University of Strathclyde
Engineering Mechanics Case Study Report

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Overview/ About the Class

Engineering Mechanics is a core first year class delivered to approximately 250 students. Because of accreditation requirements of the professional engineering institutions, similar classes are delivered to all students across the UK who are undertaking degrees in Mechanical, Civil, Chemical, Design, Manufacturing, Ship and Marine, and Architectural Engineering. To this end at the University of Strathclyde Engineering Mechanics is a compulsory course delivered to all students on accredited degree programmes in: the Department of Mechanical Engineering; the Department of Design, Manufacture and Engineering Management; and the Department of Naval Architecture and Marine Engineering. Between these three departments there are approximately 12 different degree programmes. Of the 250 students half are Mechanical Engineering, the rest of the cohort being made up of students from the remaining two departments. Engineering Mechanics is split into two cohorts, one of Mechanical Engineering students the other the remaining students.

Engineering Mechanics is a 20 credit (10 ECTS) class which is delivered in two hour sessions twice a week over two semesters (a total of 96 hours). As well as this students are expected to spend 32 hours on assignments and 72 hours engaged in private study. Four tutors are assigned to this class the year being broken into two cohorts: one of Mechanical Engineering students, the other being made up of students from the remaining departments. Two tutors are normally present in each of the classroom and tutorial sessions. All four members of the teaching team have roughly the same workload profile sharing lecturing and assessment responsibilities.

The class is designed to introduce students to the basics of mechanics for engineering applications. All the students entering the class have the basic understanding of mechanical principles acquired from high school courses in mathematics and physics together with their application to very simple problem solving. Engineering Mechanics focuses on the practical skills required to apply basic mechanical concepts to real engineering problems. Consequently, the class has been designed to introduce students to very structured problem solving and to emphasis a conceptual understanding of mechanics.

Topics covered in Engineering Mechanics comprise: One-and-Two Dimensional Kinematics; Newton's Law of Motion; Work and Energy; Linear Momentum; Rotational Dynamics; and Statics. Generally in Engineering Mechanics a topic, like Statics, is tackled over a number of classroom sessions followed by a tutorial. Because of the nature of the sessions a strict timetable is not adhered to, instead an adaptive approach is used whereby the pace of sessions is dominated by the speed in which students demonstrate attainment of concepts.

Students are assessed with eight homework exercises and two class tests. The homework exercises have a weighting of 30% (calculated from the six best homeworks submitted), while the two class tests are both weighted as being 35% each. In the second semester students who have missed homework submissions or have preformed poorly in the first semester are allowed to submit additional 'catch-up' homework for each topic. The pass mark for this class depends on the degree programme being studied. Students on the professional accredited MEng degree programmes, the majority of students, have to attain 50% or above. All other students only need 40% or above to be awarded a pass.

The class tests are 2 hours in duration and are set at the end of each semester. The class tests are split into two parts with a 50:50 weighting. The first part of the test is compulsory and contains 'concept' questions. The second part is based on problem solving questions related to each of the topics covered in the semester. Each topic is weighted equally and students only have to answer two of the available questions. Both homework and class tests are returned to

students with grades and comments. For the first class test there is also a 1 hour review session where common mistakes are addressed.

A problem solving framework of 'multiple representations' (pictorial, conceptual and mathematical) is used to grade both homework and class tests. In this framework students are required to submit answers using pictorial, conceptual and mathematical representation. For example, if a student only submits a mathematical representation of the solution (which is the primary method they would have been taught at school) then they will only be awarded 8 out of a possible 25 marks. A system of 'effort-based' marking is also applied to both homework and class tests whereby students receive 5 marks for a complete solution, decreasing if bits are missing.

Ten years ago the Department of Mechanical Engineering embarked on a redesign to radically change its teaching methods for first year students. The New Approaches to Teaching and Learning in Engineering (NATALIE) project introduced active and collaborative learning into the large lecture room through the use of Peer Instruction developed by Professor Eric Mazur at Harvard University. The physical teaching space was also redesigned to allow students to work collaboratively in this new style of teaching. Rooms were refurbished to allow group seating and an electronic voting systems (EVS) was installed (Initially ClassTalk subsequently replaced by InterWrite PRS).

Under this variation on Socratic Dialogue ('teaching by questioning'), the traditional lecture was replaced with 'active-learning' sessions which are a mix of mini-lectures, videos, demonstrations and problem-solving which are all linked together by classroom questioning and discussion. These two hour sessions are designed to aid learning through cognitive conflict and scaffolding.

A typical peer instruction class begins before the timetabled session, students being directed to background reading from the class custom textbook "16132 Engineering Mechanics – 1" published by Pearson. As well as this students are also directed to complete pre-class web assignments which have warm up questions and puzzles related to the planned in-class activities. Responses to the pre-class assignments are used diagnostically to inform the focus of the classroom teaching (Just in Time Teaching, JiTT).

Once in class a typical session begins with the tutor/lecturer giving a short explanation of the topic which is going to be covered. This explanation might be delivered using one of or a number of different methods such as a mini-lecture, video or demonstration. This is followed by a multiple choice question (MCQ) which explores the students' conceptual understanding. Students' individual responses to this question are collected using an electronic voting system which comprises of handsets wirelessly linked to a computer. The computer collates the student responses and presents a bar chart showing the distribution of the students answer. If there is a disparity in the responses students are asked to 'convince your group that you have the right answer'. The resulting peer discussion is designed to let students explore their own thinking and reasoning behind their answer and to reinforce their understanding of the concepts they are addressing. The discussion also provides an opportunity for students struggling with concepts to get a 'decoded' explanation from their peers. Following the peer discussion students are asked to vote once again on the same question or on a slightly different question on the same concept.

Other strategies used by the tutor to facilitate peer discussion include asking individual students to give an explanation of their answer, whether it be right or wrong, the tutor then opening the debate to the rest of the class to support or oppose the explanation. Again responses to the MCQs are used diagnostically. If the tutor finds the vast majority of the class has fully grasped a concept they can move onto another topic.

Original Drivers for Change

Over the last ten years the delivery of Engineering Mechanics has been transformed, the teaching methods employed within this class radically changing. In contrast the assessment methods remained fairly static with a reliance on workload intensive written formative and summative assessment. While students appeared to have greatly benefited from the self, peer and tutor feedback afforded by the peer instruction sessions, the traditional assessment regime was still focusing students on the principal goal of 'passing' assessments. The primary driver for change within Engineering Mechanics was therefore to implement a suitable assessment strategy which emphasises the process of learning rather than the product.

Aligned to this was also the recognition that not only did the students need an improved framework for time-on-task, but the tutors also needed to address the amount of time spent marking homework and class tests, an activity which might have had marginal benefits for enhancing the students' learning experience. There was also a strong argument that tutors' time would be better spent engaging with students rather than pieces of paper. By engaging with students it was believed that retention rates would be improved. Retention is not an issue for the Mechanical Engineering class but it is for the other class which is made up of students studying mechanical related disciplines. In this 'service' class there are limited opportunities to engage students with failing motivation elsewhere. A previous trail of providing online support through discussion boards prior to class tests indicates that this would have a positive impact on retention. The issue here was however deploying an already overstretched teaching team.

Phase 1 Pilot

During phase one of the pilot a new online intelligent homework system was implemented as a replacement to the traditional paper based homework. In parallel to this certainty-based marking (CBM) with EVS was also piloted. CBM has been shown to enhance students' responses to MCQs since they also have to give their confidence (certainty) in their chosen answer on a scale from low to high. The students' confidence rating has a direct impact on the mark they will receive. CBM is designed to promote meta-cognitive thinking, forcing the student to reflect deeply on the level of certainty they have about their own knowledge and understanding.

