Assessment and Development of Core Skills in Engineering Mathematics

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Abstract

Many engineering students enter Dublin Institute of Technology with core mathematical problems. Each year a diagnostic test is given to incoming first year students at both Ordinary and Honours degree levels. This test reveals deficiencies in numerous core areas of mathematics. Many students ignore the help that is available to them and limp through several years of engineering carrying a serious handicap of poor core mathematical skills. Anecdotally, engineering students at all levels can almost complete relatively complex mathematical problems, but end up with the wrong answer by making some very basic errors.

The aim of this project is to set up a "module" in core mathematics. The course material is basic but a very high pass mark of 90% is set. Students may repeat this module as often as they like until they achieve a pass mark. An automated examination for this module has been developed on WebCT and a bank of questions has been created. Initially, this project was piloted as part of the third year Ordinary Degree mathematics module in Mechanical Engineering.

Results and analysis of the students' attempts at the examination are presented. Over 90% of students achieved a pass in this module, with some students taking up to six attempts. Their results are compared with their original results from the diagnostic test completed in their first year in 2006. We also present a summary of the resources being made available to the students to help them develop their core skills.

1. Introduction

Many students upon entry to third level engineering programmes have problems with core mathematical skills. This has been borne out in the results of diagnostic tests carried out in many third level institutions, both in Ireland ([1], [2]) and in the U.K. ([3], [4]). These problems with core concepts can lead to comprehension difficulties in numerous modules, both in mathematics itself and in related subjects. In recent years, this has been exacerbated by the fact that students are being recruited from an increasingly diverse student body. This past academic year of 2008-2009, in particular, has seen the return of a large number of students to full-time education after many years in employment, due to adverse economic conditions. In this paper we discuss the maths diagnostic test carried out in the Dublin Institute of Technology (DIT) and the deficiencies in students' core mathematics revealed by this test. We then outline the details of a pilot project carried out to address these deficiencies. The results of a reflective online survey given to all the students involved are examined. The mathematics diagnostic test was also given to a selection of fourth year students and the results of this test are shown. Finally we outline future work we intend to carry out on this project.

2. Core Skills Initiative

Research conducted by the Dublin Institute of Technology (DIT) Retention Office showed that a student's mathematics grade in the Irish Leaving Certificate (the final examination in the Irish secondary school system) is a key determinant in that student's progression through engineering programmes [5]. As a result, a mathematics diagnostic test has been given to first year students for several years now and a Maths Learning Centre (MLC) has been set up in the Dublin Institute of Technology.

2.1 Mathematics Diagnostic Test

The DIT Mathematics Diagnostic Test revealed marked deficiencies in core mathematical skills [6]. The test consists of twenty questions (ten paired questions) on basic topics such as algebra, fractions, indices, trigonometry, the equation of a line, logs, quadratic equations, simultaneous equations and basic differentiation. In 2006, the mean mark obtained by first year engineering students was 55% across all programmes. More worryingly, this mean dropped as low as 29% in some programmes. A large spread was seen within most programmes, with many students scoring significantly lower than the mean mark.

2.2 Core Skills Assessment

It was decided to set up a core skills assessment in mathematics, similar to that already in existence in the Institute of Technology Tallaght, Dublin [7]. This consisted of a multiple-choice quiz on WebCT, based on a randomised question bank. The material covered by the test was basic but the pass mark was set at 90%. The questions used were based on those already in use in the DIT Mathematics Diagnostic Test. Students were allowed to re-sit the assessment as frequently as required until they passed. Ideally a pass in this module would be compulsory for progression to the next year of the course, but this is not yet the case.

3. Pilot Project

In Ireland, students who have not achieved 55% or more in Higher Level Leaving Certificate mathematics are not eligible for the four-year Honours Degree engineering programmes, but instead may enter into a three-year Ordinary Degree programme. Upon successful completion of this, they may then enter into the third year of the Honours degree. The pilot group chosen was third-year students in the Ordinary Degree in Mechanical Engineering in DIT.

3.1 Project Overview

The "core skills assessment" was worth 10% of the mathematics module. In the first instance, the third-year students re-sat the Mathematics Diagnostic Test that they had taken in first year in 2006. Those who scored 90% received nine marks out of ten, whilst those who scored less than 90% received no marks and had to take the core skills assessment at a later date. These students continued to sit the core skills assessment on a monthly basis until they achieved the required pass mark of 90%. After their first attempt, students were given access to a WebCT site with resources tailored for each question and were also encouraged to attend the MLC. After their second and subsequent attempts, special classes on problem topics were provided. At the end of the year, students were asked to fill in a reflective online survey on the core skills assessment.

