Using Simple Tests to Identify Students Needing Support in Engineering Mathematics

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Abstract

Within large first year classes it can be difficult to identify, at an early stage, those students who are struggling to adapt to studying at a University. In mathematics, many universities adopt a policy of early diagnostic tests to try to identify those struggling with the background material, however this can often identify those who have been away from formal learning for a long time who will not have problems adapting to study within a university environment. In addition, any support provided to students may not be directly related to their studies and such support is often not taken up by those who need it, but instead taken up by those who do not.

This paper presents an approach using simple tests which may be repeated weekly to identify those students who are struggling. To complete the first year mathematics course, a student must pass five such tests covering the basics of algebra, the use of calculators, vectors and matrices, differentiation and integration. In each test ten multiple choice questions are asked and a student is deemed to have passed the test when they correctly answer all questions at a single attempt. In advance of the tests, students are shown an example test and told that each of the 10 questions will be on the same topic as in the example. They are therefore able to revise the basics before the test, know the topics that will be present in the test and know that they cannot try to be strategic in their approach by avoiding what they perceive to be hard topics. Students who fail to achieve 100% at each attempt, are given feedback on their attempt, encouraged to seek further support during tutorials, and required to take the test again the following week. Experience has shown that at each attempt between 60% and 80% of students pass the test. Within two tests it is therefore possible to narrow down the list of students struggling with the basics to about 10% of the class.

An added benefit is that the tests provide early events for monitoring attendance and those students failing to engage are quickly identified. Personalised emails are sent to each student after each test detailing their test performance, or inviting them to identify problems they are having. The paper concludes by correlating the test results with overall performance in the first year engineering mathematics course.

Introduction

One of the major challenges in devising a support scheme for students struggling with mathematics is that often resource is taken by students who do not need the support, while those that do require support are often those with poor engagement and do not immediately recognise that they are struggling. Traditional support mechanisms such as tutorials are generally attended by those who are engaged and putting on extra tutorials general misses those students who really need the help. Allied to this, is that many students who struggle with mathematics in the yearly years of university have fundamental weaknesses in their underlying mathematical skills and it is these insecure foundations which are the primary cause of students failing to progress in mathematics (Engineering Council, 2000).

When marking mathematics exam papers it was noticed that many students were able to recall and use the new concepts that had been taught, but were making errors in simple mathematics that was assumed to have been covered by students before they arrived at university. Often marks were being taken away from students for making errors where no marks would have been gained by getting it correct, for example, correctly factorising a quadratic polynomial.

An approach that is often taken is to have a diagnostic test, administered either in paper or online, at the beginning of the course and an approach sometimes linked to this is to have an online quiz that students must get a threshold mark in by the end of the year. These approaches, while giving useful information on the general level of ability of the class, and possibly guaranteeing a certain level of core knowledge by the end of the year, do not clearly identify those students who are not engaged with their learning, or who are struggling with the basics (LTSN MathsTEAM, 2003).

Many universities, in recognising the difficulty of mathematics for some students, have set up Mathematics Support Centres (Matthews *et al*, 2012) but often these centres are used by self-referring students rather than ones who have been specifically identified as needing help.

To try to address these weaknesses, a series of simple tests were introduced to cover the fundamentals of each area of mathematics covered in the year 1 mathematics course. Initially two tests were introduced but this has been expanded to five tests over the years. As the concepts are so fundamental and at such a low level, the requirement is for each student to achieve 100% in each of the five tests. Tests are timetabled for one hour but students can usually complete the test in between 10 and 20 minutes. Students who are struggling usually take longer but time taken to complete the test is not a strong indicator of success.

The approach detailed is used for all first year students in Engineering at the University of Glasgow, a class size of up to 400 students. Before the test students are directed to an example of the test on the course Moodle. Each question in the example mirrors a question in the test, usually with only the parameters changed. The first sitting of each test is taken in a normal lecture period, and marked within 3 days.

A typical profile of results for one sitting of a test taken by 288 students is shown in Table 1. This result is typical of the outcome for a test and shows that almost all students get the majority of questions correct, but that some have serious weaknesses in the basic mathematics.

Mark	100	90	80	70	60	50	40	Total
Number	209	63	12	1	2	0	1	288
Percentage	72.6%	21.9%	4.2%	0.3%	0.7%	0.0%	0.3%	100%

Table 1: Typical profile of marks for a test.

Students may take the tests as many times as necessary to achieve 100%. In practice, between 60% and 80% of students pass the tests at each sitting. Taking a figure of 70% pass rate means that, for a class of 400, 120 have to take the first resit, 35 have to take the second resit with only 10 failing three times. It is these 10 individuals in whom extra help can be focussed with the dual aims of helping the student understand the issue with which they are struggling and allowing a personal relationship to develop between the student and someone on a position to help and advise them.

Content of the Tests

The tests comprise 9 or 10 questions about the fundamentals of mathematics. Calculators are allowed in all except the first test, and all except the second test are multiple choice with one correct answer out of 5 options.

The five tests used for 2014–2015 were:

1. Algebra

No Calculator, 10 multiple choice questions. Example questions are:

factorise $x^2 - 5x + 4$; solve the equation $x^2 - 20x + 84 = 0$; evaluate $\sqrt[3]{-216}$; simplify $\frac{5\sqrt{20}}{2\sqrt{15}}$, expressing your answer in surds (i.e., using square roots).