CBM was piloted as formative assessment with the intention of it eventually being used for summative assessment. For the purposes of the pilot each of the two student cohorts were given a one hour MCQ test. Tutors spent approximately 30 minutes explaining the principles of the CBM before the students began the test. Students noted their response for each of the MCQ's on paper before entering their answers via EVS for automatic grading.

About the technology:

The online intelligent homework system piloted was *'MasteringPhysics'*. The technology and methodology behind MasteringPhysics was developed by MIT and is now marketed by Pearson Education. MasteringPhysics is the first Socratic tutoring system which allows students to work through homework problems in an intelligent series of steps with hints, questions, alternative sub-problems and instant automated feedback/commenting. The benefit of this guided approach to assessment is the focus is on the process, students working towards a solution using graded steps, rather than the product, the completed homework exercise.
Furthermore, MasteringPhysics allowed tutors to design homework exercise using a databank of thousands of pre student tested questions. This meant that tutors could concentrate on engaging with their students rather than spending hours designing homework exercises.

Online homeworks were designed to tie in with topics being presented in class. Initial evidence showed that the students were spending considerably more time and effort on the new homework exercises. Because the online homework system automatically grades students work, staff marking time was reduced from 4-5 hours per written homework to almost zero. The time tutors spent on homeworks was primarily spent on analysing student activity and grades (which was primarily for the purposes of the pilot). Because of the increased time on task and improved mastery of learning the second class test was reduced from 2 hours to 1 hour.

Evaluation

First year students were given access to the online intelligent homework system from the beginning to the end of their second semester (January 2006 – April 2006). Over 12 weeks students complete 4 online homeworks. As part of the submission for each of the homeworks students were given the opportunity to included comments which were collected by the class tutor. All the students' actions (mouse clicks, keyboard entry etc) were also recorded for analysis. Anecdotal evidence from students was collected during class sessions pertaining to the homework system and CBM MCQ tests.

Initial responses from students indicated that students adapted well to the online homework system. Feedback indicated that the main areas in which students had problems were: the understanding of the question being set because of the Americanisation of terms; and using the equation editor to enter mathematical notation. The implementation of CBM produced unexpected results. In particular the distribution of expected grade and actual grade were misaligned, some student even receiving an overall negative mark. The initial analysis indicated that because CBMs use radically different grading regime, students have not had enough time to develop their own personal response strategies.

Jim Boyle elaborated on the impact of the phase 1 changes

> *Up until the start of the REAP project, homework exercises, more or less on a fortnightly basis, were highly structured for a problem solving strategy that was specified to them and as a consequence of that academic staff had to mark them every two weeks but we marked on a system called effort based grading so they were graded on effort but the effort being, did they followed the problem solving strategy rather than on whether they got the right answer, but that of course was a big burden. It took up the time of the academic staff to mark 250 course works every 2 weeks. The effect on the academic staff of course was that didn't have the whole class to mark. Because the students were spending a lot of time on Mastering Physics, we just gave them a 1 hour class test and the impact on the academic staff member of course was that it was half the amount of marking for a 1 hour test instead of a 2 hour test, which essentially meant that we could mark it in 2 days instead of 4 or 5 days, full days.*
>
> *Students commented when we asked them about tutorials that they had to come to the tutorials to get help but the help away from tutorials MasteringPhysics was that it was quite good because they could get support without having to talk to someone and because the system itself supported them with all the sub-questions and hints. The effect on students seemed to be really positive. We had a lot of comments saying that they really liked working in that system. We did some PRS questionnaires at some point towards the end of the second semester and asked them how much they liked them using Master in Physics. They felt very strongly that it helped. They did like the system but said they didn't like the Americanisation of it and would have liked it to be tied into the textbook more. Unfortunately our textbook is conceptually based whereas the one used for Master of Physics is algebra based.*

Phase 2 Pilot

Following on from the success of the pilot for the next academic year it was planned that the MasteringPhysics online homework system would be fully implemented in both semesters and both class tests would be reduced from 2 hours to 1 hour. However in a change to the original plan, WebAssign was chosen as the on-line homework system to be implemented in the session 2006-7. As Jim Boyle explained

> *What happened over the summer of 2006 was that we had been using MasteringPhysics for free and that was the way it appeared to work with it, if you wanted to use it free, you could work with it for a year and all their experience is that once people use it they can sign up to it but when we asked Pearson the cost of it, well they promised us it would be tied into the costs of their textbook for this current academic year but they said that it was going to be delayed for a year and the cost that they were proposing we thought was excessive. Then we were contacted by WebAssign to say they had a different type of system and it was considerably cheaper than MasteringPhysics, which is a learning system whereas WebAssign is a testing system although randomised so that the students can get something different. So we decided for the second year of the REAP project to use WebAssign. We didn't do a big high profile thing of WebAssign this year as we did for MasteringPhysics, like videos that showed them all of the research that has been done. This year we jut said it do your homework online and that was it. We purposely didn't do a big sell on it and just said we want to see what your reaction to it is. From the academic staff point of view it's roughly the same I mean we've had absolutely no homework at all to mark this year.*

While the use of CBMs was inconclusive in the pilot it was intended that these would be trailed again in 2006-7. It was believed that many of the issues encountered with the CBM were as a result of students not having enough time to adapt and normalise to the new marking regime. Plans included adapting some of the existing MCQ questions provided by the publisher with the custom course textbook with CBM. This revised question bank was to be used as part of the *Just in Time Teaching*, already employed as part of the Engineering Mechanics class.

However the plans to use CBM with this year's cohort have been stalled, as Jim explained,

> *This year we did it twice with the students and they didn't react very well to it, not what that means is that we need to spend more time thinking about it plus we need to be spending more time telling the students what it's about.*

Future plans include looking at the possibilities of setting it up on-line with CBM built into multiple choice questions on WebCT. Jim elaborated,

> *We looked at that last year for WebCT in that it came with a textbook e-pack but the way Pearson do things, all the MCQs that they had were all posted on, although they tell you, you get a WebCT e-pack, in fact it's an e-pack that points to a Pearson site and you can't change the Pearson site so we couldn't modify the MCQs to put in the level of confidence but we think in reviewing what we are going to do next year, we think what we will try to do is to put a little CBM package into WebCT which is easier I think. In the WebCT quizzes that you can create in five minutes, as far as we can see we can have an instant code to allow the students to put in their confidence levels as well so we'll just do that next year and see how they get on with formative assessment.*

Evaluation Methodology

Qualitative anecdotal evidence was collated from course leader interviews, two student focus groups, and class grades averages were compared across cohorts for sessions 2005-6 and 2006-7.

Course redesign in relation to David Nicol's 7 Principles of good feedback practice & Gibbs & Simpson's first 4 conditions of good assessment practice

Principle 1: Helps clarify what good performance is (goals, criteria, expected standards)

Exlpicit criteria

The online intelligent homework system *MasteringPhysics'* piloted in Phase 1 allowed students to work through homework problems in an intelligent series of steps with hints, questions, alternative sub-problems and instant automated feedback/commenting. The focus was on the process, students worked towards a solution using graded steps, rather than the product, the completed homework exercise.

