USING CONTINUOUS ASSESSMENT TO GENERATE CONTINUOUS LEARNING IN ENGINEERING MATHS

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Abstract: The mathematics for first year aerospace and mechanical engineering students is delivered through two half-modules, one in each semester. Each course is taught over 12 weeks with a 2-hour lecture and 1-hour tutorial class per week. Students attend lectures as a single group but are divided into smaller groups (of 40 – 50 students) for tutorials. In these more informal classes, students work through practice questions. Solutions are provided on the university’s intranet a few days after the tutorial. The lecturer has been concerned that these classes are not as productive as they could be. Downloading of tutorial solutions was observed to be low throughout the semester although a surge in usage occurred just before mid-term tests and the exam.

Therefore, an experiment is underway in the first semester course with the tests being replaced by a system of continuous assessment based on the tutorial questions. In 2010/11, assessment involved an exam and four tests (one every third week). In 2011/12, students were awarded one or two marks each week, over ten weeks, based on their performance in the previous week’s tutorial questions. The marks available from continuous assessment counted towards 15% of the module mark. On average, 79% of the class presented work for assessment each week and motivation was generally not a problem. More uniform attendance at lectures and tutorials occurred in 2011/12 and exam performance improved significantly. The continuous assessment encourages weekly practice and there is some evidence that this has enhanced the students’ mathematical skills.

Keywords: mathematics, continuous assessment, attendance, first year.

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1. INTRODUCTION

The author has eleven years of experience teaching mathematics to diverse groups of engineering students (Cole, 2011). This includes large classes of first year (Stage 1) aerospace, chemical, civil and mechanical engineering students (class size up to 300) and more specialised second year (Stage 2) classes for aerospace students (typical class size is 20). The smaller class size at Stage 2 has allowed a more interactive approach and a mixture of formal teaching and student practice within the sessions. Student feedback suggests they enjoy this involving style of teaching. Ensuring that active and productive learning occurs across the larger class is much less straightforward but continuous assessment may be applied to achieve this goal.
The term “continuous assessment” is used to indicate that the students are being assessed on and off throughout the course rather than just at the end of it (Rowntree, 1987). Continuous assessment can be particularly advantageous in providing opportunities for feedback for both students and teacher as the course proceeds (Miller et al., 1998). Thus, any remedial work necessary can be attempted well in advance of the final exam. Miller et al. (1998) also list difficulties with continuous assessment – some tests encourage surface learning and give little opportunity to measure students’ understanding of broader principles while students may be so focused on the next test that in-depth reading gets neglected.

Croft et al. (2001) emphasise the importance of first year engineering students engaging actively and early in learning maths and explain a system of computer assisted assessment (CAA). This involved three tests over the semester, counting towards 20% of the module mark. Students were encouraged to work together on trial tests with the aim of promoting regular practice. The authors concede that such CAA tests do not sufficiently assess understanding in maths but believe the system is beneficial – the continuous practice helps students to master basic mathematical techniques and higher level skills can be assessed in the traditional final written exam.

Davis et al. (2005) have detailed the HELM (Helping Engineers Learn Mathematics) resource which includes a CAA regime. Typically, five tests were held over a semester. Students could practise repeatedly on trial tests before each summative test which was unsupervised and contributed between 5% and 10% of the module mark. The authors ran supervised, paper-based tests containing similar questions to those on the CAA tests and noticed some tendency to perform better in the CAA tests. A further concern is that some students reported not opening their workbooks until just a day or two before the tests. While this testing regime promotes activity, it would be interesting to investigate whether students’ learning and understanding of maths is enhanced in the long term.

Incorporation of problem solving (Holton, 1998; Sazhin, 1998) into the teaching and/or assessment seems to be helpful but this may depend on there being useful feedback. In considering the nature of coursework in maths modules and the assessment weight given to it, Challis et al. (2010) report that frequent (even weekly) small assignments in the first year promote engagement but that quick marking and feedback are vital. Cox (2007) also emphasises the importance of feedback – it should be personal, concise, encouraging and designed to help students to learn, which is the main purpose of coursework.

An investigation of factors influencing success in first year maths (Anthony, 2000) showed that while lecturers gave strong support to regular practice of examples, students rated this factor much lower. Students believed studying for tests, clearly presented lectures and regular attendance at classes were more important for success. Students’ reluctance to devote time to unassessed tasks (Gibbs and Simpson, 2004) has been my experience also (Cole, 2011). For example, Figure 1 shows the number of downloads of tutorial solutions each day over the semester for the Further Mathematics 1 module (Stage 1, 2nd semester). Use of tutorial solutions outside of the class was generally low; the peaks in usage correspond to the assessments – two class tests and the exam.

Therefore, by employing some of the ideas presented by Fradkin (Reed, 2003), an attempt was made to implement a continuous assessment system based on the weekly tutorial problems. The aim was to avoid the irregular activity focused on a few class tests over the semester, while simultaneously making the weekly tutorial class more productive. This paper
describes the module and the assessment systems used. The methodology for evaluating the effectiveness of the new assessment method is presented before the findings are analysed.