2. Calculator Test

Calculator required, 10 questions. Example questions:

Evaluate $\cosh 2.1$; evaluate $\sinh^{-1} 7.5$; evaluate $\sin^3 x$ or $\sin x^3$ where $x = 1.9$; find 2 solutions between 0 rad and 2π rad of $x = \cos^{-1} 0.35$.

3. Functions, Vectors and Complex Numbers

Calculator required, 10 questions, multiple choice. Example questions:

If $y = f(x) = x^2 + 2$, the value of $f(x+2)$ is …; find the argument of $z = 3 - 2j$ (answer must be in radians); find z^3 when $z = 3e^{-j\pi/5}$; determine the magnitude of $\bar{A} = 3\bar{\imath} - 2\bar{\jmath} - 2\bar{k}$.

4. Differentiation and Matrices

Calculator available, 9 questions, multiple choice: Example questions:

Differentiate $3t + 2f$ with respect to f, t is a constant; differentiate $\ln x$ with respect to x; evaluate the determinant of a 2-by-2 matrix; multiply together two 2-by-2 matrices.

5. More Differentiation and Integration

Calculator available, 10 questions, multiple choice. Example questions:

Differentiate a sum of two functions; differentiate a product of two functions, differentiate using the chain rule, from values of the first and second derivatives of a curve at a point, identify a point of inflection, maximum, zero crossing or a vertical asymptote; integrate $3t + 2f$ with respect to f, t is a constant; integrate $1/x$ with respect to x, evaluate $\int_1^4 x^2 dx$.

Main reasons for Student Failure

There are three main reasons why students fail to get 100% in the tests:

- Lack of attention to detail;
- Rushing the question paper;
- Fundamental problems or misunderstandings.

Most students who fail for the first two reasons usually complete it successfully the second time and only fail one or two of the tests. Those students who fail for the third reason are the ones who is often difficult to identify by other means and some students, despite apparently having the mathematical; qualifications, really struggle with basic mathematical concepts and operations.

Following a test, each student receives a personalised email stating either:

1. that they have passed the test;
2. that they have failed the test and identifying which questions they got wrong, or;

3. that they failed to attend the test and reminding them of the next opportunity to take the test.

The emails also remind students of the help available to them in tutorials and the Student Maths and Statistics Support available in the Student Learning Service.

The above approach enables identification of students with poor fundamental mathematical skills and at present they are encouraged to see help. At later stages of re-testing students are marked when they hand in their test and if they fail, they are given an immediate opportunity to review their answers. Those failing again are given individual tutoring in the questions they have repeatedly failed. This is usually only necessary for a few students each test. In this way all students who remain engaged will eventually pass all five of the tests. Students who do not engage and do not complete all of the test do not receive a grade for their first year mathematics course and therefore do not continue to subsequent years of their degree programme.

For each student, the number of resits required to pass all five tests (missing an opportunity to take a test is considered a failed attempt) has been evaluated and this has been compared with the outcome of the end of year exam in Engineering Mathematics, and the resit exam. The outcome is summarised in Table 2.

Number of resits required to pass 5 tests	Number of Students	Passed Exam First Time		Passed at resit	Total Passeed	
		Number	Percentage	Number	Number	Percentage
0	116	104	89.7%	10	114	98.3%
1	58	45	77.6%	11	56	96.6%
2	46	41	89.1%	1	42	91.3%
3	21	13	61.9%	4	17	81.0%
4	16	10	62.5%	3	13	81.3%
e5 (range 5–16)	27	6	22.2%	7	13	48.1%
Total	284	219	77.1%	36	255	89.8%

Table 2: Comparison of number of resits required to pass all tests with overall success in the course

The conclusion that can be drawn from Table 2 is that support currently provided to students who are able to complete the tests with one or zero resits gives a high pass rate amongst those students. The overall pass rate tails off as the number of resits required to pass the tests increases. Where a student requires an average or one or more resit per test then it can be seen that the success rate of these students, even after the resit, is less than 50%. Fortunately, there are relatively few students (approximately 10%) who fall into this category and therefore the additional help required can be targeted towards these students.

Conclusions and Further Work

The approach of using a series of simple tests to identify weaknesses in fundamental mathematics has proved useful. The number of students failing to pass the test each time quickly identifies those students who require additional help.

Extra help for these students is currently made available through course tutorials and also through the Mathematics Support Centre of the University. At present attendance is not compulsory but consideration is now being given as to how students may be required to seek help with their maths.

Feedback from students has general been positive, particularly from later year students looking back at their year 1 experience. One comment received is typical of many:

> “I never understood, and hated, surds at school and would always avoid them in questions, but they are actually really easy … the 100% test forced me to learn how to do them as I couldn’t hope to get by on other questions”.

Areas for further development include investigating the use of multiple randomised paper versions of the test at one time (to avoid copying by some students), or a move to online tests with individualised questions and opportunities for immediate feedback and personalised support.

This paper presents results from the 2014–15 academic year and further research into earlier years would provide more certainty over the relationship between the number of resits required to pass the tests and success in the course. Additional research is also required to look at degree outcomes of students and how they relate to their performance in the first year Mathematics course.

References

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