mechanics than themselves. The majority of students, 59%, thought that other students had studied the same amount. Just over a quarter, 26%, of students thought that other students had studied more than them, with a smaller number, 14%, thinking that others had previously studied less mechanics than them. Further analysis was carried out, with the replies from this question being reviewed in terms of the number of mechanics modules they had studied. This indicated that students who had not studied any mechanics modules or at most one module thought other students had studied more than them. For example Table 5.1 shows that 30% of students had studied zero or one module of mechanics, which corresponded to the 26% of students who thought others had studied more than them (which can be seen in Appendix P). Similarly, those who had studied two modules (51% - Table 5.1) generally thought that others had studied the same amount (59% - from question five) and those that had studied three or more modules (18% - Table 5.1) generally thought students had studied less (14% - from question five). Overall this indicates that students had a good awareness of what others in the group had studied.

In the second part of question eight, see Figure 5.7, students were asked to complete which modules they had studied. In addition, students had to indicate if they had chosen to study each module or if they had no choice. Table 5.2 shows the data collected.

<table>
<thead>
<tr>
<th>Module</th>
<th>M1</th>
<th>M2</th>
<th>M3</th>
<th>M4</th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
<th>S4</th>
<th>D1</th>
<th>D2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Studied (% of 68)</td>
<td>60 (88%)</td>
<td>47 (69%)</td>
<td>12 (18%)</td>
<td>4 (6%)</td>
<td>56 (82%)</td>
<td>19 (28%)</td>
<td>2 (3%)</td>
<td>1 (1%)</td>
<td>17 (25%)</td>
<td>4 (6%)</td>
</tr>
<tr>
<td>Chose to Study (%)</td>
<td>22</td>
<td>66</td>
<td>42</td>
<td>50</td>
<td>7</td>
<td>16</td>
<td>0</td>
<td>0</td>
<td>35</td>
<td>25</td>
</tr>
<tr>
<td>Had no Choice (%)</td>
<td>78</td>
<td>34</td>
<td>58</td>
<td>50</td>
<td>93</td>
<td>84</td>
<td>100</td>
<td>100</td>
<td>65</td>
<td>75</td>
</tr>
</tbody>
</table>

Table 5.2 – Modules studied by students

In Table 5.2 the modules studied and number of students who studied them are shown in the first two rows. Row three shows the percentage of the students who studied the module that chose to study it. Row four shows the percentage of the students who studied the module that had no choice but to study the module. For example, 47
students studied M2 with 66% of these 47 students choosing to study the module and 34% of the 47 students having no choice but to study the module.

A number of observations can be made from Table 5.2. One concerns reviewing the numbers and percentages of students who studied the first two module of a strand. A high percentage of students had studied at least M1 (88% of the 68 students) and a high percentage had studied at least S1 (82% of the 68 students) with relatively few students studying D1 (25% of the 68 students). This shows the popularity of these modules. In addition, a high number of students studied M2 (69%) compared to 28% who had studied S2 and the 6% who had studied D2. It should be pointed out that these figures are for the percentage of students who had studied a given module, hence a student who had studied the first three modules of mechanics will be included in the figures for M1, M2 and M3, not just for M3.

A second area of interest from Table 5.2 concerns considering those who had chosen to study the modules and those that had no choice but to study them. To begin with, in reviewing the first two modules of a strand, it can be seen that the majority of students had no choice but to study a first module of a strand, i.e. 78% of those studying M1 had no choice, 93% of those studying S1 had no choice and 65% of those studying D1 had no choice. In looking at the second module of a strand (M2, S2, D2) then the figures change slightly. More students were given the choice to study M2, with only 34% of those who studied it saying they had no choice but to study it. However, 84% of students who studied S2 were not given the choice, and 75% of students who studied D2 were not given the choice. For many students if they had studied a module then they had not had a choice but to study it, however it is encouraging that a good percentage (66%) of students studying M2 had chosen to study it.

It is possible to suggest reasons why many students had no choice in the modules they studied. This may be due to a school not offering a choice of modules to study or because they have particular staff expertise in a given strand and consequently only offer that strand. This type of suggestion stems from analysis conducted in section 4.4.4 on the questionnaires to schools in 2004 and 2006 and discussion in section
4.5.3. However, within this questionnaire this idea was probed in more detail with two further questions (nine and ten) on it, see Figure 5.8.

In question nine, students were asked if they had not been given a choice to study a module by their school, then why this was. There were several options given and the largest number of students (30%) indicated that they thought that the school made them study particular modules because they would be useful for future careers. More interestingly the second most common response by students (25%) indicated that teachers thought it would be easier to get a higher mark on the modules they made students study. This agrees with research by Matthews and Pepper (2006: 69) as discussed in section 4.5.3. This may well be a reason why so many students who studied statistics module had had no choice but to study them; Table 5.2 shows that 93% had no choice but to study S1 and 83% had no choice but to study S2. Slightly fewer students (18%) cited small class sizes as a reason why they were not given a choice. The other three possibilities were less common; 10% mentioned a teacher skills shortage, another 10% mentioned large class sizes and 8% cited a lack of pupil interest as a reason why no module choice was given.

9 If your school did not give you a choice on certain modules, why do you think this was?
   (tick all that apply)
   
   Small Class Sizes  16%
   Large Class Sizes  10%
   Lack of Pupil Interest  8%
   Teacher Skills Shortage  10%
   Those modules studied were useful for future careers  30%
   Teachers thought it would be easier to get a higher mark on these modules  25%
   Other: __________________________

Would you have liked to have been given a choice?
   YES  72%
   NO  28%

Please explain your last answer: __________________________

10 If your school gave you a choice of certain modules, why did you choose the modules you did?
   (tick all that apply)
   
   Career Aspirations  33%
   To be with friends  7%
   Teacher Advice  3%
   Would be useful for further study  41%
   Easier to get a higher mark  16%
   Other: __________________________

Figure 5.8 – Second questionnaire questions nine and ten
A second part to question nine asked if students would have liked to have been given a choice and if so why. Some 72% of students said that they would have liked to have been given a choice and cited reasons such as:

- Now I have to play catch up all the time (with their mechanics)
- I feel disadvantaged compared to students that had studied mechanics in A-level Mathematics
- It would have been more beneficial to my degree to have studied mechanics

These indicate that these students thought it would have been better to have been able to study more mechanics, however such reasons may have been because students were looking back retrospectively. If students, whilst at school, did not recognise or were not aware of the benefits of studying mechanics, then they may not have now said that they would have preferred a choice at school. This is supported by the comments made by the 28% who said they wouldn't have liked to have a choice. A typical comment being: 'It was useful to have studied a number of different types of modules (referring to M1 and S1)'.

Question 10, see Figure 5.8, asked students who had been given a choice of which modules to study, why had they chosen the modules they studied. The two most popular reasons were that they would be useful for further study (41% of students) and for career aspirations (33%). The third most popular reason, cited by 16% of the students, was that it was easier to get a high mark. These three results would indicate that students recognised the importance of studying certain modules (and in particular mechanics modules) for both their further study and career aspirations. Moreover the fact that relatively few cited that they chose modules because they were easier to get a higher mark in may correlate with the larger percentage of students who chose to study M2.

The previous few questions in the questionnaire reviewed the reasons why students had studied certain modules. Questions 11 and 12 built upon this by asking students
(question 11) if they had studied mechanics modules and whether this had helped with their first year university modules. Similarly (question 12) asked whether studying statistics modules had helped. 88% of students indicated that having studied mechanics modules in A-level Mathematics had been helpful in their first year modules and 96% said that having studied statistics in A-level Mathematics had not been helpful. Comments made as to why students found studying mechanics in A-level Mathematics useful included: 'Think I would have struggled if I hadn't studied mechanics at A-level' and 'Although I may not have done extremely well, it helps grasp the concept the second time round by already having some basic knowledge'.

Overall the consensus was that studying mechanics in A-level Mathematics gave some useful background to the first year of study at university. Conversely, the high percentage of students (96%) that said having studied statistics in A-level Mathematics was not useful cited reasons such as 'Never met any statistics at university so it was pointless' and 'S1 was no real help, it was more plugging numbers into equations'.

Finally, question 13 asked students if they thought it mattered, for their degree, which applied modules were studied in A-level Mathematics. A high proportion of students, 83%, said that it did matter. The majority of these students went on to suggest that 'as much mechanics as possible, but at least M1 and M2'. This was a very positive finding, in so much that there is an obvious recognition, by students, of just how important and useful it would have been to have studied mechanics modules in A-level Mathematics. As mentioned previously, this may be because students had given an opinion retrospectively at the end of their first year university programme. However, these comments stand to highlight that such awareness needs to be made to both those students in school about to embark on a A-level Mathematics course and to those teaching students who wish to go onto study engineering at university. Alternatively, university courses need to be modified to accommodate those who do not have a background in mechanics.

5.5.3. Summary of Results

Within this chapter much data has been collected and reviewed from a second questionnaire given to mechanical engineering students to discover 'what prior
mechanics knowledge is helpful for studying engineering'. Eleven of the most salient points are:

i. 75% of the 78 students had previously met 25% or less of the material contained within the first year university mechanics module

ii. 70% of the 68 students who had studied A-levels had studied two or more modules of mechanics, which was similar to the result from all 703 students in the questionnaire to three universities

iii. 46% of students thought their lecturer assumed more prior knowledge of mechanics than they had, with another 42% suggesting that the lecturer assumed the correct amount of prior knowledge

iv. A high percentage of students had no choice but to study M1/ S1/ S2 (78%/ 93%/ 84%)

v. 66% of those who studied M2 choose to study it

vi. 30% of students indicated that they thought that their school made them study particular modules because they would be useful for future careers

vii. 25% of students indicated that teachers thought it would be easier to get a higher mark on the modules they made students study

viii. 72% of those students who were not given a choice of which modules to study would have liked to have been given a choice

ix. 88% of students indicated that studying mechanics in A-level Mathematics had been helpful for their first year university modules

x. 96% of students indicated that studying statistics in A-level Mathematics had not been helpful for their first year university modules
83% of students indicated that it did matter which applied modules you studied in A-level Mathematics and that the more mechanics studied the better.

As can be seen from the statistics outlined above, data collected from the students has given an insight into their thoughts and opinions on what prior mechanics knowledge is helpful for studying engineering at Loughborough University. In particular, the fact that so many students highlighted the importance of studying mechanics prior to embarking on an engineering course emphasised the concerns over the reduction in both the availability and uptake of mechanics in schools, as discussed in Chapter 4 (section 4.5.3). The major points detailed here will be discussed further in section 5.7.

5.6. Follow-up Interviews

In an effort to construct a questionnaire to determine what prior mechanics knowledge is helpful for studying engineering and which was relatively short, simple and easy to complete, it was apparent that there would be difficulties in obtaining detailed information. For that reason it was decided to conduct follow-up interviews to gain a better understanding of the students' thoughts and opinions on what prior mechanics knowledge is helpful for studying engineering. It would have been possible to use focus groups (as described in 3.5.3), however in this instance it was thought that students may have been more forthcoming with their personal feelings and opinions in a one-to-one interview.

5.6.1. Interview Structure

When the questionnaire, described in section 5.5 was administrated, a memo was attached to the front. This indicated that students would be invited to attend an interview after completing the questionnaire and receive a nominal payment for their time. On this memo students marked whether they would be willing to be considered for interview; approximately 44% of the students (34 out of 78) marked that they would be. Of these a sample of 10 students (nearly a third of those who gave consent to be interviewed) were selected. This sample consisted of a range of students who had studied different numbers of mechanics modules in A-level Mathematics,
including some with 'other' qualifications. These students were contacted via an email address that they had provided on the memo. Of the 10 students contacted eight were available to be interviewed and participated (and received a nominal payment).

Considering a specific part of the methodology, that of payment, there are various positive and negative aspects to offering payment for attendance at an interview. One of the most concerning, i.e. negative, is if students just want to participate 'for the money', that is just turn up and simply do as little as possible to 'earn their money'. It is very difficult to address this issue prior to an interview, but if a student has such an attitude in an interview then the interviewer needs to react to this and use their expertise to obtain appropriate answers. The main use of payments in interviews is to obtain interviewees. If for whatever reason, e.g. time of year, few or no participants are forthcoming to be interviewed then offering some payment generally increases the level of interest. Without payment participants will ask themselves what is to be gained (perhaps for themselves) from attending such an interview. Academics may appreciate the worth of such research but invariably this will generally not be as common with students. Hence, some other means need to be used to gain their interest and payment is one of the simplest options; other options could be textbooks or vouchers to name but two. However, cash being the most versatile may be most useful.

Students were invited to individually attend an interview which lasted between 30 and 45 minutes. An interview schedule was drawn up, which consisted of questions to complement those in the questionnaire and additional ones to probe more into specific areas, such as their first year mechanics module. Although an interview schedule had been constructed it was intended that these interviews would be more open and transitory rather than being a regimented list of questions. In most cases this construction had been successful and in only one case was a student not very forthcoming with answers. In such a case the interviewer (the author) recognised this early in the interview and made every effort, via reassurance and confidence building, to gain as much information as possible.
During the interviews students' responses were noted down. The notes taken during each interview were reviewed immediately afterwards and any other points that may not have been taken down were noted. Once all interviews had taken place the reviewed notes were analysed. Both quantitative and qualitative analysis was conducted. It would have been beneficial to have had access to computer programmes such as Nvivo, as described in 3.5.3, to conduct qualitative analysis, but awareness of such programmes only occurred after analysis had already been conducted. The analysis of the interviews will now follow.

5.6.2. Feedback from Interviews

The follow-up interviews, to the questionnaire detailed in section 5.5, involved asking questions that built upon questions asked in the questionnaire and these will now be reviewed.

Firstly, as mentioned previously (5.5.2) it would have been beneficial to ascertain why a student said they did or did not enjoy studying mechanics (questionnaire - question three) and this was addressed in the interview. Of the eight students interviewed two had said they did not enjoy studying mechanics and six had said they did. Those that did enjoy studying mechanics gave reasons such as:

- I am more interested in the subject
- It is more useful and has practical applications
- It is easier to visualise and so it comes more naturally

There was also the opportunity to ask if the students enjoyed the subject at school. These six students said that they did enjoy studying the subject at school, where appropriate, in whichever course they studied. The reasons given were the same as for why they enjoyed studying it at university. However, the two students who said they did not enjoy studying mechanics cited reasons such as:

- Mechanics is interesting but difficult due to the number of steps involved in each calculation
- I do not like the university style of teaching
When probed about studying mechanics at school, both students said they had enjoyed it, with one mentioning that they liked the teaching style at school. Hence there had been a change in opinion on enjoyment of the subject, seemingly from this student's dislike of university teaching (perhaps not in all classes, but certainly the one in question).

Students then confirmed their prior level of mechanics knowledge (questionnaire - question four). Most found it difficult to put a single figure on it, instead reiterating which interval was most appropriate.

<table>
<thead>
<tr>
<th>Student</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Qu. 5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Everyone else studied?</td>
<td>M1</td>
<td>Some</td>
<td>-</td>
<td>M1</td>
<td>-</td>
<td>M1</td>
<td>M1+</td>
<td>M1</td>
</tr>
<tr>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Possibly M2</td>
<td></td>
</tr>
<tr>
<td>Qu. 6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lecturer Assumed?</td>
<td>M1</td>
<td>M1</td>
<td>-</td>
<td>M1</td>
<td>-</td>
<td>M1+</td>
<td>M1</td>
<td>M1</td>
</tr>
<tr>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M2</td>
<td>M2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>M2</td>
<td></td>
</tr>
<tr>
<td>Qu. 7 Info On School</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type</td>
<td>State 6th Form</td>
<td>IND. Senior School</td>
<td>State 6th Form</td>
<td>State College</td>
<td>IND Grammar</td>
<td>IND 6th Form</td>
<td>State 6th Form</td>
<td></td>
</tr>
<tr>
<td>Size (Studying A-levels)</td>
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<td>150</td>
<td>1000+</td>
<td>300</td>
<td>-</td>
<td>150</td>
<td>1500</td>
<td>250</td>
</tr>
<tr>
<td>Number studying maths</td>
<td>70</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>-</td>
<td>12</td>
<td>200</td>
<td>30</td>
</tr>
<tr>
<td>Qu. 8 No. of Mechanics Studied</td>
<td>2</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 5.3 - Data from follow-up interviews
Questions five, six and seven were followed up and the data obtained can be seen in Table 5.3. The table shows that all students (except students three and five – who had not studied A-level Mathematics and hence could not comment on its mechanics modules) expected that other students had studied some mechanics and in most cases two modules. Furthermore, the students thought the lecturer assumed at least what they had said that the other students had studied. For example if students thought other students in their class had studied M1 and M2 they also thought the lecturer assumed at least M1 and M2. This reiterates that there is a general expectation that the university mechanics module requires prior knowledge of mechanics and that students expect other students to have such knowledge.

Also in Table 5.3 is data on the type and size of school where each student studied. This was to show that the students interviewed did not come from the same type of school. This proved to be the case with students having studied at different types of schools, including independent and state schools, as well as at colleges, (which were defined by the student to be those that have stand alone years 12 and 13), 6th forms, (defined by the student to be those where years 12 and 13 are within a school), along with senior schools and traditional grammar schools.

In reviewing the comments made by the students on the choices they had in the modules they studied in A-level Mathematics (questions nine and 10), they generally suggested that looking back they would have liked to have studied more (or as much as possible) mechanics. Several students commented that where no choice was available it was generally because the school had traditionally taught certain modules, which may not have included mechanics. This may suggest that schools are teaching to their strengths, perhaps in order to get the highest grades for their students.

Students' response to being asked if they thought they were at an advantage if they had studied mechanics, was universally 'yes'. However, the degree to which it was an advantage was varied, even between students who had studied the same number of mechanics modules previously, i.e. the four students who had studied two mechanics modules. It was noted that the students mentioned that there had been a big divide between studying only one mechanics module and studying more, even if it was only
one more, i.e. M2. In addition, when asked about the mechanics content studied within A-level Physics, students mentioned that they thought it was only equivalent to having studied M1, with it being 'basic and elementary'. Nonetheless it was invariably beneficial to have met the material, however basic, on more than one occasion so that the learning was reinforced.

In response to question 13 from the questionnaire, which asked if students thought that it mattered which applied modules had been studied in A-level Mathematics, students confirmed that they thought that to have studied as much mechanics as possible would be beneficial. Students once again mentioned that they thought students would enter university having studied at least M1 and M2. Furthermore they highlighted the usefulness of meeting mechanics prior to entering onto an engineering course, particularly because of the way it is taught at school. For example, at school material is generally introduced over a longer period of time.

The follow-up questions discussed so far have focused on students' prior knowledge and experience of mechanics; however, in the interviews, questions were also asked on studying mechanics at university. All students felt that mechanics at university was interesting yet challenging. Just how challenging the mechanics was did seem to reflect upon each student's prior knowledge. Particularly the two students who had not studied A-level Mathematics, both commented that they would have been in a better position if they had studied mechanics within A-level Mathematics.

Most students pointed out that university level mechanics was a big step up from that studied in A-level Mathematics. They also referred to the way mechanics is taught as being important. Each student did have their own preferred teaching style but commented that clear presentation of the various steps within concepts and ideas was paramount to gaining a good understanding. Moreover, students reiterated that those teaching should familiarise themselves with the background of each intake of students and that by completing a simple questionnaire, as described in 5.2, an understanding (even a basic one) of the group of students can be gained. Thus, even if the programme or teaching were not modified, at least there would be a basic understanding of the abilities of each year's specific intake.
Thus, in summary within this section details of follow-up interviews with students have been described. These allowed more specific questions to be posed and more depth to be given to those asked in the second questionnaire to students. A number of useful comments arose with students being able to voice their thoughts and opinions on the subject of mechanics. A feature of the interviews was the students’ indication of the overwhelming benefit of having studied as much mechanics as possible before embarking on an engineering course. However, there was also support for those teaching (specifically mechanics but also in general) to have an understanding of the prior knowledge of their student intake each year.

5.7. Summary and Discussion

The purpose of this chapter was to gain an understanding of students’ prior knowledge in mechanics. In order to achieve this, both interviews and questionnaires have been used. Results from these have built upon and been contrasted with analysis conducted on the situation in schools, which were discussed in the previous chapter.

Two important areas in the methodology concerned the construction and administration of a questionnaire. The first questionnaire entitled ‘prior learning in mathematics’ was administrated in 2003-2004 and was successful in acquiring suitable data from students. In particular, it gathered information on what modules students had studied in A-level Mathematics; it also collected details of students’ ‘other’ qualifications where appropriate. The response rate of approximately 50% was primarily because of the time and method of administration, i.e. in lectures and tutorials midway through semester one.

This first implementation of the ‘prior learning in mathematics’ questionnaire did stand to inform future developments, both in terms of construction and administration. Consequently, an improved and shorter second version of the questionnaire was produced to be given to students in 2004-2005. In addition, the administration process was changed with the questionnaire being included within a mechanics diagnostic test at the start of the semester. This significantly increased the number of replies and
consequently the response rate. Subsequently, analysis of results from both intakes was conducted. Results obtained allowed for generalisations to be made as to which type of module was studied more often. However, the focus of the questionnaire had been to specifically gain an understanding of what mechanics modules students had studied.

Discussion into the concern towards students who had not studied two or more modules of mechanics in A-level Mathematics was seen. Approximately 37% of students in the 2003-2004 intake had not studied two or more modules of mechanics. By comparing the results for the two intakes (2003-2004 and 2004-2005) it was evident that there had been little change in the number of mechanics modules students had studied prior to entry to university. A review of the percentage of students who had studied two or more modules of mechanics for specific departments enabled it to be seen that students in different departments had different levels of prior knowledge in mechanics.

To further the research into what prior knowledge of mechanics students had upon entry to university, the questionnaire was administrated at two other universities. It was found that a significant proportion of the students 26%, 37% and 54% (for Nottingham University, Loughborough University and Leicester University respectively) have studied little or no mechanics prior to entry to a university engineering degree.

It has been necessary to produce a questionnaire to gather data on which modules students had studied in their Mathematics A-level. At the beginning of 2006 it emerged that such information will become available to universities, via UCAS, for students entering university in Autumn 2006. It is believed that this information will not go directly to departments but to the university centrally and thus departments would need to request such information.

In addition to questioning which A-level Mathematics modules students had studied prior to entry to university, a questionnaire on 'what prior mechanics knowledge is helpful for studying engineering at Loughborough University' was given to students.
This allowed information to be gathered on what students' perceptions were of the mechanics they thought they needed for their engineering course. Many interesting statistics arose from the data collected. In particular, a very high percentage of students (88%) commented that studying mechanics in A-level Mathematics had been very useful for studying their degree (mechanical engineering). Also of interest was that 46% of students said that their lecturer assumed they had more mechanics knowledge than they had. Thus reiterating the importance of academics gaining an understanding of what prior knowledge of mechanics students have.

It was also decided to use follow-up interviews to gain more detailed responses from students and ask some additional questions. This proved useful as the students gave feedback on both their prior mechanics knowledge and their experiences of a first university module of mechanics. Students indicated that the mechanics module studied at university was challenging but interesting and that the level was much more difficult than studied at A-level. However, they noted how helpful it had been to be exposed to the material in the context of A-level Mathematics, particularly the way it is taught, i.e. over a longer time span.

Overall, the construction of two questionnaires allowed for data on students' prior knowledge of mathematics and in particular which mechanics modules they had studied to be collated, as well as finding out their opinions on the usefulness of studying mechanics. This has indicated that a significant percentage (32%) of (1087) students had studied little or no mechanics (zero or one module) prior to entry onto a university programme that will require them to study and use mechanics. However, the research methods described in this chapter have not been able to establish exactly what knowledge of mechanics students actually have; even though students may have studied two modules of mechanics in A-level Mathematics it does not imply that they know and understand the material contained within them. Consequently, in the next chapter the implementation and analysis of a mechanics diagnostic test administrated to engineering (and physics) students will be discussed. The connection between students' performance in the mechanics diagnostic test and their assumed prior knowledge of mechanics will be seen.
6. Diagnostic Testing of Loughborough University Undergraduates

6.1. Introduction

In Chapter 4 it was seen that in the 2006 sample of 225 schools, 16% of schools did not offer any mechanics modules to students in A-level Mathematics, with a further 46% of schools offering only one module of mechanics. Among the engineering intake at three universities, incorporating 1087 engineering students, it was found (in Chapter 5) that approximately one in three students (32%) entered university having studied at most one module of mechanics in A-level Mathematics courses. Thus, a significant number of engineering students will enter having studied little or no mechanics prior to university. Even those that have studied mechanics modules may not have high grades in them nor have a good understanding of the material. Thus, a mechanics diagnostic test was created to ascertain the level of knowledge of mechanics of incoming students. It would also be possible to relate this to a student's prior knowledge with respect to how many mechanics modules they had studied in A-level Mathematics.

In this chapter a brief background to diagnostic testing will be given. Following this a mechanics diagnostic test developed by the author will be discussed; this will include detail on its structure and administration. Next several components of analysis of both the results from the test and the test itself will be presented. This will entail conducting statistical analysis of how different groups of engineering students performed on the test, as well as how those who had not studied A-level Mathematics did. Assessment of the mechanics diagnostic test itself will also be carried out, along with a comparative review of the mathematics diagnostic test given to students at Loughborough University. Finally, a summary and discussion will be given.

6.2. Recent Research on Diagnostic Testing

From a study by Hibberd (1995: 323), entitled 'The mathematical assessment of students entering university engineering courses', diagnostic tests were seen to be effective, efficient and valuable as a tool in which to detect at a very early stage any
significant gaps in knowledge of an individual student. They also allowed for the provision to 'inform and assist future planning of lectures, seminars and classes or for more general use for revision purposes.' A similar outlook on mathematics diagnostic testing was portrayed by academics who wrote in the LTSN report 'Diagnostic testing of Mathematics', MathsTEAM (2003).

In the past ten years much work has been done nationally on the 'mathematics problem' including a report by the London Mathematical Society (1995) entitled 'Tackling the mathematics problem'. In the year 2000 a recommendation was made to all universities, Hawkes and Savage (2000: 4) that those students embarking on mathematics based degree programmes should have a diagnostic test on entry. It stated that:

"Diagnostic tests play an important part in:
• identifying students at risk of failing because of their mathematical deficiencies,
• targeting remedial help,
• designing programmes and modules that take account of general levels of mathematical attainments, and
• removing unrealistic staff expectations."

It also found that "At least 60 Departments of Mathematics, Physics and Engineering give diagnostic tests in mathematics to their undergraduates."

At Coventry University the mathematics department administers several mathematics diagnostic tests to various groups of students, including engineering students. These include both paper-based and computer-based tests. Several journal articles have been published on the findings and their implications from these long-standing tests, e.g. Lawson (2003), which focused upon reviewing the changing incoming ability of students entering Coventry University between 1991 and 2001.

The MLSC at Loughborough University carries out mathematics diagnostic testing of many students who are studying a number of different degrees. Each year results are collated from approximately 750 first year engineering students, including those on a
foundation course. Approximately 250 mathematics and physics students sit a
different mathematics diagnostic test. Robinson and Croft (2003: 181) stated that
"Early indications are that the diagnostic test is a useful vehicle for identifying
students in need of extra support..." which arose from reviewing 1000 results from a
mathematics diagnostic test that is taken annually by students at the university.

Responses to questions in the mathematics diagnostic test for engineering and
foundation students at Loughborough University were analysed by Lee (2003). The
mathematics diagnostic test contains 40 multiple-choice questions that are split into
two sections, one on number (12 questions) and one on algebra (28 questions). Lee
(2003: 43) concluded that: "Questions in the algebraic section were answered
considerably worse than those in the number section." This highlights that students
are more proficient in certain topics and that establishing which topics they don't
perform well in can be useful for structuring extra support.

