THE LEARNING OF CONCEPTS IN STRUCTURAL ENGINEERING WITHIN A PROBLEM BASED LEARNING ENVIRONMENT

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ABSTRACT

Students have difficulties in grasping the concepts of structural behaviour. They tend to concentrate on manipulation of equations and memorising particular solutions. This obscures the underlying principles, the abstract concepts. This paper presents the results of a study on how effectively these structural concepts are being acquired during a course of study based on problem based learning (PBL). The use of PBL has arisen in many professional disciplines over the last 30 years as an effective means of delivering the range of graduate capabilities required by industry and the authors' institution has made a substantial commitment to PBL as a teaching and learning methodology. A new course structure is described that incorporates team project work; model building and testing; tutorials/problem solving sessions; discussion sessions; and laboratory experiments. Results are presented that highlight the difficulties and successes associated with the approach. The findings demonstrate great student interest and interaction (both with other students and with staff). However the research highlights challenges with regard to the development of their understanding of structural behaviour.

INTRODUCTION

Conceptual Understanding of Structural Behaviour

In the modern working environment it is essential for a structural engineer to have an understanding of abstract concepts in structural behaviour and an ability to use them qualitatively for the following reasons:

- During the early design stages qualitative decisions have to be made – without the time and resources available for analysis. Unworkable designs can be modified or eliminated early, and resources can be dedicated to practical and efficient possibilities.
- Without understanding the underlying behaviour an inappropriate (invalid) analysis may be selected. In particular a critical mode of behaviour may be overlooked.
- When selecting an appropriate software package and subsequently modelling the structure it is necessary to appreciate the significant modes of behaviour.
- When checking results from computational analysis these skills assist in identifying errors.
- When the design is found to be inadequate in some way (excessive deflection, for example) then an appropriate modification can be made.

Students have difficulties in grasping key concepts of structural behaviour. They tend to concentrate on manipulation of equations and memorising particular solutions. Possibly encouraged by:

- A feeling of security in memorising known solutions.
- The style of examination/appraisal that is generally adopted.
- A history of such teaching/learning style throughout their education.

Lack of conceptual understanding of structural behaviour has been recognised by the profession for a long time. Cowan and Brohn highlighted the problem as early as 1977(1) and The Institution of Structural Engineers' Sub Committee on Education published a report in 1989(2) highlighting such concerns by senior designers. The Institution still hosts the 'Qualitative Analysis of Structural Behaviour Study Group' with an email discussion list(3). More recently work in this area by Geoff Taplin(4) and Paul Steif(5) has provided fresh insights into effective techniques. In addition, work has been conducted on conceptual understanding in the sciences and in particularly

Physics at Monash University through its Understanding Physics Project (UPP – 1998-2000[6]).

There has been a movement in engineering and other professional disciplines towards problem (and project) based learning as an effective means of delivering the range of graduate capabilities required in a rapidly changing world, eg teamwork and communication, problem solving, autonomous learning, as well as technical skills. Engineers Australia recognises this in their accreditation requirements(7) and consequently the school has made a substantial commitment to this methodology in the new program in Civil and Infrastructure Engineering. In this approach a task or challenge is presented to the students at an early stage in the course – before methods and materials specific to that problem have been provided. The problems are open-ended design-based tasks and the students work on these over several weeks. Students work in groups and are assisted in developing group working skills – managing the flow of work, assigning tasks to individuals etc. Resources such as design material are available and parallel lectures and tutorials cover key theoretical concepts but not specifically on the topic assigned. The approach is proving successful with positive feedback from students, Engineers Australia (at the recent accreditation) and industry. However these approaches set new challenges when it comes to students' development of conceptual skills. This paper presents initial findings of a study of how effectively students acquire conceptual skills in such a learning environment.

Background – The Course

A New Civil and Infrastructure Engineering Program commenced at RMIT in 2004. The program focuses on educating students on the whole of lifecycle performance of infrastructure (as opposed to design and construction) and on the responsibility of the engineer with regard to sustainability of the built environment. The program was developed with a theme for every year of the four year Civil Engineering Degree program. The theme for the first year was 'Engaging in the Profession'. The following issues were identified as crucial in achieving the proposed objectives(8,9).

- Develop the conceptual understanding required by a graduating civil and infrastructure engineer
- Develop the graduate attributes proposed by Engineers Australia
- Adopt problem (and project) based learning methods to facilitate the development of the above
- Engage students in the profession with a theme of sustainability

In mapping out the teaching program for each year, it was observed that in order to cover Civil Infrastructure content in the later years, two first-year subjects were needed – 'Statics' and 'Structural Analysis'. Both have been designed to offer a variety of activities and learning experiences for the students. Typically the Structural Analysis course comprises:

- Problem Based Learning Task 1: A major design project is tackled in a team – a carport structure. This project is approached using the PBL methodology described above and as such falls into the pedagogical classification of constructivist teaching. Students are encouraged in the process through workshops.
- PBL Task 2: A beam made of balsa wood – designed and fabricated by the students. This model building and testing exercise provides real active experience. Students are encouraged to discuss the rationale of their design choices and even to conduct preliminary testing of materials or prototypes. This exercise, as above, is an example of the constructivist approach to teaching and learning.
- Lectures/tutorials/problem-solving sessions to introduce topics and impart conceptual understanding. The lectures were used to introduce concepts and theory through traditional direct instruction – typically a structural behaviour or response would be highlighted and then the behaviour explained analytically. Tutorials were then used to assist the students to tackle problems themselves – working in groups at first and then individually
- Discussion sessions to facilitate reflective thinking (quizzes were introduced later)
- Laboratory experiments to facilitate concrete experience

- Tests and final examination to ascertain individual understanding of the concepts

There is no formal structural analysis course in the second year. The two second year structures courses are based around design problems – one in steel and one in concrete. The two courses use a mixture of the PBL techniques described above and traditional lectures to introduce the basic design concepts. The new course format commenced in 2004 and hence to date the first year has been taught for the second time and the second year for the first time. It is these courses that have been the focus of this research.

Research Rationale

The first stage was to identify key concepts that challenge the current year 1 and year 2 students. This was achieved by:

- Testing and observing their performance at targeted questions – in particular failure rates for specific errors.
- Testing and then studying scripts to determine thinking processes.
- Interviewing and observing students to identify their solution processes and misconceptions.

The second stage was to develop more concepts-based tutorial material and techniques to assist students in developing the targeted concepts.

The final stage was to change the style of assessment to be more concept-based.

The procedure adopted for the study was as follows:

- Test the first year half way through the semester and identify key concepts of interest and capabilities.
- Interview/observe first year students at mid-semester – identify learning processes with regard to key concepts.
- Change first year tutorials to emphasis key concepts.
- Test first year capabilities at key concepts at end of semester – compare with performance half way through semester.
- Test second year students at end of semester – compare the results with the first year. (The second year has taken the same course in the preceding year without the altered tutorials).
- Produce additional on-line material for use in future years (future work).
- Monitor the results for years 1 to 4 in future years (future work).

RESULTS

General

The findings presented here are based on:

- 6 classroom tutorial exercises.
- A test examination given to the first year (at mid semester) and second year (at end of semester).
- Interviews of first year students (a selected group) – to identify solution rationale and misconceptions. Students were selected to represent a cross section of ability and errors produced in the mid-semester test.
- Analysis of the second year examination papers from their first year final examination (taken in 2004).
- Analysis of the first year's final examination.

Key Results

Students were assessed at performing qualitative and quantitative tasks. A horizontal beam was taken as the basic structural form and the students were asked to assess deformed shape, shear force, bending moment and which surface (top or bottom) was in tension. Boundary conditions included pin joints, simple and fixed supports and the loading included point loads, applied moments and distributed loads.

114 scripts were returned by the first year in the mid semester test and 91 by the second year.

Shear Force Assessment

At the mid-semester point the first year was successful at calculating the value of shear force at any given point along a beam. There were 3 instances where this skill was assessed. On average 71% of the class were successful at this task with 76% being successful two out of three times or more. At the end of the semester – following 5 weeks of tutorials based on more concept based and qualitative based material the success rate in the final examination was 75%. The same mid-semester test as given to the first year was also given to the second year at the end of the semester and the average result achieved was 85%.

Shear Force Distribution

Shear force is calculated at a cross section in a beam – this value can be plotted as a distribution along the beam. In the mid-semester test the first year results showed that 65% were successful in plotting a shear force distribution. This did not improve significantly by the end of the semester with 67% being successful in the final assessment. The second year achieved an 85% success rate – the same percentage as they achieved for assessing shear at a point.