In terms of highlighting specific learning outcomes, the course leader emphasised the conceptual basis for the course and explained how specific learning criteria may not be appropriate in this context,

> *They are told about a particular learning outcome as something that engineers do, not as a particular learning outcome but as a thing for engineers.*

Expected standards

The expected standards of the homework assignments are variable as Jim illustrated,

> *What we do is we take the best out of ten, because students have others things to do so we know that sometimes they can't do the homework so sometimes they miss a homework assignment or 2 so of the ones that have been doing assignments consistently they are getting close to full marks for it. What we don't know is, when the problems are coded in WebAssign they can see the coding and it's easy, it's the same in the title, it's easy, moderate or difficult and we do a mixture of all three of them and we usually do at least two difficult problems and they seem to be understanding the difficult problems so they are not e-mailing us or standing in class telling us stop using this, we want to do something else, but the issue for us is we don't have contact with them and we don't know where they are getting the support from because normally they get their support from the tutorials. Some of them do come to the tutorials to ask questions but the vast majority of them don't. Now I don't know whether that's a good thing or a bad thing.*

Goals

Students are provided with limited discussions about their career goals at the first year stage as part of a longer term view on their development, as Jim elaborated,

> *They go through an induction as part of their personal development plan, they go through the induction but what we decided in this department with our students because the majority of them were staying with us for 5 years is not to through career at them in year 1, but to do it in year 2, that's when they start to come to the professional studies class (PDP). We think it's just too far away you now it's 5 years*

away and they've just come to start, most of them don't know what they want to do and so.

Student and tutor perspective on goals, criteria and expected standards

Students in group 1 considered the homework assignments, written questions in class and end of chapter questions to provide clear criteria for what would be expected of them in the exam. However while group 2 students agreed that the criteria were clear, one student questioned the loose interpretation of expected standards across the class. The students in group 1 felt that the similarity between the homework questions and the exams provided explicit criteria for what would be expected of them in assessment. This was reinforced by additional preparation assignments. One student commented,

We always get written questions in class, we always get a written one at the end but they've also got to be handed in and marked by a tutor so we get them every so often as well.

In addition, there was an abundance of end of chapter questions in the textbook, which students believed to be very useful for their assessment preparation. One student in group 2 indicated that although the criteria were clear, the expected standard was open to some degree of interpretation by the students. As he described,

You can either think full marks is good or ah I've just lost a couple. It's really up to your own discretion.

Principle 2: Facilitates the development of self-assessment (reflection in learning)

Access to the online homework system gave students the opportunity to not only receive feedback as a result of an assessment, but through the automated Socratic dialogue students also receive continual feedback during the assessment and were able to immediately self correct. This way students didn't have to wait until they receive feedback from their tutor to have their misconceptions clarified, instead gaps in knowledge were addressed immediately and lead-on tasks were not impinged.

Student Perspective on Self-assessment

Students in the focus group expressed appreciation of all of the on-line facilities available for their ability to induce more reflection than a traditional lecture based course would as well as for their efficiency and learning value.

Principle 3: Delivers high quality information to students about their learning

Initial responses from students indicate that students adapted well to the online homework system. Feedback indicated that the main areas in which students had problems with the MasteringPhysics system were: the understanding of the question being set because of the Americanisation of terms; and using the equation editor to enter mathematical notation. These problems have been addressed by the switch to WebAssign so that students this year received clear and timely on-line feedback throughout the year.

Student Perspective on On-line Feedback

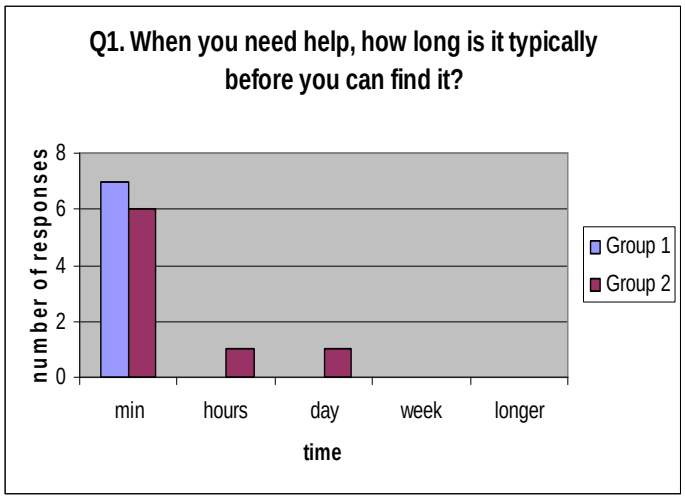
Students in group 1 liked the immediacy of feedback and the hints to how close they were to their desired performance but students in group 2 found this a little frustrating and wanted more formative feedback on performance.

Students liked the timeliness of the feedback on the WebAssign, with one commenting that they preferred it to the more traditional format,

> *Because you do get feedback right away and you can try it a couple of times and try different methods'* and another student claiming, *'I'd say pretty much everything I've learned in that class has been from WebAssign because it's very easy to sleep through lectures but when you've got the homework to do, there's not really any avoiding it*'.

All of the students in group 1 and 75% of students in group 2 indicated in their questionnaire responses that help was available within minutes and at the longest, help would be available within the day (*Figure 1*). The response from both groups to this question reflects the dialogue in the focus groups suggesting that feedback was freely and immediately available from either

Figure 1: Length of time between identifying problem and obtaining help



Students also liked the WebAssign system because it indicated to them how close they were to the correct answer and this was seen a useful way in which to encourage the student to strive to achieve the correct answer. Students in group 2 expressed a desire for more written feedback and when provided, they were equally interested in receiving both summative and formative feedback. In support of some additional written generic feedback one student commented that it would be useful

> *If everybody was getting one question wrong, they posted up a feedback solution or something like that so you could actually see where you are going wrong as opposed to it just being a big cross next to it.*

Another student added that,

> *I think that WebAssign gives you 5 attempts, it would be quite useful if by the 4th attempt you went wrong, it gives you a clue as to where you went wrong to get the right answer rather than continually saying you are between 10 and 100% of the correct answer.*

Principle 4: Encourages teacher and peer dialogue around learning

Tutor/peer verbal feedback

The traditional lecture was replaced with 'active-learning' sessions which are a mix of mini-lectures, videos, demonstrations and problem-solving which are all linked together by classroom questioning and discussion. These two hour sessions are designed to aid learning through cognitive conflict and scaffolding. The course leader did however express some concerns that the shift to electronic support reduced the opportunities for staff dialogue with students, as Jim described,

> *We have lost contact with the students this year. We don't know them as well because we're not chatting to them in tutorial times because they are by and large not coming and we don't mind that if they don't need to come to tutorials to do the web assign assignments, it's just that we don't want to lose that.*

Student perspective of tutor dialogue.

Students in both groups considered there to be adequate provision of help in tutorials when required and attendance was on a need only basis. Low tutorial attendance enhanced the quality of tutor dialogue but comments in group 2 indicated that is several students were stuck on one problem, the system was less effective. Despite the apparent satisfaction with the level of staff feedback and explanation, some of the students indicated in their questionnaire responses that they did sometimes continue to feel stuck enough at times for the problem to hold up their work rate.

Students appeared to be confident that an adequate level of verbal tutor feedback was available to them in tutorials, but most of them only attended them on a needs basis. As one student commented,

> *You can work away through the questions and if you need help it's there from tutors and that and they're more than willing to help and work your way through it with you so that you get a complete understanding of it and the same in tutorials if there is anything after the WebAssign, if there has been any problematic questions, they'll flag that up and work through that as a way of finding mistakes and learning from them.*

The poor tutorial attendance was not as a result of any dissatisfaction with tutorials but rather to high satisfaction with the online homework exercises and the course as a whole. Students seemed to feel very well supported and simply knowing that high quality support was available to them on request was enough to afford them a confident approach to learning. A consequence of this confidence was that they tended to seek staff support only as a last resort as they were confident enough in their peer's capabilities to seek peer feedback in the first instance in response to occasions where they felt stuck in relation to a coursework problem.