6.3. A New Mechanics Diagnostic Test

As has been outlined in section 6.2 the mathematics diagnostic test, which is sat by
engineering students at Loughborough University, has been successful at identifying
students in need of extra support. In order to ascertain what level of mechanics
knowledge engineering students have upon entry, a second 'mechanics' diagnostic test
was administered to students from several engineering departments at the beginning
of the 2004-05 academic year. This worked in conjunction with the questionnaire
(referred to in Chapter 5), to gather information on and form a better understanding of
the students' knowledge of mechanics upon entry to the university.

6.3.1. Background to Mechanics Diagnostic Tests

With there being a large number of universities throughout the country using
mathematics diagnostic tests, see MathsTEAM (2003), effort was made to establish
whether there was already a suitable mechanics diagnostic test available. This search
consisted of reviewing relevant literature, using Internet search engines and speaking
with researchers and lecturers in the area. Through a discussion with Professor Mike
Savage from Leeds University, a mechanics diagnostic test that had been given to
their students some ten years ago was found. However, this particular mechanics test was discontinued some years ago, with one of the reasons for this being that the students found the test very difficult. Results began to come out very low and thus the test did not differentiate between the students' abilities and hence, over time it ceased to be useful.

A mechanics test that is given to students in the department of Mechanical and Systems Engineering at Newcastle University, see Anderson (1997), was found. This is quite a specialized case in that John Appleby, under Teaching and Learning Technology Programme (TLTP) Phase 1 funding, created a computer program called Diagnosys. This was primarily a mathematics diagnostic test that used a bank of mathematics questions to give students a random selection of questions on specific topics. However, there was also a bank of mechanics questions written. The mechanics test, generated by the Diagnosys system using the mechanics bank of questions, was not as systematically researched and evaluated as the mathematics test, but (at Newcastle University) has been used along with the mathematics test for some years. It provided some feedback to students on their deficiencies in mechanics and also informed tutors. Over 60 institutions have used the Diagnosys program. All only used the mathematics test though with the mechanics test having not been widely marketed. An insight into the results from the Diagnosys programme can be seen by reviewing comments made during a workshop entitled 'A mathematics toolkit for scientists', Appleby (2001):

John has analysed the results of his students over several years, and has found a strong correlation between performances in the diagnostic test and results in the first year mathematics examination (surprisingly, there is no correlation between this examination and A-level)

As will be seen shortly, ideas from both these tests were used in producing a mechanics diagnostic test at Loughborough University. However, subsequent to the development of the mechanics diagnostic test at Loughborough University, due to work undertaken as part of a project for the Higher Education Academy Engineering Subject Centre, Robinson et al (2005), another mechanics diagnostic test was discovered.
At Strathclyde University, within the mechanical engineering department, a computer-based mechanics diagnostic test is used (although it originates from Arizona State University in the USA). This test is used to help the students recognize gaps in their knowledge.

6.3.2. Structure and Administration of Mechanics Diagnostic Test

With experience of administrating a mathematics diagnostic test to large groups of students (circa 1000 overall per annum) here at Loughborough University and the findings that are obtained from the results, see Robinson and Croft (2003: 177-181), it was decided that the mechanics test would be constructed similarly. Therefore, the mechanics test was to be a paper-based, multiple-choice, Optical Mark Reader (OMR) marked test. In particular, it would focus upon establishing if students were able to use and apply basic concepts from mechanics. In the academic year 2003-2004, the examination board OCR included the following topics in their Mechanics 1 (M1) module:

- Force as a vector
- Equilibrium of a particle
- Newton's Laws of motion
- Linear momentum
- Kinematics of motion in a straight line

It was found that the mechanics module, M1, from other examination boards generally contained similar topics.

Since 2003, the mathematics diagnostic test administrated at Loughborough University has incorporated a system of 'dual questioning' and research has been conducted into this, see Lee & Robinson (2005). In the dual questioning method questions are asked in pairs, i.e. questions one and two would be on the same area of a topic, questions three and four would be on another area of either the same topic or another topic. This method allowed it to be seen what kind of understanding a student had of a given topic area. In general if a student:
• Had a good understanding of a topic, they would correctly answer both questions
• Did not understand the topic, they would answer both questions incorrectly
• Had some understanding, but may have an incomplete knowledge or had made a slip, they would answer only one of the questions correctly

Lee & Robinson (2005: 160) concluded that:

To get full advantage of the paired question approach it is essential that the pair test exactly the same skill and have the same number of steps involved

Consequently, it was felt that it would be difficult to adhere to the dual questioning approach in a mechanics diagnostic test, i.e. testing the same skill and having the same number of steps. Subsequently, it was decided to set three questions on each of the five 'Mechanics 1' topics (from OCR as mentioned previously), although in the end only two questions were set on one of the topics (linear momentum) because there was not much depth to material covered in the topic in the module. These 14 questions formed the basis of the test and were to be the discriminators between students who had studied none or one or more modules of mechanics. As well as these questions, one question was set on each of the five 'Mechanics 2' topics, in order to identify those students who had studied a higher number of mechanics modules. Also included were five 'other' questions, which did not directly fall into the topic titles given above, but that were common misconceptions and thus regarded as right for inclusion. Such questions in the test would also distinguish between the more able students. The actual test can be seen as Appendix N. In total there were 24 questions.

There were a few questions that were used from Diagnosys (permission for this was granted by the creator) and modified so that they were suitable for a paper-based test. Two questions on misconceptions in mechanics were from the publication 'Mechanics in Action', Savage & Williams (1998). The rest of the questions were created by the author from variations of previous A-level examination mechanics questions (from the MEI board) and text books (MEI textbooks).
An example, question 17 in the mechanics diagnostic test, can be seen in Figure 6.1:

17.

What does the gradient of a displacement-time \((t,x)\) graph represent?
(Where: \(t\) is time and \(x\) is displacement)

A) Acceleration, B) Velocity, C) Displacement, D) None of these, E) Don't Know

Figure 6.1 – Example of question from mechanics diagnostic test (Q17)

This shows how the questions are laid out, with multiple-choice answers, including option E of 'Don't Know', which is common to all questions. Students were encouraged to choose this if they did not know how to do the question and not just guess, so that it was clear what they had and had not studied.

Once the test had been written it was trialled by three people. Although these were not students about to enter onto an engineering university course, they were people who had studied A-level Mathematics within the previous three years. Two had studied mechanics modules in A-level and one had not. This indicated if the level of the questions was appropriate, which in most instances it appeared to be, as well as checking on how long it took to complete. The scores from the trialists were such that the person who had not studied mechanics scored the lowest. A slight concern was shown over the length of time it took trialists to complete the test, which was towards the upper time limit of 50 minutes (as this is the length of a lecture). However, it was thought that incoming students, having just studied the material, would complete the test more quickly. Once the test had been completed by our trialists, it was reviewed by Mr David Holland who is the Deputy Chairman and Chief Mechanics Examiner for MEI, and who has written MEI's A-level mechanics module exams for several years. The feedback provided was positive and only minor recommendations were made on the wording of some questions, which were subsequently implemented.

The questionnaire (referred to in Chapter 5) was then integrated into the mechanics test paper and administered to several groups of engineering students at the beginning of the 2004-2005 academic year. These were aeronautical, automotive, electrical,
mechanical and manufacturing engineering students. Within these groups there were potentially in the region of 500 students who would sit the mechanics diagnostic test.

6.4. Results and Analysis

In this section the results from the mechanics diagnostic test will be detailed and analysed. This will begin with overall analysis of engineering students results. Following this, those students who indicated that they did not study A-levels will be considered. Finally in this section, analysis of how students performed in the different topics will be reviewed.

6.4.1. Mechanics Diagnostic Test Results and Analysis

In total 450 engineering students completed the mechanics diagnostic test, which was administrated in a tutorial session in the first week of term. This resulted in a high response rate of over 93% of registered students completing it. This, along with data on each department and overall statistics can be seen in Table 6.1. For example, 123 out of 130 electrical engineering students, 94.62%, took the test gaining an average result of 63.58% with a standard deviation of 23.34%.

The mean mark for all students who took the test was 69.84%, equivalent to answering approximately 17 correct out of the 24. The median mark was actually 71% (or 17 out of 24) and the modal mark was 75%. These marks are high, however discussion into the reasons why this may have been the case can be seen later in this chapter (6.4.4).

<table>
<thead>
<tr>
<th>Department</th>
<th>No. of students in department</th>
<th>No. of students who sat Mech DT</th>
<th>% of those on course</th>
<th>Mech DT Average</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aeronautical/Automotive</td>
<td>139</td>
<td>133</td>
<td>95.68</td>
<td>77.21</td>
<td>20.95</td>
</tr>
<tr>
<td>Electrical</td>
<td>130</td>
<td>123</td>
<td>94.62</td>
<td>63.58</td>
<td>23.34</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>61</td>
<td>54</td>
<td>88.52</td>
<td>65 85</td>
<td>15.40</td>
</tr>
<tr>
<td>Mechanical</td>
<td>156</td>
<td>140</td>
<td>89.74</td>
<td>69 77</td>
<td>12.94</td>
</tr>
<tr>
<td>TOTAL</td>
<td>486</td>
<td>450</td>
<td>92.59</td>
<td>69 84</td>
<td>16.13</td>
</tr>
</tbody>
</table>

Table 6.1 – Table of departments, number of students and their averages in the test
One of the goals of the mechanics diagnostic test was to ascertain the level of mechanics knowledge, with respect to the number of A-level mechanics modules students had studied. The number of mechanics modules students had studied was collated with their mechanics diagnostic test result and can be seen in Table 6.2. For example, Table 6.2 shows that 95 students had studied one mechanics module, which equated to 21.23% of the total students who sat the test, and obtained an average of 65.85% in the mechanics diagnostic test. Also cumulatively 27.98% of students had studied zero or one module of mechanics.

<table>
<thead>
<tr>
<th>Mechanics</th>
<th>No. of students</th>
<th>% of students</th>
<th>Cumulative %</th>
<th>Mechanics DT Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mech Modules</td>
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<td></td>
</tr>
<tr>
<td>0</td>
<td>30</td>
<td>6.76</td>
<td>6.76</td>
<td>59.93</td>
</tr>
<tr>
<td>1</td>
<td>95</td>
<td>21.23</td>
<td>27.98</td>
<td>65.85</td>
</tr>
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<td>2</td>
<td>207</td>
<td>46.14</td>
<td>74.12</td>
<td>74.55</td>
</tr>
<tr>
<td>3+</td>
<td>67</td>
<td>14.88</td>
<td>89.00</td>
<td>81.25</td>
</tr>
<tr>
<td>Don't Know</td>
<td>49</td>
<td>11.04</td>
<td>100</td>
<td>48.20</td>
</tr>
<tr>
<td></td>
<td>448</td>
<td>100</td>
<td></td>
<td>69.84</td>
</tr>
</tbody>
</table>

Table 6.2 – Average diagnostic test results for engineering students who have studied different numbers of mechanics modules

Two pertinent points can be drawn from this table. Perhaps of most interest is that those students who have studied more mechanics modules scored on average higher on the mechanics diagnostic test and this will be discussed further in subsequent paragraphs. Secondly, the cumulative figure for those students that had studied no modules or at most one module of mechanics was 27.98%. This is similar to the figure of 32% seen in Chapter 5 (section 5.4.2) for the cumulative total from the 1087 engineering students (of which this 450 is a subset).

In Table 6.2 the response 'Don't Know' indicates that either the student could not remember how many mechanics modules they had studied or that they had not studied A-levels. Also, the reason why only 448 results were returned from the 450 students was because two students either did not mark anything on their answer sheet or their results were unreadable by the OMR (for the question on number of mechanics.
modules studied). For subsequent analysis this 'Don't Know' group will be excluded and considered on its own. Thus the following analysis will be conducted on 399 students.

Initial checks needed to be made to ensure that the results form a normal distribution, in order to conduct subsequent statistical analysis. Figure 6.2 shows the distribution of the number of mechanics modules students had studied; the approximate normal distribution curve is also detailed.

![Figure 6.2 - Distribution of number of mechanics modules students studied](image)

From Figure 6.2 it can be seen that the number of mechanics modules students studied is approximately normally distributed, with a mean of 1.8 modules and a standard deviation of 0.81 modules.

Figure 6.3 shows the distribution of the mechanics diagnostic test marks. Again this approximately follows a normal distribution with a mean of 72.6 and a standard deviation of 13.66.

The plots of the diagnostic test results for students in each of the groups, i.e. those who studied one module of mechanics, two modules of mechanics, can be seen in Appendix Q. There it is shown that the results for students in each of the groups also
follow an approximate normal distribution. Thus statistical analysis can now be carried out.

![Distribution of mechanics diagnostic test marks](image)

Figure 6.3 – Distribution of mechanics diagnostic test marks

A scatter plot of the mechanics diagnostic test mark for each student was made with respect to the number of mechanics modules each student had studied. A line of best fit was placed on the plot and a specific correlation coefficient ($R^2$) value was calculated, see Figure 6.4.

A definition of a correlation coefficient ($R$) from web reference [10] can be seen in Appendix R. The formula for $R^2$ known as 'the coefficient of determination' is:

$$R^2 = \frac{\sum (x - \bar{x})(y - \bar{y})}{\sqrt{\sum (x - \bar{x})^2 \sum (y - \bar{y})^2}}$$

In Figure 6.4, $x$ denotes the number of mechanics modules studied and $y$ denotes the mechanics diagnostic test result for a student. $\bar{x}$ denotes the average number of mechanics modules studied and $\bar{y}$ denotes the average mechanics diagnostic test result.

From web reference [11]:

169
The coefficient of determination, $R^2$, is useful because it gives the proportion of the variance (fluctuation) of one variable that is predictable from the other variable. It is a measure that allows us to determine how certain one can be in making predictions from a certain model/graph.

**Mechanics DT result versus Number of Mechanics Modules Studied**

![Graph showing linear regression line](image)

Figure 6.4 – Plot of individual's mechanics DT result versus number of mechanics modules studied.

In Figure 6.4 a linear line of best fit of $y = 7.422x + 59.372$, gives a $R^2$ value of 0.1947. Thus, 19% of the variation in a student's mechanics diagnostic test can be attributed to the number of mechanics modules they had studied. In order to know if the R value is positive or negative the gradient coefficient of the line of best fit needs to be considered. In this case the gradient coefficient is +7.422, so there is a positive correlation.

Although the $R^2$ value is low, it still shows positive correlation between the two variables. There is a great deal of difference in the range of $R^2$ values that are regarded as being acceptable and this is usually a reflection on a given piece of research. For example, in Hunt et al (1995), when reviewing the number of first year university modules passed with respect to a mathematics diagnostic test then an $R^2$ value of 0.09 was taken as being acceptable (in other parts of their analysis $R^2$ values of 0.24 and 0.44 were also taken).
Further information, than that obtained from in Figure 6.4, can be gained by constructing both a box and whisker plot, see Figure 6.5 and a plot of confidence intervals for the means of the groups, see Figure 6.6.

In this the box represents the inter-quartile range, which contains 50% of the values. The whiskers are lines that extend from the box to the highest and lowest values, excluding outliers, which are points that are between 1.5 and 3 box lengths from the upper and lower edges of the box (where box length is the inter-quartile range). The line across the box indicates the median. Hence, the positive linear correlation that was found previously can also be seen in this plot and is described by both the boxes and the median lines. The fact that there is no overlap of the median lines is reassuring, in so much that the groups are not in line, i.e. the median for the group who have studied two modules is not higher than the median for the group who had studied three modules. As with the median lines, none of the boxes of a lower group
are higher than the box of a higher group. In Figure 6.5, the outliers are indicated with an 'O' and the number of students in each group (who had studied a given number of modules) is indicated on the x-axis. Here, it can be seen that in the sample of 399 students, there are relatively few outliers, indeed only 7 out of 399 (1.56%).

Figure 6.6 - Plot of confidence intervals

Figure 6.6 gives a plot of the 95% confidence intervals for the population mean of a group. So, for example in looking at the group who had studied two mechanics modules, the 95% confidence interval indicates that the mean for the population is within the interval of 73% to 76% in 95% of the cases. In the groups who had studied one, two or three mechanics modules the intervals are relatively small, although the group who had studied no mechanics modules have slightly larger intervals, up to a maximum interval of approximately 12%. It is important that there is little overlap between the confidence intervals for the different groups as this indicates that a result could be generally related to a single group.

From the analysis conducted it appears that groups of students who have studied a given number of mechanics modules in Mathematics A-levels perform differently in the mechanics diagnostic test. A specific statistical test can be used to examine whether there is a difference between the mean scores (on the diagnostic test) of the groups depending on the number of mechanics modules they have studied. This is a
one-way ANOVA test; see web reference [12] for further details of the method. Firstly a null hypothesis, which is to be tested, is stated:

Null hypothesis: There is no difference between the mean mechanics diagnostic test result for each group of students who have studied a given number of mechanics modules in Mathematics A-levels.

Data was taken from relevant spreadsheets and ANOVA analysis was conducted using the software SPSS. Table 6.3 shows the result of the test in the standard output format.

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F Value</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>14544.09</td>
<td>3</td>
<td>4848.03</td>
<td>32.05</td>
<td>.00</td>
</tr>
<tr>
<td>Within Groups</td>
<td>59751.17</td>
<td>396</td>
<td>151.27</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>74295.26</td>
<td>399</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6.3 – ANOVA analysis of mechanics DT results

Using the standard procedures for ANOVA testing, an F value of 32.05, as seen in Table 6.3, was obtained and gives a significant result of less than 1%. Hence it can be concluded that the null hypothesis, that the group means are equal, can be rejected and the group means are in fact not equal. This result does not indicate what the difference is in the means of the groups, only that there is a difference. However from the analysis preceding the ANOVA test, it is evident that the results in the mechanics diagnostic test increase significantly with the number of mechanics modules students had studied.

6.4.2. Analysis of 'Don't Know' Group

Analysis has been done with respect to the number of mechanics modules students have studied and how well they do in the mechanics diagnostic test. However, in Table 6.2 there were a large number of students who fell into the 'Don't Know' (which will be abbreviated to DK) group. Further attention will now be given to this group.
Within the DK group there were 49 students (11% of the sample). They answered Don't Know to question three, which asked how many mechanics modules they had studied. To reiterate, students were asked to complete the Don't Know box for questions one to five if they had not studied A-level Mathematics or if they could not remember what modules they had studied. It was anticipated that there would be relatively few students who could not remember what modules they had taken and so it was expected that the majority of the students in the group would be those who had not studied A-level Mathematics (or alternatively overseas students entering offering ‘other’ qualifications and thus had not studied A-level Mathematics).

The DK group average of 48.20% was someway below the whole group average of 69.84% and was also 10% less than the group who had studied zero mechanics modules. Upon looking at the group who answered DK to question three, the students within this group could be put into categories. The first was whether the student was British or Overseas. Reviewing manually each of the student's records did this. The second was whether they were a 'new' student, i.e. had just entered the university, or if they were a 'returning' student either from a foundation course or having changed courses or repeated a year. Reviewing their ID number did this. With these categories the diagnostic test marks can be seen in Table 6.4.

| Category         | British or Overseas | DT average
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>New students</td>
<td>11 – Overseas</td>
<td>49.09 %</td>
</tr>
<tr>
<td>(32)</td>
<td>21 – British</td>
<td>45.81 %</td>
</tr>
<tr>
<td></td>
<td>32 – Total</td>
<td>46.94 %</td>
</tr>
<tr>
<td>Returning students</td>
<td>0 – Overseas</td>
<td>50.59 %</td>
</tr>
<tr>
<td>(17)</td>
<td>17 – British</td>
<td></td>
</tr>
<tr>
<td><strong>OVERALL</strong></td>
<td><strong>49 students</strong></td>
<td><strong>48.20 %</strong></td>
</tr>
</tbody>
</table>

Table 6.4 – DT Results for various groups

Here, the 'new' British students did not score very highly, with the overseas students doing only slightly better, still having a low mark compared to the overall average of
69.84%. However, the 'returning' British students did as well as the 'new' overseas but again still having a low average compared to the overall average. Therefore, there does not seem to be any one particular group of students, i.e. British, overseas, new or returning, to explain why the DK group did not score as highly as other students. Therefore, the reason may simply come down to the fact that the group as a whole had not studied A-level Mathematics.

6.4.3. Analysis of Returning Students

When gathering the data on those that had entered DK to any questions, data was also sorted for all the 'returning' students. In total (from the 450 students) there were 58 students who had an overall average of 62.00%. Thus, the returning students as a whole do not account for the low average mark.

E.g. Returning Students (58) 57 - British DT average = 61.84 %
1 – Overseas DT average = 71 00 %

Some of the returning students had studied a Foundation year, which included a module in mechanics. However, the 38 students who had studied a foundation year averaged 60.79% in the mechanics diagnostic test. This result compared well with the group of students who had studied zero modules of mechanics, whose average was 59.93%. However, this is lower than the overall of 69.84%. Hence, it is not obvious that returning students performed, on average, any worse then any other group of students.

6.4.4. Diagnostic Test Question and Topic Analysis

Alongside reviewing how students scored on the test as a whole, it would also be very beneficial to consider further how individual questions and topics were answered. This information can be used to do several things, including selecting appropriate topics and materials for students to revise including specific mathematical techniques
Table 6.5 – Ranking of question topics of mechanics DT

Table 6.5 gives information on how the topics in the mechanics diagnostic test ranked according to the percentage of correct responses. As described earlier, the topics are with respect to the examination board OCR and thus for other examination boards some topics may be in other modules. Information in the table also includes how many questions were in each topic and at what level (Mechanics 1, M1, Mechanics 2, M2, or mixed). For example, the topic of 'equilibrium of a particle' was ranked in fourth place and contained three questions that were at M1 level. Students scored an average mark of 82% for the three questions, which were 9, 10 and 11.

In Table 6.5, it can be seen that in general the M1 questions were answered better than the M2 questions, with the exception of question number 23 on the M2 topic of 'equilibrium of a rigid body'. In retrospect it would seem that this particular question could have been guessed intuitively without prior knowledge of the principle of moments. This may also have been the case with the centre of mass question (number 22), where the answer could have been intuitively answered without any specific...
knowledge on centres of mass. Again, in retrospect, this is something that should be avoided if possible. However, in reviewing the coefficient of restitution question (number 25), which requires a non-intuitive answer, i.e. prior knowledge of the topic being required, it can be seen that this was answered correctly by less than 50% of students. This made it one of the five worst answered questions of them all. It is certainly not good practice to have questions that could be answered intuitively as this can lead to misunderstanding, not only in terms of a student's own knowledge but also in terms of giving the impression that a topic is known and understood.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Qu. No</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>13</td>
<td>91</td>
</tr>
<tr>
<td>14</td>
<td>12</td>
<td>73</td>
</tr>
<tr>
<td>23</td>
<td>14</td>
<td>21</td>
</tr>
</tbody>
</table>

Table 6.6 – Ranks of questions 12, 13, 14

The group of M1 questions on Newton's laws of motion were ranked eighth behind several M2 topics. One reason for this could have been that one of the three questions (number 14) was answered considerably worse than the other two in the topic (see, Table 6.6). For example the average of questions 12 and 13 was 82%, which would have ranked the topic in equal fourth place in Table 6.5. Question 14 was actually more difficult than the other two in the topic, and would be one of the more difficult questions on an M1 topic.

Interestingly Table 6.7, which looked at the ranking of the individual questions, indicated that almost two-thirds (15 out of the 24 questions) were answered better than the average mark for the mechanics diagnostic test, which was 69.84%. Consequently nine questions were answered worse than average. In looking at this further, if the two groups are separated and averages taken, as in Table 6.8, then it can be seen that the two groups are not spread equally about the overall average of 69.83%. This indicates that there was a greater range of results for the bottom nine questions. This is supported by the larger standard deviation for the bottom nine ranked questions (as opposed to the top 15 ranked questions). This is what would be expected in so much that the M2 questions would be answered less well.
Table 6.7 – Ranking of individual questions of mechanics DT (above average and below average)

In constructing in detail the marks and rankings for both individual questions and topics, it can be seen that a lot of the questions were answered well, in particular most of the M1 questions, with only two being answered below the overall average. It is somewhat surprising however, to find the group who have studied no modules having an average of 60% (as seen in Table 6.2).

<table>
<thead>
<tr>
<th>Rank</th>
<th>Qu. No.</th>
<th>Result (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9</td>
<td>98</td>
</tr>
<tr>
<td>2</td>
<td>15</td>
<td>93</td>
</tr>
<tr>
<td>3</td>
<td>23</td>
<td>93</td>
</tr>
<tr>
<td>4</td>
<td>13</td>
<td>91</td>
</tr>
<tr>
<td>5</td>
<td>7</td>
<td>91</td>
</tr>
<tr>
<td>6</td>
<td>11</td>
<td>90</td>
</tr>
<tr>
<td>7</td>
<td>6</td>
<td>89</td>
</tr>
<tr>
<td>8</td>
<td>19</td>
<td>85</td>
</tr>
<tr>
<td>9</td>
<td>17</td>
<td>81</td>
</tr>
<tr>
<td>10</td>
<td>18</td>
<td>78</td>
</tr>
<tr>
<td>11</td>
<td>16</td>
<td>77</td>
</tr>
<tr>
<td>12</td>
<td>22</td>
<td>75</td>
</tr>
<tr>
<td>13</td>
<td>8</td>
<td>73</td>
</tr>
<tr>
<td>14</td>
<td>12</td>
<td>73</td>
</tr>
<tr>
<td>15</td>
<td>27</td>
<td>71</td>
</tr>
</tbody>
</table>

Table 6.8 – Spread of averages

<table>
<thead>
<tr>
<th>Rank</th>
<th>Average</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top 15</td>
<td>83.86</td>
<td>8.88</td>
</tr>
<tr>
<td>Bottom 9</td>
<td>46.44</td>
<td>18.39</td>
</tr>
<tr>
<td>All</td>
<td>69.83</td>
<td>22.54</td>
</tr>
</tbody>
</table>

Difference: Top 15 and All averages = 14.03

Difference: Bottom 9 and All averages = 23.39

Table 6.8 – Spread of averages
The fact that, as seen in the previous subsection, there is a significant difference between the groups of students who have studied different numbers of mechanics modules is good. However, this does not explain the high average of 60% for the group who have studied no modules. Reviewing the individual questions has indicated that a lot of questions were answered well and there are several possible reasons for this. As mentioned earlier reviewing the questions indicates that at least 50% could be answered well with a reasonable knowledge of mathematics, not necessarily mechanics knowledge. One possible reason for this could be that with some of the questions in the early mechanics topics it is inherently possible to answer them correctly using:

- Other mathematics skills, not necessarily mechanics skills, e.g. Question seven, using trigonometry for calculating forces
- Intuition, e.g. Question 22, calculating the centre of mass of a simple shape
- Natural ability/ guesswork, e.g. Question 13, calculating acceleration or Questions 15 and 16, on linear momentum

Another explanation is that nearly all engineering students will have studied A-level Physics as well as A-level Mathematics. As discussed in Chapter 2, within A-level Physics there are modules that contain mechanics material. Therefore, it is possible that students could have some experience of mechanics, especially the basics that is covered in M1, having indicated (on the questionnaire) that they had not studied any mechanics in A-level Mathematics. It is anticipated that if the questionnaire and mechanics diagnostic test were implemented again this information could be obtained.

6.5. Assessment of Mechanics Diagnostic Test

As described, the mechanics diagnostic test discriminated between the students in terms of their knowledge of mechanics and thus gave an indication of which students are more likely to encounter problems with their first year mechanics and other related modules. However, as this was the first time the mechanics diagnostic test had been administrated it needed to be evaluated. There are two components to this; firstly a
discussion on item analysis and secondly a discussion on the distracters used. Following this, a comparison will be made with the mathematics diagnostic test and item analysis will subsequently be conducted on the mathematics diagnostic test.

6.5.1. Item Analysis of Mechanics Diagnostic Test

As described by Ebel and Frisbie (1991: 225):

Item analysis can indicate which items may be too easy or too difficult and which may fail, for whatever reasons, to discriminate properly between high and low achievers.