Bending Moment Assessment

Generally students find bending moment a more complex concept than shear force. As for shear, the bending moment can be calculated at a section on a beam and as a distribution varying along the beam. Both first and second year students were very successful at calculating values of bending moment at sections in beams. The first year at mid-semester demonstrated that 75% of the class were capable of calculating the correct BM at a point (on three occasions in the same test). This value did not change in the final assessment. The second year demonstrated a 79% success rate in the same test.

Bending Moment Distribution

The plotting of bending moment diagrams is a task that students generally find difficult. Only 40% of the first year at mid semester and 39% in the final assessment were successful in an example that was fundamentally different from previous (classroom/tutorial) examples. The results for the second year were not significantly different with 38% successful. The type of errors produced was significantly different between the two years. 30% of the first year at mid semester and 34% in the final assessment produced a fundamental error with regard to assigning a zero bending moment at an inappropriate location. Nobody in the second year made that error.

DISCUSSION

Both the first and second year showed good capability at calculating shear and bending moment values at points in a beam. The students had been introduced (in lectures) to a sequential mathematical approach that they had practiced in tutorials. Observation during tutorials and interviews showed that in general they were very comfortable with this systematic approach. The second year had undertaken two team based exercises in designing a steel and a concrete frame structure. This had resulted in their practicing these skills and hence accounts for their slightly improved performance over the first year (85% versus 75% success). The students acquired this ability though traditional lecturing, provision of worked examples and then tutorial work. There were capable of this at mid-semester, before they had to tackle the problem in their PBL exercises.

In the case of shear distribution the second year was appreciably more successful than the first year (85% versus 67%). This is consistent with the second year having practiced this technique during their design projects (as above). Observation showed that the first year students were generally using the sequential mathematical approach adopted for point values and extending this to shear distributions. Many of the second year students however were able to draw the distributions without explicitly formulating the equations. This demonstrates how the sequential step-by-step approach has formed the basis for a deeper understanding of the concept of shear force distribution. This deeper learning has occurred as a result of the PBL courses in the second year.

Both years were significantly less successful at assessing bending moment distributions (38% and 39% resp.). Examination of the scripts and interviews showed that both years were trying to apply the sequential mathematical approach to develop equations and then to plot the equations. This is complicated as different equations have to be developed for different regions of loading. Furthermore, the question did not ask for values at all points and hence the effort was not necessary. Practicing engineers rarely generate such equations but generate the bending moment distributions using a mixture of concepts such as superposition, equilibrium, deflected shape, curvature, shear force and moment. In addition further analysis of the scripts and subsequent interviews revealed that of the 75% of first year students who could calculate bending moment at a point, over half exhibited misconceptions when it came to relating their numerical result to structural behaviour – deflected shape, curvature and stress.

In an attempt to improve the student's conceptual understanding, following the mid-semester test the tutorial sessions were modified to focus on the key concepts of shear force and bending moment distributions and their relationship between each other and with deflected shape. In particular more qualitative tutorial material was introduced – to take the focus away from the equations. There were 4 significant workshops on this subject.

The results for the first year show that there was insignificant improvement in the students' ability in assessing bending moment and shear distributions – despite the emphasis in the workshops in the second half of the semester. The authors noted that attendance was not good at these sessions and a study of attendance shows a strong link between attendance and success. However this does not necessarily imply cause and effect. **Figure 1** shows the first year performance at plotting bending moment distribution in the final assessment related to attendance at tutorials/workshops.

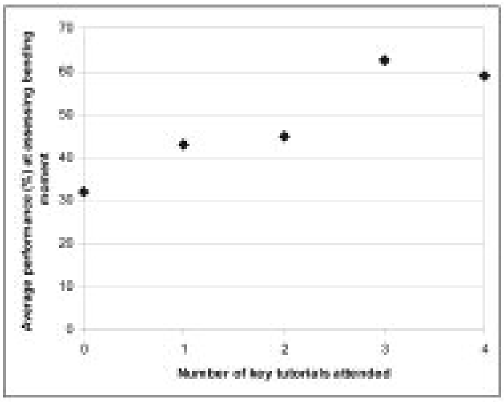

Figure 1 - Performance at assessing bending moment versus attendance at tutorials

The attendance records show similar trends with respect to shear force distribution with students' performance varying from 40% for students who did not attend tutorials to over 70% for those who attended 3 or more. On-line material is being developed with the aim of engaging those students who are choosing not to attend the more traditional workshops. This will be made available to all years but will be a fundamental part of the first two year's study. In addition a greater variety of structural forms will be studied in the second year courses.

Despite the similar performance of the first and second year students in assessing bending moment distribution, it was noted that the second year did not produce distributions with particular (zero moment) inappropriate characteristics. Hence the second year students have improved their conceptual understanding through the two PBL design courses. However, despite the second year having successfully assessed and manipulated bending moment distributions in the PBL tasks this particular ability does not appear to extend to the assessment of other similar problems – the knowledge gained is too specific.

CONCLUSIONS

1. The first year problem/project based courses on statics and structural analysis successfully develop the basic skills in assessing internal forces at a point in a structure and a good understanding of the concept of shear force distribution. This is achieved by means of a lecture and tutorial approach.
2. Despite being able to assess bending moment at a point students (both first and second year) have a problem in grasping the concepts of bending moment distribution. This understanding is not significantly improving through the second year PBL courses.
3. The second year students are improving specific analytical skills as a result of their two design based courses.
4. The effectiveness of tutorials and workshops is dependent on the attendance rate. Ability at concept based tests is directly related to workshop/tutorial attendance

5. In design based courses in a problem based learning environment it is necessary to incorporate specific mechanisms to ensure that structural skills at the conceptual level are developed.

REFERENCES

1. **Brohn, D. and Cowan, J.**, 1977, *Struct. Engr*, 55, Vol 1, 9-17
2. **IStructE**, 1989, *Qualitative Analysis of Structures*, London, UK
3. **IStructE Study Group**: *Qualitative Analysis of Structural Behaviour* http://www.bolton.ac.uk/qasb/
4. **Taplin, G.**, 1997, '*Developing qualitative analysis abilities in structural engineering*', 9th Conference of the Australian Association of Engineering Education, Ballarat
5. **Steif, P.**, 2004, '*An Articulation of the Concepts and Skills which Underlie Engineering Statics*,' 34rd ASEE/IEEE Frontiers in Education Conference, Savannah, GA,
6. **Understanding Physics Project, 1998-2000**, Monash University, www.education.monash.edu.au/centres/sciencemte/teachinglearningphysics.html (accessed 5 Feb 2006)
7. **Institution of Engineers**, Australia (1999) *Manual for the Accreditation of Professional Engineering Programs, Canberra*, http://www.ieaust.org.au/membership/res/downloads/AccredManual.pdf (accessed 29 May 2005).
8. **Hadgraft, R. G.**, (2003) Program Renewal for Sustainable Engineering at RMIT University, 2003 *ASEE annual conference*, Nashville, June 2003, paper 1353.
9. **Hadgraft, R., Xie, M. and Angeles, N.**, (2004) Civil and Infrastructure Engineering for Sustainability, *2004 ASEE annual conference*, Salt Lake City, June, paper 1608.

USE OF E-LEARNING IN ENGINEERING MATHEMATICS

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ABSTRACT

Engineering Mathematics is a fundamental and an essential component for those studying engineering courses. This is because mathematical skills are required and necessary for the understanding of almost every conventional engineering subject. As a result it is compulsory in almost every engineering program. It differs from more conventional engineering subjects in that it can easily be taught totally theoretically, without the need for practical exercises. As a result it may be thought to be more suited for an e-learning environment compared to other application oriented engineering subjects where practical exercises are more essential. This paper looks at issues that arise due the use of electronic media in the teaching of engineering mathematics. It looks at a real case where engineering mathematics was taught with significant use of electronic media. In the case examined WebCT, an e-learning medium and tool that has gained popularity for use in distance learning, was utilised significantly, both as a publishing medium and for assessment.

Implementation of mathematics in an E-learning environment has aspects similar to implementations of other engineering subjects. It also suffers from implementation problems in its own right. Traditional lecture and tutor roles and interaction with students are still indispensable and fully worked problems still essential. They provide insight to important aspects, which are otherwise undetectable when digital media is used.

METHOD

This study is based on a first year group of students on a foundation degree programme in engineering. The study was on an introductory mathematics module in the first semester of the first year of the programme. The group constituted of 63 registered students, of which 74.6 % were male and 25.4% female. Lectures and tutorials were provided every week during the duration of the course. In addition the students had a supervised laboratory session every week.

The Web Environment

The E-learning component was employed using a commercial internet package, WebCT(1,2). The web based resource page constituted of the following components: module handbook, calendar, laboratory exercises, laboratory exercise submission, quizzes and self-test, tutorials, lecture notes, notes, bulletin board and email.