The students tended not to attend tutorials unless they required specific help, with one summing up the reason as,

> *I don't really feel I need them generally because you get everything out of the lectures because you have the PRS questions and stuff so if you don't understand you can go and read the textbook.*

Another commented that,

> *I think that the WebAssign stuff pretty much sums up what you've done in the class so you know you're doing ok if you can do that easily enough.*

They also indicated that if they did feel that they were stuck on a problem, they would post questions on the discussion board and would receive answers from classmates. They seemed to be very confident about the competence of their peers in answering queries because they knew that the responses were being monitored by staff and that the tutors would intervene if they appeared to be veering off-track. There was support for the proposition of tutorials being run in labs, although one student cautioned,

> *I think it's a good idea, I just don't think it should be too computer based, I think you need to be able to still write down and still be able t do the calculations manually and still have someone there to give you feedback and it can't become too computer based.*

Again the students in group 2 viewed the tutorials primarily as a means of obtaining verbal tutor feedback if they felt that they needed it but rarely felt the need to attend because as one described,

> *The help's there when you need it so, but most of the information, because the homework is online anyway, you can get most of the information by discussing it in your groups or going on the internet and checking it in your textbooks.*

Face-to-face tutor feedback was highly valued and the students felt that they benefited from the low tutorial attendance because it resulted in them having more on-to-one time with tutors when they really needed it. Like the students in the first focus group, those in this one indicated that if they did get stuck on occasion, they made use of the discussion forums and tutorials to obtain extra help and that this was sufficient for them. However the students did indicate some concern over instances where a large group of students were getting stuck on the same thing as they did not feel that they could help each other then.

There was a mixed response in both groups on the focus group questionnaires concerning the student's work being held by being unable to understand something (*Figure 2*). It is somewhat surprising that three of the students in group 1 agreed with the first statement while expressing during the focus group very little concern about having any difficulties with being stuck. Discussions from the second focus group had revealed that if a lot of the students were stuck on the same thing, the learning process could break down a little and students in this group did also indicate that they would have appreciated a little more written feedback to help to understand how to improve their understanding. This was reinforced by responses on the questionnaire (Figure 3) which indicated that students in focus group 2 were more concerned about getting held by becoming stuck on a problem than those in the more highly performing students in focus group 1.

Figure 2: Degree to which work is held up by lack of understanding

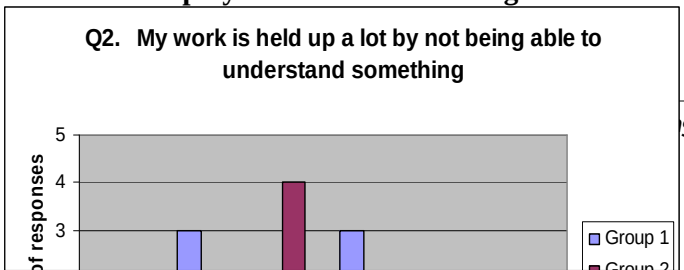
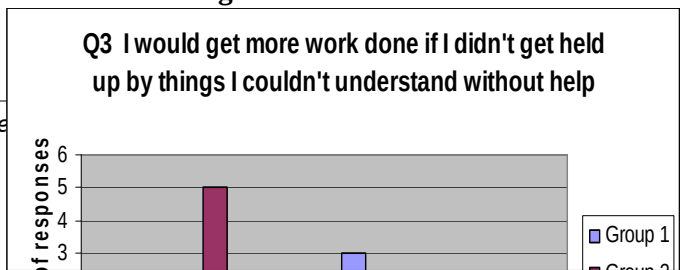
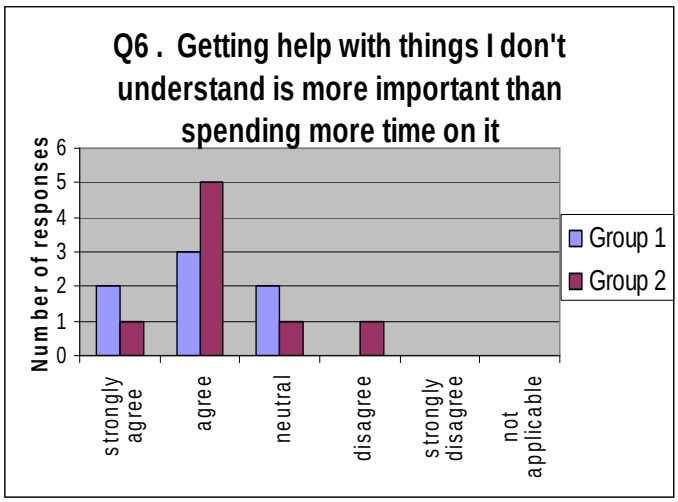


Figure 3: Effect of blocks in understanding



Most of the students indicated on the questionnaire that they agreed that getting help with problems increased their understanding more than simply spending more time on it and this is reflected in the focus group discussions of their use of the tutorials and/or discussion boards when they felt the need for additional help.

Figure 4: Focus group student responses to the relative importance of getting help and time on task



Peer feedback

Opportunities for peer formative feedback have been built in to the course by the provisions of social seating arrangements in a custom built lecture theatre. As Jim expanded,

> *All of our students in Mechanical Engineering are put into a group of four and they are in that group of four in all of their classes and so that group shares a lot with their own group.*

Student perspective of peer dialogue.

Students enjoyed the idea of working in groups as they considered this to be something that they will have to do in their future engineering career. Group 1 students supported EVS use to promote tutor and peer dialogue and to compare class responses in order to self assess. This support for EVS was also reflected in the drawing exercise. EVS was also thought to be useful for providing feedback during lectures and the level of explanation when students did not understand something was considered to be very good. Although the students agreed that the best quality of feedback was from the tutors, they indicated that their first option for

obtaining help would be to approach friends. This included the groups of four that they were split into during the lectures as well as personal friend s or other students on the course who lived close to them. The students also said that they often worked in their groups in the lab to do their homework exercises, although some preferred to do at home because of the flexibility. Students also indicated that they appreciated being able to see their fellow student's scores. Students in both groups felt that they benefited from the experience of working with peers, multiple opportunities for reflection as well as the two week window to complete the task. Students in group 2 also highlighted the flexibility of the system but cautioned that the numerous opportunities for resubmission could reduce effort in some cases. One participant in focus group 1 pointed out that the homework system was effective,

> *Because you can confer but all the numbers are different so you can't copy each other but you can help with the methods.*

Students in both groups tended to seek peer verbal feedback or posted questions to the discussion board if they felt stuck with a problem and the results of the questionnaire suggest that students in both groups generally felt that help was quickly available in some form or another when they needed it and that this help was effective in helping them to progress their understanding. The students in group 2 suggested that they tended to attempt the homework exercises individually and then if they had problems they would join other in their group to discuss it before making another attempt. Again if it was more convenient to do this with students who lived nearby or were good friends, the students were quite happy to work in alternative groups.

Principle 5: Encourages positive motivational beliefs and self esteem

After each of the focus groups had been completed, the students were asked to fill in a short questionnaire and a drawing exercise. For the drawing exercise, the students were asked to draw what they were currently thinking about in the module, give up to five keywords to sum up the issues in their drawing and provide a short explanation of their drawing.