3.2 Results

On the first attempt, eleven students out of a class of thirty-four achieved the 90% pass mark. Eight students were close to passing, with marks greater than 80%, while several students only achieved a score of 50%. The mean

mark for the class was 78%, with a standard deviation of 13%. Twenty-seven of the students involved had sat the Mathematics Diagnostic Test in both 2006 (in their first year) and 2008 (as part of this project). These students achieved a mean mark of 65% in 2006, which increased to 81% in 2008. This shows that students are improving their core mathematical ability as they progress through the course, but also highlights the fact that many are still struggling with core mathematical concepts in later years. By the end of the year, thirty students out of thirty-four had achieved over 90%, with up to six attempts at the assessment allowed. Of the four students who did not pass, one had dropped out of the course, and the lowest result achieved by those remaining was 67% after two attempts, with the others achieving 83% and 87%, also after two attempts.

3.3 Reflective online survey

A reflective online survey was given to the class at the end of the year and there were twenty-two responses. Firstly, students were asked to rate the statement "Doing this exercise has made me more confident about maths in general" on a five-point Likert scale. Twelve out of the twenty-two respondents either agreed or strongly agreed with this statement, as can be seen in Figure 1.

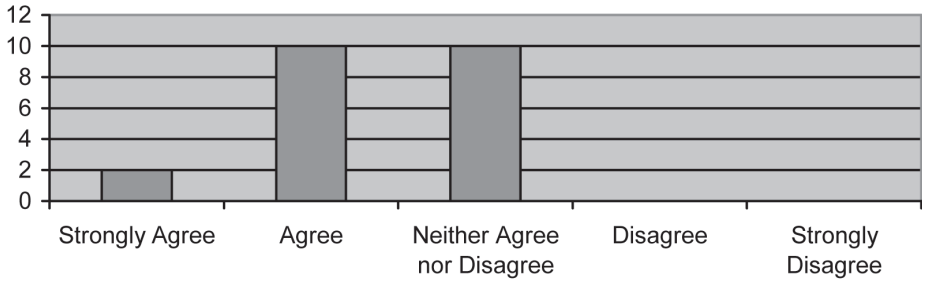

Figure 1: Increasing confidence in mathematics: Summary of twenty-two student responses to the statement that "Doing this exercise has made me more confident about maths in general".

Next, students were asked if doing this exercise had increased their ability to do basic mathematics. This time, fourteen students either agreed or strongly agreed with the statement, as shown in Figure 2.

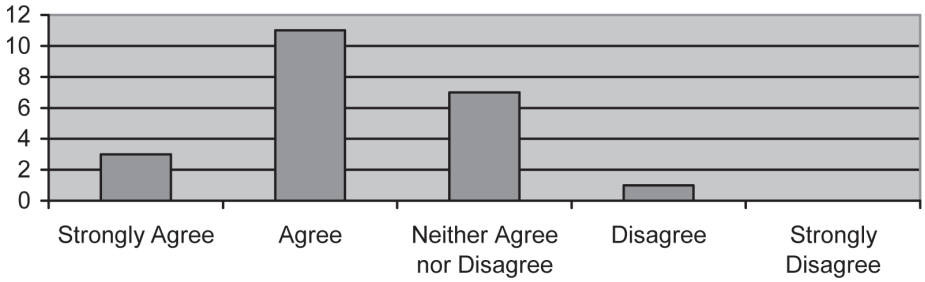

Figure 2: Increasing mathematical ability: Summary of twenty-two student responses to the statement that "Doing this exercise increased my ability to do basic maths".

It should be recalled at this point that several students passed the exercise on the first attempt, and these students are therefore unlikely to agree with this statement. Therefore, if we exclude those students who passed the test the first time, we see from Figure 3 that thirteen out of fifteen students agreed that doing this exercise increased their ability to do basic maths. This is rather strong confirmation that weaker students felt that this exercise was beneficial to them in improving their knowledge of core mathematical concepts.

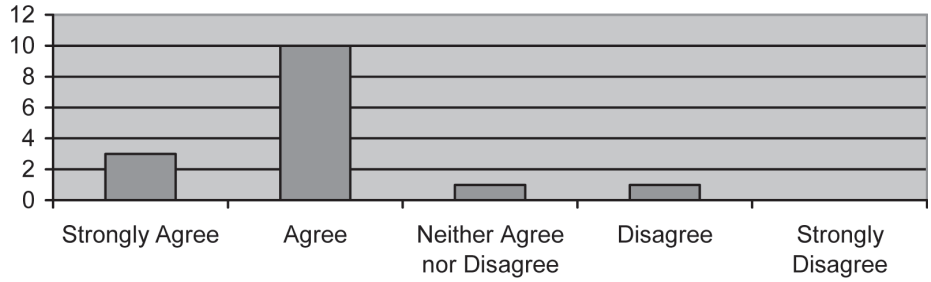

Figure 3: Increasing mathematical ability: Summary of fifteen student responses to the statement that "Doing this exercise increased my ability to do basic maths", taking into account only those students who did not pass the first time.