The handbook and calendar provided information on the module events, assessment, topics, etc. The bulletin board and email were used for announcements, communication and discussion on both information and learning matters.

The tutorials, lecture notes, notes and laboratory exercises comprised of learning material implied by their name. The lecture notes and notes differed in that they also contained some example solutions.

The module was assessed by a series of online quizzes and computer based laboratory exercises whose reports were submitted electronically and a hand written test at the end of the module.

Electronic Assessment

The labs were computer based utilising a readily available commercial package. The submission deadline was the end of the following day. Laboratory exercises could therefore be performed and submitted from home or any other location.

Quizzes were held fortnightly from the third week of the commencement of the course. The quizzes were supervised and were to be completed within an hour. A password was provided at the beginning of each quiz.

Self-test quizzes covering material in the next quiz were posted at least a week before the quiz. Once a quiz had been attempted it became available as a self-test quiz. Quizzes and self-test quizzes were such that questions had different variable values for different students. This made copying and assistance from fellow students more difficult. Quiz questions were limited to those that required a single numerical answer or were multiple-choice.

For the quizzes no feedback was provided apart from the correct answer. In this way students were not tempted to enter wrong answers so as to obtain the working out of the problem, which in cases could prove detrimental(3).

In tutorials quiz questions were discussed. The correct method for solving questions was given and clarified in these tutorials. Misconceptions were made apparent and in some cases were the reason some students answered particular quiz questions wrongly.

Data Collection

Statistics on the students' use of the module resources in E-learning environment on the module resource page were automatically logged by the E-learning package (WebCT). In particular the frequency of resource access in the E-learning environment were collected. A non-mandatory questionnaire was also utilised for evaluation. Students' comments during the course of the module were also noted.

RESULTS

The students generally found the e-learning package easy to use. 78.5% found nothing negative about the e-learning tool. 64% reported to have used the tool consistently throughout the duration of the module as opposed to 20.5% who used it more towards the end. Only 7.8% used it more at the beginning of the module. At the end of the module the 76.6% of the students preferred to have computer based quizzes as opposed to written ones.

Students were asked to rate the different tools and material of the E-learning environment in the order of 'which they liked most'. Online quizzes scored highest followed by information resources, namely notes, lecture slides, tutorial questions and laboratory solutions. The bulletin board and calendar of events scored the least. These results are shown in **table 1**.

Facility	Points
Bulletin board	108
Event calendar	93
Lab. Solutions	125
Lab. Submission	165
Lecture slides	163
Notes	168
Online quizzes	188
Tutorial questions	155

Table: Best features of E-learning tool

The students reported that they used the E-learning tool mainly for mandatory assessment activities, which in this instance were quizzes and the submission of laboratory reports.

Given the option on whether to perform laboratory exercises from any location with or without supervision, only 12.8% opted for no supervision at all. Of the 87.2% who opted to have assistance 41.2% of them opted to always have tutor assistance, with the others opting to attend supervised sessions when they found it necessary.

Other key aspects cited on the E-learning experience was that it makes catching up easy as the electronic site is a repository of most of the information required on a module therefore enabling self assessment and learning.

Instant feedback was another feature that appealed to the student. This was indicative from complaints on the time it took to receive feedback on laboratory exercises, which had to be evaluated manually. Feedback on laboratory work was delayed due to both workload on the assessors and the significantly large number of students involved.

The statistics of the total access frequency for the module are shown in **figure 1**. Laboratory

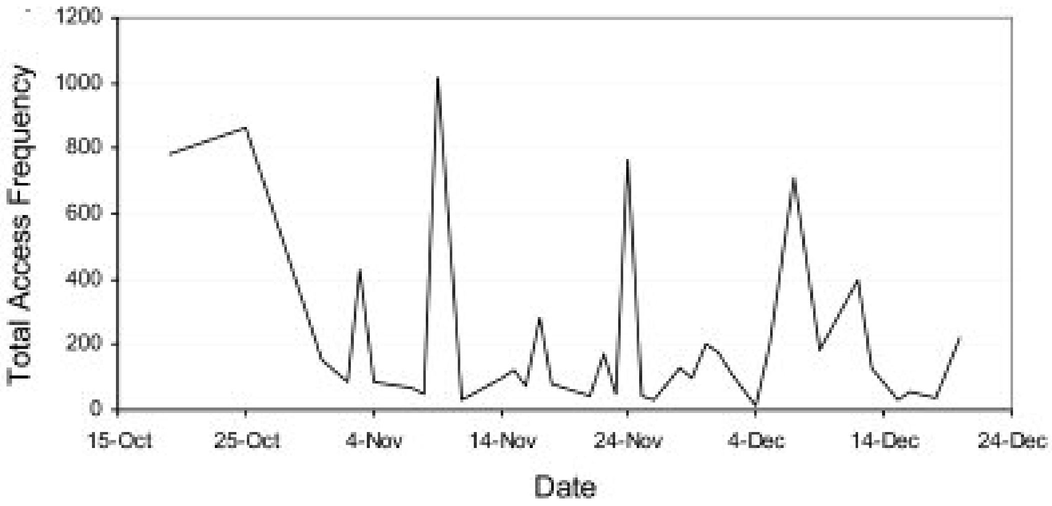

Figure 1: Total access frequency over time

reports were submitted weekly until November the 25th. Quizzes were held fortnightly corresponding to October 13 and 27, November 10 and 24, and December 8.

Students generally performed much better in the written test at the end of the module than they did in the quizzes. The average in the written test was 50.1% while the average for the quizzes was 46.8%.

In the written test the worst performance was on areas not tested in the quizzes. Some areas were not tested in the quizzes due to a combination of limited time, limitations of the tool used and, the effort, technology and knowledge required to implement particular questions.

Attendance of lectures was generally good, being mostly above 60%. Attendance of lectures was generally less than that of quizzes and laboratory sessions.

DISCUSSION

From **figure 1** it is apparent that E-learning access of the students is assessment driven. This is apparent from the peaks that occur in weeks that the students had quizzes. This corresponds to the peaks before and on the dates of the quizzes. The greatest use of the E-learning resources occurred at the end of the module just before the written test. Student study behaviour being assessment driven is expected and also occurs when no electronic learning resources are used. However in this instance the students are using digital media to reinforce their preparation for written assessment. Indeed some students reported that it improved learning ability.

The preference of 87.2% students to have supervised laboratory sessions is an indication that the students valued direct contact with educators allowing for instant answers to questions or problems they were encountering.

It is interesting that the students liked an assessment resource (quiz) most and valued the communication tools least. The communication tools were valued least probably because alternate communication means exist and also probably they were not as informative and as beneficial regarding actual module material as the other resources.

The improved performance of the students in the written test at the end of the module can be attributed to the test largely covering material covered in the quizzes and the test carrying a greater weighting than that of all the quizzes combined hence the students taking it more seriously. However this does not rule out improved ability due to using self-test quizzes.

Students clearly welcome E-learning as it provides them avenues to use their time efficiently allowing them to cope better to the increasing demand on their time to fulfil not only educational requirements but also career, financial and other social needs.

It drastically reduces time spent on assessment by instructors (normally about 75% of the time spent on a module when no electronic assessment is used[4]) to as low as 30%. This should increase the quality of education by affording instructors more time to concentrate on improving and updating the delivery and content of courses.

Although savings in time tend to increase with increasing numbers of students, and has been deemed to be negative for small numbers of students in some studies(4), it still proves beneficial in the long run after the completion of the critical developmental period. Even where small numbers are involved its benefit of allowing students to test themselves and learn from their mistakes privately(5) is not diminished. In addition students can benefit from a large variety of questions developed over a period of time from contributions from a variety of sources.

Poor performance in areas not tested in quizzes can be attributed to students focusing on passing the quizzes, which is in some way detrimental to learning(6). This was however resolved to some extent, by having the written test at the end of the module, in which the areas omitted in quizzes were also included (students were informed accordingly).

Development of E-learning material is challenging, especially when the required tools and/or knowledge are not already in place within the department or institution. This is because it requires skills and/or knowledge, which the instructor may not have. These skills include making schematics and animations, and knowledge in information technology (IT) such as networking. Skills required to develop interactive material for mathematics (as well as in other fields) are much more demanding than those required for publishing only(7). Usually advanced IT and programming knowledge is required.

Clearly the implementation of interactive or assessment requiring general solutions (e.g. algebra and calculus), abstract mathematics (e.g. proofs of theorem or identity) and indeed sketches or diagrams is nontrivial. This is still a milestone that is yet to be overcome in online assessment in mathematics.