![Figure 1: Daily number of downloads of tutorial solutions over the semester](Further Mathematics 1, 2009/10). © iNEER 2011

### 2. CURRICULUM DESIGN

#### 2.1 The module – Engineering Mathematics 1

The author was given responsibility for this first semester module in 2010/11. Together with a second semester course (Further Mathematics 1), it represents the mathematics teaching (20 CATS points in total) for first year aerospace and mechanical engineering students (class size is approximately 150). The syllabus in Engineering Mathematics 1 is mainly a repetition of A-level topics – logarithms, polynomial equations, trigonometry, complex numbers, differentiation and integration – although effort has been made to demonstrate engineering applications. In first year engineering mathematics, an in-depth knowledge is not the predominant goal; rather, it is aimed to provide students with a good grounding in a range of fundamental topics relevant to engineering. It is also desired that students’ confidence in their mathematical ability should be enhanced.

Teaching takes place over 12 weeks with a 2-hour lecture and 1-hour tutorial / exercise class per week. Students attend lectures as a single large group but are divided into smaller groups of 40 – 50 students for exercise classes. A formal teaching style is generally employed in lectures with effort made to present the material clearly and in a logical manner. Numerous worked examples are included to help reinforce the material being taught and allow demonstration of potential pitfalls in the solutions. Typical engineering applications are incorporated to illustrate the usefulness of mathematics to engineers – this makes the lectures more interesting. Summary sheets containing key results are provided at the conclusion of major topics to help students extract the main points. Some active learning elements are included (e.g. requiring students to complete an example) to promote thinking and learning during the lectures.
In the more informal exercise classes, the students work through a sheet of practice questions. The number of questions varies from about 10 to 40 depending on the topic and students are not expected to complete them within the class time. Answers are attached with the questions while worked solutions are provided on the University’s intranet a few days after the class. The tutorial groups occur simultaneously so each is supervised by a postgraduate student who is not expected to teach formally but rather assist students with any queries as they work through the questions. Thus, students had followed the lecturer presenting worked examples during the lecture. They then attempted questions themselves in the subsequent tutorial class and had one-to-one support, as required, from the postgraduate supervisor or lecturer, who visited each group.

In 2010/11, assessment involved four 15-minute tests in weeks 3, 6, 9 and 12 of the semester. Each test counted towards 10% of the module mark and was paper-based, requiring students to solve about five problems. The final exam contributed the remaining 60% of the module mark. In 2011/12, the four tests were replaced with a weekly assessment of tutorial work. One or two marks were awarded in each of weeks 3 – 12, the total available from this continuous assessment being 15%. Students were expected to complete the tutorial sheet at home and bring their work to the following tutorial class for marking. The lecturer quickly checked each student’s work within the class. Typically he allocated the marks based on their answer to a particular question (not identified to the students in advance) but also scanned their work to check that a reasonable attempt had been made at the complete set of questions. The exam therefore counted for 85% of the module mark in 2011/12.

2.2 The students
Most of the aerospace and mechanical engineering students enter university directly from school. In recent years, a large majority of them have achieved at least grade B in A-level mathematics but the class usually includes a small group of students with much lower qualifications in maths. Figure 2 shows that the entry profile for the classes in the last two years is very similar. The diverse nature of the class is emphasised by a few students with A-level further maths (about 8% of the total in both years).

![Figure 2: A-level maths grades for the students taking Engineering Mathematics 1 in 2010/11 and 2011/12.](image-url)
3. METHODOLOGY

Quantitative data has been used to evaluate the effectiveness of the new continuous assessment strategy. Lecture and tutorial attendance figures give a measure of student engagement with the course. In both years, the lecture occurred on Fridays 9 – 11 am with the tutorial hour following immediately. Marks awarded for tutorial work illustrate the level of participation each week. The exam marks provide evidence of whether students are achieving the learning outcomes and of the quality of their understanding (Ramsden, 1992). The structure of the exam was very similar in the two years – students had 75 minutes to answer eight questions. Since students use past exams to prepare for their own exam, it was not possible to use identical questions in the two years. However, a question can be adjusted so that it appears different even though the underlying method that is being tested is unchanged. Three questions from 2010/11 were deliberately retained for 2011/12 and adjusted in this way. By comparing corresponding data from the two years, the impact of the continuous assessment can be judged.

4. EVALUATION OF CONTINUOUS ASSESSMENT STRATEGY

4.1 Attendance

Figure 3 shows the lecture attendance rate over the semester in both years. The mean attendance was slightly higher (81% compared to 76%) in 2011/12 but the more notable difference is that attendance was more uniform in 2011/12. This is important – with one week’s lecture material following on from the previous week’s, a more regular attendance should give students a better opportunity to understand the content. The more uniform attendance is probably prompted by the weekly assessment of students’ work in the following tutorial hour in 2011/12.

The more consistent pattern in attendance in 2011/12 was repeated for tutorials (Figure 4), again probably due to the weekly assessment occurring in these classes. The irregular attendance in 2010/11 is characterised by distinctive peaks in attendance corresponding to the class tests held in weeks 3, 6, 9 and 12. The class tests generally attracted a higher attendance (> 90%) than any other classes over the two years – there being 10% of the
module mark available for each test, while only 1% or 2% for each tutorial assessment in 2011/12, was undoubtedly a factor in this behaviour. On the day of the week 12 test in 2010/11, there was unusually severe weather (snow) which made travelling difficult. This explains why the attendance was lower than might be expected on that day, given that a test was occurring.

