EVALUATING ASSESSMENT IN AN ENGINEERING MATHEMATICS MODULE

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Abstract
Teaching tertiary mathematics to engineers is a worldwide issue. This paper discusses an evaluation of assessment methods with the goal of improving student learning in an engineering mathematics module. It tests the hypothesis that there can be a substantial impact on student learning by encouraging sufficient, relevant and productive out-of-class active learning activities.

A detailed description of these assessment processes is presented along with data to appraise their effectiveness with regard to enhancing student learning. This is discussed and it is shown that continuous active learning can successfully improve learning.

Keywords
Engineering mathematics, declining mathematical skills, active learning, motivation, content, teaching, learning, assessment.

Introduction

Engineering education reform is being considered, planned or embraced by many universities around the world. The CDIO Initiative (www.cdio.org) is an international organisation which is promoting such change. Crawley *et al*. [1] describe the comprehensive methodology that this initiative has developed for redesigning engineering degree programmes and the philosophy underpinning the need for change in engineering education. This need for change is being fuelled by stakeholder feedback; employers want proficient engineering graduates who can 'hit the ground running'. Essentially, engineering graduates should understand how to conceive, design, implement and operate the value-added products and systems associated with their discipline – hence CDIO.

The School of Mechanical and Aerospace Engineering at the Queen's University of Belfast has been an active member of CDIO since 2003 and has an ongoing change management plan for curriculum reform based on the CDIO principle and methodology. Four years ago a new degree programme in Product Design and Development started. This programme was developed entirely on the CDIO ethos.

There is only one engineering mathematics module scheduled in the new Product Design and Development degree programme. Therefore, this module has to ensure that the students are adequately prepared with the prerequisite skills that they need for all the other scientific and analytical modules on the degree programme. The success of this module, which is scheduled in the first semester of the first year, is of paramount importance to their eventual success on this programme.

The mathematics module has now run for two years. This paper discusses the assessment strategies employed in each of these years, with that in the second year being developed to address the shortcomings found after carefully evaluating the first year of the module.

Preparing the Engineering Mathematics Module

Applying the CDIO strategy to developing a mathematics module required careful deliberation. In a CDIO teaching environment a key consideration was to ensure that the mathematics module could integrate with the rest of the course and espouse the same learning strategies inherent in the other more design orientated modules; this was considered essential if the students were to stay motivated and engaged throughout the module.

Teaching mathematics to engineers is a worldwide issue, so a systematic approach was applied to developing the mathematics module, supported by the best current pedagogical paractices [2]. Relevant content was ensured by conducting interviews with all the teaching staff on the Product Design and Development programme and the teaching methods were varied to include active and interactive learning in class. A diagnostic test was developed for the beginning of the semester to identify the varying abilities of the students so as to help prepare the pace and content of the module. The initial assessment strategy for the first year consisted of a class test half way through the semester and an exam at the end of the semester.

The breakdown of the contact hours was two-thirds lecture classes and one-third tutorial classes. In the lecture classes the students were given the opportunity to actively and collaboratively practice the mathematical topics and their applications as they were presented, as advocated by Penner and Ruhl respectively [3,4]. In the tutorial classes the students could work individually or in groups to complete worksheets associated with each of the mathematical topics from the lectures. Complete solutions to these worksheets were presented in subsequent tutorial classes; usually one week later. Much time and effort was put into ensuring that these solutions were explained in great detail to the apparent satisfaction of the students.

Year 1

In the first year of the module the general feedback from the students was positive in relation to the content and pace of the lectures. Attendance at the lectures and tutorials was also good, with the respective averages being more than 75%.

Knowing that the exam questions would be directly based on these tutorial worksheets, the intention was that the students would endeavour to complete them each week, in-class and out-of-class, thereby effectively maximising their learning potential. In general, this did not happen; with only about 20% of the class actually completing all the worksheets in the allocated time. This failure to engage in the intended learning exercises was critical. Learning mathematics is all about practising and applying the theory – it is key to understanding the subject. Therefore, it was vital to appreciate how this could be remedied.

The subsequent performance of the students in the class-test and exam clearly indicated that their learning was not being maximised to the extent that it was hoped. The average mark in the exam for those that attended was 45%. In addition, the students also struggled with the analytical content in other modules, further corroborating the fact that the mathematics module was not providing the expected learning environment to develop their mathematical skills.

Rust [5] clearly suggests that assessment directly influences student learning to the extent that "*if work does not have marks attached many students will either not do it at all or only do it in a perfunctory way*". Gibbs [6] argues that "*assessment works best to support learning when a series of conditions are met*". He examines these conditions in detail, noting that "*what influenced students most was not the teaching but the assessment*", and, in relation to coursework, argues that:

1. Examinations are very poor predictors of any subsequent performance, such as success at work.
2. Coursework marks are a better predictor of long term learning of course content than are exams.
3. In experimental studies in which students have either studied exam-based or assignment based courses, the quality of their learning has been shown to be higher in the assignment based courses.