There are two primary measures (or indexes) considered in item analysis. These are:

- The index of item difficulty (i.e. how difficult the question was / how many students correctly answered the question)
- The index of discrimination (i.e. how the question discriminates between the good (upper 25%) students and the poor (lower 25%) students)

The item difficulty gives a value between 0 and 100; with the higher value indicating the question was easier. The item discrimination can take values between -1 and 1. A value between 0 and 1 shows a positive discrimination between the upper and lower groups, whereas a value between 0 and -1, shows a negative discrimination. Ebel and Frisbie (1991: 232) discussed the calculations for these measures and produced a table giving an indication of what the values of the index of discrimination represent, see Table 6.9.

<table>
<thead>
<tr>
<th>Index of Discrimination</th>
<th>Item Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.40 +</td>
<td>Very Good Items</td>
</tr>
<tr>
<td>0.30 to 0.39</td>
<td>Reasonably good but possibly subject to improvement</td>
</tr>
<tr>
<td>0.20 to 0.29</td>
<td>Marginal items, usually needing and being subject to improvement</td>
</tr>
<tr>
<td>Below 0.19</td>
<td>Poor items, to be rejected or improved by revision.</td>
</tr>
</tbody>
</table>

Table 6.9 – Item discrimination - description of values
Table 6.10 shows the outcome of the two indexes for the 24 questions of the mechanics diagnostic test. For large groups of students the method involves calculating an estimation for the item difficulty from students in the upper 25% and lower 25%. These answers are what are shown in Table 6.10 for the item difficulty. However, the actual item difficulty for each question, as opposed to this estimation have already been shown in Table 6.7. Hence, it can be seen that the estimations are a reasonable estimate of the actual values.

In Table 6.10, for the item difficulty, it can be seen that there is a large range of values, from 24.55 to 96.88, although 19 of the questions were correctly answered by more than half of the students (as indicated by an item difficulty value of more than 50).

With respect to the item discrimination, 16 out of the 24 (67%) questions had a value of 0.30 or above (in fact 0.35 or above), which indicated the questions were reasonably good or very good. The eight questions, which had discrimination values below 0.30, were the eight 'easiest' questions as determined by the item difficulty. Thus, this indicates that the easiest questions did not discriminate very well between the upper and lower 25% of students.

These two simple measures have given a brief insight into the questions on the diagnostic test. However, as stated by Case and Swanson (2001: 107), "We recommend that attention be focused on the pattern of responses rather than on the difficulty level or discrimination index." Thus, the pattern of responses is now considered.

The students whose score on the mechanics diagnostic test was in the top 25% of results and bottom 25% of results were separated from the rest. These were labelled as the High and Low groups. Then, for each of these groups the percentage of students in the group who choose each of the five possible answers on each question in the test was collated. An example of this can be seen in Table 6.11, where 98.21% of the High group chose the correct answer C and 72.32% of the low group also chose C for
question six. The corresponding Tables for the other questions can be seen in Appendix S.

<table>
<thead>
<tr>
<th>Qu. Number</th>
<th>Item Difficulty</th>
<th>Item Discrimination</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>85.27</td>
<td>0.26</td>
</tr>
<tr>
<td>7</td>
<td>85.71</td>
<td>0.25</td>
</tr>
<tr>
<td>8</td>
<td>71.88</td>
<td>0.47</td>
</tr>
<tr>
<td>9</td>
<td>96.88</td>
<td>0.06</td>
</tr>
<tr>
<td>10</td>
<td>54.46</td>
<td>0.71</td>
</tr>
<tr>
<td>11</td>
<td>86.61</td>
<td>0.23</td>
</tr>
<tr>
<td>12</td>
<td>68.30</td>
<td>0.44</td>
</tr>
<tr>
<td>13</td>
<td>87.05</td>
<td>0.17</td>
</tr>
<tr>
<td>14</td>
<td>27.23</td>
<td>0.40</td>
</tr>
<tr>
<td>15</td>
<td>87.95</td>
<td>0.22</td>
</tr>
<tr>
<td>16</td>
<td>74.11</td>
<td>0.36</td>
</tr>
<tr>
<td>17</td>
<td>77.23</td>
<td>0.35</td>
</tr>
<tr>
<td>18</td>
<td>72.77</td>
<td>0.49</td>
</tr>
<tr>
<td>19</td>
<td>85.27</td>
<td>0.22</td>
</tr>
<tr>
<td>20</td>
<td>45.09</td>
<td>0.53</td>
</tr>
<tr>
<td>21</td>
<td>24.55</td>
<td>0.38</td>
</tr>
<tr>
<td>22</td>
<td>72.32</td>
<td>0.46</td>
</tr>
<tr>
<td>23</td>
<td>90.18</td>
<td>0.18</td>
</tr>
<tr>
<td>24</td>
<td>58.93</td>
<td>0.63</td>
</tr>
<tr>
<td>25</td>
<td>47.77</td>
<td>0.67</td>
</tr>
<tr>
<td>26</td>
<td>65.18</td>
<td>0.55</td>
</tr>
<tr>
<td>27</td>
<td>62.05</td>
<td>0.62</td>
</tr>
<tr>
<td>28</td>
<td>45.98</td>
<td>0.49</td>
</tr>
<tr>
<td>29</td>
<td>65.18</td>
<td>0.52</td>
</tr>
</tbody>
</table>

Table 6.10 – Item difficulty and item discrimination for the 24 questions of the mechanics diagnostic test

<table>
<thead>
<tr>
<th>Qu. 6</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>Unknown</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>0.89</td>
<td>0.89</td>
<td>98.21</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Low</td>
<td>4.46</td>
<td>14.29</td>
<td>72.32</td>
<td>0.00</td>
<td>8.93</td>
<td>0.00</td>
</tr>
<tr>
<td>ALL</td>
<td>1.56</td>
<td>7.11</td>
<td>88.89</td>
<td>0.22</td>
<td>2.22</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Table 6.11 – High and Low group responses to question six

Firstly, in all 24 questions a higher percentage of the High group correctly answered each question, than did from the Low group. This was seen previously by the fact that the discrimination index for all questions was positive.
Secondly, when considering the questions that were answered the worst, comparing the percentage of students in each group that answered the question correctly gives some interesting findings. For example, the first question that was not answered very well was question 10. Overall 57.56% answered it correctly, with 90.18% of the high group answering it correctly, compared to only 18.75% of the low group. In most instances this was the case for the questions answered the worst, i.e. questions 14, 20, 21, 24, 25, and 28. In addition, in many of these questions students in the low group chose option E, which was 'Don't Know' and hence admitted that they didn't know how to answer the question. For example, in question 10, 56.25% of the low group chose E and for question 25, 57.14% of the low group chose E. This indicates that such questions worked well because they enabled the better students to obtain the correct answer, while the lower attaining students generally indicated that they didn't know how to answer the question.

Also of interest when undertaking item analysis is to consider how the distracters performed. In 19 out of the 24 questions, over 90% of the students in the high group answered the question correctly. This meant that there were very few students who chose each of the other distracters. However, in only 10 out of the 24 questions, over 50% of the students in the low group answered the question correctly. This meant that a large percentage of students in this group chose one of the distracters or option E signifying that they didn't know how to answer the question. In many questions it was evident that one or sometimes two of the distracters attracted the most (incorrect) responses and this was particularly the case for those students in the high group who incorrectly answered a question. Basically, this indicates that all distracters were not as good as each other. However, in virtually all of the questions it was extremely difficult to create three equally likely and plausible 'other' solutions than the correct one. Therefore, although students chose in general only one or two of the distracters, when an examiner reviews the results they are able to detect the mistakes that students were making. For example, in question 14, it was possible to distinguish that the majority of those who answered the question incorrectly (56.22%) had multiplied by two instead of divided by two. This type of outcome is considered to be constructive and indicative of a reasonable question, as although students had selected only one (or
at most two) distracters, upon review it was possible to observe the reason for their incorrect answer to the question.

Overall, the questions in the mechanics diagnostic test had distinguished between the high and low attaining students. The questions had enabled it to be seen if students didn't know the answer to the question, which was particularly evident for the lower attaining students. Distracters had given insight into students' misunderstandings, although having three good quality distracters rather than just one or two could improve questions. When there was little discrimination between students in the high and low groups, questions were very well answered. It may be that these questions could be made more difficult. The likely effect of this would be to bring down the overall (high) average for the test and produce a higher percentage (greater than 66%) of good discriminating questions. However, the easiness of such questions is likely to be more to do with the nature of the topics involved (required) within the test then just the fact that such questions were 'made' easy. Consequently, when trying to assess basic topics in mechanics, easier questions may be inherent in such a test.

6.5.2. Comparisons with the Mathematics Diagnostic Test

From work done in the previous sections, the mechanics diagnostic test appears to have been quite successful in differentiating between students who had studied different numbers of mechanics modules. It can also be recalled that the students sat a mathematics diagnostic test at the start of their programme. It would be useful to establish if there was any overlap in performance of the two (mechanics and mathematics) diagnostic tests. In reviewing the two tests it can be seen whether the same students do equally as well in both tests and also how the students performed overall as a whole on both tests.

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>No of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanics DT</td>
<td>69.99</td>
<td>16.03</td>
<td>442</td>
</tr>
<tr>
<td>Mathematics DT</td>
<td>72.04</td>
<td>16.55</td>
<td>442</td>
</tr>
</tbody>
</table>

Table 6.12 – Averages of two diagnostic tests.
Firstly, Table 6.12 indicates the overall mean and standard deviations of the two tests in the academic year 2004/2005. This shows very little difference between them. Secondly, Tables 6.13 and 6.14 indicate the percentage of students who fall into a certain group (determined by their mechanics diagnostic test and mathematics diagnostic test result respectively). The intervals were constructed to sort the groups:

- Less than 50% i.e. those who were perceived to be in the need of extra support
- Between 50% and 70% i.e. those who were above the lower level but scored up to the average for the test (approximately 70% for each test)
- Greater than 70% i.e. those who did better than average

Again, it can be seen that the figures for both are very similar. Although the two tests appear to be sorting the students into similar groups, it does not necessarily follow that the same students perform the same in both tests. To demonstrate if this was the case, a scatter plot was produced, see Figure 6.7.
Figure 6.7 – Scatter plot of mechanics and mathematics diagnostic test results

A $R^2$ value of 0.31 (corresponding to a $R$ value of 0.56) indicates that there is correlation between the two tests and looking at the plot shows this to be a positive correlation. This suggests that those who do better in the mathematics diagnostic test, in general do better in the mechanics diagnostic test as well. This is an interesting general finding, but to establish if there are any further connections between how students did in the mechanics diagnostic test and how they did in the mathematics diagnostic test more work would have to be undertaken. In the scope of this project it was decided not to consider further the relationship between the two (mathematics and mechanics) but instead to consider how the mechanics/ mathematics diagnostic test result related to overall first year performance - this forms the basis of Chapter 8.

6.5.3. Item Analysis of Mathematics Diagnostic Test

As with the mechanics diagnostic test it would be constructive to conduct item analysis on the mathematics diagnostic test in order to review it. Table 6.15 shows the values for the item difficulty and item discrimination, for each of the 40 questions on
the mathematics diagnostic test. In addition, in the final column the associated comment from Ebel and Frnsbie (1991: 232) on the item discrimination, i.e. how good the question was, is given.

<table>
<thead>
<tr>
<th>Qu Number</th>
<th>Item Difficulty</th>
<th>Item Discrimination</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>44.37</td>
<td>0.43</td>
<td>Very good</td>
</tr>
<tr>
<td>2</td>
<td>92.79</td>
<td>0.11</td>
<td>Poor</td>
</tr>
<tr>
<td>3</td>
<td>92.12</td>
<td>0.13</td>
<td>Poor</td>
</tr>
<tr>
<td>4</td>
<td>95.05</td>
<td>0.08</td>
<td>Poor</td>
</tr>
<tr>
<td>5</td>
<td>86.26</td>
<td>0.27</td>
<td>Marginal</td>
</tr>
<tr>
<td>6</td>
<td>54.28</td>
<td>0.71</td>
<td>Very good</td>
</tr>
<tr>
<td>7</td>
<td>77.03</td>
<td>0.41</td>
<td>Very good</td>
</tr>
<tr>
<td>8</td>
<td>66.89</td>
<td>0.61</td>
<td>Very good</td>
</tr>
<tr>
<td>9</td>
<td>89.64</td>
<td>0.17</td>
<td>Poor</td>
</tr>
<tr>
<td>10</td>
<td>84.01</td>
<td>0.28</td>
<td>Marginal</td>
</tr>
<tr>
<td>11</td>
<td>90.32</td>
<td>0.18</td>
<td>Poor</td>
</tr>
<tr>
<td>12</td>
<td>92.79</td>
<td>0.10</td>
<td>Poor</td>
</tr>
<tr>
<td>13</td>
<td>78.38</td>
<td>0.36</td>
<td>Reasonable</td>
</tr>
<tr>
<td>14</td>
<td>91.44</td>
<td>0.09</td>
<td>Poor</td>
</tr>
<tr>
<td>15</td>
<td>85.81</td>
<td>0.21</td>
<td>Marginal</td>
</tr>
<tr>
<td>16</td>
<td>52.03</td>
<td>0.69</td>
<td>Very good</td>
</tr>
<tr>
<td>17</td>
<td>73.87</td>
<td>0.45</td>
<td>Very good</td>
</tr>
<tr>
<td>18</td>
<td>54.50</td>
<td>0.70</td>
<td>Very good</td>
</tr>
<tr>
<td>19</td>
<td>84.46</td>
<td>0.26</td>
<td>Marginal</td>
</tr>
<tr>
<td>20</td>
<td>75.23</td>
<td>0.44</td>
<td>Very good</td>
</tr>
<tr>
<td>21</td>
<td>72.30</td>
<td>0.53</td>
<td>Very good</td>
</tr>
<tr>
<td>22</td>
<td>69.59</td>
<td>0.57</td>
<td>Very good</td>
</tr>
<tr>
<td>23</td>
<td>77.93</td>
<td>0.38</td>
<td>Reasonable</td>
</tr>
<tr>
<td>24</td>
<td>62.84</td>
<td>0.56</td>
<td>Very good</td>
</tr>
<tr>
<td>25</td>
<td>43.69</td>
<td>0.56</td>
<td>Very good</td>
</tr>
<tr>
<td>26</td>
<td>71.40</td>
<td>0.47</td>
<td>Very good</td>
</tr>
<tr>
<td>27</td>
<td>68.02</td>
<td>0.49</td>
<td>Very good</td>
</tr>
<tr>
<td>28</td>
<td>41.22</td>
<td>0.66</td>
<td>Very good</td>
</tr>
<tr>
<td>29</td>
<td>64.41</td>
<td>0.58</td>
<td>Very good</td>
</tr>
<tr>
<td>30</td>
<td>55.86</td>
<td>0.60</td>
<td>Very good</td>
</tr>
<tr>
<td>31</td>
<td>67.79</td>
<td>0.48</td>
<td>Very good</td>
</tr>
<tr>
<td>32</td>
<td>67.79</td>
<td>0.57</td>
<td>Very good</td>
</tr>
<tr>
<td>33</td>
<td>83.56</td>
<td>0.32</td>
<td>Reasonable</td>
</tr>
<tr>
<td>34</td>
<td>56.98</td>
<td>0.59</td>
<td>Very good</td>
</tr>
<tr>
<td>35</td>
<td>50.90</td>
<td>0.76</td>
<td>Very good</td>
</tr>
<tr>
<td>36</td>
<td>60.36</td>
<td>0.74</td>
<td>Very good</td>
</tr>
<tr>
<td>37</td>
<td>70.50</td>
<td>0.50</td>
<td>Very good</td>
</tr>
<tr>
<td>38</td>
<td>59.68</td>
<td>0.67</td>
<td>Very good</td>
</tr>
<tr>
<td>39</td>
<td>48.42</td>
<td>0.72</td>
<td>Very good</td>
</tr>
<tr>
<td>40</td>
<td>33.11</td>
<td>0.47</td>
<td>Very good</td>
</tr>
</tbody>
</table>

Table 6.15 – Item difficulty and item discrimination for the 40 questions of the mathematics diagnostic test

In Table 6.15, for the item difficulty, it can be seen that there is a large range of values, from 33.11 to 95.05. In fact 35 out of the 40 questions were correctly
answered by more than half of the students (as indicated by an item difficulty value of more than 50). With respect to the item discrimination, 31 out of the 40 (78%) questions had a value of 0.30 or above, which indicated the questions were reasonably good or very good. The nine questions, which had discrimination values below 0.30, were the nine 'easiest' questions as determined by the item difficulty. Thus, this indicates that the easiest questions did not discriminate very well between the upper and lower 25% of students.

From this initial analysis it can be seen that the mathematics diagnostic test, like the mechanics diagnostic test, discriminated between the students. Again, further analysis with respect to distracters, in the mathematics diagnostic test, could be reviewed. However, for this project such detailed focus on the mathematics diagnostic test is not required.

6.6. Summary and Discussion

Within this chapter the idea of diagnostic testing as a method of ascertaining a student's level of knowledge upon entry to university has been introduced. A new mechanics diagnostic test was developed and given to engineering students at Loughborough University. These students already sat a mathematics diagnostic test, which looked to identify students that may be in danger of failing. The mechanics diagnostic test was used to independently diagnose a specific issue of concern, that of the students' prior knowledge of mechanics upon entry to university.

Structuring and administrating expertise was built upon from the mathematics diagnostic test. The structure was similar in that it was a paper-based, multiple choice, OMR marked test. There were three questions on each of the M1 topics and one question on M2 topics, along with a few 'other' questions that did not fall specifically into a topic. Administration consisted of giving the test in a tutorial period in the first week of term, which resulted in over 92% of students registered on the given courses completing the diagnostic test.

In total there were 450 students who completed the mechanics diagnostic test from several engineering departments, with an overall average result of 70%. These
students were categorised into groups according to how many mechanics modules they had studied, which was obtained via a set of questions (as discussed in Chapter 5) at the start of the test. Statistical analysis was then carried out; this included a plot of each individual student's mechanics diagnostic test mark against the number of mechanics modules they had studied in A-level Mathematics. The line of best fit and R^2 value for the data were calculated. A plot of the 95% confidence intervals and a box-whisker plot were also created and reviewed. Finally, a one-way ANOVA test was conducted to test the hypothesis that there was no difference between the mean mechanics diagnostic test result for each group of students who had studied a given number of mechanics modules in Mathematics A-levels. The outcome of the ANOVA test indicated that the hypothesis should be rejected and that there was in fact a difference. Furthermore, reviewing all the analysis gave indication that the results in the mechanics diagnostic test increase significantly with the number of mechanics modules students had studied. This is an important conclusion and one that has many implications for engineering educators. For example, this emphasises that those students entering university having studied differing amounts of mechanics (as concluded from Chapter 5) do not enter with the same level of knowledge in mechanics as would be expected those who have studied more mechanics modules did do better on the mechanics diagnostic test. This will be further discussed in relation to students overall first year performance in Chapter 8.

Another area that was reviewed concerned looking at a group of students who answered 'Don't Know' to the questions on which A-level modules they had studied. To reiterate students were asked to complete 'Don't Know' for all the boxes if they had not studied A-level Mathematics. It was found that this group did not score well in the diagnostic test, generally being some 20% below the average for the whole group. Several areas were considered including if they were British or overseas students or if they were new students or returning students. However, this did not seem to make much difference to their diagnostic test mark. Therefore, there does not seem to be any one particular group of students to explain why the DK group did not score as highly as other students, other than the fact that they did not study A-level Mathematics.
The overall average was quite high at 69.84% and even the group of students who had studied no mechanics modules scored reasonably high at nearly 60%. There were several reasons put forward for this including that in some questions in the early mechanics topics, it may be inherently possible to answer them correctly using:

- Other mathematics skills, not necessarily mechanics skills
- Intuition
- Natural ability/ guesswork
- Mechanics knowledge picked up from A-level Physics

Consequently, this test could have been regarded as being accessible to all students, in so much as to allow many students to succeed in the test and score highly. However, it was able to discriminate students according to their prior mechanics knowledge.

Comparisons between how students did in the mechanics diagnostic test and the mathematics diagnostic test showed that there was very little difference between the mean and standard deviation of the two tests. When sorted into certain mark intervals (<50%, 50% to 70%, >70%) again very little difference between the tests were found, although it did not necessarily follow that the same student performed the same in both tests. Consequently, a scatter plot was produced that showed that there was a positive correlation, which suggests that it can be concluded that on average those who do better in the mathematics diagnostic test, in general do better in the mechanics diagnostic test as well.

Finally, item analysis of both diagnostic tests was conducted. This analysis indicated that both (mechanics and mathematics) tests were good at discriminating between the high and low scoring students.

Consequently, within this chapter further analysis to that conducted in Chapter 5, in gaining an understanding of incoming students knowledge of mechanics has been undertaken. The implemented research methods of questionnaires and diagnostic testing have proven to be both suitable and useful. Through work detailed in the previous three chapters, the issue of incoming university students' knowledge of mechanics has been reviewed with respect to the schools situation as well as through
actually questioning and testing students. Knowing the viewpoint from the university lecturer would be valuable in giving a further perspective on the 'mechanics problem'. Hence this will be detailed in the next chapter (seven). Following this, in Chapter 8, consideration will be given as to whether students' first year performance can be predicted. This will include data collected from the research methods described in this chapter.
7. Engineering Academics' Perspective

7.1. Introduction

In the context of assessing what are the repercussions in higher education of the changes in the teaching and learning of mechanics in schools, several areas have already been considered. Firstly, information was collected from schools, which primarily looked at the uptake and availability of mechanics modules in A-level Mathematics. Secondly, information on the number of mechanics modules studied was collected, from relevant undergraduate students in three universities, and analysed. In addition, at Loughborough University opinion was sought on what prior mechanics knowledge students thought would have been useful for studying an engineering degree. Various methods had been used to collect all this data including: questionnaires, interviews and diagnostic tests. In order to get a more complete picture, it would be beneficial to gain an insight into the subject from appropriate academics in universities. Hence, this chapter introduces and discusses opinions and data collected from academics at universities, using an online questionnaire and follow-up interviews. Such methodology allowed for a greater understanding of how academics perceive issues surrounding a student's knowledge of mechanics upon entry to university.

7.2. Questionnaire to Engineering Academics

There were a number of areas of interest from which information was sought from academics, including gaining an understanding of what they perceive is a students' prior knowledge of mechanics and the teaching of mechanics. It was decided that the most suitable method for obtaining such information was via a questionnaire and more specifically, an online questionnaire. Details of the online questionnaire and reasons why it was appropriate now follows.

7.2.1. Design and Implementation of Questionnaire

As has been discussed in Chapter 3, it is very important that the design and implementation are reviewed when using questionnaires for collecting data. The
implementation of the questionnaire is considered first. Ways in which the questionnaire could be sent to as many relevant academics as possible was reviewed. Dr Sarah Williamson of the HEA Engineering Subject Centre informed the authors that the Engineering Subject Centre had a mailing list of academics. Although the authors were not able to obtain a copy of the list (for data protection reasons) she suggested that an online questionnaire be prepared and then staff in the HEA Engineering Subject Centre would email those on their mailing list with the link to the questionnaire. The mailing list had over 600 names of engineering academics, support staff and other related staff, with contacts in almost every engineering department in the UK.

Producing an online questionnaire would be significantly more cost effective than mailing a questionnaire (if, as discussed earlier, a researcher had expertise in creating online documents). Once the questions were prepared, Paul Newman, a web designer in the Mathematics Education Centre, constructed an online version of the questionnaire. Subsequently, the questionnaire was made available via an active webpage.

The questionnaire contained questions in sections entitled:

- Participant's details
- Section 1 - Introductory questions (to assess their suitability for answering the questionnaire)
- Section 2 - Gaining an understanding of students' prior knowledge in mechanics
- Section 3 - Teaching of mechanics
- Section 4 - Mechanics (support) materials
- Section 5 - Monitoring A-levels

Each of the sections contained several questions, which meant that the questionnaire was approximately six pages in length. However, when transferred into a webpage that scrolled down, the questionnaire did not appear as long. In addition, as the design of the questionnaire focused around radio buttons (buttons that you click), along with
space for comments to be made, it did not take long to complete. Estimations were that, if the required information was known, it would take at most 10 minutes to complete. Once the webpage had been created the online questionnaire was trialled by sending an email with a link in it to six relevant engineering academics at Loughborough University. The replies to this trial also formed part of the final data collection, as no major problems were mentioned by those who completed it. The final online questionnaire entitled 'Students' Exposure to Mechanics' can be seen at web reference [13] and in Appendix T.

People on the contact list were sent an email, see Appendix U, describing the work being carried out and a link to the online questionnaire was included. They could then log onto the website, provide the required data and then submit the questionnaire. It was also made a feature that the first part requiring personal data (Title, Forename, Surname, Email Address, University, Department) was made compulsory so that a questionnaire was not submitted without knowing who it came from.

7.2.2. Replies and Analysis

An email was sent on 28th June 2004 to those on the HEA Engineering Subject Centre mailing list. Within a week 21 replies had been received back, in addition to the six trialists. The email was then re-sent to those on the list who had not replied to encourage them to complete the online questionnaire. An additional six replies were received following the second email. Therefore a total of 33 replies were received from academics in 19 different universities. In five of the universities more than one reply was received back. A list of the replying universities and the number of replies can be seen in Table 7.1. Analysis and comments on each section of the questions in the online questionnaire will now follow.
Table 7.1 - Universities replying to academics questionnaire

Firstly, it is important to consider why there was a relatively low response rate; one reason for this could have been the timing of the administration. The fact that the online questionnaire was administrated at the end of June, which coincides with a busy period when many academics are exam marking and some attending conferences, may have contributed to the number of academics who did reply. A second reason may be that for a significant percentage of those on the mailing list the questionnaire was not relevant. However, it is difficult to estimate just how many academics this would have included. Perhaps a better response rate would have been achieved if those who the questionnaire was appropriate for could be selected from the list. However, this would have had to have been done by the HEA Engineering Subject Centre staff and could have taken some time (if suitable filters were not inbuilt into their mailing list). Other aspects, such as the length of the questionnaire...
and type of administration (emailing) could also have been a factor in obtaining a low response rate. In particular, as had been seen when the prior learning in mathematics questionnaire was administrated to chemical engineering students via email, (see 5.2.1) a very low response rate of only approximately 10% was received.

A review of the responses will now be given. As previously mentioned participants were required to complete their personal details before starting section one. Academics came from many different departments including:

- Aeronautical and Automotive Engineering
- Chemical Engineering
- Civil Engineering
- Electrical Engineering
- Engineering Mathematics
- Engineering and Technology
- Informatics
- Manufacturing Engineering
- Material Engineering
- Mechanical Engineering
- Systems Engineering

**Section one review**

In section one academics were asked if a knowledge of mechanics was important for students studying in their department. Of the 33 replies 31 said yes. If a participant answered no then they were not required to complete any other sections, as the focus of the questionnaire was towards mechanics. In this section participants were also asked how many first year students there were in their department. Sizes ranged from small groups of 15, 30, 35 students, to large ones of 200, 250 students. The mean number of first year students in a department was 129, with a median size of 120. In total there were 4271 first year students in the departments of the academics who replied, of which for 4050 first year students a knowledge of mechanics was important.
In section two there were questions on gaining an understanding of students' prior knowledge in mechanics. Only six of the academics knew which modules in A-level Mathematics their students had studied, 23 answered that they did not know and four cited the question as non-applicable, indicating that their department did not need students to have studied A-level Mathematics. As a follow-up to this, for those that did know what modules in A-level Mathematics their students had studied, they were asked how many students had studied A-level Mathematics and how many modules of mechanics they had studied. In total there were 683 students (81%) who had studied A-level Mathematics out of the 845 students in the relevant departments. However, some of those who marked that they did know how many students had studied A-level Mathematics did not mark how many had studied each number of mechanics modules. Consequently information was given on 380 students. Note these are not the Loughborough University students (who were surveyed in Chapter 5). The number of students who had studied a given number of mechanics modules can be seen in Table 7.2.