The drawings from group1, which was comprised of a group of highly performing students contained images of friendly looking lecturers, thumbs, students saying *'Ah I understand now'* and references to the lecturers practice of applying problems to *'real life situations'*. Keywords included: *Interactive learning; amusing; interesting; enjoyable; well resourced; excellent tutors; fast paced; challenging; thought provoking,* Explanations included career aims which correlated with the keywords and illustrations, but the illustrations has also been used to convey deeper messages about the students reflections on their learning. While the exercise indicated that most of the students felt very satisfied with the course, they acknowledged that there were peaks and challenges on the course. One prominent feature in the drawings and explanations was that the students appeared to be motivated to a considerable extent by career aims, with one student commenting,

> *I like this class as I feel it is a major stepping stone in getting closer to the career I want as it is one of the most important classes.*

The pedagogical benefits of the interactive software that were highlighted in the focus group discussion were reinforced by a student who had illustrated the lecturer demonstrating the motion of a plane as the only image in the box. This was accompanied by the following explanation,

> *Interactive learning stops my mind wandering and keeps me focussed during the lecture. Another example of this is the PRS.*

The drawings for group 2, which had more of a mixture of students in terms of performance contained images of group discussions, software and a path winding round mountains, a person thinking outside the box and a figure surrounded by arrows pointing in different directions among other images. Keywords included: *Team, unsure, uphill; different learning styles for understanding; hazy concepts and clueless.* In the explanation section students suggested that it is important for them to talk as a group and engage in peer work outside of class. This reflects the general enthusiasm for social networking and peer support that was strongly voiced in the focus group.

The course appears to have inspired some *'thought'* as described by one student along with a drawing of a student thinking outside the box. In explanation of this the student suggested that *'Mechanics has a lot of stuff that is counter* intuitive' and this notion of being forced to reflect on the material presented in different is in line with the conceptual focus of the lectures and the EVS use and problem solving attributes of the WebAssign that was highlighted in the focus group. Another student who had selected the keywords '*different learning styles for understanding'* to accompany a scene of lectures and software described the importance of the PRS, lectures, WebAssign and group work to help students to understand the coursework. The idea of this complete package of learning reflects comments made by several students on the focus group and is clearly an important element of the course redesign. The redesign may also have helped to improve the atmosphere and behaviour of staff and students in the lectures. A student who depicted lecturers engaging in *'random banter'* seemed to reflect the relaxed light hearted atmosphere of the course that some of the students in the focus groups alluded to. Discussion in the lectures and the application of theory to practice may have helped to achieve this while not detracting from the objectives of the course.

However despite the enthusiasm for the course and the redesign that the majority of the students vocalised in the focus group, some students still appear to be struggling with certain aspects of the course and this has been apparent in the drawing exercise. The student who had illustrated a winding road through the hills with keywords '*road, unsure, uphill'* explained that he had experienced the course as being like *'a journey to an unknown destination with hills to overcome'*. Moreover the student who had depicted himself as being surrounded by arrows with the keywords '*clueless, in the dark, unsure and lost'* explained that, *'I don't really know where I am on this course right now'*. Sadly it appears that a minority of students even with the easier modes of communications in place may still continue to struggle to seek help from either staff or peers. This particular student did not vocalise his struggles and the information only came to light when he could illustrate his fears quietly and anonymously.

Principle 6: Provides opportunities to close the gap between current and desired performance

The repeated learning cycle of on-line homework submissions and immediate feedback has provided the students with multiple opportunities to practice and develop skills between assessments.

Student/Tutor perspective on opportunities to close the gap between current and desired performance

Students in group 2 supported the frequency and chapter alignment of assessments but pointed out concerns about practice opportunities for all of the exam type questions. There was support in focus group 1 for the multiple opportunities to reflect on the material with one student noting,

> *I quite like how you can stop and start it and go back to it.*

Students felt very satisfied with the frequency of assessments as they were given an opportunity to be assessed at the end of every chapter which provided them with multiple well distributed opportunities to consolidate knowledge and reflect on their performance before the end of term exam. They also liked the fact that there were clearly defined segments to be assessed on and as one student pointed out,

> *I think that given the fact that each assessment is based on a chapter, if you mess up on one its not necessarily going to affect you on the next one.*

Principle 7: Provides information that can be used to help and shape the teaching

Students in the Phase 1 pilot were directed to complete pre-class web assignments which had warm up questions and puzzles related to the planned in-class activities. Responses to the pre-class assignments were used diagnostically to inform the focus of the classroom teaching (Just in Time Teaching, JiTT).

However revisions to this year's course have witnessed a change to this format and as a result a change in the staff/student interaction. Staff on this year's course seem to have been able to obtain less feedback from the students than in previous years, as Jim described,

> *We haven't done it for this year's class but what we did for the past 2 years was just in time teaching so we posed questions on-line of the type of questions that they would get in class, like MCQs but we wouldn't put them as MCQs, we would put them as short answer questions and we encourage the students to go on-line now, what we don't do is like many universities who do just in time teaching do is they give grade points for going on-line and contributing things. We decided not to do that and what we were getting last year and the year before was probably about 30 students, well that's just looking at my class but 30 students out of 150 would try it and then we'd comment during class on how they'd tackled that question.*
>
> *What we've found this year is that 1st year students haven't used the WebCT discussion forums an awful lot. We encouraged them to ask questions on WebCT rather than send e-mails. Overall this year, we have had less contact with them because they're not coming to the tutorials and they haven't engaged in WebCT whereas in previous years we would have had the night before a test hundreds of posting onto WebCT. We told them about it and showed them previous year's postings and the types of comments that were made but this year they just didn't do it, well they did but it wasn't hundreds of postings, it was probably about 30 that we got.*

Student perspective on staff action on feedback

EVS was considered by students to be a useful diagnostic means of gauging generic student understanding, which was well responded to by the lecturer with expanded explanations. One student summed up what others appeared to feel about the use of EVS in lectures, by describing how,

> *There is always discussion afterwards, the tutors also base how quickly to work through the rest of the course depending on how their questions are answered, if a lot of people are struggling he'll slow down and expand on what you've been saying and expand on it slowly but if it's an easy topic and everyone's getting it right then they'll speed up the course and give you more time on other sections.*

Condition 1: Sufficient assessed tasks are provided for students to capture sufficient study time

Since the homework system is browser based, it can be accessed by students anywhere on or off campus. This means that the system is much more flexible than in more traditional formats and allows the students to work around their other commitments and lifestyle. As Jim noted,

> *You just need to look at the times that they are accessing the system like 2 in the morning. It's generally late at night that they do it apart from close to exam time.*

Student perspective

Students in group 1 enjoyed the flexibility that the system gave them in being able to work from home but they tended to mix this with working in groups in the labs at other times. Group 2 students also appreciated the flexibility of being able to access the resources online when and where it was convenient for them and felt that this enabled them to achieve greater time management. One student also commented that using the keyboard was more efficient than writing but that the time spent on this subject compared to others varied depending on the tasks at that time.

Condition 2: These tasks are engaged with by students orienting them to allocate appropriate amounts of time and effort to the most important aspects of the course

Initial evidence showed that the students were spending considerably more time and effort on the new homework exercises. Because of the increased time on task and improved mastery of learning the second class test was reduced from 2 hours to 1 hour.

Student/Tutor perspective on distribution of time on task

Students in group 1 were enthusiastic about the efficiency of the WebAssign system and supported the pedagogical benefits of the multiple deadlines in order to build progressive skills. Students in group 2 agreed on the increased efficiency and added that flexibility and greater time management were further benefits. The support from both groups for the efficiency of the system was reinforced by the questionnaire responses.

