ADAPTING TO ENGINEERING EDUCATIONAL AND TEACHING CHALLENGES

K. D. Dearn*1, A. Tsolakis1, A. Megaritis2 and D. Walton1

1 School of Mechanical Engineering, University of Birmingham, Birmingham B15 2TT, UK.
2 Mechanical Engineering, School of Engineering and Design, Brunel University, West London, Uxbridge UB8 3PH, UK.

Abstract: The widespread reduction in teaching hours and increase in student numbers has resulted in pressure to reduce syllabuses. The increased number of students with varied cultural background and the need for multi-disciplinary teaching in order to reduce teaching duplication and costs, introduces the need for teaching innovation and teaching methods that are effective. Difficulties are also arising in providing academic support particularly in tutorials. Even worse, a cultural situation is developing where the expected work levels for students are vague. This paper addresses these issues and looks at how syllabus contents in core engineering modules can be retained by concentrating on student self-learning. Three phases of student centred learning are proposed. First is the subject material itself and how this needs to be written and presented to the student. Engineering encompasses fast advances, new technologies and applications that need to be integrated within the modules, while still equipping students with fundamental knowledge as well as communication and interpersonal skills. The second is a preliminary tutorial system in which students, working in student centred learning groups, start by answering broadly based questions designed to test their understanding of the subject before attempting the third phase, that of solving traditional type tutorial questions. Educational advantages that merge traditional methods of engineering education delivery with new and innovative methods, are described in this paper. It also includes details on the deeper understanding exhibited by students, illustrates a greater student involvement and enhanced tutorial support, as well as staffing implications and problems encountered.

Keywords: Student-centred, small group, learning, formative assessment, diversity

*Correspondence to: Dr K D Dearn, School of Mechanical Engineering, University of Birmingham, Birmingham B15 2TT, UK, E-mail: k.d.dearn@bham.ac.uk, t. +44 121 414 4190

1. INTRODUCTION

This paper describes a development in engineering education where the aim has been to overcome several problematic areas arising from large student group sizes, modularisation, perceived changes in undergraduate study patterns and increased cultural diversity in the student body. The development recognises an intermediate stage in learning in between receiving information and attempting to apply it- that of actually understanding what is being taught. This has implications about the manner in which subsequent tutorial sessions are held. In this respect, the whole emphasis is placed on self-learning, aided by what are referred to as Student Centred Learning Groups (SCLG’s). The paper discusses the methods tested within the subject areas of
Mechanical Engineering Design (MED) and Thermo-fluids (ThF), including the style and production of student self-learning packages and the setting up of distinctly different tutorial systems to cope with the change in learning emphasis. The benefits, to the student, the lecturer and the institution are described as are problems that have been experienced.

2. BACKGROUND TO THE CHANGES

The School of Mechanical Engineering at the University of Birmingham runs four distinct undergraduate programmes. Within the mechanical programmes “core” subjects are taught through all three or four years. Specialisation or options are offered in level 3. MED and ThF along with mechanics, structural mechanics, and control are non-optional, core topics. In the second year, the subjects are split into a theoretical study of machine elements, design practice component and ThF.

Before the current system, MED and ThF were separate courses comprising individually of a 72 hour contact time with a three hour examination. Each syllabus covered a wide variety of topics in great detail. Changes to the syllabus and the professional engineering institution accreditation requirements meant that extra material was included in the programme. This halved the contact hours for each syllabus. This reduction in time meant that a number of topics had to be taken out, but overall it was still possible to run the course in the same way. Still further rationalisation, caused by broadening the practical design and laboratory components of the course led to the theoretical elements being reduced to 24 hours. The material was taught for two hours a week for one term, with the examination being merged from MED and ThF at the end of the year, six months after the students had completed the course, not a satisfactory arrangement.