4.2 Participation in continuous assessment

Figure 5 shows the fraction of the class who presented their tutorial work for assessment each week. The mean value is 79% but this is influenced by the very low figure in the last week. On the last day of term, students weren’t too concerned to attend the final tutorial and collect a potential 2% of the module mark. In general, however, participation was relatively high and consistent over nine of the ten weeks of assessment. This suggests that, despite reducing the available marks to at most 2% each week, motivating the students to attempt the work was not a problem. This is a pleasing result. Although many of the topics in this course are covered previously at A-level, the lecturer believes students would benefit greatly from more practice. For example, he has previously observed that some students with good grades in A-level mathematics have not mastered certain integration techniques; there is sometimes confusion in taking a rule for differentiating (product rule) and applying it to an integration problem. The new assessment system seems to promote regular practice and, by working on many problems each week, it is hoped that students’ mathematical skills will be enhanced.

![Figure 5: Proportion of class presenting work for assessment at weekly tutorial in 2011/12.](image)

One third of the class submitted their work on all ten occasions and a further 24% of students presented their answers on nine occasions. About 10% of the class participated in fewer than four of the ten assessments. Of these 13 students, four didn’t attend the exam – some were thinking about withdrawing from the degree programme. The other nine students attended and passed the exam – perhaps students in this small group were confident they could pass the module based on their exam performance only and there was no need to make the effort over the semester to gain just a few extra marks.

The proportion of the class participating in the weekly assessment (Figure 5) may seem higher than that actually attending the tutorial (Figure 4). This is because the attendance figures include seven students resitting from the previous year while the assessment data ignores these students – typically, resit students were not expected to complete the continuous assessment but were assessed by exam only.
A weakness of the new assessment system, with much of the work being done out of class, is the potential for student collusion and this would be difficult to detect in a class of 150 students. Thus, the marks available from the tutorial work had to be low but not so low that devoting time and effort to the work each week gave little reward in terms of marks. With 85% of the overall mark coming from the exam, a student who gains a high mark from the tutorials through using another student’s work is still some way off passing the module.

4.3 Exam results
The exam in 2011/12 was aimed to be of a similar style and level of difficulty as that in the previous year to allow any impact of the continuous assessment to be investigated. Table 1 shows that the average mark in the exam was significantly higher in 2011/12. A significant improvement in performance in the integration question was also detected. Marks in the complex numbers and differentiation questions were slightly higher in 2011/12 but the difference was not significant – this may be because student achievement in these topics was already relatively high. The other five questions examined different topics in the two years and it is possible a similar standard of difficulty was not achieved – this may account for some of the variation in the exam average. However, there is some evidence that the weekly practice has benefited the students, particularly in one of the more difficult topics (integration).

<table>
<thead>
<tr>
<th></th>
<th>mean mark</th>
<th>significant difference</th>
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<tbody>
<tr>
<td>Exam as a whole /60</td>
<td>41.7</td>
<td>47.8</td>
</tr>
<tr>
<td>Exam question: complex numbers /6</td>
<td>4.1</td>
<td>4.4</td>
</tr>
<tr>
<td>Exam question: differentiation /6</td>
<td>5.3</td>
<td>5.5</td>
</tr>
<tr>
<td>Exam question: integration by parts /6</td>
<td>3.3</td>
<td>3.9</td>
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Table 1: Mean marks for the exam and particular exam questions in 2010/11 and 2011/12.

Figure 6 displays a moderate correlation ($r = 0.52$) between exam and continuous assessment marks. Given that the mark is allocated in a coarse way to the weekly tutorial work, it is not surprising that the continuous assessment total is not a good predictor of exam performance. The continuous assessment system was designed primarily to encourage students to practise regularly and it is noted that the higher exam scores were achieved mainly by students who participated successfully in the continuous assessment.

![Figure 6: Students’ exam and continuous assessment totals in 2011/12.](image-url)
5. CONCLUSIONS

This paper has reported on the implementation of continuous assessment in a first year engineering mathematics module provided for a class of 150 aerospace and mechanical engineering students. In 2011/12, students were expected to work through a set of questions each week and bring their work to the following tutorial class for marking. One or two marks were awarded in each of weeks 3 – 12, the total available being 15%. The system aimed to promote consistent practice over the semester and avoid irregular bursts of activity associated with preparing for mid-term tests. In 2010/11, assessment was based on four tests (worth 10% each) and a final exam. The module syllabus and class times in 2011/12 were unchanged from the previous year and the intake qualifications of the students were very similar in the two years. Thus, the impact of the continuous assessment can be evaluated.

Attendance at lectures and tutorials was more uniform in 2011/12 and exam performance improved significantly. On average, 79% of the class presented work for assessment each week and motivation was generally not a problem. The continuous assessment encourages weekly practice and there is some evidence that students’ mathematical skills were enhanced.

6. REFERENCES