<table>
<thead>
<tr>
<th>No of Students</th>
<th>No. of students studied A-levels</th>
<th>% of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Studied 0 Mechanics modules</td>
<td>87</td>
<td>380</td>
</tr>
<tr>
<td>Studied 1 Mechanics modules</td>
<td>138</td>
<td>380</td>
</tr>
<tr>
<td>Studied 2 Mechanics modules</td>
<td>145</td>
<td>380</td>
</tr>
<tr>
<td>Studied 3 Mechanics modules</td>
<td>10</td>
<td>380</td>
</tr>
</tbody>
</table>

Table 7.2 - Number of mechanics modules studied

It can be seen from Table 7.2 that 87 students (23%) of the 380 students who had studied A-level Mathematics had studied no mechanics modules. Furthermore, 36% had studied only one module of mechanics and therefore in total 59% of these students had studied at most one module of mechanics. It is clear that this is a large proportion of students and is much higher than the 32% obtained in the survey of engineering students at Loughborough, Nottingham and Leicester Universities. This finding reinforces the statement in Chapter 5 that the results from the three
universities involved in the earlier survey may not reflect the true situation in the country as a whole. The situation may be worse than predicted in the earlier survey.

In section two another question asked if there had been a change, in recent years, in the number of mechanics modules students had studied. It was intended that this question would only be answered by those that had completed the previous two parts to the question, but some of the other academics also completed it. Consequently, there were seven academics who said there had been a change, one who said that there had not been a change and four that 'hadn't considered' it. Of the seven that had noted a change, six had said that there had been a decline in the number of modules of mechanics their students had studied and the other said there had been no change.

Academics were also asked, in section two, if they ascertained the students' knowledge of mechanics in any other way. There were 10 academics who said that they did and nine of these used a diagnostic test. It was not clear if this was a specific mechanics diagnostic test or if mechanics questions were contained within a mathematics diagnostic test. Some of these academics were from Loughborough University, where the authors had administered a diagnostic test to engineering students. Of the others, it was only confirmed in two cases that the diagnostic test was a mechanics test as opposed to a mathematics test.

In summary, from the responses in this section, it can be seen that relatively few academics (17%) are aware of the mechanics modules, which their students have studied within A-level Mathematics. Only two departments in the survey, independently of the authors, used a diagnostic test in mechanics. Thus many academics are unaware of the detail of their students' prior study in mechanics.

**iii Section three review**

Section three contained questions on the 'teaching of mechanics'. This was an important section because it would give an insight into the different ways in which mechanics is taught in universities. The first question aimed to establish what level of prior knowledge academics assume their students have upon entry. Academics were asked to rate the amount of prior knowledge they expect from a student in terms of the
module content from mechanics modules in A-level Mathematics. It should be noted that the contents of M1, M2, M3 and M4 were included as an attachment to the questionnaire so that academics could see what was in each module.

<table>
<thead>
<tr>
<th>Knowledge</th>
<th>No of Replies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zero Knowledge</td>
<td>11</td>
</tr>
<tr>
<td>M1 Knowledge</td>
<td>10</td>
</tr>
<tr>
<td>M1 + M2 Knowledge</td>
<td>5</td>
</tr>
<tr>
<td>M1 + M2 + M3 or more</td>
<td>0</td>
</tr>
<tr>
<td>Don't Know</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 7.3 – Number of mechanics modules expected to have been studied

Table 7.3 shows the level of prior mechanics knowledge that academics assume their students have upon entry. There were 11 academics who said that they assumed zero prior mechanics knowledge, with a further 10 citing that they expect knowledge comparable to M1 and another five academics that expected students to have knowledge comparable to M1 and M2. Therefore, it is concerning that 15 (10 + 5) out of the 26 academics (58%) assume a knowledge of mechanics which their students may not necessarily have. Finally, four academics responded with don't know.

In section three academics were also asked if they streamed students according to their prior knowledge of mechanics. Only three stated that they did stream students. The academics stated the following streaming criteria:

- Whether they are on a chartered engineering course (CEng) or an incorporated engineering course (IEng) - based on entry qualifications
- Those who had studied A-level Mathematics/ Science and those that had not studied A-level Mathematics/ Science
- Results of a test - difficult questions with hints for those who find it hard but with a reduction of available marks
In the first two cases the criteria for streaming does not directly fall into prior knowledge of mechanics, but on which course the students are on or students' general background. In terms of affecting pass rates two academics said that streaming had increased the pass rates, and one said that they had stayed the same. It may not be surprising that few departments stream students as there is a considerable amount of time and effort required when implementing such a change to a standard module, e.g. assessing the students as to which group they should be in, as well as the associated costs, e.g. having two lecturers.

The third question in section three asked if any support, with respect to mechanics, was available above that normally found on a lecture course, i.e. tutorial support. More than half, 17 academics, said that there was extra help in mechanics available. Reasons cited primarily centred on the idea that support was given to help those who were struggling to grasp the subject content. However, 13 academics said that there was no additional help available. The reasons cited can be seen in Table 7.3 (note as many options as relevant could be ticked).

<table>
<thead>
<tr>
<th>Reason</th>
<th>No of Replies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not Necessary</td>
<td>4</td>
</tr>
<tr>
<td>Timetable Constraints</td>
<td>6</td>
</tr>
<tr>
<td>Staff Constraints</td>
<td>7</td>
</tr>
<tr>
<td>Expectation of a lack of student uptake</td>
<td>5</td>
</tr>
<tr>
<td>Don't Know</td>
<td>0</td>
</tr>
<tr>
<td>Other</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 7.4 – Reasons why extra mechanics help was not given

In Table 7.4 it can be seen that extra mechanics support was not available for several reasons, with the most common cited by seven academics, being due to staff constraints. There were also high responses for timetable constraints, by six academics, an expectation of a lack of uptake by the students, cited by five academics
and that it was not necessary, cited by four academics. In addition, two marked other reasons, for example that it would place too much extra pressure on students.

Further questions probed those academics that had replied as to whether extra mechanics support was available. Firstly, they were asked who they offered support to. 14 academics said that they offer it to any student, with only two saying that they offer it only to those in need of extra support. The final academic mentioned another reason, which was 'any student, but especially those in need as diagnosed'.

Academics were then asked by what means this extra support was given. Table 7.5 shows what options were ticked.

<table>
<thead>
<tr>
<th>No of Replies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supplementary Materials</td>
</tr>
<tr>
<td>Extra Tutorials</td>
</tr>
<tr>
<td>Drop in Centre</td>
</tr>
<tr>
<td>Other</td>
</tr>
</tbody>
</table>

Table 7.5 – How extra mechanics support was offered

In Table 7.5 it can be seen that the majority of academics, eight, offered extra tutorials in mechanics. Seven academics cited that a drop-in centre was available and four that supplementary material was available. The number of hours of extra support that was available was also asked, and in general between one and five hours per week were available, although in one case it was considerably more at 12 hours. Academics were then asked how effective the support had been, by referring to pass rates. Four academics cited the pass rates as increasing, and six cited that they had stayed the same. There were a further six academics who said that they 'Didn't Know'. Several comments supporting these results were made, including:

- The students who use the extra support say they have found it invaluable
- The students that came to see me all passed the Mechanics course

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• We have had great difficulty in persuading those students who really need the help to drop-in to the Maths Learning Centre. It is generally the brighter students who use the facility

iv Section four review

Section four contained questions on mechanics support. These referred to some mechanics support material (help sheets in basic mechanics) that were being developed by the author, Dr. Martin Harrison, Dr. Carol Robinson and Dr. Ted Graham as part of a HEA Engineering Subject Centre project (and which were to be made available on the mathcentre website). There were 27 academics who said that they would welcome the material and four who said that they would not want the material. The other two did not comment. In addition 22 of the 27 said that they would be happy to be contacted to review such material as it was being developed. This indicates that there is a clear interest from those academics.

v Section five review

Section five asked questions on monitoring A-levels. The first question asked if there was a member of staff in the department of the academic who monitored developments in A-level Mathematics. Of the 30 academics that replied to this question, only 12 said that they did have a member of staff who monitored the developments in A-level Mathematics and 10 said that they didn't, with seven saying that they did not know. Therefore, in the departments of nearly one in three academics there is a member of staff who monitors developments in A-level Mathematics, thus in up to two-thirds of departments there may not be a member of staff who monitors developments.

The second question in the section asked if there was a review of the material content in the first year undergraduate course each time AS/ A-level Mathematics change so that it was in-line with the student intake for those years. The number of academics who said that this does happen was seven. This is approximately 50% of those that had said that they do review the changes. Another seven academics indicated that this
does not happen, with a further two citing that they did not know if this was the case. However, there were several interesting comments made on this issue including:

- We probably only make major changes to our embedded teaching of mathematics every three years or so. So far we have been trying to increase the back-up support to cope with changing intake

- This is an uphill struggle since the mixture of modules taken by students also varies from year to year. We can only really assume P1, P2 & P3 yet we MUST assume M1 to make any progress in the first year

vi Other comments section review

In addition to the five sections of questions there was the opportunity for any other comments to be made. There were many relevant and interesting comments made by the majority of academics who had completed the questionnaire, these included:

- I no longer teach Mechanics. The general level of preparation is not as good as it used to be

- The mathematical ability of undergraduates is a handicap in learning mechanics

- According to my experience students do not find mechanics interesting anymore. Also, we do not seem to get the same calibre of students as we did a few years ago. We must accept that good quality students do not study engineering nowadays

- We as an engineering faculty are reviewing the whole issue and would be in the market for materials - it's a real problem and is eating up resources

- We have to assume minimal knowledge quite often because of the different backgrounds of our students. Even in the case of students who have studied Mechanics, some revision has always proved useful
• It is important that our students are motivated by mechanics and see the purpose of it. Working on the basis that a good student has the ability to learn whatever he or she wants, it is the area that we are concentrating on when we are introducing engineering.

There were two questionnaires completed by academics from Scottish Universities and whilst the questionnaire was primarily aimed at students from an A-level background, i.e. English students, there were some useful comments made by the Scottish academics. There was an indication that they too had issues with the diverse knowledge of mechanics which their students had upon arrival, although not the same as the English situation, primarily because they have different pre-university qualifications.

7.2.3. Discussion of Questionnaire to Academics

A total of 33 responses to the online questionnaire were received and these were from academics in 19 different universities. The respondents represented a wide cross section of universities, engineering departments and a large number (over 4000) of engineering students for whom a knowledge of mechanics was important.

It was found that few (one in five) of the respondents were aware of the mechanics modules that their students had studied within A-level Mathematics. This lack of awareness on behalf of academics, with regards the incoming knowledge of mechanics of their students, is concerning. If they assume no prior knowledge of mechanics, as 11 of them did, then the only problem may be that those students who had studied mechanics become bored. However, if they do assume some prior knowledge of mechanics, there may be many of their students who do not have this knowledge. In fact, 15 out of 26 (58%) academics assumed a knowledge of mechanics (of at least M1) that their students would not necessarily have. Students without this assumed knowledge may quickly feel disadvantaged, may struggle with the work and this may result in them giving up the course.
As well as very little knowledge of the mechanics modules that their students had studied within A-level Mathematics, there was also lack of knowledge of developments in A-level courses. In at least a third of the departments represented by the academics in this survey, there was not a member of staff who monitored developments in A-level Mathematics. Clearly this is a worrying statistic and, with the recent changes in A-level Mathematics, will have implications for the students studying in these departments. This is an area where university staff development units or HEA subject centres could perhaps work to inform the sector about changes taking place which are directly affecting the incoming knowledge of their student intake.

The online questionnaire also drew attention to the Scottish dimension with regards mechanics. The respondents from Scotland indicated that there were also issues arising due to the varied knowledge in mechanics that their intake had upon arrival at university. These were not the same as the English situation, but nevertheless were important.

7.3. Interviews with Engineering Academics

In addition to surveying academics via a questionnaire, it was decided that more depth should be given to the study into academics' opinions and experiences in the teaching and learning of mechanics. This would allow one to ascertain specific practices and techniques employed by academics in relation to their situation, i.e. their own intake. Consequently, the various procedures and methods that were found have been reviewed and schemes for general good practice put forward.

7.3.1. Motivation For and Composition of Interviews

A method that was appropriate to acquire more detailed information was an interview. In line with the methodology for interviews (see Chapter 3), the structure and set-up for the interviews were examined. Two of the eight interviews were tape recorded as consent was given. The two telephone interviews were not recorded, as this would have required specialist equipment. It was decided to use the first interview as a trial and then review and adapt the approach accordingly for the subsequent interviews. A
script was drawn up, which incorporated specific questions and topics, which can be seen in Appendix V. It was anticipated that this schedule would be used throughout the series of interviews, although adapted to be appropriate in gaining information from each academic. The reason for this was that the information that was already known for each of the prospective academics meant clarification was sought in numerous areas that were specific to that academic. Subsequently, there were two components to each of the interviews. This involved reviewing the questionnaire completed by the academic and secondly the schedule that was used as a guide. This would allow certain areas to be quizzed further for each individual academic, but would still enable an overview to be produced from all the interviews.

7.3.2. Academics Interview Feedback

From the 33 replies to the questionnaire sent to engineering academics throughout the country (see section 7.2), six academics were chosen to be interviewed, along with another two who did not complete the questionnaire, but who have particular expertise in the area concerned. These six academics were chosen, as there was an area of specific interest in each of their departments, be it a given teaching style or type of students they have in their department. The eight academics came from five universities, namely the University of Birmingham, Coventry University, University of Leeds, University of Strathclyde and Loughborough University. The size of the departments of the academics varied, particularly in terms of student numbers, from approximately 45 (first year) students to upwards of 150 (first year) students. The academics represented students from various departments that included: aeronautical and automotive engineering, civil engineering, electrical and systems engineering, mechanical and manufacturing engineering as well as from physics. This indicates that a wide range of engineering and other relevant departments participated in the study.

The interviews were generally around 30-45 minutes in length and in most instances were carried out in the respective department at the university of the academic. There were two exceptions to this, where telephone interviews were carried out in place of a face-to-face interview. During the interviews notes were taken on the answers given to each question posed. Immediately following the interviews these notes were
reviewed and transcribed into more complete text. Both quantitative and qualitative responses were received from each of the participants. Summaries of each individual interview can be found in Appendix W.

The interview schedule that was produced and used as an overview included sections on:

i. **Student intake (Questions 1, 2 i)**

ii. **Teaching and learning of mechanics modules (Questions 2 ii, 2 iii)**

iii. **Support (Mechanics - question 2 iv, mathematics - question 3)**

Analysis of the interviews will now be given in terms of these sections.

*Student intake*

An example of a question (one) from the interview schedule can be seen in Figure 7.1.

1. **Tell us about your students:**
   - Are they from a traditional background, i.e. A-levels?
   - Are they mature?
   - Are they full-time or part-time?
   - Are they from diverse backgrounds, i.e. race, gender?

   What are the entry requirements for students in the department?

   _____ (new) UCAS Points  Subjects: ____________  ____________

   **Figure 7.1 - Academics' interview schedule question one**

Within the departments that the academics worked, there were varying degrees of student ability. This is as would be expected in any department. However, there was also varying levels of entry requirements found. Several departments required very good grades to enrol onto courses in their department. Table 7 6 gives an indication of
the general A-level entry requirements for MEng and BEng courses in the respective departments.

<table>
<thead>
<tr>
<th>Department</th>
<th>MEng</th>
<th>BEng</th>
<th>No. of Students in dept.</th>
<th>Maths Required (Grade)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aero/Auto</td>
<td>AAB</td>
<td>BBB</td>
<td>150</td>
<td>Yes (A/B)</td>
</tr>
<tr>
<td>Civil (i)</td>
<td>ABB</td>
<td>BBC</td>
<td>120</td>
<td>Yes (B/C)</td>
</tr>
<tr>
<td>Civil (ii)</td>
<td>BBB</td>
<td>CCC/DDE (BSc)</td>
<td>45</td>
<td>Yes (B/C)</td>
</tr>
<tr>
<td>Electrical</td>
<td>BBB</td>
<td>BCC</td>
<td>70</td>
<td>No</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>-</td>
<td>BCC</td>
<td>70</td>
<td>Yes (C)</td>
</tr>
<tr>
<td>Mechanical</td>
<td>AAB</td>
<td>BBB</td>
<td>150</td>
<td>Yes (A/B)</td>
</tr>
<tr>
<td>Physics</td>
<td>BBB</td>
<td>BBC</td>
<td>90</td>
<td>Yes (B)</td>
</tr>
</tbody>
</table>

Table 7.6 – Entry requirements and student numbers

So for example, AAB grades at A-level (or the points equivalent) were required for entry onto the MEng courses in the Aeronautical and Automotive department, with a corresponding figure of BBB grades at A-level for the BEng courses. Where a Scottish university has been used comparative grades have been put in terms of A-levels. In many of the departments there was also the requirement to have studied mathematics or in some instances other numerate A-levels. This meant mathematics would have been studied at the corresponding grade required for entry.

It was also determined if the students were from a traditional background of A-levels or not. It was found that in all departments at least 50% of the students were from the traditional background of A-levels (Note that in the Scottish university this is in reference to their traditional pre-university qualification, i.e. Highers/ Advanced Highers). There were varying degrees of students from the non-traditional route from a minimum of 10% up to a maximum of 50% It was also asked if there were students from differing backgrounds, i.e. from non-EU countries. However, academics found it
difficult to give an accurate indication of numbers for such groups, with it more commonly stated that 'we have some overseas students'.

In conclusion from both the varying entry requirements and the inherent varying ability of a group once on a course, it can be seen that each department has its own specific set of issues to deal with in terms of prior knowledge of mechanics. Therefore, gaining an understanding of the students' prior knowledge was something that many of the academics commented on when interviewed. Various methods had been used in the seven departments of the eight academics interviewed (two academics taught students in the same department, but were from two different departments) in order to gain information on their students, including:

- Interviews (2 departments)

- Questionnaires (1 department) [4 departments if Loughborough University staff interviewed included, i.e. where the questionnaire was the one prepared by the author]

- Diagnostic Testing (Mathematics only - 6 departments, Mechanics 1 department. [mechanics - 4 departments if Loughborough University staff interviewed included, i.e. where the diagnostic test was the one prepared by the author])

- Feedback via interaction (3 departments)

The first of these methods, namely interviews, was used by many of the academics either pre or post enrolment onto courses. Academics said that when interviewing students prior to the offer of a place on a course they were able to probe into a student's knowledge of mechanics. This method does allow for some insight into students' knowledge to be gained not only in mechanics but also in a student's general abilities. Those interviews carried out after enrolment were for a specific reason, which was concerned with a particular teaching method employed, which was group work. Hence interviews allowed students to be appropriately selected into groups.
Hence the interviews were used to select members who would form each of the groups.

The methods of questionnaires and diagnostic testing, where used, were generally used together to produce some descriptive statistics. These were then used to give detailed information on students' knowledge of mechanics, such as the number of mechanics modules studied and performance in specific topics. It was found that mathematics diagnostic testing was widespread with only one of the departments not using a stand-alone mathematics diagnostic test. However, these did not include any mechanics questions and it was only in one department (the one that did not administrate a mathematics diagnostic test) that a specific mechanics diagnostic test was used, which was a computer test that was sourced from the USA. (Note this excludes those at Loughborough University where the author administrated a mechanics diagnostic test.)

One of the problems is that although the issue of a lack of students' knowledge of mechanics may have been an institutional problem for a number of years, it has only recently been discussed nationally, see for example Mustoe (2004). As it can be time consuming to produce a diagnostic test (including a mechanics one), it would not appear that there has been a rapid movement towards producing them. Conversely, it may be that some don't perceive it to be a worthwhile thing to do.

Another technique that many academics detailed concerned feedback from students obtained via interacting with them in both lectures and tutorials. This method appeared useful if the academic was experienced and could gather the required information in this type of environment. However, there are several restrictions with this; for example this would be difficult to do with a large group or if you have a low staff: student ratio. Alternatively, in tutorials where the numbers are generally much lower there may be more of an opportunity to interact with the students. Another concern could be the time scale of gathering the information. For example, it is important that the lecturer understands the level of the students at the start of the course and not two or three weeks into a course, when valuable time for revising/introducing topics has passed.
However, consideration needs to be given to employing a suitable strategy for understanding student's knowledge of mechanics upon entry. Reviewing the responses from academics about understanding their student intake, it can be seen that various methods of doing this are being used.

**ii Teaching and learning of mechanics modules.**

In this subsection the primary focus will be on giving a summary of the differing practices found in the teaching and learning of mechanics. The rationale for this is that by reflecting upon the techniques practiced, it is possible that the methods can be reviewed, adapted and used by other academics as appropriate.

The first module in mechanics at university is usually seen as an introductory module that later modules (not necessarily mechanics ones) build upon. Therefore, it is imperative that students understand the material contained within a first module so that the more difficult applications can be taught afterwards. Consequently, it is no surprise that academics said that a first module in mechanics is important to students in many engineering departments.

It is appropriate to begin by highlighting what was concluded at the end of the previous point (i). Here it was suggested that academics gather information on student's prior knowledge of mechanics. This was an important issue as some of the good practice within the first university module of mechanics would require this type of information.

Various ideas and techniques used in mechanics modules have been discussed by academics in the interviews. These can generally be looked at in terms of module content, design and structure.

Firstly, the content refers to the material that is taught in a first module of mechanics. Several interviewees showed concern as to where the material should begin. There appeared to be different expectations as to what could be expected of entering students. In terms of traditional A-level Mathematics content, some academics expected students to have done one A-level module of mechanics, others expected
two although some said that they did teach the subject essentially from zero knowledge. This further highlights the need to ascertain just what level of prior knowledge students have. Subsequently, several staff mentioned that they spent time at the beginning of the course revising topics from A-level mechanics modules. However, again it needs to be pointed out that for some students, who have not studied mechanics at A-level, this will be new material. Nevertheless spending some time at the beginning of the module reviewing what in essence is taken to be pre-requisite information can be useful for the students.

The design and structure of a first university mechanics module are inherently connected. The design refers to the various components of a module, i.e. tutorials, lab sessions, lectures and the structure refers to how these components are put together, for example 11 weeks of lectures and tutorials and two weeks of lab sessions. Several methods were used by academics to ensure the best learning experience for their students, including:

- Streaming
- Using experienced staff to lecture the material
- Using two lecturers at one time to teach the students to encourage discussion of concepts
- Regularly assessing the students' knowledge
- Reinforcing learning by using laboratory work
- Using group work, with staff input, to aid understanding of some of the concepts

The method of streaming was in use in one department. This involved separating students and teaching them in two groups, depending on their prior knowledge of mechanics. The groups were those who had studied zero or one module of mechanics and those that had studied two or more. Detailed information of the streaming has been documented but is not referenced here in order to maintain the anonymous nature of the interviews.

Having experienced staff take a first university module in mechanics and trying to have as low a staff: student ratio as possible were remarks made by the academics
interviewed. As well as this another concept portrayed as being significant, regarded the importance of engaging the students. Particular reference was made to the benefits of having an experienced member of staff take the course and where possible more than one experienced staff member. This would increase the interaction between the students and the staff, which can be considered as good practice. This can also enable staff to engage the students personally.

Another important feature all institutions commented upon was to reinforce the learning. Periodic assessment was an option that many academics used and that was regarded as an essential part of the module design. In four of the seven departments laboratory sessions were run to engage the students and reinforce the learning. Some form of coursework could be used to constitute periodic assessment. Both laboratory sessions and courseworks could stand to reinforce the learning, by teaching the theory and then getting students to put it into practice with practical experiments. Another strategy seen was to implement group work throughout the course. This enabled students to develop many skills and also their knowledge of the subject, by each member of the group helping each other. In the department that this was used student groups were selected by the experienced academics and this was regarded as being an important feature. This allowed each group to have a mix of the skills needed and this method has proved to be very successful, especially in reducing drop-out rates.

Here the importance of a first university module in mechanics has been stated, together with various ideas and techniques that the academics interviewed have used with their students. Consideration as to what level of knowledge students have upon arrival has to be given and the subsequent material that is taught, generally as a prerequisite for later modules, needs to be reviewed. There are many ways in which to structure a module and there are several interesting techniques, such as running laboratory sessions, which can help motivate students and reinforce the material taught in a first year mechanics module. It is crucial that appropriate procedures are implemented so that the students who may struggle are identified.
Evidence of varying degrees of support was found. In many instances support in mechanics was very sketchy. On the whole mathematical support was more readily available and used than specific support for mechanics. Some universities had a support centre, although the variation in these was large. One such centre was relatively small but offered mathematics support to students from specific engineering departments. Again, the provision for actual support in mechanics was not significant, although one idea in use was to employ final year students to work in the centre. Therefore, the final year students would have had experience of the mechanics module that first year students were struggling with, although they may not necessarily have been competent with all material in the module. Feedback from the interviewee indicated that this method had worked well.

In most instances, there was an open door policy from the lecturer(s) who taught the mechanics modules. This meant that appropriate one to one support was available, although the time lecturers were available was in some cases limited. As well as this, regular tutorial sessions were found to be a useful means of supporting the learning. It was noted that it is important that attendance is monitored, which generally encourages the students to actually attend the sessions and subsequently benefit from them.

In reviewing what support and help was available to students having problems with mechanics, it was noticeable that there is currently little provision in many universities. Academics were obviously aiding their students as best they could, which would generally involve some one-to-one assistance. However, a lack of availability of support material in mechanics would generally mean students were referred back to the given text (books)/ notes for the module. Reference was made by several academics as to good resources in mathematics and that they would welcome similar resources on mechanics.
7.3.3. Summary

Within this section a summary of interviews with eight academics from various universities and departments has been given. This was a follow-up to the 33 replies from the questionnaire. The interviews highlighted many areas of interest. From the academics interviewed, insight into three main areas was looked at. These included their student intake, the teaching and learning of mechanics and the support available.

A variation in student intake was seen in the departments of the academics interviewed, which was indicated by the entrance requirements. Some evidence of gaining an understanding of their student intake was also seen. This included the use of questionnaires, interviews and diagnostic testing. The method(s) used were specific to each department. However it is evident that consideration should be given to employing a suitable strategy for understanding student's knowledge of mechanics upon entry.

The teaching and learning of mechanics was also considered. Here it was seen that it is important to review a first university module of mechanics. Monitoring incoming students' abilities can allow for an understanding of what revision or introduction to the topics should be done. Techniques used included streaming, using experienced staff and reinforcing learning via coursework or laboratories. Therefore as there are many ways in which to structure a module it is vital that a suitable method is selected for a specific group of students.

In considering what support and help was available to students having problems with mechanics, it was evident that there is currently little provision. Several academics made reference to the availability of good resources in mathematics and suggested that similar resources on mechanics would be welcomed.

7.4. Summary and Discussion

This chapter addressed the issue of students' prior knowledge of mechanics from the perspective of the university academic. With the changes to A-level Mathematics
syllabi and structure, it is clearly important for relevant university academics to be aware of the changes and to ensure that universities respond appropriately to them. An online questionnaire and follow-up interviews were used to ascertain whether staff had monitored changes in A-level Mathematics, whether they were aware of the prior knowledge in mechanics of their intake and what knowledge they assumed when they taught mechanics to first year engineering students. Where there was evidence of good practice in the teaching of mechanics it was described.

It was found that few of the respondents were aware of the number of mechanics modules and their content that their students had studied within A-level Mathematics. This lack of awareness on behalf of academics, with regards to the incoming knowledge of mechanics of their students, is concerning. In fact, 58% of the academics in the sample assumed a knowledge of mechanics that their students would not necessarily have. Students without this assumed knowledge may quickly feel disadvantaged, may struggle with the work and this may result in them giving up the course.

The academics also showed a lack of knowledge of developments in A-levels. In at least a third of the departments represented by the academics in this survey, there was not a member of staff who monitored developments in A-level Mathematics. Clearly this is a worrying statistic and there will be implications from the recent changes in A-level Mathematics, for the students studying in such departments. This is an area where university staff development units or HEA subject centres could perhaps work to inform the sector about changes taking place which are directly affecting the incoming knowledge of their student intake.

