University of Strathclyde: Department of Mechanical Engineering

16132 Engineering Mechanics - 1

A REAP project case study June 2006

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. Table 1 shows a breakdown of the workload for each tutor over the academic year.

Preparation	Lecture/Tutorial	Homework	Class Tests	Total
48hrs	96hrs	20hrs	30hrs	194hrs

Table 1 Workload distribution over the academic year for one tutor

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.

Nine 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.

Drivers for change:

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

Aligned to this is also the recognition that not only do the students need an improved framework for time-on-task, but the tutors also need to address the amount of time spent marking homework and class tests, an activity which might have marginal benefits for enhancing the students' learning experience. There is also a strong argument that tutors' time would be better spent engaging with students rather than pieces of paper. By engaging with students it is believed that retention rates will 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 is however deploying an already overstretched teaching team.

Phase one pilot: January 2006 – June 2006

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 as illustrated in Table 2. 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.

Degree of Certainty :	C=1 (low)	C=2 (mid)	C=3 (high)	No Reply
Mark if correct:	1	2	3	0
Penalty if wrong:	0	– 2	– 6	0

Table 2 Grading regime for certainty-based marking

About the technology:

The online intelligent homework system being 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 means tutors can concentrate on engaging with their students rather than spending hours designing homework exercises. Figure 1 shows a screenshot of the student view of a question in MasteringPhysics.

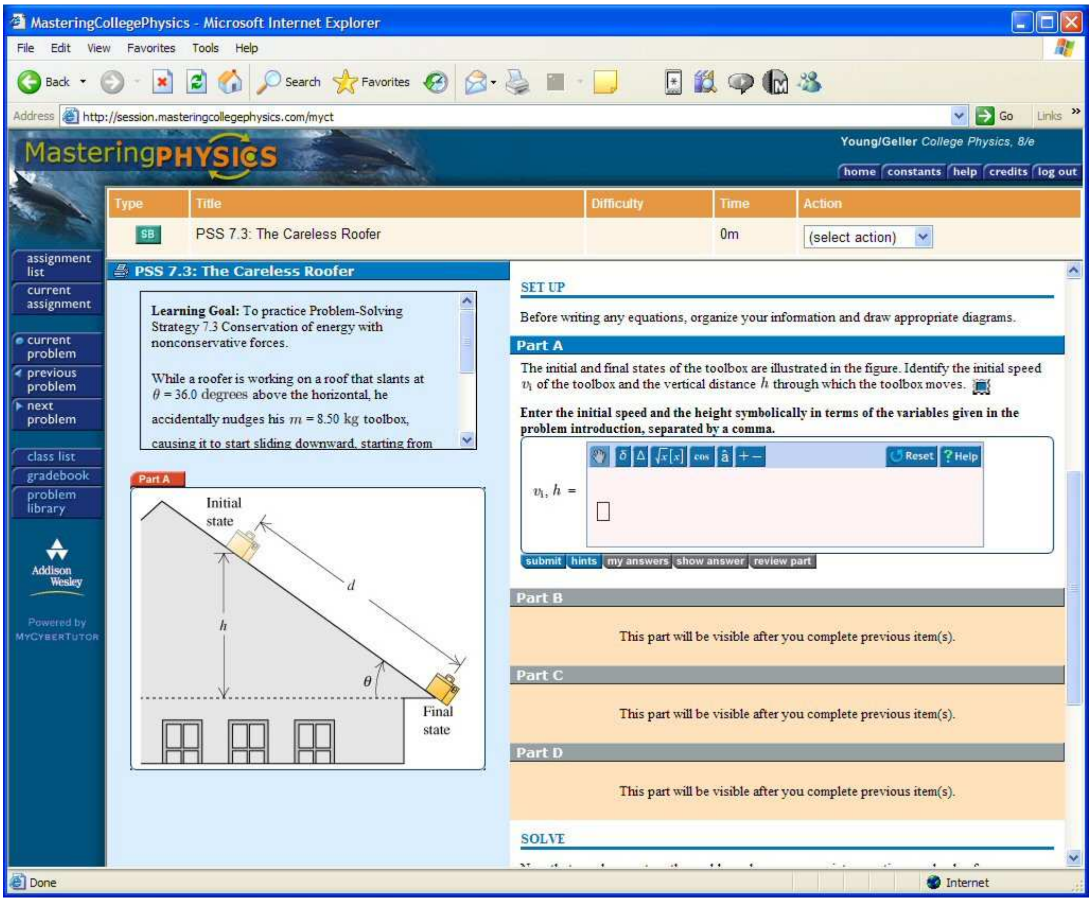

Figure 1 Screenshot of question in MasteringPhysics

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 Methodology:

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.

Results:

Initial responses from students indicate that students adapted well to the online homework system. Feedback indicates 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 has 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 indicates that because CBMs use radically different grading regime, students have not had enough time to develop their own personal response strategies.

Benefits for students

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 will be higher as students are engaged in Socratic processes which encourage deeper thinking.

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 3 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.

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.

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

Table 3 Tutor workload distribution before, during and after assessment redesign

Critical success factors:

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.

Dissemination activities:

The Department have 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.

Future plans:

Following on from the success of the pilot for the next academic year the MasteringPhysics online homework system will be fully implemented in both semesters. As a result it is planned to reduce both class tests from 2 hours to 1 hour.

While the use of CBMs was inconclusive in the pilot these will be trailed again in the next academic year. It is 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. Until the issues with the CBM are resolved they will continue to be used on a formative basis. In the next year it is planned to adapt some of the existing MCQ questions provided by the publisher with the custom course textbook with CBM. This revised question bank will be used as part of the *Just in Time Teaching*, already employed as part of the Engineering Mechanics class.

As well as the revised assessment strategy a revised evaluation strategy will also be adopted. In this strategy the focus will be on collecting longitudinal data. This will be done taking a cross-section of next first year students (c.20) and closely monitoring their marks and performance over a two year period. Regular interviews will be conducted with these students to gather information not only about the revised assessment strategy but to also record their transition into the second year of the programme where the assessment tools used are less rich.