Therefore, after careful deliberation on the aforementioned points, it was decided that a change to the assessment strategy was the most efficient means of potentially improving student learning in this module. The new paradigm involved focusing on out-of-class learning via the tutorial worksheets. If the students were encouraged to spend more of their time completing these worksheets as part of assessed coursework then learning could be improved. This obviously assumed that the attendance at lectures and tutorials would not fall.

In addition, another relevant assessment technique was uncovered that predicted extremely encouraging results with respect to improving learning in a tertiary mathematics course [7]; a technique where the peer-marking of weekly problem sheets dramatically increased exam results. The inference is that better learning was achieved by the students engaging in the learning tasks. Another worthy outcome of such an assessment technique is that it does not generate more marking for the lecturer.

Year 2

The content in the second year of the module remained the same, as did the tutorial worksheets. However, the assessment was now evenly weighted between coursework and the end of semester exam. Each tutorial worksheet was assessed and therefore there was now incentive for the students to complete them. When the total count was taken at the end of the module, 50% of the class had completed over two-thirds of all the worksheets (there were 29 worksheets in total). On average, each student completed 60% of the worksheets. The average attendance at the lectures and tutorials was 75%.

Rust espouses the importance of formative assessment [5], so it was necessary to ensure that feedback was part of the new assessment strategy for the second year. This was primarily achieved by returning the marked worksheets to the students and discussing the work where necessary.

This year, the average exam result, for those students that attended, was 59%, up 14% from the previous year. The fact that the new assessment strategy was the only difference between year 1 and year 2 of the module suggests that it was directly responsible for this improvement in exam results.

Discussion

In preparing this mathematics module, much time and effort was put into compiling the content and the manner in which it would be taught [2]. A key aspect was identifying the relevant content, ensuring it was presented in an accurate and relevant way by using appropriate examples [8, 9], and arranging for active and collaborative learning experiences to permeate the entire course [10]. As such, the best pedagogical practices were used to do this. However, the assessment in the first year of the course was rather traditional, consisting of a class test mid-semester, followed by an examination at the end of the semester.

As well as including active and collaborative learning in the actual lecture classes, it was the tutorial classes where it was expected that the students would principally engage with the subject by completing a comprehensive set of worksheets based on all the mathematical topics addressed in the lectures. This would ensure that they were gaining the necessary experience and skills through practising the application of the theory.

However, the evaluation of the first year of teaching the module produced unequivocal evidence that the students were not sufficiently engaging with the subject and thereby maximising their out-of-class learning. In contrast, their attendance at the scheduled classes was above average and their feedback on the relevance of the module was very good.

Fortunately, basic didactic theory and research provides copious advice on ways to maximise student learning in a mathematics module through simple changes in assessment strategies; essentially, assessing coursework and providing suitable feedback can encourage more out-of-class learning.

Understanding this need to maximise the students' out-of-class learning experiences was essential if the module was to succeed in subsequent years in developing the necessary mathematical skills in only seventy-two hours of in-class contact time [11]. Joughin [12] provides suitable evidence of assessment operating in this way to focus, regulate, monitor and redirect students' learning efforts, and therefore influencing out-of-class learning.

Therefore the second year of the model had a new assessment strategy that basically encouraged the students to engage in practicing mathematics by completing the tutorial worksheets at the relevant time, aligned with the learning outcomes from the lecture classes. These worksheets now represented 50% of the overall marks for the module; they were marked and returned to the students directly after being handed in.

In addition, a peer-assessment scheme [7] was piloted that had been shown to improve and maximize out-of-class learning. This effectively involves the students in a marking exercise where they are required to apply assessment criteria and model answers to a number of pieces of work. Research has shown that this type of activity can significantly improve students' performance [13]. In the particular case described by Forbes and Spence [7] the performance of the students was transformed by simply submitting problem sheets for peer assessment on six occasions during the course; all lectures and tests remained the same as before. These improvements resulted from:

- Ensuring the students did the work by making it a requirement.

- Knowing their peers would see and comment on their work encouraged the students to do it well.
- Learning from their peers regarding the standard of work, the mistakes and the innovative solutions

The simple strategy here was to generate learning activity out-of-class by changing the assessment strategy. In this case peer-assessment was a means to an end.

However, the reality of trying to implement this peer-assessment scheme proved rather more difficult than it had appeared in the paper. Forbes and Spence [7] were able to successfully instigate the peer-marking scheme so that it took about twenty minutes of class time for the students to mark each other's work; that work being one exam-type question. When the author tried this on three occasions in the second year of the mathematics module it took closer to forty-five minutes for the students to satisfactorily mark each other's work, and even then it had to be checked for accuracy. The questions and their solutions were carefully prepared and the students were guided through the marking process, but some remained confused and sceptical as to the benefits for their learning.

Nevertheless, the benefits espoused by Forbes and Spence are extremely valid and worth striving for in this type of mathematics module, so further work, research and analysis will be given to implementing this specific peer-assessment scheme.

Conclusion

A continuous assessment scheme that was introduced to encourage students to complete tutorial worksheets has been shown to improve their exam performance in an engineering mathematics module. In addition, an ambitious peer-assessment technique was trialed based on very encouraging published data. Further work is required to successfully implement this technique.

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