Although the students in focus group 1 appreciated having a two week opportunity to do the homework, they indicated that they generally left it until the last minute to complete. As a result of this, some students missed the deadline, although this was on one occasion partly due to an ambiguity in the AM/PM 12 o'clock deadline schedule. Students were relaxed about this though as they had been granted extensions and felt that if they did miss deadlines, they had some recourse to appeal. Generally they felt that there was an adequate amount of time in which to complete the homework and the deadlines were seen as a catalyst to spending more time on task. As one student commented,

> *I think if you were left to do the problem as well you probably wouldn't but the fact that you have got the deadline to do as well it kind of boosts you to do it a wee bit more so you are kind of getting more practice at it.*

Like in the previous focus group, the students in focus group 2 appreciated having plenty of opportunity to do the homework, but most left it until the last minute to complete. Again, some students missed the deadline, although this was on one occasion again due to an ambiguity in the AM/PM 12 o'clock deadline schedule. Students felt that the WebAssign had been an efficient use of time leading to constructive benefits, as one student commented,

> *I think it's managed to save a lot of time for ourselves and the tutors and given them more time to develop what they are going to talk about and give more time for them to speak to people individually if they need it. In tutorials you can speak to them rather than having to sit and mark through stuff.*

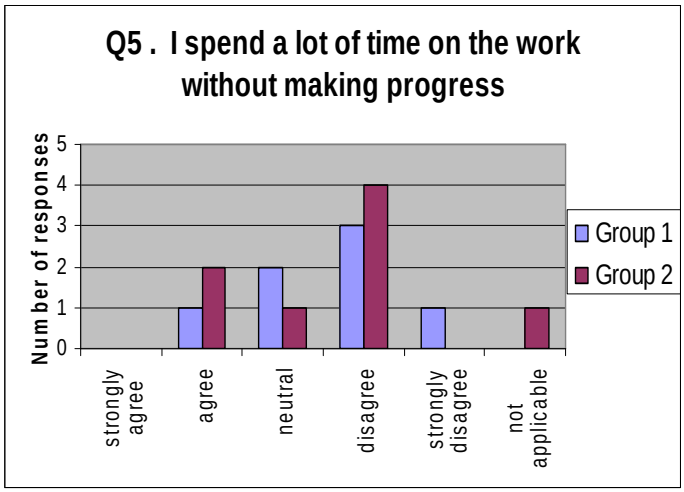
Thus although the students indicated that they spent as much time on other subjects, their use of time was felt to be particularly beneficial with the aide of the software. The even distribution of study effort afforded by the design of the deadlines was felt to be of particular use to students in order to help them to progressively build on their acquired skills throughout the duration of the course.

However, one student cautioned that

> *The fact that you get 5 attempts to log into WebAssign means you don't really out as much effort in as you would if you were writing it out and there's a hard copy of it going to someone.*

Most of the students in each group agreed in the questionnaires that they would get more work done by spending more time on it (*Figure 5*) but the students in both groups indicated during the focus group that they considered the WebAssign to be an efficient use of their time.

Figure 5: Focus group student perceptions of time on task



It is interesting to note that one of the students from group 1 had indicated that they have spent a lot of time on the work without making progress since this did not come out in the focus group, although one student had referred to ups and downs in their experience in the drawing exercise. Two students from group 2 indicated that they had spent time on work without progressing and it may be that these were the two students who indicated difficulties in the drawing exercise while again not vocalising their problems in the focus group.

Condition 3: Tackling the assessed task engages students in productive learning activity of an appropriate kind

It is perceived that the quality of learning was higher as students were engaged in Socratic processes which encourage deeper thinking. However as Jim pointed out,

> *It's difficult to tell because all the students in this mechanics course are all highly qualified. I mean they are among the best students coming out of Scottish schools.*

Student Perspective on matching task to learning materials and appropriate study

Students in both groups considered the lecture material, WebAssign, textbook and exams to be generally well aligned but students in group 2 indicated that one of the most important class test questions was not well aligned with the WebAssign content. Students in both groups felt that the January exam had been too short and were reluctant to see this exam becoming web-based because of the potential of loss of marks being picked up from markers being able to see 'workings' behind answers. They expressed that they felt that there was good alignment between the lectures, textbook and homework exercises with one commenting,

> *We tend to get it in chapters the homework in WebAssign so the chapters in lectures and everything, like the WebAssign will refer to what chapter it's from and like what part of the chapter so you can look it up really easily that way as well.*

The students were also confident that the material on WebAssign provided them with good preparation for the exam because as one described,

> *The questions on WebAssign were quite similar to the ones that came up pin the test in the last semester. So I mean if you know how to get all the way through WebAssign then you're probably going to do alright on the test'.*

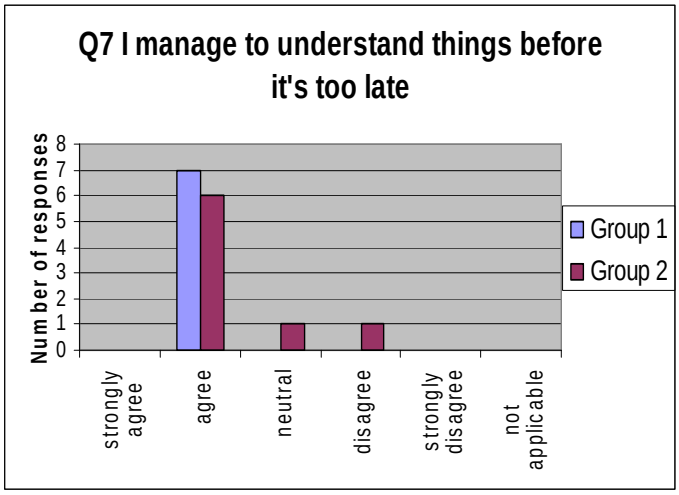
Another student reinforced this support saying,

> *There's all the end of chapter questions in the textbook. Everything you have done is in the textbook, all the PowerPoints are on-line. If you need any general revision, so there's more than enough time to pick up what you've been doing and develop on it'.*

The general feeling was that the January exam had been too short for the students. Students were not really in favour of having this put on the web as they felt that they would be unable to show their workings on numerical problems and that much of the exam content had been conceptual and thus they could envisage a way of effectively conducting on on-line exam based on a similar content. One student felt that an on-line environment would be too distracting.

All of the students in group 1 indicated in the questionnaires that they managed to understand things before it were too late (*Figure 6*). This group exclusively consisted of students who had achieved desirable performance on the class test. The two students who responded 'neutral' and 'disagree' to the statement may again have been the same students who indicated different degrees of struggles in the drawing exercise. If this is the case yet they did not vocalise it in the focus group, it may that these and similar students on the course may find it difficult to pursue feedback from their peers and or tutors in a public environment. For some of these types of students, anonymous electronic peer feedback or one-to-one staff feedback may be useful.

Figure 6: Focus group student perception of the learning cycle



Condition 4: Assessment communicates clear and high expectations

The expectations of the course and the assessments are naturally set at a high standard given the subject nature and the fact, as Jim pointed out that the students on the course were of a very high academic standard at entry level. The combination of the conceptually based lectures and problem solving format in the homework exercises facilitates a high standard of application of theory to practice in the course of assessments.

Efficiencies

Benefits for students from the Phase 1 pilot

Access to the online homework system has given students the opportunity to not only receive feedback as a result of an assessment, but through the automated Socratic dialogue students also receive continual feedback during the assessment and are able to immediately self correct. This way students don't have to wait until they receive feedback from their tutor to have their misconceptions clarified, instead gaps in knowledge can be addressed immediately and lead-on tasks are not impinged.

In the previous system of written homework it was noted that student effort had a tendency to drop off in the second semester, students submitting less homework and dropping their performance in class tests. Through the new online homework system students are not only encouraged to spend more 'time-on-task' but to also to distribute their study efforts throughout the year. It is also perceived that the quality of learning would be higher as students are engaged in Socratic processes which encourage deeper thinking.