The reduction in hours then created problems which could not simply be solved by removing more material. It was recognised that certain of the easier topics could be replaced by student learning packages, with students teaching themselves backed up by traditional type tutorials. One interesting aspect of the change to part self-learning was that in the examination, a large proportion of the student body answered questions related to the self taught component. This indicated that either students were answering questions perceived as being easier than others or that the student centred learning (SCL) was leading to a better understanding of the material and a higher confidence in problem solving.

The final changes instigated as a result of the shift towards a modular system, resulted in MED being dropped from final examinations, replaced instead by a form of continuous assessment. In a similar manner thermodynamics, fluid mechanics and heat transfer were amalgamated into one course, common for all engineering disciplines and of a significantly large attendance (approx. 300). This also induced a similar replacement of part of the examinations with continuous assessment.

One of the benefits of these changes for ThF, was the reduction in staff teaching time, by approximately 60%, as a result of the duplication of repeated lectures and material for students of different engineering disciplines. The changes in MED allowed for only one hour per week for one semester (12 contact hours) to be devoted to elements of machine design. The choice was either to drop the subject altogether and pick up the missing topics in the third year course, or re-
think how the most important parts of the course could be delivered to students in an efficient manner. We were reluctant to drop the course altogether as we believed that the material is invaluable for mechanical engineers.

To support the change in learning, the School increased the entry requirements of incoming students by 20 UCAS points and asked specifically for Mathematics and Physics A-Levels or equivalent. In the student’s first year an additional 10 credit module to reinforce maths and physics principles was introduced, in order for the students to refine their skills.

3. CHANGES IN LEARNING

To put the changes into context, consider the situation at UoB in recent years. In 1990 there were some 40 students, in total (approximately 80% Home, 20% from overseas), per year, studying mechanical engineering. By the year 2000, this number had increased to 100 in level 2, and by 2010, to 180, representing an increase of nearly 350 per cent. The growth in students has not been backed by anything like equal increases in either staff resource or provision of housing (That is not to say however that the teaching facilities, such as audio/visual equipment and support, have not improved beyond recognition). This presents two major problems relating to lectures and supporting tutorials. From a student perspective, the large groups make tutorial sessions particularly difficult to manage. At staff/student meetings the majority of criticism surrounded the issue of inadequate tutorial provision.

A recent statistic [1] revealed that in an average undergraduate lecture in mathematics, only 20 per cent of the student group was actually following what the lecturer is saying. Most students were simply taking down the information. If this information is true then it is probably also true of lectures in engineering science, i.e. for whatever reason, only around a fifth of the students understand what the lecturer is saying. If this is so, then the “standard” lecture is a relatively inefficient means of transferring knowledge.

Many educationalists would argue that the best method of learning is to teach yourself [2]. Even if this philosophy is wrong there will be many, many occasions when one will have to learn or teach oneself. While a lecture might be a useful system to impart knowledge it often fails for a number of reasons, such as:

- Students learning at different rates,
- Language difficulties can prevent students from concentrating on the material,
- Difficulty in identifying key-points for all students (dependant on background)
- Not all students can concentrate for 50 minutes, less so for several lectures in succession
- The student might just miss that critical lecture.

Even if some material is retained, most find it necessary to re-read their lecture notes before attempting tutorial sheets. Learning by direct reading is efficient because the student learns when they want to and at their rate. We looked at replacing the traditional lecture based course by a student centred learning approach based on the following strategy:

- Replace lectures with purpose written self-study material.
• Use a few hours only to introduce each new topic, using slides and overheads to show examples. Distribute study material with instructions to read and understand it.

• Set up Student Centred Learning Groups (SCLGs), with a maximum of 6 to a group, encouraging co-operative learning.

• Divide these groups into four divisions, each division having their own room and tutor.

• Devote one tutorial session to a discussion of the material presented in the study guide. The SCLGs are encouraged to work together to explore their understanding of the topic. The self-study material is interspersed with (largely qualitative) questions to stimulate and guide this debate. The tutor is on hand to provide hints and to structure the discussion. This is efficient use of time because the tutor will always be talking to at least six students. Where common problems and misconceptions are highlighted, the tutor can address the whole class. At the end of this session, a problem sheet is distributed, typically containing six to ten numerical questions designed to enhance understanding and to develop problem solving skills.