The online questionnaire also drew attention to the Scottish dimension with regards to mechanics. The respondents from Scotland indicated that there were also issues arising due to the varied knowledge in mechanics that their intake had upon arrival at university. These were not the same as the English situation, but nevertheless were important. Clearly it would be advantageous to conduct a survey in Scottish schools, similar to that carried out in England and to survey first year engineering students in Scottish Universities to ascertain the amount of mechanics they have studied prior to university.
During the follow-up interviews, good practice in the teaching of mechanics was discussed. Streaming of classes and extra support were cited as two ways that were used to try to overcome the problem of lack of prior knowledge of mechanics amongst some of the students. More than half of the respondents stated that there was extra support in mechanics available. This took the form of extra tutorials in mechanics, drop-in centres and supplementary material. There was a definite interest, from most of the academics in this survey, in the use of help sheets in basic mechanics, which the HEA Engineering Subject Centre had suggested might be useful in helping to lay good foundations in the knowledge of mechanics.

Finally, the online questionnaire revealed that the mechanics problem was indeed an issue. One academic commented that "We as an engineering faculty are reviewing the whole issue and would be in the market for materials – it's a real problem and is eating up resources."
8. Predicting First Year Engineering Students' Performance

8.1. Introduction

In this thesis it has been seen that a large percentage (approximately 32% in our sample) of students entering engineering programmes have studied little or no mechanics in A-level Mathematics. At Loughborough University as the large majority (anecdotally over 90%) of engineering students enter having studied A-levels, this obviously raises issues with how such students may perform in their (compulsory) first year mechanics module, as well as in their first year overall. To that end it was decided that linear regression models would be constructed to establish if student performance could be predicted. If this was the case then those who were predicted to perform poorly could be identified and, if possible, suitable support could be offered to them.

Within this chapter both simple linear models and multiple linear models are constructed. These models focus upon data from mechanical engineering students, although comparisons are also made to models created from data from aeronautical and automotive engineering students. Discussion of the significant factors in the models will be given along with comments on the limitations and reliability of such methods.

8.2. Simple Linear Models

Simple linear regression models aim to find a linear relationship between a response variable and a possible predictor variable by using the well-known method of least squares. Here two response variables are of interest:

- a student's overall first year performance
- a student's performance in their first year university mechanics module

In the instance of simple linear models, three predictor variables will be used, these are:
- the number of mechanics modules studied in A-level Mathematics
- a student's mechanics diagnostic test result
- a student's mathematics diagnostic test result

Each of these three variables will be considered in turn to predict student performance in their first year university mechanics module and overall performance in their first year. Therefore, in total six models will be created. It was decided that these three variables would be used to form simple regression models because such data had already been obtained in questionnaires and diagnostic tests used in this thesis. Mechanical engineering students were a particularly relevant group, as mechanics is important for their programme and there is a good range of abilities within the group.

8.2.1. Overall First Year Performance Predictor Model

A scatter plot of (109) students' overall performance in their first year against the number of mechanics modules they had studied in A-level Mathematics was created and can be seen in Figure 8.1.

![Overall Year 1 Mark versus Number of Mechanics Modules Studied](image)

Figure 8.1 - Overall year 1 mark versus number of mechanics modules studied
In Figure 8.1, with the least squares line of best fit marked on, it can be seen that there is a low positive correlation between the number of mechanics modules studied in A-level Mathematics, $x$, and a student's overall first year performance, $y$. The equation of the line of best fit, which is taken to be the simple linear regression model, was:

$$y = 1.69x + 53.87$$

Interestingly, this model predicts that a student who entered university having studied no mechanics will score only half a grade boundary, i.e. 5%, less than someone who entered university having studied three modules of mechanics in A-level Mathematics.

However, perhaps most noteworthy when considering the model is the $R^2$ value of 0.02. This indicates that only 2% of the variation in a student's overall first year performance can be explained by the number of mechanics modules previously studied in A-level Mathematics. Such a result suggests that the model created is poor.

![Figure 8.2 - Overall year 1 mark versus mechanics diagnostic test result](image)
Figure 8.2 shows a scatter plot of (123) students' overall performance in their first year against their mechanics diagnostic test result.

Again, a slight positive correlation between a student's mechanics diagnostic test mark, $x$, and their overall first year mark, $y$, can be seen. This model has the equation:

$$y = 0.20x + 42.00$$

This model predicts that a student who scored 40% in the mechanics diagnostic test will perform some 10%, i.e. one grade boundary, less than someone who scored 90% in the mechanics diagnostic test.

An $R^2$ value of 0.09 indicates that 9% of the variation in a student's overall first year performance can be explained by their mechanics diagnostic test result.

The final simple linear model created for the response variable of a student's overall first year performance, was for the predictor variable of a student's mathematics diagnostic test result. Figure 8.3 shows the scatter plot for the two variables.

![Overall Year 1 Mark versus Mathematics Diagnostic Test Result](image)

Figure 8.3 - Overall year 1 mark versus mathematics diagnostic test result (127 students)
In Figure 8.3, a similar picture to that seen in Figure 8.2 can be seen, i.e. a small positive correlation between a student's mathematics diagnostic test mark, $x$, and their overall first year mark, $y$. This model has the equation:

$$y = 0.21x + 40.31$$

This model predicts that a student who scored 40% in the mathematics diagnostic test will perform some 11%, i.e. one grade boundary, less than someone who scored 90% in the mathematics diagnostic test.

An $R^2$ value of 0.12 indicates that 12% of the variation in a student's overall first year performance can be explained by their mathematics diagnostic test result.

Therefore, it can be seen from the three models created that the most variation in a student's overall first year performance can be explained by a student's mathematics diagnostic test result. Simple linear regression models were also created to see how well performance in a first year mechanics module could be predicted and these will be discussed next.

**8.2.2. First Year Mechanics Module Performance Predictor Model**

Building upon the models created for predicting overall first year performance, simple linear regression models for predicting student performance in a first year university mechanics module will now be detailed.

A scatter plot of students' performance in a first year university mechanics module against the number of mechanics modules they had studied in A-level Mathematics can be seen in Figure 8.4.
In Figure 8.4 a positive correlation between the number of mechanics modules studied in A-level Mathematics, \(x\), and a student's overall first year performance, \(y\), can be seen. The equation for this model is:

\[ y = 3.84x + 47.11 \]

This model predicts that a student who entered university having studied no mechanics will score more than one grade boundary, i.e. 12%, less than someone who entered university having studied three modules of mechanics in A-level Mathematics.

An \(R^2\) value of 0.07 indicates that only 7% of the variation in a student's first year university mechanics module can be explained by the number of mechanics modules previously studied in A-level Mathematics. Although the predictor variable does not explain much variance in the response variable, the scatter plot highlights something noteworthy. In the scatter plot it is interesting to see that a higher percentage of students who had studied one or two mechanics modules in A-level Mathematics, scored under 40% in their first year university mechanics module, when compared to
those who entered university having not studied any mechanics modules in A-level Mathematics. This is an obvious concern, although it was evident when further analysis was conducted that of the 14 students who scored 40% or less, only one of these students sought assistance by visiting the MLSC and this was on only one occasion. It should be noted that although the MLSC did not have scheduled support specifically for mechanics during the last academic year, it will have in the academic year 2006-2007.

Figure 8.5 shows a scatter plot of (123) students' performance in their first year university mechanics module against their mechanics diagnostic test result.

![Figure 8.5 - Year 1 mechanics module result versus mechanics diagnostic test result](image)

A positive correlation between a student's mechanics diagnostic test mark, $x$, and their first year university mechanics module mark, $y$, can be seen. This model has the equation:

$$y = 0.44x + 21.44$$

This model predicts that a student who scored 40% in the mechanics diagnostic test will perform some 22%, i.e. two grade boundaries, less than someone who scored 90% in the mechanics diagnostic test.
An $R^2$ value of 0.22 indicates that 22% of the variation in a student's overall first year performance can be explained by their mechanics diagnostic test result. Thus, this predictor variable explains more variation in the response variable than any of the other predictor variables considered.

Finally, Figure 8.6 shows a scatter plot of (127) students' performance in their first year university mechanics module against their mathematics diagnostic test result.

![Scatter plot of 1st Year Mechanics Module Result versus Mathematics Diagnostic Test Result](image)

Figure 8.6 - Year 1 mechanics module result versus mathematics diagnostic test result

A positive correlation between a student's mathematics diagnostic test mark, $x$, and their first year university mechanics module mark, $y$ can be seen. This model has the equation:

$$y = 0.39x + 23.44$$

This model predicts that a student who scored 40% in the mechanics diagnostic test will perform some 20%, i.e. two grade boundaries, less than someone who scored 90% in the mechanics diagnostic test. In addition, an $R^2$ value of 0.22 indicates that 22% of the variation in a student's overall first year performance can be explained by their mechanics diagnostic test result.
At this point it should be stated, if it has not become apparent, that in these six models the same students were not necessarily included in all models. The reason for this, as will be discussed further in 8.3.1, is that data was not held on all students for all variables. For example, not all students studied A-level Mathematics and thus they could not be included in Figures 8.1 and 8.4, which considered first year performance when compared to the number of mechanics modules studied in A-level Mathematics. More specifically, in Figure 8.4 109 students were included in the analysis, whereas in Figure 8.6 127 students were included.

Thus, from these simple regression models it has emerged that a single variable can be used to explain up to 22% of the variation in how a student performs in either a first year university mechanics module or in a student's overall first year performance. However there are obviously many, many factors that could affect a student's first year performance. For this reason multiple regression models are created in 8.3 to see if producing a model from several variables would be a better predictor of first year performance.

8.3. Multiple Linear Regression Models

Multiple linear regression models are very similar to simple linear regression models but they aim to find a linear relationship between a response variable and several predictor variables, instead of just one predictor variable. In this section, a brief discussion will be held on the variables used in the models, including how data on such variables were collected. Following this the multiple linear regression models for predicting overall first year student performance and performance in a first year university mechanics module are detailed.

8.3.1. Data Collection

In order to create statistical regression models to predict student performance, a large amount of data, on 133 students studying mechanical engineering courses at Loughborough University was collected. As highlighted earlier, mechanical engineering students were a particularly relevant group, as mechanics is important for
their programme and there is a good range of abilities within the group. Data collected on these students included:

(i) Mathematics diagnostic test mark  
(ii) Mechanics diagnostic test mark  
(iii) Mathematics A-level grade  
(iv) Gender  
(v) Total A-level points score  
(vi) Whether the student was overseas or home/EU  
(vii) Whether the student studied A-level Further Mathematics  
(viii) Number of mechanics modules studied in A-level Mathematics  
(ix) Number of statistics modules studied in A-level Mathematics  
(x) Number of discrete modules studied in A-level Mathematics  
(xi) Whether the student studied with exam board AQA  
(xii) Whether the student studied with exam board OCR  
(xiii) Whether the student studied with Welsh/Northern Irish exam boards  
(xiv) Whether the student visited the MLSC in their first year of study

A student's mathematics diagnostic test mark and their mechanics diagnostic test mark were obtained from relevant staff in the Mathematics Education Centre at Loughborough University.

Data such as a student's gender, A-level points score, A-level Mathematics grade, whether they were an overseas or home/EU student, along with their overall first year result and result in their first year mechanics module were obtained from the respective department.

Data in vii-xiii, i.e. what modules students had studied in A-level Mathematics, if they had studied Further Mathematics A-level and which examination board they studied from, was obtained from students via the questionnaire that was detailed in Chapter 5. Finally, data on whether students had visited the MLSC were obtained from records held by the Mathematics Education Centre. It should be noted that students are
required to 'swipe in' with their ID card upon entering the MLSC and thus an electronic record of who has visited the MLSC is kept.

As highlighted at the end of the previous section it should be noted that data could not be collated for all 133 students on all the variables mentioned above. For example, only 127 students undertook the mathematics diagnostic test and data on students' total A-level points score was only known for 122 students. The six students who did not complete the mathematics diagnostic test may not be the same as the 11 for whom data was not known on their total A-level points score. This issue will be discussed further in section 8.4.

Once the data had been collated multiple linear regression models were produced using the statistical package SPSS. A step-wise method was used and this will be discussed within the context of creating a model next.

8.3.2. Overall First Year Performance Predictor Model

Considering the overall percentage mark, \( y_1 \), of mechanical engineering students in their first year, with respect to the 14 variables stated earlier, the following linear regression model was produced:

\[
y_1 = 0.353a_1 - 5.321b_1 + 7.781c_1 + 35.886
\]

The variables \( a_1, b_1, c_1 \) and their coefficients are those indicated in Table 8.1. Also in the table are the possible values which each of the variables could take. In Table 8.1 there are some other standard statistical measures, the standard error and the t value, which are both inherently connected to perhaps the most important measure, the level of significance. Variables in the regression models produced met a certain level of significance. This is the reason why all 14 variables are not present in the model above. Here 0.1 was chosen as the level of significance. Although, as can be seen from column six, all the significance values for variables are below 0.01 and so a higher level of significance is evident. The stepwise method used here uses both backward and forward procedures to both add and remove variables until no more variables meet the entry and removal criteria.
Table 8.1 – Multiple regression model of mechanical engineering students overall first year performance

An $R^2$ valued of 0.392 was obtained for this model. This indicates that, according to this model, 39% of the variation in overall first year result could be attributed to the variables $a_1, b_1, c_1$.

When considering this model it is important to note what value each variable could take, seen in the final column, and what affect they could have on the model. It can be seen that the variables $b_1$ and $c_1$ can only take a small number of distinct values ($b_1$ - 0, 1, 2, 3 and $c_1$ - 0, 1) whereas $a_1$ could take a larger number of (discrete) values between 0 and 100, namely [0, 2.5, 5...95, 97.5, 100] given there were 40 questions in the test. However, as each of these have a different coefficient in the model, variables can only have a certain effect on the overall model. For example, variables $b_1$ and $c_1$ multiplied by their coefficient can only take a small number of different values between -160 ($3 \times -5.321$) and 7.8 ($1 \times 7.781$) in the model, whereas $a_1$ can have an effect of up to 35.3 ($100 \times 0.353$).

Note the value of the coefficient 7.781. This shows the positive effect, of nearly one grade boundary, of students visiting the MLSC. Visiting the MLSC is seen to be useful not only for the less well-prepared students but also for the average and good students. The MLSC is a resource centre that students can visit at anytime (between 9 am and 5 pm) to obtain assistance and guidance on mathematics. A member of the
School of Mathematics is always on duty when it is open. At Loughborough the MLSC is well established and has been in operation for 10 years.

It is evident, from the value of the coefficient $b_1$ that in predicting overall first year performance, the model indicates a negative effect from having studied statistics modules in A-level Mathematics. A potential reason for this could be that the more statistics modules studied in A-level Mathematics means that less mechanics modules could have been studied, which for mechanical engineering students is likely to have a detrimental effect. Furthermore, it may well be that students who chose to study statistics modules in A-level Mathematics could have had a dislike of mechanics.

Perhaps most noteworthy is that the mathematics diagnostic test was one of the most important variables in the model, given that it could have an effect of up to 35.3% on a student's overall first year result. It was also interesting to see that the mathematics diagnostic test was a significant variable in predicting first year performance, whereas a student's mechanics diagnostic test did not emerge as being a significant variable in the model. Furthermore, when reviewing the model it was interesting to note which other variables (of the original 14) did not appear to be significant. In particular, the usual way of selecting students for university courses by their total A-level points score was not a significant variable in the model.

8.3.3. First Year Mechanics Module Performance Predictor Model

A second model was created to specifically consider what factors affected performance in students' first year university mechanics module. The same 14 variables were considered when creating the model for first year mechanical engineering students' performance, $y_2$, in their first year university mechanics module. The regression model can be seen below and the respective variables in Table 8.2. An $R^2$ valued of 0.476 was obtained for this model. This compares well with the value of 0.392 found by the model to predict overall first year performance.

$$y_2 = 0.518a_2 - 6.785b_2 + 8.949c_2 + 22.497$$
<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Standard error</th>
<th>t</th>
<th>Significance</th>
<th>Possible Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>22.497</td>
<td>6.883</td>
<td>3.289</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>$a_1$ Mathematics Diagnostic Test Result</td>
<td>.518</td>
<td>.085</td>
<td>6.088</td>
<td>.000</td>
<td>0 - 100</td>
</tr>
<tr>
<td>$b_2$ No. of statistics Modules Studied</td>
<td>-6.785</td>
<td>1.738</td>
<td>-3.904</td>
<td>.000</td>
<td>0,1,2,3</td>
</tr>
<tr>
<td>$c_2$ Visited MLSC</td>
<td>8.949</td>
<td>3.150</td>
<td>2.841</td>
<td>.006</td>
<td>0 - No, 1 - Yes</td>
</tr>
</tbody>
</table>

Table 8.2 – Multiple regression model of mechanical engineering students' performance in a first year university mechanics module

Again it can be seen that a dominant feature of the model was the mathematics diagnostic test result, which can have an effect of between 0 and 51.8 (100 x 0.518) in the model. In this model the number of statistics modules studied in A-level Mathematics again had a negative effect. The positive effect on students who visited the MLSC can again be seen as well as a lack of significance of students total A-level points score. It was very interesting to observe that the same variables emerged as being significant in both the model for overall 1st year performance and that for performance in a specific (mechanics) module. However, this may not have been surprising given the fact that the first year mechanics module is in fact a subset of the overall first year performance, since students first year mechanics module marks contribute one-sixth of the total marks for their overall first year performance. Finally, note that using ANOVA the data was checked for interactions between the variables, so that they too could be included in the models, however none were found.

In this section two regression models for performance of mechanical engineering students in their first year university mechanics module and their overall first year engineering programme have been seen. However, it is appropriate to comment on the reliability of the models created and establish if they could be extended to other groups of students.
8.4. Reliability and Further Discussion of the Multiple Regression Models

In the previous section two multiple linear regression models were created. Significant predictor variables and some that were found not to be significant were discussed. Here there will be further discussion on the reliability of the models and if they could be extended to include other groups of students.

8.4.1. Reliability of the Multiple Regression Models Created

Firstly, as discussed in 8.3.1, data for all variables could not be collated for all 133 students. In fact complete data sets were obtained for only 66 students and the models described previously were constructed using a stepwise method on the initial 14 variables, for 66 students. Subsequently, the variables that were shown to be significant were taken and regression modules were created using only these (three) variables for all students that had complete data. 107 students were used in the analysis and the regression models found, for overall performance, $y_1$, and performance in the first year mechanics module, $y_2$, were:

$$y_1 = 0.236a_1 - 2.274b_1 + 4.794c_1 + 40.611, R^2 = 0.185$$
$$y_2 = 0.412a_2 - 3.334b_2 + 7.416c_2 + 24.940, R^2 = 0.316,$$

where the variables $a_1, a_2, b_1, b_2, c_1, c_2$ can be seen in Tables 8.3 and 8.4.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Standard Error</th>
<th>t</th>
<th>Significance</th>
<th>Possible Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>40.611</td>
<td>5.092</td>
<td>7.975</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>$a_1$</td>
<td>0.236</td>
<td>.062</td>
<td>3.793</td>
<td>.000</td>
<td>0 - 100</td>
</tr>
<tr>
<td>Mathematics Diagnostic Test Result</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$b_1$</td>
<td>-2.274</td>
<td>1.254</td>
<td>-1.813</td>
<td>.073</td>
<td>0,1,2,3</td>
</tr>
<tr>
<td>No. of statistics Modules Studied</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$c_1$</td>
<td>4.794</td>
<td>2.112</td>
<td>2.270</td>
<td>.025</td>
<td>0 - No, 1 - Yes</td>
</tr>
<tr>
<td>Visited MLSC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 8.3 - Multiple regression model of mechanical engineering students overall first year performance (2)
When the models were extended to include students with complete data sets for only the three significant variables (and not all 14 variables), lower $R^2$ values were found. For overall first year performance the $R^2$ value was 0.392 for the 66 students with complete data sets but 0.185 for the 107 students who had data on the three significant variables. Similarly, for performance in the first year mechanics module the $R^2$ value was 0.476 for the 66 students with complete data sets but 0.316 for the 107 students who had data on the three significant variables. This, along with the change in size of the coefficients would indicate that the fit of the model(s) was not very robust.

There are many factors that could affect a student's performance, which have not been able to be built into the models, such as personal factors (financial issues, accommodation issues) as described in Murdock-Eaton et al (in press). Given this the values for $R^2$ found can be seen to indicate that the significant variables are of importance. When models were created considering only data from the three significant variables, $R^2$ values of 0.185 and 0.316 were obtained. This indicates that 19% of the variation in a student's overall first year result, from the many possible factors, could be attributed to the three variables detailed. Similarly, 32% of the variation in a student's first year mechanics module result could be attributed to the same three variables. This suggests that the three variables found to be significant in the models are certainly important.

However, in the simple linear regression models described earlier in 8.2.2, it could be seen that 22% of the variation in a student's first year university mechanics module
could be attributed to the single variable of a student's mechanics diagnostic test mark. Similarly, 22% of the variation in a student's first year university mechanics module could be attributed to the single variable of a student's mathematics diagnostic test mark. Thus, a more simplistic model involving only one variable could be used to explain more variation in a student's first year university mechanics module than the model created which incorporated three variables. However, the multiple regression models are good for identifying important variables, which could then be considered individually.

8.4.2. Further Discussion on Significant Factors

The significant factors in both regression models were, students' mathematics diagnostic test result, whether they had visited the MLSC in their first year of study and the number of statistics modules they had studied in A-level Mathematics.

In many universities, mathematics diagnostic tests are already in place, as reported upon in Hawkes and Savage (2000) However, other diagnostic tests may not be good predictors and certainly could not be used with our model. In addition, as reported by Perkin and Croft (2004), there is an ever-increasing number of mathematics support centres, in various forms, in universities in the UK. Again data could be collected on whether a student had visited a particular mathematics support centre. However, a university would need to develop its own regression model to establish whether students' visiting their support centre is a significant predictor. Currently, it is not easy to establish which specific modules students had studied in a particular A-level. However, from September 2006 such data will become available to universities, through a student's UCAS application. Thus, this is the only factor that can be readily used by all.

Therefore, it can be seen that another university could not just use the exact regression models used in this thesis. Other universities could create their own regression models but would this be worthwhile? Ultimately, it depends upon the motive for predicting students' future performance. If it is to determine students who may be in need of assistance then administrating a mathematics diagnostic test and then offering and monitoring subsequent support can be very beneficial, as discussed by Robinson and
Croft (2003). They comment: 'Early indications are that the diagnostic test is a useful vehicle for identifying students in need of extra support', which arose as a result of reviewing 1000 results from a mathematics diagnostic tests that is administrated annually at Loughborough University. Otherwise, those interested in creating such regression models should keep in mind the considerable amount of time and effort that would be required to produce such models.

8.4.3. Extension to Other Groups of Students

It was also decided to extend the creation of multiple linear regression models to another group of students at Loughborough, namely aeronautical and automotive engineering students. This would give insight as to whether similar significant factors to those found for mechanical engineering students would be found for this separate group of students. The 136 aeronautical and automotive students also study a compulsory mechanics module in their first year at university. Though not the same mechanics module there is a considerable amount of overlap in the material contained in both.

The same methodology that was used for the mechanical engineering students was used for the aeronautical and automotive engineering students. Multiple linear regression models were created from the same 14 variables to predict overall first year performance and performance in students' first year mechanics module. As described in 8.4.1 for mechanical engineering students, the models were initially run for all 14 variables (for 108 students who had complete data sets) but then re-run for students that had complete data sets for the variables found to be significant. The final models created for overall performance, $y_3$, and performance in the first year university mechanics module, $y_4$, were:

\[
\begin{align*}
    y_3 &= 0.149a_3 - 0.009b_3 + 4.315c_3 + 11.807, \quad R^2 = 0.244 \\
    y_4 &= 0.218a_4 - 3.721b_4 - 11.893, \quad R^2 = 0.127,
\end{align*}
\]

where the variables $a_3, a_4, b_3, b_4, c_3$ can be seen in Tables 8.5. and 8.6.
In the model for overall first year performance 119 aeronautical and automotive students were included and in the model for performance in a university first year mechanics module 113 students were included.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Standard error</th>
<th>t</th>
<th>Significance</th>
<th>Possible Values</th>
</tr>
</thead>
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<tr>
<td>Constant</td>
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<td>8.695</td>
<td>1.357</td>
<td>0.177</td>
<td></td>
</tr>
<tr>
<td>Total A-level points score</td>
<td>0.149</td>
<td>0.027</td>
<td>5.538</td>
<td>0.000</td>
<td>0-360</td>
</tr>
<tr>
<td>Exam board</td>
<td>-0.009</td>
<td>0.004</td>
<td>-2.208</td>
<td>0.029</td>
<td>0,1</td>
</tr>
<tr>
<td>Welsh/NI</td>
<td>4.315</td>
<td>2.594</td>
<td>1.663</td>
<td>0.099</td>
<td>0 - No, 1 - Yes</td>
</tr>
</tbody>
</table>

Table 8.5 – Multiple regression model of aeronautical and automotive engineering students' overall first year performance

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Standard error</th>
<th>t</th>
<th>Significance</th>
<th>Possible Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-11.893</td>
<td>18.236</td>
<td>-0.652</td>
<td>0.516</td>
<td></td>
</tr>
<tr>
<td>Total A-level points score</td>
<td>0.218</td>
<td>0.057</td>
<td>3.806</td>
<td>0.000</td>
<td>0-360</td>
</tr>
<tr>
<td>A-level statistics modules</td>
<td>-3.721</td>
<td>1.919</td>
<td>-1.940</td>
<td>0.055</td>
<td>0,1,2,3</td>
</tr>
</tbody>
</table>

Table 8.6 – Multiple regression model of aeronautical and automotive engineering students' performance in a first year university mechanics module

As can be seen from both models there are some significant factors, such as visited the MLSC and number of A-level statistics modules studied, which are the same as those found for mechanical engineering students. There are also some that were not found for mechanical engineering students, i.e. total A-level points score and having studied A-level Mathematics under the Welsh/NI examination boards.
The predictor variable that had the largest effect in both models is a student's total A-level points score. According to the model this variable could have an effect of up to 54% when predicting overall first year performance and an effect of up to 78% when predicting performance in a first year university mechanics module. This is interesting given that this was not a significant factor in the models created for mechanical engineering students.

In the model for predicting students' overall first year performance it can be seen that the variable of visited the MLSC could have an effect of approximately half a grade boundary, i.e. 4.315%, whereas the variable of studying through the Welsh/NI examination boards, although a significant predictor, has a negligible effect of only -0.009%.

In the model for predicting students' performance in their first year university module of mechanics, apart from the variable of a student's total A-level points score, which has the largest effect on the model, the only other significant variable was the number of statistics modules a student had studied; this variable could have an effect of between -3.721% and 0%.

With only two or three variables emerging as being statistically significant in the models for aeronautical and automotive engineering students, there are obviously several variables of interest that were not significant. In particular, both the mathematics and mechanics diagnostic tests were not significant variables. Interestingly, the aeronautical and automotive engineering students performed on average 8% better than the mechanical engineering students on the mechanics diagnostic test and 5% better than the mechanical engineering students on the mathematics diagnostic test.

Within this section a review of the initial models created for mechanical engineering students was undertaken and two further models were created using only the significant variables. These significant variables were then discussed before an extension to the initial study, involving creating models for another group of (aeronautical and automotive) engineering students, was undertaken. It was very
interesting to see that the significant variable that had the largest effect in the models was different to the models created for mechanical engineering students, thus emphasising the difficulty in generalising findings from such models.

8.5. Summary and Discussion

In this chapter the use of regression models to predict engineering students' performance in a first year university mechanics module and their overall first year performance was considered. Both simple linear regression models and multiple linear regression models were created and discussed.

It emerged that simple linear regression models using three different variables (individually) could be used to explain up to 22% of the variation in how a student performed in either a first year university mechanics module or in a student's overall first year performance.

When multiple linear regression models were created for mechanical engineering students three factors emerged as being significant. These included students' mathematics diagnostic test results, whether they had visited the MLSC in their first year of study and the number of statistics modules they had studied in A-level Mathematics.