Benefits for students from the Phase 2 pilot

Over the past ten years, this class has introduced group work, re-designed learning spaces, teaching-by-questioning using EVS and structured problem solving strategies. Overall the impact on the students has been profound, with high levels of attendance (even at early morning 2hr sessions on Mondays and Fridays), improved grades and an impact on retention. The unresolved issue with this class has been the style of assessment (fairly traditional written homework and tests) and the student focus on exam preparation (what is required to pass the test?!). At the beginning of this Project, the highest risk was identified as possible negative reaction to online homework for 'formative' assessment (although the homework is graded),

since the students are wholly unfamiliar with this, and shorter written tests (with less choice). During the first year of the project it became apparent that this was not a problem. Further, an evaluation undertaken towards the end of the second year of the project by the University of Glasgow partners resulted in a very positive response from the students, including those who were under-performing and struggling with the work-load.

All of the students in focus group 1 expressed their appreciation of both the WebAssign and EVS, which they felt combined to increase attention, keep focus, provide instant feedback and promote discussion. 4 students in group 2 highlighted the benefits of EVS while 6 focused on the WebAssign as being the most beneficial aspect, particularly with the on-line reference material and multiple opportunities for engagement. Social benefits of the WebAssign system were also mentioned and this theme was revisited in the drawing exercise. Students in both groups supported the dichotomy of conceptual/problem solving learning activities aided by the EVS and WebAssign systems respectively.

Benefits for staff

As identified previously a number of workload benefits are already being realised even without full implementation of the pilots. As identified in Table the assessment burden is projected to reduce from 50 hours per tutor to 15 hours once full scale implementation has been adopted. While saving have been made in time spent marking there is a financial cost in using the MasteringPhysics homework system. The Department was fortunate in being given free access to the online homework system for the purposes of the pilot. In the full implementation however there will be an annual cost of £4,000.

The primary benefit of implementing the online homework system, and potentially the CBM marking, has been the freeing up of tutor time. Even though the online homework system was only implemented in the second semester this freed up a total of 40 hours of all four tutors. Further reduction were made in the assessment burden because of the increased time-on-task afforded by the online homework system, reducing the final class test from 2 hours to 1 hour. This equated to a total of 30 hours saved in tutor marking (*Table 1*)

Through the implementation of the online homework system tutors have also been provided with an extra level of easily accessible diagnostic information pertaining to student performance. Problems students are having with particular topics can be analysed on a more granular level and through the homework comment box at the end of each homework, students have an additional way of flagging issues with the tutors.

Table 1 Tutor workload distribution before, during and after assessment redesign

Period	Preparation	Lecture/ Tutorial	Homework	Class Tests	Total	Saving
Before Pilot	48hrs	96hrs	20hrs	30hrs	194hrs	-
Pilot	48hrs	96hrs	10hrs	22.5hrs	176.5hrs	17.5hrs
Full implementation	48hrs	96hrs	~0hrs	15hrs	159hrs	35hrs

Limitations

Students in both groups had experienced only minor technical problems and were satisfied with the usability of the software. Students in focus group 1 found nothing negative to report of the experience while students in group 2 felt that they had been disadvantaged by

insufficient time on the class test and the lack of preparation for question types and one student felt let down by the lack of staff face-to-face interaction. Outcomes from the drawing exercise and the questionnaire data suggest that a couple of students from the second group and perhaps one from the first felt a little less confident than they had alluded to during the discussion and these types of students may benefit more from targeted intervention.

In group 1 responses indicated that there were only minor technical problems including one occasion when the wrong MCQ answer was provided but this was swiftly dealt with in the following lecture. Another student noted that it was possible to guess the answers as there was no opportunity to display their workings, while another pointed out that the numerical formatting could be problematic, claiming that,

> *If you don't out enough numbers after the decimal point it doesn't always accept it as the right answer and sometimes you need it up to 4 and it doesn't accept it.*

However on the whole students were happy with the practicality of the software. When questioned about its ease of use, one student described it as being,

> *Easy to log into, quick to do, you get feedback straight away and you've got a second chance if you've made a slight error.*

Although the students felt that they had not received much instruction for the technology, this did not appear to be a major problem for them.

Apart from some initial WebAssign logging in problems, students in group 2 had experienced few technical problems with the technology although again students noted that there had been little instruction but that it probably wasn't necessary.

Sustainability

The success of the use of online homework systems, directly linked to high quality (custom published) textbooks and supplementary material, has been very evident. The Department has three streams of engineering science subjects progressing through the first three years of a 5 Year Course (the 4th and 5th year being more specialist) and has already started investigating the exclusive use of available textbooks (rather than printed notes), with online assessment being introduced as this type of content becomes available. Two other classes have also started to use WebCT for formative assessment (quizzes) and summative assessment (end of semester class tests). All staff are responsible for ensuring sustainability, although it should be emphasised that the Department has a history of investing in educational initiatives and innovations, so the culture for positive change is implicit. However Jim noted,

> *I think the only issue would be if we are moving to the online system that would require the students to get key access and if the publishers in this country will be sensible about it they will make the cost of the licence fee acceptable. Our students in the first year were only ever meant to buy one or two books so they never spent more than £100, bit if the classes are working to the textbooks quite intensively and there is a large on-line component linked to the textbook then it must be priced at a sensible level. .*

Since the decisions about the curriculum are made collectively by theme groups within the department with departmental consultation rather than on an individual basis, the changes are likely to survive staff turnover. A substantial number of staff are also highly competent in IT skills and most of them are experienced in using the WebCT system.

Institutional support

Changes have been supported at an institutional level in terms of adaptations to the lectures theatre to accommodate a social seating arrangement, although this coincided with the existing refurbishment timetable. WebCT has also been adopted as the institutional VLE.

Future progress and strategic development

Three main issues have emerged – these will be investigated further in the next academic year

For many years in some classes, short 1hr written tests, often marked by other students and checked by tutors, have been used mid-term and end-of-term, to reduce the time required for a formal written test at the end of each semester. These have been quite successful over the years and appreciated by the students in terms of a reduced load at examination time. As part of this project it was proposed to use such short in-class tests using the EVS and a variety of question types. (The in-class written tests have never been used in this class, due to the frequency of written, assessed homework). Three different question types were used: standard MCQ, MCQ supplemented by *Certainty-Base Marking* (CBM) and *Ranking Tasks*. In the first year of the Project, a few practice tests were run in the 2nd Semester, followed by one graded tests. In the second year of the Project, three in-class tests were used (one practice). In fact the students did not respond well to the Ranking Tasks (although these are widely used in physics education) – after various discussions, we came to the conclusion that the written component of the Ranking Task (explanation of student reasoning) was key. Further, student reaction to CBM was very mixed – we have come to the conclusion that students need more practice in this, probably through formative online assessment, and this should be introduced very early on. How this will be handled in the next academic year will be discussed by the teaching team after the summer break. This style of in-class assessment has considerable potential in numerous ways, but we expect needs more care in implementation, especially for new incoming students who are wholly unfamiliar with this type of grading and assessment.

As highlighted in the preceding discussions, attendance at tutorials (problem solving sessions) has been sparse, although the students have not reported any perceived loss to their learning (from the Glasgow University Focus Group Study). If indeed this is an (unexpected?) outcome of the Project, there are major implications for how this time could be used (or not used) tutorials account for about one-quarter of contact time. There are various options: remove tutorials but maintain contact time and use the time in other ways (many options here), have staffed computer labs while students use Mastering Physics or WebAssign, reduce class contact and so on. This will again be discussed by the teaching team in the Autumn in preparation for next year.

There has always been feedback from students, anecdotal, in-class and online in Discussion Forums, that they forget some of the logic and arguments behind the resolution of in-class ConcepTests using EVS. This has been a common problem with the use of this technology with class discussion, and systems have appeared (and apparently been successfully used) which can capture the whole classroom experience (PowerPoint talk-through, video of in-class discussion and so on) and at relatively low cost. This possibility will also be examined for next academic year (using remaining funds form the Project) since it could be a key component of student self-study and formative assessment.