Due to time constraints and for reasons already stated quiz questions were limited to those that required a single numerical answer or were multiple-choice as implementation of answers in more complex forms such as formula and fractions is still complicated and demanding and not readily supported by the majority of electronic assessment tools.

Questions requiring a single numerical answer are in some sense disadvantageous to students in that they only test the end result and not the level of understanding, which can be ascertained only where the full working to solutions is provided. They however help students reduce making errors when solving the tested problems. Multiple choice questions on the other hand allow for guessing which can highly distort assessment, though they also make the understanding of concepts, definitions and ideas clearer.

The written test at the end of the module served as a control to assess online assessment. The test results illustrated that online assessment was effective. In addition it exposed misconceptions, which could not be revealed from the analysis of online quiz results, where only the final answers to problems were required. An important advantage of worked out solutions over the single answer online solutions, was the ability in particular to provide insight to the different manner in which different students perceive and learn the same thing and the logic they follow in solving problems, including learning difficulty aspects. This information is invaluable as it enables for teaching methods and material to be tailored to cater for the wide variety of learning avenues and needs of the students.

CONCLUSION

From the above it is conclusive that implementation of mathematics in an E-learning environment has aspects similar to implementations of other engineering subjects although it may not require as much practical work or exercises. It also suffers from implementation problems in its own right, as do other engineering subjects. Implementation of mathematics in electronic assessment suffers from hindrances due to the limitations of the complexity of solutions that can be implemented.

It is evident that E-learning in mathematics is beneficial in reducing instructors' assessment time. It is amicable to use by students. The students find electronic assessment appealing and attractive. There are indeed indications that it improves the ability of students to solve problems.

Traditional lecture and tutor roles and interaction with students are still indispensable and essential components in providing quality education. As reliable electronic assessment of fully worked problems is not yet of age, written assessment is still essential. In addition written tests provide insight to important aspects and catch misconceptions, which are otherwise undetected when digital assessment is utilised.

REFERENCES

1. http://WebCT.com.
2. **Palma, L., Morrison, R. F., Enjeti, P. N. and Howze, J. W.**, 2005, *IEEE Trans. Educ*., 28, 729-734.
3. **Chen, P. M.**, May 2004, *IEEE Trans. Educ.*, 47, 232-240.
4. **Smaill, R. C.**, Nov.2005, *IEEE Trans. Educ.*, 48, 658-663.
5. **Reinhardt, A.**, Mar. 1995, *BYTE, vol. 20*, 50-72.
6. **Perez, M. S., Sanchez, F. M. and Robles, V.**, 2005, *IEEE Trans. Educ.*, 48, 757-763.
7. **Humar, I., Sinigoj, A. R., Bester, J. and Hagler, M. O.**, 2005, *IEEE Trans. Educ.*, 48, no. 4, 664-675.

WHAT PRIOR MECHANICS KNOWLEDGE IS USEFUL FOR STUDYING ENGINEERING AT UNIVERSITY? THE STUDENT PERSPECTIVE

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ABSTRACT

In the past 5 years changes have been made to A-level qualifications in England. More specifically, there have been significant changes in A-level mathematics. This has influenced the mathematics knowledge with which engineering students, who are generally required to have studied A-level mathematics, are entering university. Moreover as mechanics has traditionally been taught within A-level mathematics there is the potential for the changes in A-level to have a major impact on the amount of mechanics studied. As many engineering students study compulsory mechanics modules in the first year of their degree, it is very important that the students' prior knowledge of mechanics is ascertained so that the curriculum may be designed accordingly.

In this paper the background to the situation is first outlined. Secondly, recent research, by the authors, which has been conducted into the uptake and availability of mechanics in schools is summarised. Then a survey of a cohort of first year mechanical engineering students will be reported upon. This investigated the prior knowledge of mechanics that these students thought was useful for studying engineering at university. Finally, the paper discusses the implications of the results for university academics and others interested in undergraduate engineering education.

BACKGROUND

Awareness of the 'mathematics problem', i.e. the lack of mathematical ability of students entering numerate degrees, has been well rehearsed over the past decade, with several major reports being produced, e.g. 'Tackling the Mathematics Problem'(1) and 'Measuring the Mathematics Problem', Hawkes and Savage(2). More recently an associated issue, labelled 'the mechanics problem', which centres on the (lack of) knowledge of mechanics of students entering engineering degrees, has risen to the fore.

In 1997, Kitchen *et al*(3) drew attention to the emerging situation. In 2004 the authors were commissioned by the Higher Education Academy (HEA) Engineering Subject Centre to review the mechanics issue at the school/university interface. The report, Robinson *et al*(4), provided information on the uptake and availability of mechanics in schools, undergraduates' prior knowledge of mechanics, as well as academics' perceptions of what mechanics they expect students to have studied.

In a recent report(5) by the Higher Education Funding Council for England's advisory group on 'Strategically important and vulnerable subjects', a workshop run by three HEA Subject Centres in 2005, entitled 'Re-invigorating mechanics teaching in science and engineering' was highlighted as appropriate and good practice. Thus, it can be seen that engineering educators are starting to become aware of the mechanics problem.

One of the areas cited as being focal to the mechanics problem is the (lack of) uptake and availability of mechanics in schools. In part this may be down to the continual changes that have occurred in the structure of A-levels and specifically A-level mathematics, Porkess(6). In the last change (September 2004) the number of applied modules students are able to study for an A-level in mathematics was reduced from three to two. Thus, students entering an engineering course, from September 2006, will have studied at most two modules of mechanics. The situation is different if the student had studied Further Mathematics, but the total numbers studying this are still very low.

Figure 1 highlights prevalent points from(4). The data is based on statistics from 242

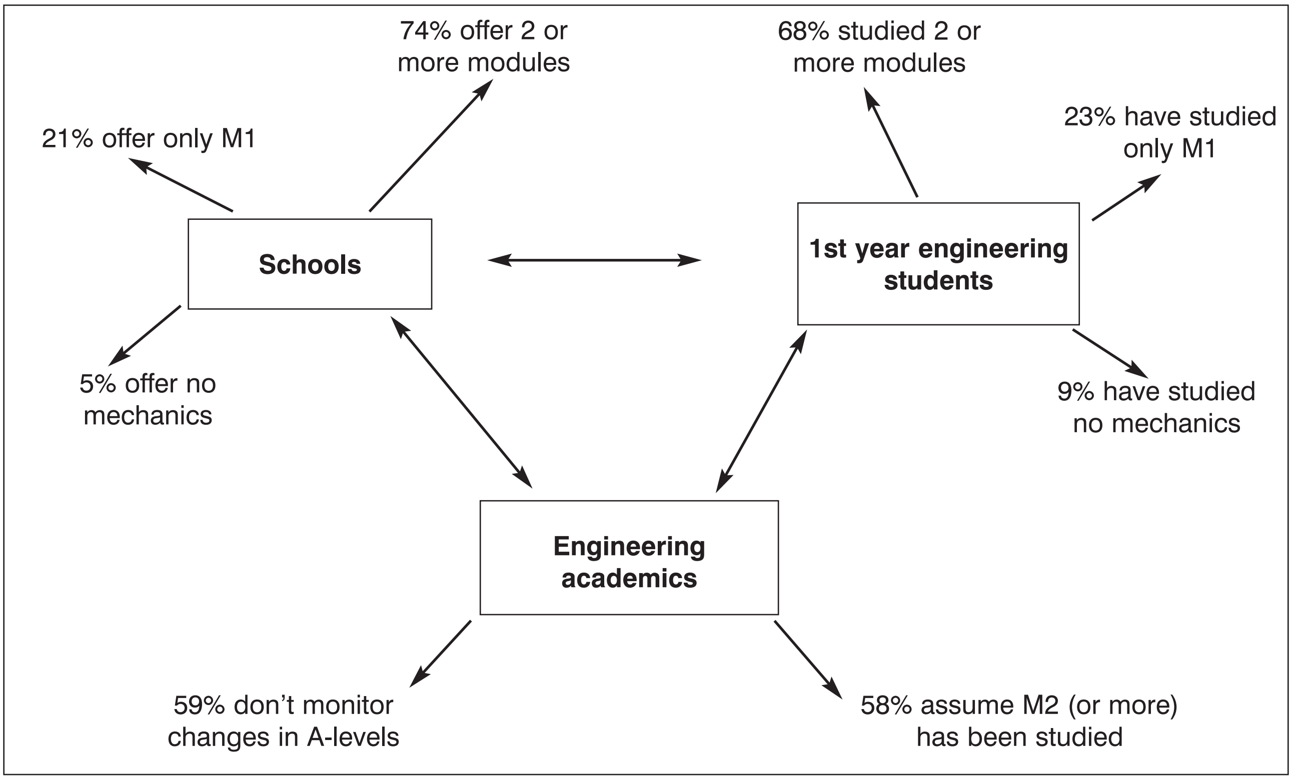


Figure 1: Availability and uptake of mechanics modules, and academics' perceptions