Models using all 14 variables, created for 66 mechanical engineering students, were found to have higher $R^2$ values than for those created for 107 students (in which only the three significant factors were considered). This highlighted that the model(s) were not very robust. However, there were obviously a large number of other factors (as detailed earlier, e.g. personal factors such as finance issues) which could have an effect on first year performance, but which were not included when creating the predictor models. Consequently, the $R^2$ values for the models created from the group of 107 students indicated that the significant variables are of importance.

However, when models were created for aeronautical and automotive engineering students, using the same initial variables as for the mechanical engineering students, several different significant variables emerged and one in particular being the
student's total A-level points score. Hence, the creation of predictor models for both mechanical engineering students and aeronautical and automotive engineering students has shown that differences can arise in the significant predictor variables, even between students from different departments within a university. Therefore, this highlights the difficulties that could arise in trying to generalise findings from a given model. Furthermore relatively low $R^2$ values were found for the models created, but were as to be expected because of all the other factors, which were not included, but that could have had an affect on the variation in the response variable. Similar findings were also detailed in a study into first year performance by Hunt et al (1995), who commented that:

It is impossible to separate out in a quantitative way the effects of preparation, motivation and ability of the student, and the course provision of the University on the success of individual students. This is because there is a great deal of feedback between the different factors. There are many other potential factors that may be involved. However, it has been possible to point out some interesting relationships and give some warnings of current and potential problems.

Thus, trying to predict students' performance can be somewhat complicated, time consuming and inconsistent primarily due to the many, many factors which could affect a student's performance.
9. Concluding Summary, Implications, Recommendations and Future Work

This research was concerned with reviewing the repercussions in higher education of the changes in the teaching and learning of mechanics in schools in England. To that end a comprehensive review of the changes in the pre-university qualifications of A-levels and specifically Mathematics A-levels was undertaken (Chapter 2). Various research methodologies were then considered and discussed (Chapter 3) as a prelude to their use in the research undertaken. The research carried out, as detailed in Chapters 4, 5, 6, 7 and 8 will now be summarised and discussed in the context of the whole project. The implications and recommendations from the research, particularly for engineering educators will also be detailed. Finally, some possibilities for future work in the area will be given.

9.1. Concluding Summary of the Research

After the initial introductory chapters (1, 2 and 3) followed discussion and analysis of the research conducted for this thesis. In considering what the repercussions in higher education of the changes in the teaching and learning of mechanics in schools in England were, several areas were reviewed. These broadly fell into four categories, which were:

- Schools' perspective (Chapter 4)
- Students' knowledge of mechanics upon arrival to university (Chapters 5/6)
- Engineering academics' perspective (Chapter 7)
- Predicting students first year university performance (Chapter 8)

The motivation for Chapter 4 had been to gain an understanding of recent trends in schools so that they could be placed in context with what was happening in universities. Specifically, interest had been in establishing just what the availability and uptake of mechanics was in schools and in particular what affect the change in structure and syllabi in September 2004 had had. The implemented mailed
questionnaires produced good response rates of 45% and 49% and analysis was carried out on the replies.

The comparative analysis between the replies in 2004 and the replies in 2006 highlighted that there was a changing picture with respect to the availability and uptake of mechanics modules (in fact a changing picture was also seen for the other mathematics strands). However, the changes seen were more of a concern than of an improving situation. The fact that the availability of mechanics, in the schools in the samples, had reduced from 74% of schools offering two or more modules of mechanics in 2004 to 60% offering two or more modules of mechanics in 2006 is noteworthy. Furthermore, additional information sought in the 2006 questionnaire enabled it to be seen that the situation may have in fact been worse. This was because those students who had been studying AS/ A-level Further Mathematics had been included in the analysis of the availability of modules. Results from the 2006 questionnaire indicated that only 38% of schools offered both mechanics modules (M1 and M2) to students studying A-level Mathematics (i.e. excluding those offering the modules only in AS/ A-level Further Mathematics). This implies that if students do want to study several mechanics modules then they may have to study either AS or A-level Further Mathematics. This is concerning given the general low number of students who, in recent years, have been studying A-level Further Mathematics. However, the change in structure and syllabi to Mathematics A-levels in 2004, as discussed earlier, may improve the situation, as will the introduction of a national Further Mathematics Network.

The main findings with respect to the uptake of mechanics modules were also stark. Given that there were approximately the same number of students studying AS/ A-level Mathematics courses in both the 2004 (13754) and 2006 (13673) samples, the noticeable reduction (from approximately 18% to 12%) in students who were studying second level modules, particularly M2 and S2, was concerning. This implied that following the change in structure and syllabi in September 2004, students were choosing or made to study (if there was no choice available) two first level modules. As discussed in section 4.4.4, this may enable students to gain the best possible mark in their A-levels, which not only benefits the students but also the school. However, for universities there may be disappointment that students cannot and are not studying
the higher-level modules, particularly if students want to go on to study STEM subjects.

It is useful to compare the findings of the uptake of mechanics in schools (from Chapter 4) with the background of students studying engineering at university (from Chapter 5). It was heartening to see that approximately 68% of 1087 university engineering students surveyed had studied two or more modules of mechanics at school. This is considerably more than those in schools in 2004 (discussed in 4.4.3) where, at most, 26% of students had studied two or more mechanics modules. However, results from the 2006 questionnaire to schools showed that at most 17% of students had studied two or more mechanics modules. Consequently it seems likely that the percentage of engineering students who had studied two or more modules may, for example in 2006, be lower than the 68% in 2004. Thus, there may be a further overall decline in the number of mechanics modules students entering engineering programmes had studied.

This possibility of decline is something that should concern engineering educators as students that have studied little (M1) or no mechanics, be it because they were unable to study it or be it that they choose not to study it, will almost certainly feel disadvantaged whilst studying a first university mechanics module, unless no prior knowledge of mechanics is assumed. This sentiment was portrayed through the questionnaires and interviews with students (discussed in Chapter 5), where they indicated how helpful it had been to have been exposed to the material in the context of A-level Mathematics, particularly as it is taught over a longer time span. This raises several important points.

Firstly, given the majority of students felt that the first university module of mechanics was challenging, meant that those that had not been exposed to mechanics previously would be under even greater strain in the module.

Secondly, the issue of time to absorb the material contained in a first year mechanics module is important. The implication is that for students entering university having studied little or no mechanics then it is difficult to 'pick up' the speed in which concepts are introduced. It follows that this then places more pressure on such
students to spend more time, than other more well prepared students, outside the lectures getting to grips with mechanics. In such instances students may seek additional help.

A third issue is how best to help students that may be in need of support, in mechanics. Within this thesis it was predominantly through questioning and interviewing academic staff (Chapter 7) in which this was reviewed. Several different strategies were discussed concerning both the teaching of mechanics and the support given to students. Specifically with respect to supporting students, it appears that there could be a great amount of transferability of support mechanisms developed for use with mathematics and this is expanded upon in 9.3.

As has just been discussed it is very useful to be able to identify which students could be in danger of failing a first university module of mechanics, as well as their first year overall. This would allow suitable support mechanisms to be put in place. To that end Chapter 8 discussed linear regression predictor models, which incorporated a large amount of data collected from both a questionnaire (discussed in Chapter 5) and a mechanics diagnostic test (discussed in Chapter 6). However, use of such models highlighted that trying to predict students’ performance can be somewhat complicated, time consuming and inconsistent, primarily due to the many, many factors which could affect a student’s performance. Nevertheless they can be of benefit because they can highlight significant predictor variables.

Also noteworthy was that when students were interviewed (Chapter 5), they indicated that they thought it would be beneficial if their lecturers had a realistic understanding of the prior knowledge of the class before the course started rather than finding out as the semester progressed.

Consequently, the two most evident repercussions in higher education of the changes in the teaching and learning of mechanics in schools in England are:

- A significant number of engineering students are currently entering university engineering degrees with little or no knowledge of mechanics
• Many academics, because of a lack of awareness of changes in qualifications, still assume a level of knowledge of mechanics from students entering engineering degrees that many will no longer have

9.2. Implications and Recommendations

The (lack of) availability of mechanics in schools is an obvious concern. There will undoubtedly be students studying A-level Mathematics courses in schools where mechanics is not available for them to study, even though for some it would benefit them if they were planning on studying an engineering degree. The number of students who are in such a situation is unknown and it would be quite difficult to obtain accurate figures for this. It would appear to be a difficult task for university academics to affect what applied modules in A-level Mathematics courses schools offer to students and indeed what students do actually study. Nevertheless, there are some possibilities.

Firstly, if more students for whom mechanics is appropriate are made aware that it would be beneficial to study mechanics in A-level Mathematics courses, then there may be an increase in numbers studying mechanics. There is not an obvious, straightforward way of doing this, although appropriate strategies include targeting careers advisors or teachers of mathematics with appropriate information, or alternatively trying to get in touch with the students themselves. Such an idea, albeit with respect to giving students information on mathematics in general, was discussed by Porkess (2006: 16). Porkess highlighted that the new Further Mathematics Network 'provides a communication route to all A-level Mathematics students and their teachers', which could be exploited by anyone who it would be appropriate for, such as university lecturers. This could be done firstly by contacting one of the central team members with for example an email, who could then forward an email to all Further Mathematics Centre managers across the country, who could then forward it to all 'schools' in their area, which would encompass the whole country. Such a channel for correspondence is an excellent opportunity that it may be wise to utilise.

Secondly, as discussed in the paper 'unwinding the vicious circle' by Porkess (2006: 12), university departments, through a change in their entrance requirements, could
encourage more schools to offer and consequently encourage more students to study AS/A-level Further Mathematics. As was shown in section 4.4.3, the availability of mechanics modules for students to study in schools was greatly increased (from 38% offering M1+M2 to 60% offering at least M1+M2) when the availability in AS/A-level Further Mathematics was included. Thus, getting as many students studying AS/A-level Further Mathematics would be a positive outcome and is highly recommended.

If no (positive) change occurs in the amount of prior knowledge of mechanics that students entering relevant degree programmes (particularly engineering) have, then obviously it will fall to university departments to establish if there is a 'mechanics problem' in their department and then determine what they can do to remedy the situation. In general there are several strategies that can be recommended, however many depend on the size and budget available in a given department. For example, streaming students according to their prior knowledge of mechanics was highlighted by academics in interviews as being a successful method of assisting the less well prepared students. However, this is obviously not a viable option for all departments because of the aforementioned costs and other possible issues, such as timetabling constraints of lectures.

Following the research that has been conducted in this project, it appears that the fundamental recommendations broadly follow that for the 'mathematics problem', as recommended by Hawkes and Savage (2000). It is to diagnose students' prior knowledge of mechanics upon arrival and then to offer suitable support to those that it is appropriate for.

9.3. Future Work

The underlying objective of this research was to review the 'mechanics problem' and discover just how widespread it was. The research described, including that on schools, university students and from academics, has provided documented evidence of the widespread nature of the situation with respect to mechanics. The discussion following on from the outcomes of the quantitative and qualitative research has given
an insight into measures that could be used to recover the situation. However, there is more work that could and perhaps should be undertaken.

9.3.1. Monitoring Changes in A-levels

The changes that have occurred in pre-university qualifications, in particular A-levels, have been central to many parts of this thesis. Thus, it stands to reason that there should be a continuation of monitoring pre-university qualifications and how they may contribute to changing incoming university students' knowledge of mechanics. Furthermore, there should perhaps be a central mechanism where all changes in A-levels are recorded and updates automatically forwarded, so that all those that the changes may affect can easily be kept informed of developments. This includes those in many university departments as well as possible employers who may employ students directly from A-levels. Perhaps HEA Subject Centres could take a lead in this.

It is worth noting that there is currently a major project entitled Pathways 14-19, which may mean changes occur to pre-university qualifications by 2010. Indeed, possible changes in A-level Mathematics are already about to be trialled.

9.3.2. Monitoring Incoming Students

As was recommended in 9.2 it has been suggested that incoming students' knowledge of mechanics should be obtained upon arrival to university. Both a questionnaire and a diagnostic test were used to do this in this thesis. From the beginning of the 2006-2007 academic year, universities will obtain information from UCAS on which modules students have studied; it would be very worthwhile for lecturers to obtain this information for many of the reasons described earlier.

In addition, via UCAS, it may be possible to gain a national picture of the number of mechanics modules that students entering onto, for instance engineering degrees, have studied. The viability of this would depend on the infrastructure of how UCAS hold such information.
It may also be plausible to host a mechanics diagnostic test online, which could be completed by students on a national scale. However, the appropriateness of a single test for such a wide audience would need to be addressed. Could for example different types of questions be supplied for a test to a given institution?

Also related to monitoring incoming students knowledge, it would be very interesting to conduct further research into the abilities and performance in mechanics of students with non-A-level backgrounds. At Loughborough University approximately 10% of engineering students enter via this non-traditional route; however in some other universities it is much higher.

9.3.3. Review of Teaching Methods and Style

In interviews with students (Chapter 5) and questionnaire responses and interviews with university academics (Chapter 7), reference was made to the teaching of mechanics at university. This is an area where a considerable amount of further research could be conducted. More specifically, consideration could be given to both the structure and content of a first university module in mechanics. An ideal module would be one that could challenge the students that were well-prepared in mechanics upon entry to university, but also enable those less well-prepared to achieve success.

Indeed, research recently conducted by Professor Clements supports the suggestion of a need for such courses to be modified accordingly. Clements (in press) concluded that:

This work provides further, independent confirmation that the findings of Robinson et al are widespread and that universities must no longer assume that entrants to engineering and other technical and scientific degree courses have the level of familiarity with concepts in basic mechanics which they have heretofore taken for granted Courses must be designed or modified to take this into account and new courses are required to impart the knowledge and skills which the students now lack

Thus, with no changes to A-level Mathematics due until at least 2010, perhaps now is the time to focus on reviewing a first university course in mechanics.
10. References


Web references:

[1] [http://www.qca.org.uk/14-19/qualifications/index_key-features.htm]

[2] [http://www.qca.org.uk/13730_14516.html]


[4] [http://www.dfes.gov.uk/aboutus/]

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[9] [http://www.mathsrevision.net/alevel/specimen.htm]

[10] [http://www.caslancs.ac.uk/glossary_v1.1/car.html]


[13] [http://www.mathcentre.ac.uk/stephen/questionnaire.html]
Appendices

A - Content of (OCR) Mechanics Modules M1-M4

M1 (2637)
Force as a vector
Equilibrium of a particle
Newton’s Laws of motion
Linear momentum
Kinematics of motion in a straight line

M2 (2638)
Centre of mass
Equilibrium of a rigid body
Motion of a projectile
Uniform motion in a circle
Coefficient of restitution and impulse
Energy, work and power

M3 (2639)
Equilibrium of rigid bodies in contact
Elastic strings and springs
Impulse and momentum in two dimensions
Motion in a vertical circle
Linear motion under a variable force
Simple Harmonic Motion

M4 (2640)
Relative motion
Centre of mass
Moment of inertia
Rotation of a rigid body
Stability and oscillations
B - Number of Students Studying A-level Mathematics Modules 2001-2006

In the following tables information collected on the number of students who sat a given module in a given examination session, e.g. June 2005, are given. Data was difficult to obtain, although more information was able to be obtained for the examination board AQA. AQA had two specifications A and B, until the new specifications, first taught in September 2004, when they only offered one specification. Data in the first table is from the 'new' specifications, whereas all others are from the Curriculum 2000 specification.

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<td>277</td>
<td>92</td>
</tr>
</tbody>
</table>
A-Level Mathematics Questionnaire

Please tick appropriate box unless asked to insert a number
If you do not offer any GCE Mathematics courses, please answer only question 8

1. Which examination board are you using for your 2003-2004 GCE Mathematics courses?
   - AQA A
   - OCR
   - Edexcel
   - CCEA (Northern Irish)
   - WJEC (Welsh)
   - Other

2. If you have changed examination board for Mathematics courses in the previous five years please complete the following:
   - Old Board
   - Year of change
   - Reason(s) for change

3. Please indicate which of these APPLIED modules you offer and approximately how many students are studying them in 2003-2004:
   (Please circle Yes / No as appropriate and write the number of students studying the module in the box)

- M1 Yes / No
- M2 Yes / No
- M3 Yes / No
- M4 Yes / No
- M5 Yes / No
- M6 Yes / No

- S1 Yes / No
- S2 Yes / No
- S3 Yes / No
- S4 Yes / No
- D1 Yes / No
- D2 Yes / No

If you offer any others, which are not listed above [excluding any pure modules], please insert below:

Please Turn Over
4 If you do not offer some/any MECHANICS modules is this due to:

- Financial Constraints
- Teacher Skills Shortage
- Lack of Pupil Interest
- Timetable Constraints

Other: ____________________________________________________________

5 If you do not offer some/any STATISTICS modules is this due to:

- Financial Constraints
- Teacher Skills Shortage
- Lack of Pupil Interest
- Timetable Constraints

Other: ____________________________________________________________

6 Do you offer students guidance on module choice?

- Yes
- No

If yes, what is the general advice given?
If no, why is guidance not given?

(Please state if no module choice is available to your students)

______________________________________________________________

7 Could you please indicate the number of students studying each Mathematics course in 2003-2004. (Include any students studying via distance learning etc. If any other courses are available please insert into spaces.)

<table>
<thead>
<tr>
<th>Course</th>
<th>Number of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS Mathematics (e.g. students in years 12 &amp; 13)</td>
<td></td>
</tr>
<tr>
<td>A-Level Mathematics (e.g. students in Year 13 only)</td>
<td></td>
</tr>
<tr>
<td>AS Further Mathematics (e.g. students in years 12 &amp; 13)</td>
<td></td>
</tr>
<tr>
<td>A-Level Further Mathematics (e.g. students in Year 13 only)</td>
<td></td>
</tr>
</tbody>
</table>

8 Please indicate the total number of students, registered on courses leading to AS or A-Level certification in ANY subject

<table>
<thead>
<tr>
<th></th>
<th>AS</th>
<th>A-Level</th>
</tr>
</thead>
</table>

Thank you for taking the time to complete this questionnaire.

If you would like to receive details of the analysis please insert a contact email address below:

______________________________

Please fax completed questionnaire to (01509) 223969

OR

Return in the accompanying envelope addressed to:

Mr S Lee, Mathematics Education Centre, W2.84, Loughborough University, Leics, LE11 3TU.
8th January 2004

Dear Head of Mathematics,

A-Level Mathematics Questionnaire

The Mathematics Education Centre at Loughborough University is currently conducting research on the implications for university engineering and science departments of the changes in the teaching and learning of mechanics in schools. As part of our research, we wish to survey a representative sample of schools nationwide to ascertain the current situation. Your school falls within this sample and your response will be valuable to us. We will disseminate our findings throughout the HE community and the results will be used to help make informed decisions on degree programme design which reflect the prior knowledge of our students.

We are particularly interested in what applied mathematics module options are presently available to your students and the choices they make. These will impact on both the numbers entering relevant university departments and the mathematical ability of those who do.

We would therefore be grateful if you could complete the attached questionnaire and return it to me, Stephen Lee, by Monday 19th January in the accompanying addressed envelope. Alternatively, you may fax it to me at 01509 223969. It should take less than five minutes to fill in. We would like to reassure you that your response will be treated in a strictly confidential manner and the result will remain anonymous. If you provide us with your email address we will be happy to send you a copy of our findings in due course.

If you have any queries regarding the questionnaire or any comments on the issues raised, then please feel free to contact me via telephone, fax, email or by enclosing a letter when returning the questionnaire.

We very much look forward to receiving your completed questionnaire.

Thank you for your help.

Yours sincerely,

S Lee

Mr S Lee
E - 2004 Pilot, Questionnaire to Schools

A-Level Mathematics Questionnaire

Please tick appropriate box unless asked to insert a number.

If you do not offer any GCE Mathematics courses, please answer only question 8.

1. Which examination board are you using for your 2003-2004 GCE Mathematics courses?

☐ AQA A
☐ OCR
☐ Edexcel
☐ CCEA (Northern Irish)
☐ WJEC (Welsh)
Other: ____________________________

2. If you have changed examination board for Mathematics courses in the previous five years please complete the following:

Old Board ____________________________________________
Year of change ____________________________
Reason(s) for change ____________________________________________
__________________________________________

3. Please indicate which of these APPLIED modules you offer and approximately how many students are studying them in 2003 - 2004:

(Please delete Yes / No as appropriate and write the number of students studying the module in the box)

<table>
<thead>
<tr>
<th>Module</th>
<th>Offered</th>
<th>Number of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>M2</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>M3</td>
<td>Yes</td>
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<td>M4</td>
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<td>M5</td>
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<td>M6</td>
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<td>Yes</td>
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<td>S2</td>
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<td>S4</td>
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<td>D1</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>D2</td>
<td>Yes</td>
<td></td>
</tr>
</tbody>
</table>

(If you offer any others, which are not listed above [excluding any pure modules], please insert below)

__________________________________________
__________________________________________
__________________________________________

Please Turn Over
4 If you do not offer some/all MECHANICS modules is this due to:

☐ Financial Constraints  ☐ Teacher Skills Shortage  ☐
☐ Lack of Pupil Interest
Other: ____________________________

5 If you do not offer some/all STATISTICS modules is this due to:

☐ Financial Constraints  ☐ Teacher Skills Shortage  ☐
☐ Lack of Pupil Interest
Other: ____________________________

6 Do you offer students guidance on module choice?

☐ Yes  ☐ No

If yes, what is the general advice given?

________________________________________
________________________________________
________________________________________

7 Could you please indicate the number of students studying each Mathematics course in 2003-2004. (If any other courses are available please insert into spaces)

<table>
<thead>
<tr>
<th>Course</th>
<th>Number of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS Mathematics</td>
<td></td>
</tr>
<tr>
<td>A2 Mathematics</td>
<td></td>
</tr>
<tr>
<td>AS Further Mathematics</td>
<td></td>
</tr>
<tr>
<td>A2 Further Mathematics</td>
<td></td>
</tr>
</tbody>
</table>

8 Could you please indicate the total number of students, within your establishment, studying all A-Leves in 2003-04 ☐

Thank you for taking the time to complete this questionnaire

If you would like to receive details of the analysis please insert a contact email address below:

Please fax completed questionnaire to (01509) 223969
OR
Return in the accompanying envelope addressed to:
Mr S Lee, Mathematics Education Centre, W2.84, Loughborough University, Leics, LE11 3TU
RE: A-Level Mathematics Questionnaire

The Mathematics Education Centre at Loughborough University is inviting you to take part in the piloting of a questionnaire. After feedback from the members in the piloting scheme this questionnaire will be sent out to over 500 schools throughout England. We would therefore ask that you read the questionnaire cover letter and complete the questionnaire as if you had received it independently from this accompanying memo.

Once you have completed the questionnaire we would like as much feedback as possible, both positive and negative comments would be appreciated. There is a list of possible areas from which comments may arise below. Please write your thoughts on these and feel free to speak on any other issues you feel may be appropriate or indeed useful.

Feedback requested on:

General layout and appearance

Question wording/structure (clarity etc):

Ease of completion (time taken, knowledge needed e.g. numbers studying courses):

Please Turn Over
Cover Letter (clarity, sufficient explanation etc):

Any other comments or observations:
**G - Profile of those that Piloted the Schools' Questionnaire**

Participant 1 - Is a member of the mathematics department at a local Independent School (who are in the sample of 500).

Participant 2 - Is a member of the MEC and who recently retired from Head of mathematics at a local High School.

Participant 3 - Is currently teaching mathematics in a local secondary school.

Participant 4 - Is Head of mathematics at a local High School (also in the sample of 500).

Participant 5 - Is a teacher of mathematics at a local High School (also in the sample of 500).

Participant 6 - Was Head of mathematics at a secondary school in Staffordshire until December 2003.

Participant 7 - Is Head of mathematics at a secondary school in Staffordshire from December 2003.

Participant 8 - Is a mathematics Ph.D. student at Loughborough University, who had previously taught mathematics at a local secondary school.

Participant 9 - Is Head of mathematics at a sixth form in Darlington, County Durham.

Participant 10 - Is Head of mathematics at another secondary school in Staffordshire.
H - Review of Charts

In Figure 4.4, which reviewed the number of students on roll in a school, it can be seen that discrete groups are created. This allowed the 243 replies to be compared with the initial sample of 500 schools. Little difference was seen between the two samples. In terms of the most common size of a school, two intervals were larger than the others. These were the 500-999 interval, with around 30% of schools being of this size. The second was the 1000-1499 interval, with around 35% of schools being of this size. All other intervals generally had less than 10% of schools in them.

Figure 4.5 showed the number of pupils in years 12 and 13. This gave a similar picture to what was seen in Figure 4.1. There was little difference (at most 4%) between the 243 replies and the initial 500 schools in each of the intervals. Around a third of the schools fell into the interval of size 100-199, with a further fifth falling into the interval 200-299.

Figure 4.6 reviewed the type of school. The majority (over 50%) of schools, both in the replies and in the initial sample were comprehensive schools. Around 20% of replies were from independent schools. In addition 20% were classified as 'other', i.e. all the different types of schools from whom replies were small, e.g. Arts colleges. There was little difference between the 243 replies and the initial sample of 500 schools.

Figure 4.7 compared the type of LEA that schools in the 243 replies were from and those in the initial sample of 500 schools. The percentage of schools in the various types of LEA were very similar for both samples.

A very similar picture to that seen in Figure 4.5 was seen in Figure 4.8, which looked at the sex of the pupils in each school. Over 80% of schools, in both samples, were mixed gender schools. Around 10% were female only schools and around 5% being male only schools.
Finally, Figure 4.9 showed the percentage of schools that were taking part in the Excellence Challenge program. There was less than 1% difference in the percentage of schools taking part in the two samples.
I - Tables of analysis of areas

Tables showing the percentage of schools that offer a given number of mechanics modules given by each specific area:

For Example: 29 13% of the 127 Admin Counties schools offer 1 module of mechanics.

<table>
<thead>
<tr>
<th>LEA</th>
<th>No of Schools</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
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</thead>
<tbody>
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<td>Admin Counties</td>
<td>127</td>
<td>315</td>
<td>29</td>
<td>13</td>
<td>30</td>
<td>71</td>
<td>23</td>
<td>62</td>
</tr>
<tr>
<td>UA - Admin Counties</td>
<td>31</td>
<td>16</td>
<td>13</td>
<td>26</td>
<td>32</td>
<td>13</td>
<td>16</td>
<td>68</td>
</tr>
<tr>
<td>UA - Met Districts</td>
<td>42</td>
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<td>11</td>
<td>24</td>
<td>26</td>
<td>19</td>
<td>0</td>
</tr>
<tr>
<td>UA - Non Met Districts</td>
<td>11</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>45</td>
<td>37</td>
<td>27</td>
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<tr>
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<td>17</td>
<td>86</td>
<td>46</td>
<td>43</td>
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<td>0</td>
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<th>6</th>
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<th>5</th>
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<td>23</td>
<td>98</td>
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<td>23</td>
<td>70</td>
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<td>11</td>
<td>25</td>
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<td>0</td>
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<th>6</th>
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<td>Comprehensive</td>
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<td>7</td>
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<td>21</td>
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<td>28</td>
<td>85</td>
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<td>20</td>
<td>25</td>
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<td>Other</td>
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<td>64</td>
<td>29</td>
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<tr>
<td>500-999</td>
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<td>21</td>
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</tr>
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<td>1000-1499</td>
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<td>9</td>
<td>41</td>
<td>25</td>
<td>88</td>
<td>30</td>
<td>59</td>
<td>25</td>
</tr>
<tr>
<td>1500+</td>
<td>50</td>
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<td>00</td>
<td>12</td>
<td>00</td>
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<table>
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<th>No of Schools</th>
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<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;100</td>
<td>66</td>
<td>7</td>
<td>58</td>
<td>24</td>
<td>24</td>
<td>45</td>
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<td>10</td>
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<td>100-199</td>
<td>70</td>
<td>5</td>
<td>71</td>
<td>27</td>
<td>14</td>
<td>28</td>
<td>57</td>
<td>25</td>
</tr>
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<td>200-299</td>
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<td>5</td>
<td>88</td>
<td>11</td>
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<td>300+</td>
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<td>15</td>
<td>22</td>
<td>32</td>
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</table>
1 Which examination board(s) are you using for your 2005-2006 GCE Mathematics courses?