Lessons learned

The change that has contributed most to the quality of student learning is the integrated approach to class re-design (in our case group work, EVS and teaching-by-questioning in a group setting) is now supplemented by high quality support material and intelligent online homework systems. Just changing one aspect we suspect would not be sufficient for a major

change. For example, some institutions have reported poor responses to the use of online homework systems, which we suspect were due to being seen as an 'add-on' to a traditional class rather than the basis for a radical re-design. The use of high quality online homework systems, used appropriately contributed most to reducing costs. Of course these are not available in all subjects and for all classes in a typical degree program, however they are available, or are being actively developed, for many fundamental science and technology subjects, especially in the early years. Apart from the comments on an integrated approach given above, the only real issue identified at the outset as being the most important implementation issue would be student reaction to the online systems. This did not arise in practice, engineering students seemed to adapt to the online system very well, with no training.

In addition to the comments above on essential lessons general advice to other departments undertaking similar projects would be to talk to practising academics who have made the change, and visit their classes (in person and online). The only thing that the course coordinator suggested that he would have done differently would have been giving more thought to the in-class testing component using the new EVS systems and the use of different question types. It had been thought that this would be fairly straightforward, but the student reaction was mixed, perhaps because this was so alien to them.

Critical success factors from Phase 1

The Department of Mechanical Engineering has a long history and experience of implementing new teaching strategies. Members of the fist year teaching team are fully conversant with the latest developments in teaching and learning. All the team involved in the re-engineering of Engineering Mechanics are also very computer literate and are aware of the latest developments in online and in-class assessment tools. Up until very recently the main barrier in implementing an online homework system has been the lack of fully realised products which support the Socratic processes embedded in the 1st year mechanics programme. Another innovation which has made the latest developments in Engineering Mechanics possible has been the introduction into the UK of custom publishing. With custom publishing different textbooks and parts of textbooks from the same publisher can be combined and printed in one publication. This process not only makes the textbook highly relevant to the class being taught but it also gives tutors access to the vast array of electronic content (e-packs, MCQs, warm-up questions etc) associated with that publication.

Critical success factors from Phase 2

The main objective (deliverable) of this Project has been to reduce the (significant) amount of marking required in a large and important 1st Year class which is delivered to over half the incoming students in the Faculty of Engineering from four departments. A typical cohort is 250 students, split between two sections and delivered by four academic staff; the subject matter is fundamental engineering mechanics, which requires a significant amount of problem solving as well as conceptual understanding. Both of these basic skills have not been well developed during secondary school physics, even with well qualified students, and both need considerable practice (and indeed a re-focussing) during the students' initial year at university. Over the past ten years the issue of conceptual understanding has been well addressed through the use of in-class discussion facilitated by Electronic Voting Systems (EVS). This has improved not only their fundamental understanding, but also examination performance, attendance at class and retention. However the problem solving aspect remained problematic and required a significant amount of staff time marking and annotating (for formative feedback) fortnightly written homework. To reduce this, at most two written problems were required to be completed using a highly structured (multi-representational) problem solving framework and strategy. At problem-solving sessions (tutorials) the students tended to focus on these homework first, and left investigations of other problems until last,

even though a structured problem set was specified. In addition they remained very much focussed on what type of problem would appear in the class tests, and tended to concentrate on those. (The class is assessed by the written homework (25%) and two 2-hr written class tests (75%) at the end of each semester). It was decided as the main objective of this Project to try to reduce the marking 'burden' using a combination of in-class tests and the next generation EVS systems (which allowed more diverse question types other than multiple choice, MCQ) and intelligent on-line homework systems.

The introduction of the online homework and testing systems has been very successful, but has led to some 'apparent' unexpected consequences. It also became apparent that in-class testing, using different question styles, would need to be developed further since the 'concept' seemed to prove strange to most students. It had been hoped that these issues would have been resolved during this academic year, which will need to be investigated further in the next academic year.

Dissemination from Phase 1

The Department disseminated early findings from the project at local and national level. Locally the Faculty of Engineering initiated a Teaching & Learning forum where REAP activities were described and discussed. Nationally an overview of the changes implemented as part of the re-engineering of Engineering Mechanics was given in a keynote speech by Prof Jim Boyle at the Institute of Mathematics and its Applications (IMA) conference on 'The Mathematical Education of Engineers', Loughborough, March, 2006.

Dissemination from Phase 2

Presentations (on the use of EVS) have been made at seminars at the University of Edinburgh, the University of Bristol and Dublin Institute of Technology.

Conclusion

The redesign of the Engineering Mechanics module is part of an on-going process of course revision which has been active over the past ten years. Changes over this period have included the introduction of active and collaborative learning into the large lecture room through the use of peer instruction and electronic voting systems (EVS) along with redesign of teaching space to promote collaborative working. Traditional lectures were replaced with 'active-learning' sessions with a combination of mini-lectures, videos, demonstrations and problem-solving. Phase one of the REAP pilot (2005-6) introduced a new online intelligent homework learning system MasteringPhysics, which was implemented as a replacement to the traditional paper based homework. This was replaced for Phase 2 (2006-7) with a testing system, WebAssign.

Qualitative evidence from student focus groups suggested that the synthesis between the homework exercises, EVS questions in class and end of chapter textbook questions provided a clear set of criteria for what kind of learning activities would be expected of students, although the expected standards were thought to be a little vague. Despite this, the vast majority of the students continued to perform at above the 90% level on assessments. Students considered the on-line facilities to be efficient and valuable tools for reflection. Students felt that they had benefited from the immediacy of the on-line feedback but while some students appreciated the hints and tips that provided information on the accuracy of students' current performance in relation to their desired goals, others requested increased opportunities for formative feedback in order to help them to improve their performance.

Tutors found tutorials very helpful and used them as required for additional help but most students found the feedback from the homework system and from peers to be sufficient

although if a lot of students had difficulties in the same area, the system did not run quite as smoothly. Students were very much in favour of the social seating arrangements and in the promotion of peer discussion through EVS and this improved their working relationships out of class as well as in. Students also generally enjoyed the flexibility of the two week window for submissions and the efficiency of the technology. They appeared to be highly motivated by holistic package of learning offered to them by the combination of lectures, EVS, multi-media use and the homework system and expressed a high degree of course satisfaction and enjoyment, although one or two did appear to be struggling more than they were willing to vocalise.

Frequency of assessment and course alignment was generally considered to be good despite some concerns about particular exam questions. Students also felt that the EVS in lectures provided lecturers with a useful diagnostic tool, upon which they acted appropriately in terms of remedial action. Some students had struggled with the mid-term exam because they felt a little under-prepared for one of the question types. In considering the merits of having the exam put on-line, students were wary of losing marks for showing their workings, but they felt that the on-line homework exercises generally prepared them well for the exam. Most students indicated that they achieved a good understanding of the course in time for assessments despite the fact that a high standard of achievement was set for students.

In sum the homework system has offered students continuous timely feedback, increased time on task and distributed learning more evenly over the year as well as promoting deeper thinking. Crucially, staff time on task has been significantly reduced while they have benefited from a diagnostic tool in the homework system, with only minor technical problems. The design appears to be sustainable and discussions are on-going for future development including a revision of CBM, moving tutorials into labs and the development of multi-media learning tools. Overall the introduction of the on-line homework system on top of the other elements of course redesign implemented over the past ten years has achieved it's aims of reducing staff marking time and in helping students to focus on the learning process rather than simply on the outcome.