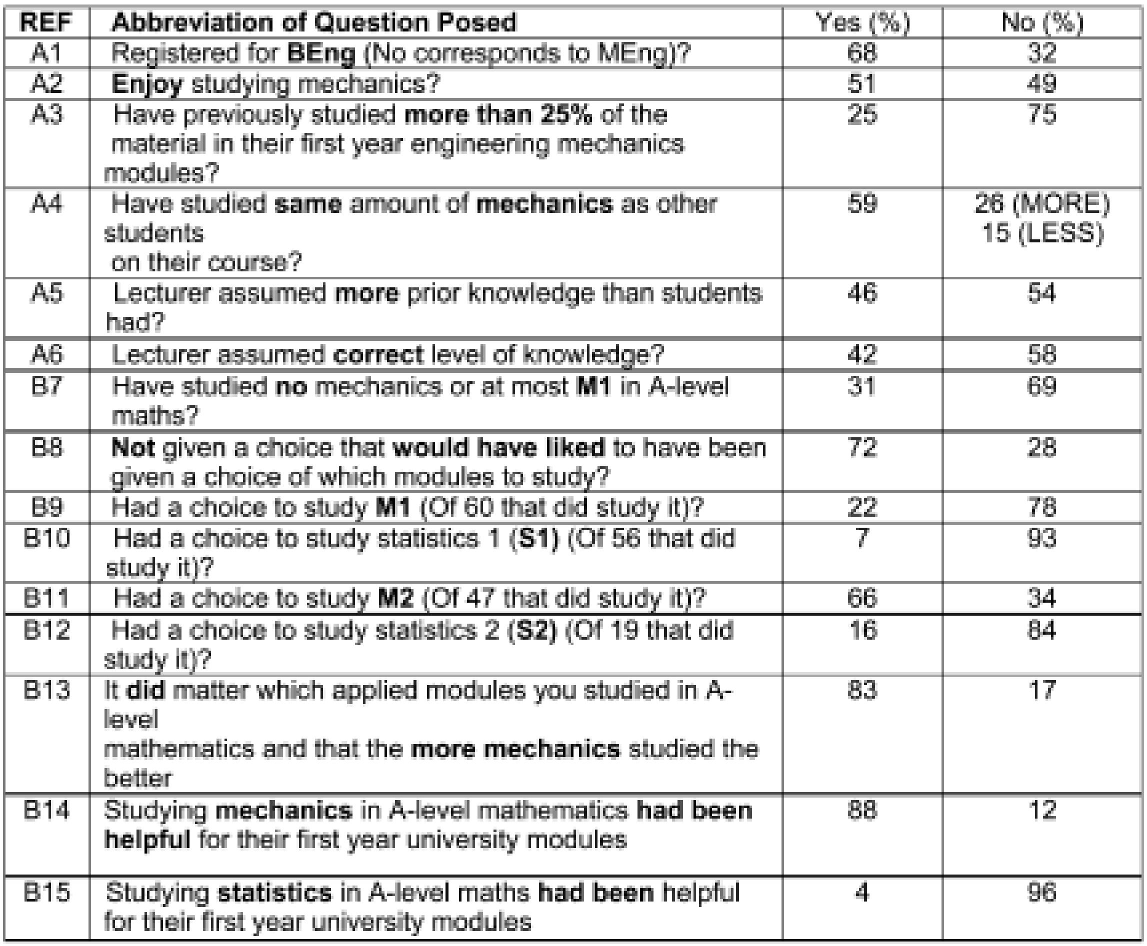
schools (the schools included 13754 students studying AS or A-level mathematics); 1087 undergraduate engineers and academics from 19 institutions. As can be seen from the content of A-level mechanics modules, given in the Appendix, the material presented in the first mechanics module (M1) is an introduction to mechanics and at a very basic level. Not until students study the second mechanics module (M2) do they start to encounter more demanding material, e.g. projectile motion and motion in a circle. Therefore, it is concerning that 21% of schools (**figure 1**) offer at most M1 to students. It is also concerning that 32% (23% + 9%) of (1087) engineering students have studied at most one module of mechanics. This is particularly relevant because 58% of academics surveyed assumed M2 as a starting point for their first year university mechanics module.

Furthermore, when reviewing the content of a first year engineering mechanics module, also given in the Appendix, it can clearly be seen that there is a considerable gulf in level between this material and that covered in the early A-level mathematics mechanics modules.

STUDENTS' PERSPECTIVE

Up until now much of the work conducted has been from the viewpoint of those involved in teaching mechanics or helping in support centres and responses gained would suggest that the mechanics problem is an important issue. It needs to be ascertained whether students think there is an issue with the amount of mechanics assumed as prior knowledge and the knowledge of mechanics which they have. Clearly this will vary for students on different courses. This article focuses on mechanical engineering students. The two main reasons for this are that mechanics is an important part of their degree and if one group of students were to perceive there was a problem it would be this group.

Firstly, a questionnaire was produced. In-line with good practice, Cohen *et al*(7), the questionnaire was piloted. Few changes were made following the pilot before it was administrated to all the students registered on first year mechanical engineering courses at Loughborough University, which has a large Engineering Faculty with some 3000 students. 152 first year students were registered on mechanical engineering courses and in a



REF	Abbreviation of Question Posed	Yes (%)	No (%)
A1	Registered for **BEng** (No corresponds to MEng)?	68	32
A2	**Enjoy** studying mechanics?	51	49
A3	Have previously studied **more than 25%** of the material in their first year engineering mechanics modules?	25	75
A4	Have studied **same** amount of **mechanics** as other students on their course?	59	26 (MORE) 15 (LESS)
A5	Lecturer assumed **more** prior knowledge than students had?	46	54
A6	Lecturer assumed **correct** level of knowledge?	42	58
B7	Have studied **no** mechanics or at most **M1** in A-level maths?	31	69
B8	**Not** given a choice that **would have liked** to have been given a choice of which modules to study?	72	28
B9	Had a choice to study **M1** (Of 60 that did study it)?	22	78
B10	Had a choice to study statistics 1 (**S1**) (Of 56 that did study it)?	7	93
B11	Had a choice to study **M2** (Of 47 that did study it)?	66	34
B12	Had a choice to study statistics 2 (**S2**) (Of 19 that did study it)?	16	84
B13	It **did** matter which applied modules you studied in A-level mathematics and that the **more mechanics** studied the better	83	17
B14	Studying **mechanics** in A-level mathematics **had been helpful** for their first year university modules	88	12
B15	Studying **statistics** in A-level maths **had been** helpful for their first year university modules	4	96

Table 1: Indication of questions posed and results obtained

lecture towards the end of their first year (May 2005) 78 students completed the questionnaire, which represents a 51% response rate. In surveys it had been previously found that by administrating them at the start of term (particularly year 1) a very high response rate could be achieved. However, this was not possible as the questionnaire elicited responses on their first year studies.

The questionnaire consisted of two sections, the first eight questions predominantly asked about mechanics at university and how much of it students had studied previously. The second section (6 questions) was only for students who had studied A-level mathematics (68 out of the 78 students - 87%) and asked if they had been given a choice of which modules to study (at A-level) and which they had found useful for their degree. Table 1 gives a brief description of the questions and answers. A discussion of the results will now follow.

Initially we shall consider the 78 responses to the first section, A, of questions. Of the 78 students that completed the questionnaire 68% were registered on BEng courses, with the other 32% registered on MEng courses (**table 1** - A1). This was similar to the percentages for the whole group (of 152 students), where 75% were registered on BEng courses and was thus a representative sample, in terms of degree course, of the year group.

Interestingly, there was a near equal split between those that enjoyed studying mechanics (51%) and those that didn't (49%).

(**Table 1** - A2). Those who didn't enjoy mechanics had generally studied 2 or less mechanics modules in A-level, whereas those who enjoyed studying mechanics had entered university having studied varying amounts, from none to 4 modules. When asked how much of the material in their first year engineering mechanics module they had met prior to coming to university (**table 1** - A3) 75% of students said 25% or less of the module. By relating this to the number of mechanics modules previously studied, this includes over a third of students who had studied little or no mechanics at A-level. Perhaps even more striking is that half of this group had actually studied 2 modules previously.

Next it was sought to establish if students thought that other students in their class (of 152 students) had studied the same (59%), more (26%) or less (15%) mechanics (**table 1** - A4). Interestingly over half of the students that said other students had studied the same as them, had studied 2 modules, with a further quarter having studied only one module.