• Devote a second tutorial session to a more traditional problem class in which students are helped with their numerical work. The students continue to work together in their SCLGs. In many cases the students can help each other to work through the questions. Where necessary, the tutor can assist a group or the whole class.

• The process is repeated with the introduction of a new topic and the distribution of a new set of self-study material. After the completion of two topics, the students sit a test. The process then starts again for the next two topics.

• The approach reinforces our requirement that for every timetabled hour the student shall put in at least another hour of their own time.

• Self study is promoted by including research (journals and technical papers) and industrial and governmental reports references in addition to standard text books. SCL is also supported by industrial visits, seminars and workshops that include both pedagogical and engineering expertises.

The approach differs from that described by [3] in that the students do not necessarily report back to the teacher, although when they do so the other groups are able to hear what is being said and so gain from seeing what alternative solutions (and problems) others arrive at. The method is similar to that of Bligh [4] in that the tutor is permitted to join the group and help in the discussions if requested. Recognition was made of the useful experience of resource-based learning (RBL) [5] particularly in respect that if you take a conventional course and simply replace some of the teaching with a learning package without making any other changes, this is unlikely to produce a very effective or enjoyable alternative. The approach taken by the authors meets the requirements of resource based learning in that the course design involved different uses of the students’ time, different learning activities, different assessment, different uses of class contact and new and independent learning skills. Similar too, are the use of mainly electronic materials, written and collated by the tutors as a substitute for some aspects of teaching and library use. Our approach makes use of computers in the same manner that McDonald [6] has made use of integrating computer-based skills with functional teamwork and communication, skills embodying cooperative learning and in the way that Heffer et al [7] has used student centred learning developed for IT in overcoming problems of coping with the dramatic increase in student numbers.
The principal learning mechanism described in this paper focuses on full-time, campus-based students. It seeks to instil a cooperative (with both fellow students and academic staff) but ultimate student driven learning culture that exploits the understanding stage of the learning cycle, through in part use of online-based learning resources.

4. CHANGES IN UNDERSTANDING

As previously stated, a major objective of this shift to student-centred learning was an enhanced student understanding of the material presented. This is achieved by the inclusion of challenging qualitative questions in the study guides and the first tutorial session devoted to a discussion of the topic. It is the authors’ intention that the questions should not impede the students’ progress through the material. They are instructed to pass over questions that they cannot answer and to discuss them later in their SCLGs. Some of the questions encourage the students to challenge the statements and assumptions in the study guides. The learning material is also integrated with the tutor’s personal research and research from the wider school.

5. CHANGES IN TUTORIAL SUPPORT

By organising students into small groups and encouraging them to discuss engineering topics more widely, the role of the non-lecturing tutor is extended. On traditional courses, tutors are often post-graduate researchers who are familiar with the problems on the tutorial sheets and are able to give students individual advice on mathematical techniques. Under this new system, tutors are expected to provide a deeper background to the subject as well as to coach skills. They must also be ready to intervene pro-actively rather than wait for requests for assistance. This requires a certain time overhead for the main teacher to ensure that the tutors are fully conversant with the material and that they understand the teaching objectives of the sessions. This is made easier if more than one member of academic staff is available to team-teach the subject although, clearly, this will not always be possible. Nevertheless, good tutoring is a vital component of this method - it is most certainly not the author’s intention that student-centred learning in this context should be synonymous with remote learning.

6. CLASS TEST

Class tests now replace part of the examination (fully replaced in the case of MED). The tests have been designed to contain the questions on one side of a sheet of paper and for the other side to be used for the solutions. Extra sheets are provided if needed. They assess learning but also test the conceptual understanding of real life engineering problems that require both an understanding of fundamental engineering theory and the context of the actual problem. Setting the tests in this manner, means that the student cannot take the sheet away so they can be used again in the future. The questions vary in difficulty, which enables all students to provide solutions to some if not all the questions. In this way the diverse nature of the cohort can be offset (i.e. to assess fundamental knowledge rather than ability to read quickly in English). Immediately after the test is over the students are shown correct solutions. This provides instant feedback and means that marking the tests can be more relaxed. Tutors mark their tutor group using a common mark sheet. This means that marking the test papers is not an onerous task. It
also indicates weaknesses in the understanding of the students, providing a positive feedback mechanism for the course material.