<table>
<thead>
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<th>Exam Board</th>
<th>Yes</th>
<th>No</th>
</tr>
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<tbody>
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<td>AQAA</td>
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<tr>
<td>OCR</td>
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<tr>
<td>Edexcel</td>
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</tr>
<tr>
<td>CCEA (Northern Irish)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WJEC (Welsh)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Other: ____________________________

2 If you have changed examination board for Mathematics courses in the previous six years please complete the following:
(If you have changed more than once, please state so but only complete for last change)

<table>
<thead>
<tr>
<th>More than one change?</th>
<th>Yes / No</th>
<th>How many changes?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Previous Board</td>
<td></td>
<td>Year of last change</td>
</tr>
<tr>
<td>Reason(s) for change</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3 Please indicate which of these APPLIED modules you offer and approximately how many students are studying them in 2005-2006:
(Please circle Yes / No as appropriate and write the number of students studying the module in the box)

<table>
<thead>
<tr>
<th>Module</th>
<th>Yes / No</th>
<th>Number of students</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>Yes / No</td>
<td></td>
</tr>
<tr>
<td>S1</td>
<td>Yes / No</td>
<td></td>
</tr>
<tr>
<td>D1</td>
<td>Yes / No</td>
<td></td>
</tr>
<tr>
<td>M2</td>
<td>Yes / No</td>
<td></td>
</tr>
<tr>
<td>S2</td>
<td>Yes / No</td>
<td></td>
</tr>
<tr>
<td>D2</td>
<td>Yes / No</td>
<td></td>
</tr>
<tr>
<td>M3</td>
<td>Yes / No</td>
<td></td>
</tr>
<tr>
<td>M4</td>
<td>Yes / No</td>
<td></td>
</tr>
<tr>
<td>M5</td>
<td>Yes / No</td>
<td></td>
</tr>
<tr>
<td>M6</td>
<td>Yes / No</td>
<td></td>
</tr>
<tr>
<td>S3</td>
<td>Yes / No</td>
<td></td>
</tr>
<tr>
<td>S4</td>
<td>Yes / No</td>
<td></td>
</tr>
<tr>
<td>Further Maths</td>
<td>Modules Only</td>
<td></td>
</tr>
</tbody>
</table>

(If you offer any others, which are not listed above [excluding any pure modules], please insert below)

<table>
<thead>
<tr>
<th>Further modules</th>
<th>Number of students</th>
</tr>
</thead>
</table>

Please Turn Over.
4 If you do not offer M1 and/or M2 in A-level Mathematics is this due to:
(Please tick all that apply)

- Financial Constraints
- Teacher Skills Shortage
- Lack of Pupil Interest
- Timetable Constraints
- Mechanics being most difficult of applied modules

Other: ________________________________

5 If you do not offer S1 and/or S2 in A-level Mathematics is this due to:
(Please tick all that apply)

- Financial Constraints
- Teacher Skills Shortage
- Lack of Pupil Interest
- Timetable Constraints
- Statistics being most difficult of applied modules

Other: ________________________________

6 Do you offer students guidance on module choice?
- Yes
- No

If yes, what is the general advice given?
If no, why is guidance not given?
(Please state 'NO MODULE CHOICE' is available to your students, if this is the case)

______________________________

7 Could you please indicate the number of students studying each Mathematics course in 2005-2006. (Include any students studying via distance learning, etc.
If any other courses are available please insert into spaces)

<table>
<thead>
<tr>
<th>Course</th>
<th>Number of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS Mathematics</td>
<td></td>
</tr>
<tr>
<td>A-Level Mathematics</td>
<td></td>
</tr>
<tr>
<td>AS Further Mathematics</td>
<td></td>
</tr>
<tr>
<td>A-Level Further Mathematics</td>
<td></td>
</tr>
</tbody>
</table>

8 Please indicate the total number of students, registered on courses leading to AS or A-Level certification in ANY subject
(i.e. all students in the school in Year 12 and Year 13)

- AS
- A-Level

Thank you for taking the time to complete this questionnaire

If you would like to receive details of the analysis please insert a contact email address below

Please fax completed questionnaire to (01509) 223969
OR
Return in the accompanying envelope addressed to:
Mr S Lee, Mathematics Education Centre, Loughborough University, Leics, LE11 3TU
1 Which examination board(s) are you using for your 2005-2006 GCE Mathematics courses?

- AQA
- OCR
- CCEA (Northern Irish)
- Other: ____________________________ (Welsh)

2 If you have changed examination board for Mathematics courses in the previous six years please complete the following:

- More than one change? Yes / No
- How many changes? ________
- Previous Board ____________________
- Year of last change ____________
- Reason(s) for change ____________________________

3 Please indicate which of these APPLIED modules you offer in AS/ A-level Mathematics and approximately how many students are studying them in 2005 - 2006:

(Please circle Yes / No as appropriate and write the number of students studying the module in the box)

<table>
<thead>
<tr>
<th>Module</th>
<th>Yes / No</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>D1</td>
</tr>
<tr>
<td>S1</td>
<td>D2</td>
</tr>
<tr>
<td>M2</td>
<td>S2</td>
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<td>D3</td>
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</tr>
<tr>
<td>M5</td>
<td>S6</td>
</tr>
<tr>
<td>M6</td>
<td>S7</td>
</tr>
</tbody>
</table>

4 Please indicate which of these APPLIED modules you offer in AS/A-level Further Maths and approximately how many students are studying them in 2005 - 2006:

(Please circle Yes / No as appropriate and write the number of students studying the module in the box. If you do not offer Further Mathematics tick here)

<table>
<thead>
<tr>
<th>Module</th>
<th>Yes / No</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>D1</td>
</tr>
<tr>
<td>S1</td>
<td>D2</td>
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<tr>
<td>M2</td>
<td>S2</td>
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<tr>
<td>S3</td>
<td>D3</td>
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<td>M3</td>
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<tr>
<td>M5</td>
<td>S6</td>
</tr>
<tr>
<td>M6</td>
<td>S7</td>
</tr>
</tbody>
</table>

(If you offer any others, which are not listed above [excluding any pure modules], please insert below)
5 If you do not offer M1 and/or M2 in A-level Mathematics is this due to:
(Please tick all that apply)

- Financial Constraints
- Teacher Skills Shortage
- Lack of Pupil Interest
- Timetable Constraints
- Mechanics being most difficult of applied modules

Other: ________________________________________________________________

6 If you do not offer S1 and/or S2 in A-level Mathematics is this due to:
(Please tick all that apply)

- Financial Constraints
- Teacher Skills Shortage
- Lack of Pupil Interest
- Timetable Constraints
- Statistics being most difficult of applied modules

Other: ________________________________________________________________

7 Do you offer students guidance on module choice?

- Yes
- No

If yes, what is the general advice given?
If no, why is guidance not given?
(Please state NO MODULE CHOICE is available to your students, if this is the case)


8 Could you please indicate the number of students studying each Mathematics course in 2005-2006. (Include any students studying via distance learning, etc)

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<tr>
<th>Course</th>
<th>Number of Students</th>
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</thead>
<tbody>
<tr>
<td>AS Mathematics (e.g. students in years 12 &amp; 13)</td>
<td></td>
</tr>
<tr>
<td>A-Level Mathematics (e.g. students in Year 13 only)</td>
<td></td>
</tr>
<tr>
<td>AS Further Mathematics (e.g. students in years 12 &amp; 13)</td>
<td></td>
</tr>
<tr>
<td>A-Level Further Mathematics (e.g. students in Year 13 only)</td>
<td></td>
</tr>
</tbody>
</table>

9 Please indicate the total number of students, registered on courses leading to AS or A-Level certification in ANY subject
(i.e. all students in the school in Year 12 and Year 13)

AS: ___________________ A-Level: ___________________

Thank you for taking the time to complete this questionnaire

If you would like to receive details of the analysis please insert a contact email address below:

Please fax completed questionnaire to (01509) 223969
OR
Return in the accompanying envelope addressed to
Mr S Lee, Mathematics Education Centre, Loughborough University, Leics, LE11 3TU

QEMA06 1 - 1
L - Questionnaire to First Year University Students – 2003·04
Prior Learning in Mathematics

1 University Degree: ____________________________________________

2 Student ID: _________________________________________________

3 Maths Qualifications Held: 
(Please tick)
A-Level Maths
A-Level Further Maths
AS-Level Maths
AS-Level Further Maths
Other Maths Related
Result / Grade / Percentage

<table>
<thead>
<tr>
<th>Result</th>
<th>A (80+)</th>
<th>B (70-79)</th>
<th>C (60-69)</th>
<th>D (50-59)</th>
<th>E (40-49)</th>
<th>(40&lt;)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

(please specify name and result) ____________________________________________

4 Please indicate (circle) year results were obtained:

5 Please indicate Exam Board of your college/sixth form course:
AQA
EDEXCEL
OCR
CCEA (Northern Ireland)
WJEC (Wales)
Other (Please state) ____________________________________________

6 If modular please circle modules taken & indicate (tick) box that corresponds to module result: (If result unknown please still circle modules taken)

Result / Grade / Percentage

<table>
<thead>
<tr>
<th>Module</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
<th>P5</th>
<th>P6</th>
<th>M1</th>
<th>M2</th>
<th>M3</th>
<th>M4</th>
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</tbody>
</table>

Other Modules Taken 
(State module / result) ____________________________________________

Thanks for taking the time to complete this questionnaire. Good luck with your studies.
M – Questionnaire to First Year University Students – 2004 - 05

Prior Learning in Mathematics

1 University Degree Programme: __________________________________________________________________________

2 Student ID: __________________________________________________________________________

3 a) Please indicate (tick) Exam Board of your college/sixth form mathematics course:

- AQA
- EDEXCEL
- OCR
- OCR (MEI)
- CCEA (Northern Ireland)
- WJEC (Wales)
- Other (Please state) _____________________________________________________________________

3 b) Please indicate (tick) which mathematics modules you studied:

<table>
<thead>
<tr>
<th>P1</th>
<th>M1</th>
<th>S1</th>
</tr>
</thead>
<tbody>
<tr>
<td>P2</td>
<td>M2</td>
<td>S2</td>
</tr>
<tr>
<td>P3</td>
<td>M3</td>
<td>S3</td>
</tr>
<tr>
<td>P4</td>
<td>M4</td>
<td>S4</td>
</tr>
<tr>
<td>P5</td>
<td>D1</td>
<td>D2</td>
</tr>
</tbody>
</table>

Other Modules Taken (State modules) ______________________________________________________________________

4 Please state if you have studied any mathematics qualifications other than A-level:
(e.g. International Baccalaureate) ______________________________________________________________________

Thank you for taking the time to complete this questionnaire.
N – Mechanics Diagnostic Test

Loughborough University
Mathematics Education Centre

Mechanics Quiz For Engineering Students

Sept. 2004

The purpose of this quiz is to inform future curriculum design and to enable development of appropriate resources for students on Engineering and Physics courses

Instructions

1. This quiz comprises of two sections. Section A contains 5 questions on your prior studies in mathematics. Section B contains 24 questions based on topics in Mechanics from A-level Mathematics.

2. For each question you are provided with four possible answers (A, B, C, or D), one of which is correct, together with a ‘don’t know’ response, (E). If you can do a question, select the appropriate answer and mark the corresponding box of the answer sheet provided.

If you do not know how to do a particular question then choose the ‘don’t know’ response. Please DO NOT GUESS. This is important because we would like to know which type of quiz questions are unfamiliar to the group.

3. Answer as many questions as you can. Try not to dwell on questions, as you will need to work swiftly through the quiz. You should work entirely on your own, and not consult friends or textbooks.

4. Calculators can be used.

5. As a guide this quiz should take 40 minutes to complete.

Where g is used in the text, it represents the acceleration due to gravity and may be taken to be 10 m s\(^{-2}\).
Section A

If you did not study AS/ A-level mathematics or further mathematics please answer E for each of these questions and proceed to Section B. If you did study mathematics at AS/ A-level then please select the appropriate answer for each.

1. Which examination board did your school/ college use for AS/ A-level mathematics?
   A) AQA
   B) EDEXCEL
   C) OCR
   D) CCEA, WJEC or Other
   E) Don’t Know or N/A

2. Which PURE modules did you study?
   A) None or only Pure 1
   B) Pure 1 and Pure 2
   C) Pure 1, Pure 2 and Pure 3
   D) Pure 1, Pure 2, Pure 3 and Pure 4 or more
   E) Don’t Know or N/A

3. Which MECHANICS modules did you study?
   A) None
   B) Mechanics 1
   C) Mechanics 1 and Mechanics 2
   D) Mechanics 1, Mechanics 2 and Mechanics 3 or more
   E) Don’t Know or N/A

4. Which STATISTICS modules did you study?
   A) None
   B) Statistics 1
   C) Statistics 1 and Statistics 2
   D) Statistics 1, Statistics 2 and Statistics 3 or more
   E) Don’t Know or N/A

5. Which DECISION and DISCRETE modules did you study?
   A) None
   B) Discrete 1
   C) Discrete 1 and Discrete 2
   E) Don’t Know or N/A
What is the HORIZONTAL COMPONENT of a force, with magnitude $F$, which is acting at an angle $\theta$ to the horizontal? Answer by selecting one of the following:

A) $\frac{F}{\cos(\theta)}$, B) $F \sin(\theta)$, C) $F \cos(\theta)$, D) $\theta \cos(F)$, E) Don't Know

In this question you are not required to do any calculations. Select the correct answer by reviewing the diagrams.

A particle is acted upon by two forces, of magnitudes 2 N and 5 N, in the directions shown in the diagram above. Of the diagrams below, which shows the resultant of these two forces?

A) 3 N
B) 6.2 N
C) 6.6 N
D) 3.2 N
E) Don't Know
8.

A particle is acted upon by two forces, of magnitudes 50 N and 100 N, in the directions shown in the diagram above. Of the diagrams below, which shows the resultant of these two forces?

A) B) C) D) E) Don't Know

M1 - Equilibrium of a particle

9.

The force vectors acting on a particle are shown in the diagrams below. Identify which of the particles shown are in equilibrium.

A) B) C) D) E) Don't Know
A particle of mass 6 kg is attached to one end of a light inextensible string. The other end of the string is attached to a fixed point. A horizontal force of magnitude $P$ newtons is applied to the particle, which is in equilibrium under the force of gravity. The string makes an angle of 30 degrees with the vertical. What is the value of the Tension, $T$, in terms of $g$?

A) $\frac{12g}{\sqrt{3}}$, B) $4g$, C) $(12\sqrt{3})g$, D) $2g$, E) Don’t Know

A block is on the point of sliding down an inclined plane. The correct force diagram including the forces of weight, $W$, normal reaction, $N$, and friction, $F$, is?

A) B) C) D) E) Don’t Know
M1 - Newton's laws of motion

12.

In the diagram above, a vehicle is moving uphill at a constant velocity. The components of the forces, parallel to the hill, $F_1$, $F_2$ and $F_3$ are given. Which row, below, gives a correct value for $F_4$?

- A) 2 kN 2 kN 1 kN 3 kN
- B) 1 kN 2 kN 1 kN 5 kN
- C) 1 kN 2 kN 1 kN 4 kN
- D) 1 kN 2 kN 2 kN 6 kN
- E) Don't Know

13.

A body of mass 8 kg is acted upon by a force of 80 N. What is the acceleration of the body in m s$^{-2}$?

- A) 640 m s$^{-2}$
- B) 0.1 m s$^{-2}$
- C) 100 m s$^{-2}$
- D) 10 m s$^{-2}$
- E) Don't Know
14.

Particles A, of mass 6 kg and B, of 2 kg, are attached to the ends of a light inextensible string. The string passes over a smooth fixed peg and the system is released from rest with both parts of the string taut and vertical. Neglecting all resistances to motion, what is the magnitude of the acceleration of A, in terms of $g$?

A) 2$g$, B) 3$g$, C) 4$g$, D) $\frac{1}{2}g$, E) Don't Know

M1 - Linear momentum

15.

Particles A and B collide head-on into each other, with speeds 3 m s$^{-1}$ and 5 m s$^{-1}$ respectively. Particle A has a mass of 0.5 kg and particle B has a mass of $y$ kg. If after the collision both particles are brought to rest, what is the value of $y$?

A) 0.1, B) 0.3, C) 0.5, D) 0.7, E) Don't Know
A body X, of mass 8 kg, moves with a velocity of 8 m s\(^{-1}\) and collides head-on with another body Y, of mass 9 kg, moving in the opposite direction at 7 m s\(^{-1}\). Before the collision, which body’s momentum is less in magnitude?

A) Y, B) X, C) Both Equal, D) Both 0, E) Don’t Know

M1 - Kinematics of motion in a straight line

17.

What does the gradient of a displacement-time \((t,x)\) graph represent? (Where: \(t\) is time and \(x\) is displacement)

A) Acceleration, B) Velocity, C) Displacement, D) None of these, E) Don’t Know

18.

The approximate motion of a falling sky-diver is shown in the \((t,v)\) graph above. \(t\) seconds after he had jumped out of the plane his downward velocity was \(v\) m s\(^{-1}\) and he landed after 20 seconds. Using the information in the graph, calculate the height from which the jump was made.

A) 625 m, B) 440 m, C) 500 m, D) 460 m, E) Don’t Know
The velocity-time \((t,v)\) graph shows the variation in the velocity, \(v\), of a particle over time, \(t\). Which of the following statements best represents the behaviour of the particle? It moves with

A) Constant Velocity,  
B) Uniform acceleration,  
C) Variable deceleration,  
D) Variable acceleration,  
E) Don’t Know

A ball is thrown and, under the action of gravity, it follows the path shown above. Neglecting air resistance, which of the following diagrams indicates the correct resultant force on the ball at positions A, B and C?

A)  
B)  
C)  
D)  
E) Don’t Know
A bob, of mass m, is attached to a light inextensible string and rotates in a horizontal circle of radius r with an angular speed \( \omega \) about the vertical axis z. Ignoring air resistance, what forces act on the bob?

A) \( mg \)  
B) \( mg \)  
C) \( mg \)  
D) \( mg \)  
E) Don't Know
M2 - Centre of mass

22.

The diagram shows a uniform semi-circular lamina. Which of the diagrams below indicates where its centre of mass lies? (Note: each possible centre of mass is marked with a X)

A) ![Diagram A]

B) ![Diagram B]

C) ![Diagram C]

D) ![Diagram D]

E) Don’t Know

M2 - Equilibrium of a rigid body

23.

A uniform beam is in equilibrium under two forces of magnitude 16\(g\) and 2\(g\) at a distance of \(x\) metres and 2 metres respectively from a pivot. What is the value of \(x\)?

A) 4 m, B) 2 m, C) \(\frac{1}{2}\) m, D) \(\frac{1}{4}\) m, E) Don’t Know
A golf ball is hit at an angle of 12 degrees to the horizontal at an initial speed of 75 m s\(^{-1}\). If it travels a horizontal distance of 80 metres under the action of \(g\) (with \(g = 10\) m s\(^{-2}\)), using the equation of trajectory (below), find the vertical height \(y\), to the nearest metre.

\[
y = x \tan(\theta) - \frac{g x^2}{2 u^2 \cos^2(\theta)}
\]

(Where: \(x\) is the horizontal distance; \(u\) is the initial speed and \(\theta\) is the initial angle, to the horizontal)

A) 11 m, B) 13 m, C) 15 m, D) 8 m, E) Don’t Know

In a direct collision the velocities before and after are connected by the relation

\[
v_2 - v_1 = e(u_1 - u_2),\]

where \(e\) is the coefficient of restitution. What values can \(e\) take?

A) \(-1 \leq e \leq 1\), B) \(0 \leq e \leq 1\), C) \(0 \leq e \leq 2\), D) Any value, E) Don’t Know
M2 - Energy, Work and Power

26. What is the kinetic energy of a car of mass 800 kg moving with a speed of 10 m s⁻¹?
   A) 40 000 joules, B) 8 000 joules, C) 4 000 joules, D) 80 000 joules E) Don't Know

27. A ball is projected vertically upwards, from the ground, with initial speed u m s⁻¹. The ball moves freely under gravity. After it has reached its maximum height it falls vertically downwards until it reaches the ground. Given the greatest height reached above the ground is 25 metres and that air resistance is negligible, find the initial speed in terms of g, using the formula \( v^2 = u^2 + 2as \).
   A) \( 7 07g \), B) \( \sqrt{(25g)} \), C) \( \sqrt{(50g)} \), D) \( 5g \), E) Don't Know

28. A uniform beam, which is in equilibrium, is hung by two light inextensible ropes, which have tensions \( T_1 \) and \( T_2 \) respectively, as shown in the diagram above. Identify the ratio of tensions \( T_1 : T_2 \)
   A) 2:1, B) 3:2, C) 1:3, D) 1:2, E) Don't Know

29. Consider the equation \( X = \frac{1}{2} g t^2 \).
   If \( g \) is acceleration due to gravity, \( t \) is time and the \( \frac{1}{2} \) is a numerical constant, then identify what the correct SI units are for \( X \)?
   A) m s, B) s, C) m, D) m s⁻², E) Don't Know
| Q6 | C |
| Q7 | C |
| Q8 | D |
| Q9 | B |
| Q10 | A |
| Q11 | C |
| Q12 | C |
| Q13 | D |
| Q14 | D |
| Q15 | B |
| Q16 | A |
| Q17 | B |
| Q18 | C |
| Q19 | D |
| Q20 | A |
| Q21 | A |
| Q22 | C |
| Q23 | D |
| Q24 | A |
| Q25 | B |
| Q26 | A |
| Q27 | C |
| Q28 | D |
| Q29 | C |
What prior mechanics knowledge is helpful for studying engineering at Loughborough University

Please tick appropriate box unless asked to insert text

1. What is your student ID?  
   (Note all data will be treated confidentially)

2. What university degree programme are you studying?  
   e.g. BEng Mechanical Engineering

3. Do you enjoy studying mechanics?  
   YES ☐ NO ☐

4. How much of the material in your Engineering Mechanics module had you met prior to university?  
   0% - 5% ☐ 6% - 25% ☐ 25% - 45% ☐ 50% - 100% ☐

5. Do you think other students on your course had studied:
   MORE ☐ THE SAME ☐ LESS ☐
   mechanics than you prior to university?

6. Did the lecturer(s) assume that you had:
   MORE ☐ THE CORRECT AMOUNT OF LESS ☐
   prior knowledge, of mechanics, than you actually had?

7. Did you study A-level mathematics?  
   YES ☐ NO ☐
   If NO - Please state what mathematics qualification you obtained prior to entry to university

8. Did you study a FOUNDATION year?  
   YES ☐ NO ☐

Please STOP here if you did not study A-level mathematics

If you studied A-level mathematics or further mathematics:

Which applied modules, i.e. mechanics, statistics, discrete, etc. did you study?  
(Please indicate with a tick in ROW A)

Also put a tick in  
ROW B to indicate if you chose to study the module  OR  
ROW C if you had no choice

<table>
<thead>
<tr>
<th>Module</th>
<th>M1</th>
<th>M2</th>
<th>M3</th>
<th>M4</th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
<th>S4</th>
<th>D1</th>
<th>D2</th>
</tr>
</thead>
<tbody>
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OR

OTHER

Please turn over
9. If your school did not give you a choice on certain modules, why do you think this was? (tick all that apply)

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<td>Teachers thought it would be easier to get a higher mark on these modules</td>
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Other: ____________________________________________________________

Would you have liked to have been given a choice?

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Please explain your last answer.

YES/ NO because ______________________________________________________

10. If your school gave you a choice of certain modules, why did you choose the modules you did? (tick all that apply)

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Other: ____________________________________________________________

11. If you studied A-level mechanics modules have they helped, with your first year university modules?

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Please explain your last answer.

YES/ NO because ______________________________________________________

12. If you studied A-level statistics modules have they helped, with your first year university modules?

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<th>Option</th>
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Please explain your last answer.

YES/ NO because ______________________________________________________

13. Do you think it matters, for your university degree programme, which applied modules you studied at A-level? YES | No

If YES What A-level modules would you advise prospective students to study and why?

____________________________________________________________________

If NO Why does it not matter which modules you study at A-level?

____________________________________________________________________

Thank you for completing this questionnaire
What prior mechanics knowledge is helpful for studying engineering at Loughborough University

Please tick appropriate box unless asked to insert text

1. What is your student ID? (Note: all data will be treated confidentially)

2. What university degree programme are you studying?
   e.g. BEng Mechanical Engineering 68% BEng 32% MEng

3. Do you enjoy studying mechanics?
   YES 51% NO 49%

4. How much of the material in your Engineering Mechanics module had you met prior to university?
   0% - 5% 28% 6% - 25% 49%
   25% - 49% 22% 50% - 100% 3%

5. Do you think other students on your course had studied:
   MORE 26% THE SAME 59% LESS 14%
   mechanics than you prior to university?

6. Did the lecturer(s) assume that you had:
   MORE 46% THE CORRECT 42% LESS 12%
   prior knowledge, of mechanics, than you actually had?

7. Did you study A-level mathematics?
   YES 87% NO 13%
   If NO - Please state what mathematics qualification you obtained prior to entry to university

8. Did you study a FOUNDATION year?
   YES 14% NO 86%

Please STOP here if you did not study A-level mathematics

If you studied A-level mathematics or further mathematics.

Which applied modules, i.e. mechanics, statistics, discrete, etc. did you study?
(Please indicate with a tick in ROW A)

Also put a tick in ROW B to indicate if you chose to study the module or if you had no choice

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Please turn over
9. **If your school did not give you a choice on certain modules, why do you think this was?**
   *(tick all that apply)*
   - Small Class Sizes: 18%
   - Large Class Sizes: 10%
   - Lack of Pupil Interest: 8%
   - Teacher Skills Shortage: 10%
   - Those modules studied were useful for future careers: 30%
   - Teachers thought it would be easier to get a higher mark on these modules: 25%

   **Other**

   **Would you have liked to have been given a choice?**
   - YES: 72%
   - NO: 28%

   **Please explain your last answer:**

10. **If your school gave you a choice of certain modules, why did you choose the modules you did?**
    *(tick all that apply)*
    - Career Aspirations: 33%
    - To be with friends: 7%
    - Teacher Advice: 3%
    - Would be useful for further study: 41%
    - Easier to get a higher mark: 16%

   **Other**

11. **If you studied A-level mechanics modules have they helped, with your first year university modules?**
    - YES: 88%
    - NO: 12%

   **Please explain your last answer:**

12. **If you studied A-level statistics modules have they helped, with your first year university modules?**
    - YES: 4%
    - NO: 96%

   **Please explain your last answer:**

13. **Do you think it matters, for your university degree programme, which applied modules you studied at A-level?**
    - YES: 83%
    - NO: 17%

   **If YES**
   - What A-level modules would you advise prospective students to study and why?

   **If NO**
   - Why does it not matter which modules you study at A-level?

**Thank you for completing this questionnaire**
Q - Normal Distribution Plots

Don't Know group

2 Modules Group

0 Module Group

3+ Module Group

1 Module Group

Diagnostic Test Result

Diagnostic Test Result

Diagnostic Test Result

Diagnostic Test Result

Diagnostic Test Result

Std. Dev = 16.33
Mean = 68.2
N = 45.00

Std. Dev = 11.50
Mean = 74.5
N = 207.00

Std. Dev = 17.45
Mean = 59.9
N = 30.00

Std. Dev = 12.27
Mean = 81.3
N = 87.00

Std. Dev = 12.24
Mean = 66.2
N = 95.00
A correlation coefficient is a number between -1 and 1, which measures the degree to which two variables are linearly related. If there is perfect linear relationship with positive slope between the two variables, we have a correlation coefficient of 1; if there is positive correlation, whenever one variable has a high (low) value, so does the other. If there is a perfect linear relationship with negative slope between the two variables, we have a correlation coefficient of -1; if there is negative correlation, whenever one variable has a high (low) value, the other has a low (high) value. A correlation coefficient of 0 means that there is no linear relationship between the variables.
### S - Mechanics Diagnostic Test Item Analysis

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This questionnaire consists of five short sections, which explore student's exposure to mechanics. We anticipate it will take around five minutes to complete.