Finally in the first section of questions, students were asked if the lecturer(s) assumed that they had more (46%), the correct amount (42%) or less (12%) prior knowledge, of mechanics, than they actually did (**table 1** – A5/ A6). Further analysis revealed that the 12 students who had studied 3 or 4 mechanics modules said the lecturer assumed less. The results for the assumption that the lecturer had assumed more and the correct amount by and large correlated to the groups who had studied little mechanics, i.e. 0 or 1 module and those that had studied two modules respectively.

Considering the second section, B, of questions that were only for students who had studied A-level mathematics (68 out of the 78 students - 87%), it can be seen (**table 1** – B7) that 31% of the students in the sample had studied *at most* one module of mechanics within it. The results of this questionnaire compare well with the results from the questionnaire completed by 1087 engineering students(4), as 32% had studied at most one module of mechanics (it should be noted that these 78 students are contained within the total of 1087 students).

It is interesting to note that 72% of our A-level sample (**table 1** – B8) had not been given a choice of which applied modules to study but would have liked one. Also, in a separate question 30% of students indicated that they thought that their school required them to study particular modules because they would be useful for future careers, and another 25% of students indicated that teachers thought it would be easier to get a higher mark on the modules they required students to study. These are interesting reasons; the first demonstrates that many schools are taking into consideration what they believe students are going to do after their A-levels; the second indicates that they are looking to achieve the best possible results for the school. A useful avenue for further work would be to follow up and investigate responses from schools themselves.

Thus it can be seen that although engineering educators may try to encourage potential engineering students to study mechanics, for example by running mechanics workshops Lee *et al*(8), students may still not be able to study mechanics at school. Teachers would also need to be convinced of the benefits, be confident of teaching the subject and have enough students to warrant separate classes, in order to improve the situation. This is particularly interesting when compared with results from the schools questionnaire (**figure 1**) where 26% of schools did not offer anything more than M1. In addition, where a school responded that they did offer M2 it may be the case that only those studying Further Mathematics could study it and it was not available for all students.

With respect to the choices available to respondents of this questionnaire:

- 78% of the 60 students that studied M1 *had no choice* (**table 1** – B9)
- 93% of the 56 students that studied S1 *had no choice* (**table 1** – B10)
- 34% of the 47 students that studied M2 *had no choice* (**table 1** – B11)
- 84% of the 19 students that studied S2 *had no choice* (**table 1** – B12)

This indicates that the vast majority of students who studied M1, S1 and indeed S2 had no choice but to study each module, whereas those who studied M2 had made the choice to study it.

Although this is a relatively small sample it raises the question whether it would be better, for university educators, if two particular applied modules were made compulsory in the study of A-level mathematics, e.g. M1 and S1. At least then academics would know what students had studied and thus have a better idea of where to start their courses. From the viewpoint of engineering students (**table 1** – B13) 83% of students said that it did matter which applied modules you studied in A-level mathematics and that the more mechanics studied the better. Furthermore, 88% of students said studying mechanics in A-level mathematics *had been* helpful for their first year university modules (**table 1** – B14), but 96% of students said that studying statistics in A-level maths *had not been* helpful for their first year university modules (**table 1** – B15), although it may be useful later. Thus, a compulsory requirement to study both M1 and M2 would be the best recommendation by engineering students, although this would not necessarily be the best suggestion for other courses.

In addition to surveying students with a questionnaire it was also decided that a more informed analysis could be obtained by speaking with individual students through follow-up interviews.

Follow-up Interviews

Ten students from the 78 who completed the questionnaire were selected to attend follow-up interviews based on how they completed the questionnaire. This selection was made to get a cross-section of students that had studied different numbers of mechanics modules. A small payment was offered and eight of the ten students attended the scheduled interviews.

In the interviews students were asked to expand on the answers selected in their completed questionnaire and answer additional questions.

Firstly, an understanding of why students did or did not enjoy mechanics was gained. Of the eight students six said that they did enjoy the subject and offered reasons such as:

- I am interested in the subject
- It is useful and has practical applications
- It is easier to visualise and so it comes more naturally then (for example) statistics

The two students that didn't enjoy mechanics cited these reasons:

- Interesting but difficult due to number of steps involved in each calculation
- Did not like university style of teaching

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. In particular the two students who had not studied A-level mathematics (who had studied vocational BTEC qualifications) both commented that they thought they would have been in a better position to start an engineering degree if they had studied mechanics within A-level mathematics (as a consequence of discussions with other students on their engineering course).

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 indicated that those teaching should familiarise themselves with the background knowledge in mechanics of their students. Thus, even if the course were not changed, at least there would be a basic understanding of the abilities of each year's specific intake.

The follow-up interviews proved useful as the students gave feedback on both their prior mechanics knowledge and their experiences of a first university module of mechanics. Furthermore, they indicated that the level was much more difficult than studied at A-level. Consequently, it had been beneficial to firstly have studied some mechanics and secondly it had been helpful to have been exposed to the material in the context of A-level mathematics, particularly the way it is taught, i.e. over a longer time span.

DISCUSSION AND IMPLICATIONS

In this paper an appreciation of a recent concern over the (lack of) knowledge of mechanics of students entering engineering degrees has been described.

Brief summaries of the major findings from(4) were given. These highlighted the availability and uptake of mechanics in schools, undergraduates' prior knowledge of mechanics and academics' perceptions of what mechanics they expect students to have studied. In addition, in this paper the student perspective on whether there is a mechanics problem was sought. Questionnaires and follow-up interviews were used to do this.

One of the most prevalent points was that a large percentage (46%) of students stated that lecturers assumed more prior knowledge of mechanics then the students actually had. This is important as an assumption, by a lecturer, that students have more knowledge then they actually do, could (and does) cause problems. This is especially the case for the less well prepared students. This highlights that many students do feel that there is a gap in assumed knowledge and actual knowledge.

Although the total of 78 replies to the questionnaire, from mechanical engineers was relatively small, anecdotal evidence (for example, from students seeking help with mechanics at the mathematics learning support centre at Loughborough University) suggests that students in other engineering disciplines also perceive a similar problem. Future work includes extending the questionnaires/follow-up interviews to students from other disciplines and from other universities to gain a more comprehensive overview.

Earlier the possibility of making certain applied modules in A-level mathematics compulsory, so that academics knew what students had studied when they came to university, was discussed. This would be the ideal situation, although this is not likely to be forthcoming in the immediate future. Hence universities will need to act to alleviate the situation.

Findings from a national survey of academics, as described in(4), highlighted current good practice. The strategies adopted included:

a) Determining students' prior knowledge of a given subject, e.g. mechanics, upon arrival, particularly by questionnaires and diagnostic testing.

b) Offering appropriate follow-up support, for example offering additional help (from tutors or peers), providing additional resources (e.g. free online resources available from www.mathcentre.co.uk, including mechanics) or offering specialist assistance (e.g. from a mathematics support centre).

c) Reinforcing learning by using laboratory work and regularly assessing students' knowledge.

Thus in conclusion, this paper has given an insight into a potential gap in knowledge of mechanics by engineering students upon entry to university. Several strategies have been suggested which if implemented can have a positive effect on a student's performance.

REFERENCES

1. **Tackling the Mathematics Problem**, 1995, a joint report of the LMS, IMA and RSS. Available online at: http://www.lms.ac.uk/policy/tackling/report.html (accessed 10 January 2006).
2. **Hawkes, T. and Savage, M. D.**, (eds.), 2000, Measuring the Mathematics Problem, *Engineering Council Report*. Available online at: http://www.engc.org.uk/documents/Measuring_the_Maths_Problems.pdf (accessed 10 January 2006).
3. **Kitchen, A., Savage, M. D. and Williams, J.**, 1997, The Continuing Relevance of Mechanics in A-level Mathematics, *Teaching Mathematics and It's Applications*, 16(4), 165-170.
4. **Robinson, C. L., Harrison, M. C. and Lee, S.**, 2005, *The Mechanics Report – Responding to the Changes in the Teaching and Learning of Mechanics in Schools*. Commissioned by the UK Higher Education Academy Engineering Subject Centre. Available online at: http://www.engsc.ac.uk/downloads/resources/mechanics.pdf (accessed 10 January 2006).
5. **HEFCE**, Strategically important and vulnerable subjects, 2005, Available online at: http://www.hefce.ac.uk/pubs/hefce/2005/05_24/ (accessed 10 January 2006).
6. **Porkess, R.**, 2003, The new AS and A Levels in Mathematics, *MSOR Connections,* 3(4), 12-16.
7. **Cohen, L., Manion, L. and Morrison, K.**, 2000, *Research Methods in Education,* RoutledgeFalmer, London, UK.