7. PROBLEMS

In addition to the resource problem there were some other aspects of the course that can be improved for next year. From the students’ point of view the most common difficulty was lack of time to complete the material. The course was organised in such a way that each of the four topics covered was allocated the same number of hours, although some topics were more lengthy and demanding than others. The twelve contact hours were diminished by the need to run the class tests. In future it is hoped that these tests will be scheduled outside normal class hours to provide two additional tutorial hours for the larger topics.

Some students felt uncomfortable that they were not tutored by the main course lecturer and suspected that those who were might have an advantage. In future years, the main lecturer will tutor a different division each week and a set of minimum learning outcomes for each session will be agreed by the tutors to ensure a more even presentation of material.

At the start of the course, some students did not prepare for the tutorial sessions and for them the classes had little value. This is in part due to the students’ lack of experience of this type of learning. This lack of experience also requires that a significant proportion of teaching time must be devoted to explaining the philosophy of the teaching approach and the importance of private study. As these methods gain acceptance in the School, it is to be hoped that the students will be more accustomed to them.

The students expected the class tests to be more difficult than they eventually found them to be and devoted much study time to revision. This reflects the mode of working encouraged inadvertently by other teaching methods - that of last minute cramming. The broadly-based class tests had the major advantage of highlighting deficiencies in student understanding. In one case, the vast majority of students revealed a consistent misunderstanding of a particular mechanism. This indicates a shortcoming of the original material which can be corrected. It also provides the teacher with the opportunity to provide feedback and correct this misapprehension. A narrower examination may not have revealed such problems.

8. FEEDBACK

A detailed post course review, in which students are questioned on a variety of issues relating to the module they have just completed (principally for QAA purposes. Results from three of the seven questions asked to students are shown below. These questions relate to in interest, understanding and intellectual content of the module.

[Relating to the figure below: Did you find this module intellectually challenging? (a. It was extremely challenging, b. Yes - but I coped, c. It was pitched at the average student, d. It was not at all challenging, e. No. It was a challenge to keep awake!) Do you feel that your understanding of engineering has been increased? (a. Yes, b. No, c. I am even more confused) Did you find the module interesting? (a. Yes - all the time, b. Yes - most of the time, c. Some of the time, d. Generally no, e. No)]
Figure 1 Student feedback comparison 2009-10 with 2008-09
9. CONCLUSIONS

Under the traditional system a lot of teaching staff time is spent on lecturing and in lectures. A lot of student time is spent on attempting tutorial questions. Similarly, a lot of teaching staff time is spent on writing examination papers, moderating and marking them and attempting to tutor, while for the students a lot of time is spent learning and revising. At the end the only feedback is the examination mark.

Under the system described in this paper, the emphasis is on student centred learning for both basic understanding of the course material as well as self tutoring. When tutorial help is needed the fact that the tutor is speaking to a group means that the tutorial advice is efficient in terms of student/staff ratios. The key finding of this renovation of teching has been:

- Contact hours were reduced without loss of content
- Teaching efficiency has increased (tutor and student time was used more efficiently)
- increased student understanding of module content (as shown by average marks increase of the mcq class tests)
- encouraged a more uniform learning process
- Post graduate tutors learn to tutor at a deeper level
- Students take on more responsibility for their own learning (students welcomed the approach)
- students liked being given the opportunity to discuss the subject and being asked broad questions before having to attempt detailed analytical tutorial question sheets,

We believe that the method leads to good learning habits. There is a more uniform learning process with less cramming because in order to achieve good marks the student must learn and apply their knowledge throughout the courses.

10. REFERENCES