Your details  (Please note these are required fields)

Title
Forename
Surname
Email Address
University
Department

Section 1 - Introductory questions

Q1.1
A knowledge of mechanics is important for many engineering courses. Is it important for the students in your department?

Yes ☐
No ☐

Q1.2
Please indicate the total number of first year students in your engineering department:

Number of students

If you answered NO to Q1.1 then please do not complete any further sections, simply scroll to the bottom of this page and submit the questionnaire.

Section 2 - Gaining an understanding of students' prior knowledge in mechanics
Q2.1
For the first year students in your department, who arrive at university with an AS/A-level mathematics qualification, do you know which mechanics modules they have studied within their mathematics AS/A-level?

Yes C
No C
Not Applicable C

If Yes:

i. Please give the number of first year students in your department that have studied AS/A-level mathematics

Number

ii. Please give the number of first year students in your department that have studied:

0 Mechanics Modules
1 Mechanics Module only
2 Mechanics Modules only
3+ Mechanics Modules

iii. Have you noticed any changes in recent years in the number of mechanics modules studied by incoming students?

Yes C
No C
Haven't Checked C

If Yes have they:

Increased C
Decreased C
Stayed the same C

If you do not know which mechanics modules your students have studied within their AS/A-level, then:

We have prepared a short questionnaire to use with students to find out this information. If you would like to use this with your students then please indicate here.

Yes C
No C
Q2.2
Do you ascertain your students' prior knowledge in mechanics by any other means?

Yes ☐
No ☐

If Yes:

i. What methods do you use? (tick all that apply)
  - Questionnaire ☐
  - Diagnostic Test ☐
  - (Mechanics or containing some mechanics questions)
  - Personal Interview ☐
  - Other ☐ (Please state)

Section 3 - Teaching of mechanics

Q3.1
What prior knowledge in mechanics do you assume at the start of an undergraduate's course?

In terms of A-level Mathematics module content:
  - Zero Knowledge ☐
  - M1 Knowledge ☐
  - M1+M2 Knowledge ☐
  - M1+M2+M3 or more ☐
  - Don't know ☐

(For more information, see the list of contents for the modules)

Q3.2
Do you stream students according to prior knowledge in mechanics?

Yes ☐
No ☐

If Yes:

i. What are the criteria for streaming?
ii. How effective has this method been? In terms of first year pass rates, have they

- Increased ☐
- Decreased ☐
- Stayed same ☐
- Don’t know ☐

(Please give further details if required)

Q3.3
Do you provide extra mechanics support over and above the usual lecture / tutorial system?

- Yes ☐
- No ☐

If No:

1. Why do you not offer any extra support? (tick all that apply)
   - Not necessary ☐
   - Timetabling constraints ☐
   - Staff constraints ☐
   - Expectation of lack of uptake by students ☐
   - Haven’t thought about it ☐
   - Other (Please state)：

If Yes:

1. Who do you offer the support to?
   - Any student ☐
   - Only those in need ☐
   - Other (Please state)

2. By what means do you offer extra support? (tick all that apply)
Supplementary materials □
Extra tutorials □
Drop in centre □
(e.g. Mathematics/Engineering support centre)
Other □ (Please state) __________

iii. If applicable, how many hours of extra support are available to students each week?
Number of hours __________

iv. How effective has this extra support been? In terms of first year pass rates in modules with
mechanics, have they:
- Increased □
- Decreased □
- Stayed same □
- Don't know □

(Please give further details if required)

Section 4 - Mechanics materials

Q4.1
If LTSN Engineering produced materials for undergraduate engineering students which covered
mechanics topics from A-level mathematics, would you be interested in using them?
- Yes □
- No □

If Yes:

i. Would you be willing to be contacted to provide feedback on the draft material?
- Yes □
- No □

Section 5 - Monitoring of A-levels

Q5.1
Do you have a member(s) of staff who monitors developments in mathematics AS/A-levels?

Yes ☐
No ☐
Don't know ☐

If Yes:

Do you review the material content of a first year undergraduate course each time mathematics AS/A-levels change so that it is in-line with the student intake for those years?

Yes ☐
No ☐
Don't know ☐

(Please give details for your answer)

Q5.2

If LTSN ran a workshop to keep you informed about the changes in A-level mathematics and issues surrounding mechanics would you like to receive information about it?

Yes ☐
No ☐

Final Comments

If there is anything you would like say regarding student's exposure to mechanics, or if you have any comments about this questionnaire, please enter them in the box below.

(Submit questionnaire)
Dear Engineering Lecturer,

You have received this email because you are on the LTSN Engineering email list.

LTSN Engineering is currently funding a project entitled 'Responding to the changes in the Teaching and Learning of Mechanics in Schools'. Details of this project, including its objectives can be viewed on the following link to Loughborough Universities' Mathematics Education Centre:

http://mec.lboro.ac.uk/staff_web_pages/clr/pages/external_projects.html

We have prepared a short questionnaire, which we invite you to complete (Please complete the questionnaire on behalf of your department i.e. views of your department not you personally). The questionnaire is to be answered online and can be found at:

http://www.mathscentre.ac.uk/stephen/questionnaire.html

Although the questionnaire is aimed at those involved with mechanics at undergraduate level, in which case completion will take around five minutes, if this topic is not relevant to your department, then we would ask that you still complete the first section (this will take only 30 seconds) and submit it. Alternatively, if you feel that there is a member of your department who may be in a better position to complete the questionnaire then could you please forward this as appropriate (please also contact me via email s.lee2@lboro.ac.uk to indicate that you have forwarded the responsibility of completing the questionnaire).

We would be grateful if you could complete the online questionnaire by Friday 2nd July.

We would like to thank you for your continued support.

Yours sincerely,

Stephen Lee

Mathematics Education Centre (W2.84)
Loughborough University
Email: s.lee2@lboro.ac.uk
V - Schedule for interviews with Academic

We would like to begin by gathering some information on the way in which mechanics is taught to engineers at your university.

From the questionnaire that you completed back in June, we see that mechanics is important for students in your department, of which there were approximately XXX

1. Tell us about your students:
   - Are they from a traditional background, i.e. A-levels?
   - Are they mature?
   - Are they full-time or part-time?
   - Are they from diverse backgrounds, i.e. race, gender?

   What are the entry requirements for students in the department?
   __________ (new) UCAS Points   Subjects: __________   __________

2. Do your engineering students study a mechanics course in the first year?

   (If not) Do they study any module(s) which has a significant amount of mechanics?

   (If yes) Could we ask some specific questions on this module?

   i) From the earlier questionnaire we send you mentioned that prior knowledge of modules M1 and M2 are assumed, is this what is required for this module?

      YES  NO

      Do you know if your students have this prior knowledge? or is assumed that they do?

      YES  NO

      (Show our prior learning QE and quote findings)

   ii) How is the mechanics taught to engineers? and by whom?

      Weekly tutorials?   Team Teaching (different staff for topics)?

      Labs?   Software?   Chalk and Talk?

   iii) Information on the Module details?

      - How many credits is it worth?
        (10 credits 1 semester? / 20 credits 2 semesters? - 120 credits per year)

      - How important is it?
(Do students need to pass it (at a certain level) to move to the next year)?

- What is attendance like for the module? (Request Figure)
  (How does compare to other 1st year modules? lower/ average/ higher)

- How do students do in the module in terms of pass rates (Request Figure)
  (How does it compare to other 1st year modules? lower/ average/ high)

  Why do you think this is? (prior knowledge/ course structure)

  (is a module spec available to us?)

iv) Do you have any support or support material dedicated to mechanics?

  If YES:

  What is available?

  How many hours in the support centre are dedicated to mechanics?

  If No:

  Do you feel that students would benefit from support material in this area?

  What would you suggest be included in such material?

  (See examples of worksheet)

3. In terms of mathematics for engineers in general:

  Do you have any support mechanisms in place?
  i.e. support centres/ extra workbooks/ worksheets?

  How effective are these? (how do you know this?)

  (If no) Is this because support is not needed or due to other constraints?
W - Interviews with Academics

Visit to a Civil Engineering Department (1)

On Wednesday 10\textsuperscript{th} November 2004, a visit to a civil engineering department at a university was undertaken. Approximately 90 minutes were spent in a Mathematics Support Centre speaking to lecturer A.

As this was the first undertaking of an interview valuable experience of interviewing was obtained. Skills were developed on questioning and both eliciting and recording responses.

From the first group of questions on what type of student intake the department had, it was indicated that around 10\% were from BTEC route and therefore around 90\% from traditional A-levels. Entry requirements were of the order of 22 old UCAS points, which is equivalent to B, B, C grades or 280 new UCAS points. It was mentioned that although the entry requirements has not been reduced, the significant number of students (countrywide) with higher grades meant that the students were not necessarily of the same standard as in previous years. The department use to require Mathematics and Physics A-levels, however the requisite for physics was no longer there. Although it was found that students who had studied the mathematics had generally offered physics as well.

An increase in students subscribing for a foundation year meant that the foundation course was now of the order of 100 students, although a high percentage of these do not stay on to start a full engineering course. Within the foundation course there is an approximate mathematical content of 50\% (with 17\% being mechanics).

Section two questions on the specific mechanics module(s) did not yield specific responses, with the explanation that lecturer A was not responsible for the module. However, they did indicate where we could find the module specification for the 'statics and dynamics' module. Upon returning to Loughborough we were able to obtain this. This indicated that it was a two-semester module worth 20 credits, which
was delivered through lectures tutorials and lab sessions. Further details are available within the module specification.

Due to the large variation of students who took the module (i.e. mechanical engineers, chemical engineers etc) there were study packs for the different groups, which they had to do if they had not been taught an aspect.

In terms of support there was no direct mechanics support although there had been enquires in the Mathematics Support Centre on the topic. The Mathematics Support Centre itself was well stocked with mathcentre single sheets on mathematics topics. Final year undergraduates staffed it, although some second and third year students also worked there. It was staffed, for 12 hours, at times when the students had free periods, by the (second and third year) students and for six hours on a Tuesday, when most students are free, by an ex-teacher.

Lecturer A concluded by taking us through the universities system and retrieving some of the 2003-2004 examination papers, which included:

'Introduction to Mechanics' module for foundation students

'Statics and Dynamics' module for first year engineers

'Modelling Concepts and Tools A&B' for chemical engineers
Visit to a Civil Engineering Department (2)

On Wednesday 15th December 2004, a visit to speak to Lecturer B, a civil engineer in a School of Building and the Environment at a university was undertaken.

Information on the background of the students entering onto the civil engineering courses was gathered. Firstly, the background of the students was very much dependant on which course they had enrolled onto. Those who signed up for the charted course had a higher entry standard than those on the incorporated engineering course (IENG) who, not only needed a lower points score to enrol but there was no requirement for A-level mathematics. There were around 45 first year students studying civil engineering, with approximately 30 students on the charted course and 15 students on the incorporated course. Approximately half of the students came from schools and had a traditional background of A-levels, however there were very few females enrolled. Also there were several EU students and increasingly more middle-eastern students.

It was said that mechanics was important and this was because the students do a lot of structural work that requires knowledge of mechanics. As well as this the fact that this knowledge is built upon by further modules highlights how crucial it was to have an understanding of it.

At the beginning of a civil engineering course students sit a diagnostic test that is essentially a mathematics diagnostic test. This test comes from the mathematics support centre that administers several mathematics diagnostic tests, which includes both paper-based and computerised tests.

Details of a first course in mechanics were given. Although it was said that there was an assumed knowledge of M1, it was obvious that if students were being taken onto the incorporated course without A-level Mathematics then this assumption would not be feasible. However, encouragingly it was said that the first three or four weeks of the course were given to revision (for some, or perhaps new material to some on the incorporated course) of basic (A-level) mechanics. To support the lecturing of the
course, computerised tutorials were produced. These consisted of random questions administered via Web CT. Students could take the questions as many times as they liked. Students found these useful but some concern was shown that these questions were easier than the final examination questions.

The module itself could be classed as an important one because students were required to pass it in order to progress to the second year of their course. If students fail the module they are able to re-sit it in September, however if they fail this re-sit they are required to redo year one of their course. It was pointed out that there was a trend that virtually all of those on the charted course passed the module and that a lot of those on the incorporated course failed the module. Perhaps this highlights just how those not coming in with A-level Mathematics (or high qualifications) struggle to cope with a first course in mechanics. It was suggested, by the lecturer, that streaming the students into the two groups (charted – incorporated) would be beneficial. However, with such small numbers he felt this would be difficult to justify in terms of costs. This further highlights the need for good support, particularly in the area of mechanics.

Within the civil engineering department, staff operate an open door policy. This is useful as students are able to speak to the specific lecturer, but this could be very time consuming if a large number of students regularly seek assistance. It was also pointed out that it was generally the brighter students who sought this extra help and not those struggling who actually need or would benefit from it. There is also access to the universities mathematics support centre, which is open for over 20 hours a week. The civil engineers also select some year 3 students to help the first year students for two to three hours a week, although this is general and not specific to the mechanics.
Visit to a Mechanical Engineering Department (1)

On Monday 20th December 2004, a visit to speak to Lecturer C, from a mechanical engineering department at a Scottish university, was undertaken.

In their questionnaire they mentioned that although the Scottish education system is different to the English one they too have issues with students and mechanics.

The students came from traditional backgrounds with a split of approximately 20% entering with Highers and 80% entering with Advanced Highers. The department was seen to be good and unusually had around 50% of students living away from home (in Scotland students tend to live with their parents and go to their local university) Although not many foreign students were enrolled this was increasing all the time Students were required to have Higher grades ABBBB for the BEng course or AAAAB for the MEng courses, including mathematics and physics. Hence, these subjects had to have been studied to grade B, but in reality nearly all entered with an A grade. If advanced Highers were offered then grades AAB were required.

As opposed to the English system, where mechanics modules are only studied in some A-level Mathematics and Physics courses, in Scotland there are many more opportunities to study it. However, again it is important to know what has been studied. Lecturer C said that generally their students had studied 'technical' higher, which contains circular motion and other relevant mechanics topics. The mathematics advanced higher did not contain any mechanics, only the advanced higher in applied mathematics did.

Lecturer C, along with three other (experienced) colleagues, teach the first year module 'Engineering mechanics'. In 1998 they had a drop out rate of 25% when there was a university wide drop out rate of 20%. Changes were made to the course so that there were:

- Groups of 4 students
- Problem based learning, mechanical dissection for 1/3 of the time
- Studio learning for 1/3 of the time
- Computers (labs) for 1/3 of the time
The group selection is made when students are interviewed at the start of the course. Although this has an initial high cost time wise, it was considered to be very much worthwhile. Factors that are looked at include:

- Home/away (unusual 50% live away from home)
- Halls (same)
- Introvert/ extrovert
- Good with computers
- High grades in ... mathematics/ physics

It was found that nearly all the groups get on well, but if they don't then they make formal meetings with the group and assign work. Research found that a super group, i.e. best 4 students in a group, would generally fail.

Although there were some reservations by students when starting the course (as it was different to others and obviously different to their previous education, only 6 out of 137 left due to the setup. Consequently at the start of the second year students were requesting the same style course. Final year students would use Socratic dialogue.

In the module 'Engineering Mechanics One' lecturers had 4 hours of contact with the students. It was a 20 credit module (out of a 120 credit a year system). Mathematics was taught for two hours following a two hour engineering mechanics lecture.

The lectures consisted of overheads and bookwork. The text used was 'Applied Mechanics – Hannah + Hillier'. They would not generally try new things themselves but used tried and tested researched methods. A Harvard style of period instruction was used but also in lectures students would give individual responses followed by group discussion.

The assessment for the module included:

Coursework/ class tests/ homework every two weeks.
Effort based learning (just look at it then grade it i.e. all there gets five. If discrepancies: do a second pass by giving it back out and getting students to mark each others).

In the module they 'feed' the difficult topics step by step and spend lots of time on certain areas, i.e. one to two hours on normal reaction. Videos from calpol, Mechanical universe videos are also used to look at the problems historically.

Support is given by having the lecturers available (obviously this is easier when there are four compared to perhaps the more usual one). Content is also given by Force Concept Inventory, where no vectors are used throughout the course.

A Mechanics Base Line test is used when students enter the course and it is for their benefit (to see which areas that are weak in) but also for the staff. It was noted that if students have done some topics before this could sometimes hinder them, i.e. circular motion, constant acceleration.

The mechanical engineers also do service teaching for product designers, with more varied qualifications and all subjects have a drop off in attendance.
Visit to a Mechanical and Manufacturing Engineering Department

On Monday 17th January 2005, a meeting was held with Lecturer D who teaches a first year group of Manufacturing students, Engineering Science, which contains mechanics.

It was felt that mechanics was important to students as it is used in several key areas of a manufacturing course. As the courses in mechanical and manufacturing engineering were accredited there were requirements for certain material to be covered. However, students studying for a BSc did not have the same requirements (these students were based in the Design and Technology department, but taught modules by the Mechanical and Manufacturing department).

Interesting discussion into students' prior knowledge was had. It was recognised that gaining information on students' knowledge (of mechanics) upon entry was very useful, both in terms of a simple questionnaire and a diagnostic test. However, concern was shown that even with this information people (staff/lecturers) did not have an up-to-date knowledge of what this represented. Even younger members of staff would base results on what they had experienced or expected, i.e. some content of mechanics to have been studied. It was suggested that information should be readily available or sent to relevant staff on current development of education content prior to university i.e. changes in A-level and GCSE. As well as more specific information on topics in relevant courses, i.e. What is in Mechanics modules.

There was discussion into preparing students for university. Suggestions that appropriate resources could be sent prior to the start of a course were considered, being it worksheets or an actual textbook. This was partly due to the way the beginning of term is structured, in so much that lecturers couldn't afford not to present material in the first few weeks, but that students did not always absorb this information. This is particularly important if (A-level standard) revision material is being looked at. Noting that some students may not have actually studied the material the first time round (e.g. see questionnaire to students results that 33% had studied at
most one module) makes it doubly hard, if they are quickly shown information that is new to them.

The course that Lecturer D taught to first year manufacturing engineers was Engineering Science. It was said that an assumption of zero mechanics was not strictly correct as he did expect them to have seen some mechanics at A-level. The topics taught in the module were regarded as introductory rather than difficult. The prescribed text of Hibbler was described as 'not the ideal text for the course' but was used where relevant.
Visit to an Aeronautical and Automotive Engineering Department

On Thursday 3rd February 2005, a meeting was held with Lecturer E who teaches a first year group of Aeronautical and Automotive students, Engineering Mechanics.

Students within the department were all of a very good standard Entry requirements for the BEng course were BBB, with a B in mathematics and for the MEng were AAB, with an A in mathematics. Most of the students (over 90%) came from the traditional background of A-levels.

The module Engineering Mechanics was taught in a traditional manner in semester 2. There were several reasons why it was in semester two, including time tabling constraints (for both suitable lecturers and modules) and requirements to have certain modules in semester 1 (obviously this was not one of those). It was said that the fact that the module was in semester two did not matter as students did not do any relevant mechanics in semester 1 (to compare with students who go straight into a module like this first semester) however, students may have 'settled' into university life in general better by the second semester.

The module was taught in the traditional manner, which consisted of 22 hours of lectures and 11 hours of tutorials, along with 2 labs sessions. Registration was taken in the tutorials in order to maintain attendance. This appeared to work well. A tutorial was staffed by a member of staff and a research student, with class sizes of the order of 25 students. The lectures were given by a single lecturer who scribed onto the overhead and students took notes (at least one example was given for a technique each lecture). It was said that in the department lecturers tended to offer out printed notes, but this was not the case for this module. The class of 150 students were lectured all together.

The course consisted of two areas, statics and dynamics. Another lecturer took the second area dynamics. This module stood as a pre-requisite for a second year module in dynamics and consequently effort was made each year into making sure students had the necessary knowledge for this second module. With an average mark of
approximately 55% the module was similar in performance to the rest in the department. There was no outside help given, in the sense that tutorials were the only available help, although students could always go to the mathematics learning support centre, but it was reported that this does not happen often.

Few changes had been made to the module in the past few years (Lecturer E had taken the module for 5 years) although feedback from students, which comes from a form at the end of the module, had induced some small changes. For example students asked for more examples and applications to aeroplanes and automobiles.

In this instance it appears that there are few problems encountered with the mechanics. The view of Lecturer E was that it was purely down to the calibre of students. This was in addition to the fact that he had not been aware of the changes that had taken place with A-level maths in the previous five years. This indicates that a traditional 'standard' lecture course can work when given to bright students.
A Telephone Interview with a Member of a School of Education

On Friday 28th January 2005, a telephone interview was conducted with Lecturer F, who is a Senior Lecturer in Mathematical Education. They have a wealth of experience in both research and teaching at undergraduate and postgraduate level with mathematicians, physicists, and engineers. They have also taught in a wide range of schools.

In response to the question ‘what is the view of an ex school teacher to the lack of knowledge of mechanics of students to university?’ Lecturer F suggested that the schools cannot be blamed. In a typical school with a sixth form an average of 12-20 students would be expected to be studying A-level Mathematics. The onus of the school is on the students doing as well as they can in the subject with the resources (staff numbers, staff experience etc) available. To that end if in reality students get better grades having not studied mechanics then that is the way it will be. Consequently, it is likely that many students entering engineering and physics courses may not have studied mechanics. Hence, the responsibility is projected onto the universities.

Universities could step up their requirements and in essence ask for a certain number of mechanics modules but this would require ALL universities to ask for it, which is unlikely. Otherwise prospective students would go to another institution that did not have such requirements. Or as the case is at the moment NO (or very few) universities specify this type of requirement. This would also be the case with the growing emphasis (from the MEI examination board) of asking universities to ask for students to have studied AS Further maths. It was said that the expectation that if universities started asking for this qualification then schools would be able to offer it would not be forthcoming. More so that schools would find it difficult (due to the same reasons that they don’t currently) to offer it.

Lecturer F teaches a first course in mechanics for physicists. They employ a streaming system where by the group (of about 90 students) are split into two groups,
which depends on if they had studied 1 or less modules of mechanics in A-level mathematics or if they had studied two or more. The split is generally about one third (who have studied 0 or 1 module) and two thirds. The students then study the same course with the same notes but with two different lecturers. Semester one involves Particles (up to SHM) and semester two deals with rigid bodies. This year after marking the current exam scripts (January 2005) students look to have been badly taught in areas (either at school or at university) and have picked up bad habits.

It was said that there were several key factors. Firstly it is important that you ‘find the right person(s) to teach the students’ and secondly that the ‘approach’ is important. The smaller groups allow for a more ‘personal touch’ to lecturing, somewhat like a conventional school teacher with a class of 30.

It was noted that a similar approach (splitting students into groups) had been carried out in Newcastle university, but had been stopped because the two ‘groups’ worked out that one was labelled the ‘clever’ group and one the ‘thick’ group. Consequently the students behaved in such a way, and those in the lower group did badly.

The students also sit a diagnostic test (of pure maths) at the beginning of the year. It was noted that ‘what you do with it and thereafter’ is important.

(The mechanics diagnostic test that was discontinued 10 years ago was one that was given to MATHS students who studied the applied mathematics degree. It was discontinued as the students did not really know enough to do well in it.)

It was mentioned that there are some modules within A-level Physics that contain some mechanics. However, it was said that the mechanics is not difficult and does not contain the stuff that is generally required in a first undergraduate course (e.g. problems with lifts). The elementary mechanics would generally consist of putting numbers into given formulae.

The problem of the gap of knowledge in mechanics of students entering university was looked at in terms of what could be changed. It was categorically stated that it
was significantly easier to change the syllabus at university level than to try and change the A-level Mathematics syllabi. There are several reasons; one is that changing the courses at university would serve to develop a course suited to the students that are coming in to your particular establishment as opposed to changing the A-level syllabi, which would not serve individual universities. Moreover it would be another guise for one syllabi to fit all that we currently have.

It was suggested that the best approach would be separate the students on their prior knowledge. If this is not possible, e.g. due to staffing, then extra resources should be made available. For example, through a support centre or from the lecturer. However, additional work (or an additional program of work) should not be given, in the sense that you will overload the students, who are likely to be the weaker ones who already have to do more work to be on a level playing field. A suggestion that extra ‘information sheets’ on the topics of concern would be good.

A further telephone interview was held with Lecturer G, who also teaches the Physics students mechanics and who has a wealth of experience and knowledge in the area of mechanics. Lecturer G made the following comment in support of those given by Lecturer F:

- Students come from traditional background.

- Students who have 0 or 1 module streamed from those with 2 or more. The lower group do same content just over 2 semesters rather than one

- About 10% come from the foundation.

- Need a compulsory first university course in mechanics. Mechanics is a ‘good investment’ transferable skills to other areas and a ‘vehicle for teaching key skills’.

- Physics, over past ten years has been changing and the mechanics that is contained within it is qualitative, i.e. no maths.
Visit to a Mechanical Engineering Department (2)

On Thursday 17th February 2005, a meeting was held with Lecturer H of a Mechanical Engineering department, who teaches a first course in mechanics to electrical engineers (engineering mechanics to second year electrical and systems engineering students).

Lecturer H is a professor of mechanics of materials and heads an Applied Mechanics group (of 17 staff) within the department. Lecturer H has experience of teaching mechanics in various countries, including Russia and Germany along with the UK.

Students entering into the electrical engineering department where required to have grades in the region of BBB or 300 points and having studied two numerate subjects. It was reported that in the engineering mechanics module that students took (approximately 70) in the second year, there was a great scatter in the abilities and levels of students. This was not only with respect to mechanics but also to their underlying mathematical ability.

The module Engineering Mechanics was taught in a traditional manner in semester 1 and 2 of the second year for electrical and systems engineers. Over the past few years there had been many changes to when the module was delivered. As the module was being service taught by the mechanical engineering departments, the electrical engineering department still made the underlying decisions. The module had been taught in the students first year and then was changed to the second year. It was previously a 10 credit module over a single semester, but inline with current changes to the departments structure they have changed it to a two semester module worth 20 credits and consisting of 26 hours of lectures and 13 hours of tutorials. The extra time that had become available was filled with problem classes, where students would have the opportunity to do lots of examples. The lecturers and tutorials were taken by Lecturer H and were run in the same way. Support was available personally through Lecturer H and the mathematics learning support centre as also said to be a place to seek assistance, particularly with respect the problems with the underlying maths.
Attendance was taken in both lectures and tutorials and it was said that this was an important factor in students doing well in the module. The material, although taught in the second year was effectively at first year level as this was an introduction to mechanics. There was an interesting discussion into the worth of the material to electrical engineers and also with respect to other countries. Firstly, it was indicated that these students may not necessarily need the material and it was more to give them a wider breadth of engineering knowledge. This is one of the reasons why it had been moved several times between the first and second year. This led to evidence of how engineers are taught in other countries. For example, in Germany students study a 5-year engineering course and the first two are spent giving a broad introduction to engineering education. Hence it was stated that with only a 3-year course students were not able to receive this introduction, unless they studied a foundation year, and so material in the first year is found to be core material and hence for them perhaps mechanics is not core.

The module involved a revision of A-level or equivalent material in the first few weeks. Topics were introduced and students were to gain a general understanding of all the elements. Formula sheets were given in the examination, so that students did not spend time learning 'unnecessary' formulae so that time could be better spent learning the concepts and applying them. Informal feedback via interaction with the students was successfully used to gain an understanding of the level of the students. It was also indicated that the teaching was very important. Reference was made to a younger inexperienced staff member whose results had been poor. Thus it was felt that the module would be better given by an experienced member of staff. In the sense of teaching and not necessarily solely on knowledge.