8. **Lee, S., Robinson, C. L., Croft, A. C. and Bamforth, S. E.**, 2005, Magic of mechanics, *MSOR Connections*, 5(2), 33-37.

APPENDIX

Summary of Mechanics modules taken from OCR Specification:

M1 (2637): Force as a vector; Equilibrium of a particle; Kinematics of motion in a straight line; Newton's Laws of motion; Linear momentum.

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

1st year Engineering Mechanics module content:

Statics: Introduction; Force systems: moment and couple, resultants; Equilibrium: mechanical system isolation, equilibrium conditions; Structures: plane trusses, frames and machines; Distributed forces: centroids, beams; Friction: principles, application in machines.

Mechanics of Materials: Concepts of stress: direct and shear stresses. Thin-walled cylinders. Analysis of stress and strain: plain stress, principal stresses, maximum shear stress, Mohr's circle, plane strain, measurement of strain, relations involving E, G and V.; thermal deformations and stress, stress concentrations, Torsion: twisted circular shaft, torsion formula, angle of twist; thin-walled hollow members. Stresses in beams: classification of beams, shear and moment in beams, load, shear and moment relationships, shear and moment diagrams, pure bending, assumptions in beam theory, normal strain-curvature relation, normal stress - the flexure formula, the shear formula; shear-stress distribution in rectangular beams and flanged beams.

Dynamics: Motion of Particles: rectilinear motion; position, velocity and acceleration, graphical methods; curvilinear motion; rectangular components, tangential and normal components, radial and transverse components. Kinetics of Particles: Newton's Laws, units, equations of motion, rectilinear motion, curvilinear motion. Work and Energy: potential energy, conservation of energy, power and efficiency. Impulse and Momentum: impulsive motions, conservation of momentum, impact, energy and momentum steady streams of particles, systems gaining and losing mass. Kinematics of Rigid Bodies: rotation, angular velocity, velocity diagrams, instantaneous centre of rotation, angular acceleration, acceleration, acceleration diagrams. Mass Moment of Inertia: mass moment of inertia, paralleled axis theorem, radius of gyration, composite bodies. Impulse and Momentum: conservation of angular momentum, impulsive motion.

THE EFFECT OF ENGINEERING STUDENTS' ATTITUDES ON LEARNING MATHEMATICS

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Harper Adams University College, United Kingdom

ABSTRACT

Engineering students arrive at university with a range of qualifications in mathematics. In recent years many students have achieved success in engineering mathematics in this university, aided by a revised module structure and the provision of mathematics support. The most successful students are not always the most highly qualified, but are often those with good attitudes towards learning mathematics.

The attitudes of students to learning mathematics have been explored through student questionnaires, with a view to determining student characteristics, other than qualifications, which affect their performance. The aim was to find out what attitudes students held, particularly regarding their confidence as many appear to lack confidence on entry. Also surveyed were: their perceived ability and liking of mathematics, which factors they consider helped or hindered their learning mathematics, and how this had changed, for example from the first to second year.

Findings of engineering students' attitudes towards learning mathematics are summarised and comparisons made with non-engineering students. The necessity of mathematics and its use in practical engineering applications were found to be important. In general, factors which promote effort, confidence and success in engineering mathematics are sought in order to try to foster these (through teaching methods, etc.) and thereby further improve student performance and confidence.

BACKGROUND

Harper Adams University College is a small specialist HE college based in Shropshire specialising in land-based, rural and food subjects. Engineering degrees are offered in Off Road Vehicle Design, Agricultural Engineering, Engineering Design and Development for BEng, BSc and FdSc/HND awards. The primary difference between the student award groups is the students' mathematics qualifications and background. Students entering BEng programs are expected to have a sound 'A' level mathematics background, whereas for BSc and FdSc/HND the intake is more varied, the minimum requirement being GCSE grade C. During the past 5 years provision of mathematics support and a changed module content (including revision of essential mathematics) have much improved student retention and achievement. Mean examination scores for mathematics for engineering students are currently often in 60%'s and 70%'s reflecting good progression and achievement.

Recent improvements at Harper Adams contrast with past poor retention (especially in 2000) and with the general widespread concern over engineering and science students' learning of mathematics. Students' declining skills on entry to university is one area of concern: '*For many years concern has been expressed about the decline in mathematical skills possessed by entrants to engineering and science degree programmes*'. Mustoe(1). The effect of students' attitudes and confidence is also worthy of consideration. '*There is growing evidence of the importance of students' attitudes and beliefs about mathematics for their achievement and successful applications of the subject*.' Ernest(2). The *'mathematics problem' is usually described as a skills problem, but this has two aspects: the knowledge of mathematical techniques/facts, and the confidence to make use of them . . . To develop students' mathematical confidence is a slow process, which cannot be achieved through quick remediation, unlike the problem of "filling in" some gaps in mathematical knowledge*'. Kent and Noss(3).

One of the aims of the ESRC study 'Students' Experiences of Undergraduate Mathematics', which investigated single honours mathematics students, was '*to understand better . . . why* *some maintain or develop more positive attitudes than others*.' Brown *et al*(4). The work described in this paper seeks similarly to identify and understand factors, including student attitudes, which impact upon undergraduate engineers' and natural and social scientists' learning of mathematics and statistics, as part of a longitudinal study at Harper Adams University College, which commenced early 2005.

METHODOLOGY

In May 2005 Mathematics Learning Questionnaires were administered to Harper Adams undergraduate students seeking the students' views on learning mathematics and statistics. Responses were obtained from students representing every undergraduate mathematics and statistics module in the university, seven different modules. Modules surveyed included mathematics for engineers, statistics for natural and social scientists, at certificate and intermediate levels. Open and closed questions gathered information on qualifications, students' attitudes and students' views on aspects of the modules. Different versions of the questionnaire were used according to which module the students had taken and which year.

250 questionnaires were completed of which 46 were completed by engineering students (29 first years and 17 second years). The total annual entry into engineering programs is relatively small, approximately 50, and only the BEng students, approximately 20, continue to study mathematics into the second year. Thus the number of questionnaires completed was a good response rate from the student cohorts (approximately 67%). Students' responses relate primarily their mathematics for engineering modules, however the first year engineers had also taken a mathcad based engineering statistics module to which some responses regarding learning statistics refer.

Objective data such as Age, Gender, Mathematics Grade, whether the student had studied 'A' level Mathematics was gathered at the start of the questionnaires. More subjective data such as attitudes was gathered using a mixture of closed questions (generally 5 point Likert scales), e.g. asking students to rate their overall confidence in mathematics on a scale of 1 (low) to 5 (high), and open questions such as 'How would you describe your *attitude* towards learning mathematics?'

In considering students' 'confidence', three levels of questions were posed: an overall confidence, a confidence for each of 11 different topics studied, and a confidence to *apply* these topics in the future, for example for a project or at work. One aim of the questionnaires was to quantify students' confidence in these respects, but another aim was to also validate considering confidence in this manner. 'Confidence in Life in general' was also asked for, for use as a benchmark against which to compare other confidences.

The BSc Engineers group completed the pilot version of the questionnaire, after which minor changes were made to the other versions, for example two extra questions were added (e.g. about enjoyment of mathematics), and two Y/N/U responses were changed to 1-5 scales to gather more sensitive responses.

Questionnaire responses were analysed using Excel, SPSS and Genstat for quantitative data, and by identifying themes and common responses for open questions.

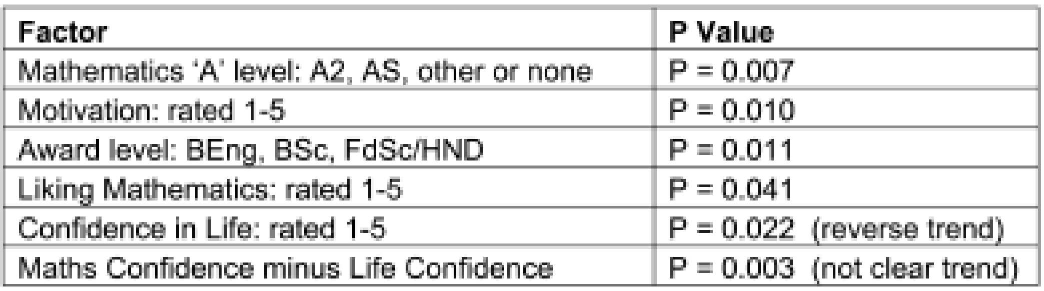
RESULTS

Relationships between Mathematics and Statistics Marks and other Factors

The BEng students were more qualified in mathematics than their BSc and FdSc/HND counterparts, and generally achieved higher examination marks, despite their curriculum and examination being more difficult. Overall Mean module marks: BEng 79%, BSc 63%, FdSc/HND 52%.

Significant relationships were found to exist between first year engineering students' overall mathematics module marks and the following shown in **table 1**.

The relationship between students' liking of mathematics, motivation and confidences with their overall module percentage mark demonstrates some inter-relationships between attitude and performance.



Factor	P Value
Mathematics 'A' level: A2, AS, other or none	P = 0.007
Motivation: rated 1-5	P = 0.010
Award level: BEng, BSc, FdSc/HND	P = 0.011
Liking Mathematics: rated 1-5	P = 0.041
Confidence in Life: rated 1-5	P = 0.022 (reverse trend)
Maths Confidence minus Life Confidence	P = 0.003 (not clear trend)

Table 1: Results of ANOVA tests for comparison with 1st year mathematics marks

Factors which did not give significant results, but for which clear trends were visible, were whether students liked statistics and whether they liked the subject more as a result of the module, and GCSE Mathematics Grade (GCSE grade and % marks: A 76%, B 73%, C 61%, D 42%).

Other factors for first year engineers which did not give any significant differences or show any clear trends were Age, confidence in Mathematics, whether students used the Maths support and whether or not students had experienced a moment when the mathematics had become clearer, and whether or not students were dyslexic. Higher Confidence in Mathematics was generally associated with higher motivation and module marks, except for very low confidence which was also associated with high motivation and module marks.

For first year non-engineers' statistics module marks there was a very highly significant relationship between GCSE mathematics grade and statistics module mark (P <0.001), and there was also a very highly significant relationship between GCSE mathematics grade and students' confidence in mathematics (P <0.001).

Students' Confidence in Mathematics, Statistics and Life

With regard to confidence in mathematics, the three first year engineering award groups appeared similarly confident at mathematics, all between 3.2 - 3.4 (on a scale of 1-5, 5=high) and all three groups felt generally more confident after the module, with averages of approximately 4 (of 5). The BEng students were for many other questions slightly stronger than the BSc and FdSc/HND students. See **table 2**.

Comparison of Confidence in Mathematics, Statistics and Life

Comparing confidence in Mathematics, Statistics and Life, all engineers' groups were on average more confident in Life, than in mathematics, than in statistics. Second year engineers were also asked to rate their general confidence in their ability in engineering. The overall ranking of students' confidence was as follows.

First Year Engineers'	Life >	Maths >	Statistics
Confidence:	3.8	3.3	2.9

2nd Year				
Engineers'	Life>	Engineering>	Maths>	Statistics
Confidence:	4.1	3.8	3.7	3.3

Generally engineering students' attitudes towards statistics were worse than those towards mathematics, both in confidence in their ability (mean for statistics 2.9 and for mathematics 3.3) and in liking of the subject (mean for statistics 2.8 and for mathematics 3.4)

Mathematically able non-engineering students taking first year statistics modules had a different pattern of confidences. Non-engineers with Maths 'A' level and/or GCSE grade A students tended to be more confident in Maths than statistics or life. Unlike the non-engineers with lower maths qualifications whose confidences were similar in ranking to the engineers' but were overall much lower.

Student Group	No. Students	Confidence in Mathematics	Confidence in Statistics	Confidence in Life	More Confident?	Maths - Life Confidence	Like Mathematics	Like Statistics	Like Maths More After Module	Motivation Rating	Would Choose to Study Mathematics
BEng 1st year	15	3.3	3.0	3.7	4.2	-0.4	4.0	3.0	4.0	4.0	83%
BSc 1st year	8	3.2	2.7	3.9	4.1	-0.7	3.3	2.6	3.3	3.4	100%
HND 1st year	6	3.4	3.0	3.8	3.9	-0.4	3.4	2.9	3.7	3.4	50%
Total 1st year	29	3.3	2.9	3.8	4.0	-0.5	3.4	2.8	3.7	3.5	81%
BEng 2nd year	17	3.7	3.3	4.1	4.1	-0.4	3.6	2.8	3.3	2.3	88%

Table 2: Summary of Engineers' Results

Non-Engineers' Confidence:

A level Mathematics or GCSE Grade A students:

Maths > Life > Statistics
4.1 3.5 3.4

GCSE Mathematics Grade B or below students:

Life > Maths> Statistics
3.7 2.8 2.6

In all cases students' confidence and liking of statistics was generally the lowest.

Results of Open Questions

Open questions revealed varied opinions. Engineers attitudes towards studying mathematics were often positive (e.g. 'good attitude, willing to learn', 'positive', 'hard working and positive') but also reflected an understanding that Maths was necessary for engineering (e.g. 'It has to be done so you might as well get on and do it', 'A necessity'). Holding the perspective that 'mathematics is necessary for engineering' appears to override a lack of confidence or dislike of the subject. Whilst not being a complete cure for negative attitudes, it does appear that this *necessity* is a powerful motivator.

For non-engineers their confidence was generally established a long time ago (e.g. 'forever', a long time), particularly at the start of secondary school and during GCSE's. For the Harper Adams engineers some responses indicated a long time/forever(10) or during secondary school(4), but more responses(11) described a change in confidence since learning mathematics at Harper Adams. This was consistent with other responses which showed that some students had gained confidence at university.

Differences in attitude were evident for different student groups, particularly between first year engineers and non-engineers. First year engineers were more motivated: average motivation 3.5 and 83% would choose to study mathematics, compared to first year non-engineers' statistics motivation of 2.7 of whom only 31% would choose to study the statistics modules. This also reflects a difference between learning maths and statistics.

A common student comment was that more practise would improve their learning. Approaches which appear to help improve student motivation are: to emphasise the necessity and relevance of the module, and practical applications. First year non-engineer statistics students had a very positive view towards the use of computer tools (Excel), which was the most common feature which students considered had helped their learning.

Second year engineers commented that aspects which helped their learning included: clear examples, mathematics support, linking the maths to practical work and real situations, doing the work and good teaching. The majority of second years considered that their confidence and ability had increased since the first year, partly due to use and practise (e.g. 'improved confidence because use all the time') and also due to teaching received, with the mathematics support mentioned specifically.

CONCLUSIONS

- Harper Adams Engineers were generally found to have good to medium confidence in their mathematical ability at the end of their first and second years of study.
- Comparing engineering students' confidence in their ability in mathematics with their confidence in Statistics and Life in general gave on average:
- Confidence in Life > Mathematics > Statistics
- Many engineers' considered their confidence in mathematics to have changed and improved whilst at this university. Others considered their views to be long-standing.
- The majority of Harper Adams engineers, 81%, would choose to study mathematics, whereas for non-engineers only 31% would choose to study statistics
- A common motivating attitude of the engineers was '*Maths is necessary', 'has to be done'*
- Features cited by students as having been helpful, and improved their confidence and ability, included Mathematics support, doing examples, good teaching and links with practical applications of the mathematics
- The questions posed to students relating to confidence: overall, by topic and for applying topics, appear to have gained meaningful responses.
- Students' mathematics qualifications were shown to have a significant effect on marks

Can the findings of this study be generalised and applied to the wider teaching of university engineering mathematics? In particular, are these findings from a small institution, with small group classroom style teaching and diverse student intake, generalisable to other universities where mathematics is often lectured to large groups followed up by smaller tutorials classes? The *necessity* of mathematics for engineers as a motivator for students and the features listed by students as helpful (namely: doing exercises, clear teaching, mathematics support and knowing practical applications of the maths) are not only applicable to the institution studied. Similarly, the inter-relations between past and current success, and experiences, with confidence and liking of the subject do also have wider relevance. Thus these findings, which one might consider generally consistent with common-sense about teaching mathematics, could potentially be applied to the wider university teaching of mathematics to engineers.

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REFERENCES

1. **Mustoe, L.**, 2003. *Foreword to Maths for Engineering and Science.* LTSN MathsTEAM. 2.
2. **Ernest, P.**, 1991. The Philosophy of Mathematics Education. London: Falmer Press. In: Ernest P., The Mathematical Attitudes, Beliefs and Ability of Students. '*Maths for Engineering and Science*'. LTSN MathsTEAM. 4-5.
3. **Kent, P. and Noss, R.**, 2003. *Mathematics in the University Education of Engineers*. [On-line]. The Ove Arup Foundation. Available from: http://www.theovearupfoundation.org/arupfoundation/pages/download25.pdf [Accessed 4 February 2006].
4. **Brown, M., Bartholomew, H. and Rodd, M.**, 2003. *An examination of one Group of Failing Single Honours Students in One University*. MSOR Connections. 3 August. 17-20.