The students were then asked which resources they had used to prepare for these examinations, and their responses are shown in Figure 4. Six had used the online resources made available, three had attended the special classes and two had used books in the library. None had used the MLC. There are several possible explanations for this: one is that if students do not get into the habit of attending in first year, they may be reluctant to go in later years; another is that DIT is split over four main campus locations, which are not close together, so the number of hours available on any given campus are rather limited. Fifteen students had not done any study for the test, although these were mainly the students who passed the first time around or who narrowly failed and passed on the second attempt. However, it is clear that some of the weaker students in the class, in terms of core mathematical knowledge, were encouraged to do additional work on their mathematical skills in their own time.

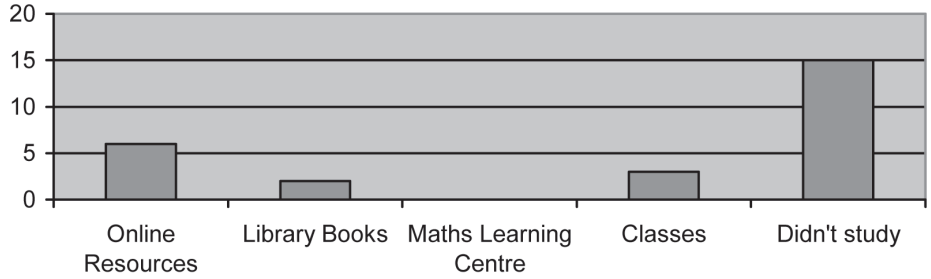

Figure 4: Resources used: Summary of twenty-two student responses to the question "What resources did you use?" Students could opt for more than one resource.

Finally, students were asked if they felt that the 90% pass mark was too high and, rather amazingly, none of the respondents agreed that it was, as shown in Figure 5.

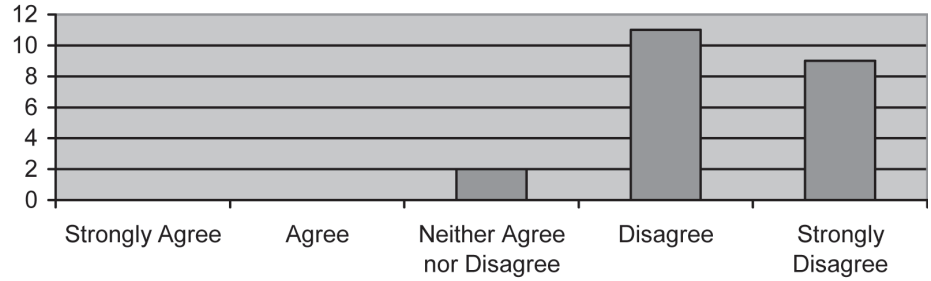

Figure 5: Pass mark: Summary of twenty-two student responses to the statement "The 90% pass mark is too high".

Overall, the students were fairly positive about the core mathematics exercise and there were five positive comments in the survey, such as:

> *"The core maths exam is an excellent addition to the continuous assessment content. A great way for helping people to cope with maths in college. It refreshes your memory on maths topics that haven't been studied since secondary school."*

There were only three negative comments in the survey and these were about negative marking, and that it was possible to copy other people's tests. In the future it will not be possible to copy as we have expanded the database of questions so that it is unlikely people will have a similar question to their neighbour.

Of the thirty-three students who completed the year, twenty-two responded to this survey, including one of the three students who failed to pass the test. Looking at the spread of marks these students received in second year, the full spectrum is represented, from the top of the class to those who failed second year Mathematics but passed by compensation. As a result, the sample seems representative of the class as a whole. Most importantly of all, fourteen students responded that this module improved their ability to do core mathematics, which was the aim of the initiative.

3.4 Sample Group of Final Year Students

Finally, it was decided to test a small subgroup of final-year students who had already completed an Ordinary degree and subsequently continued into the Honours degree programme.Thirteen students volunteered to retake the diagnostic exercise. These students only had to retake the test, no credit was awarded to them irrespective of how well or badly they did.

While the mean mark for this group was 84%, only five out of thirteen scored more than 90% while two scored less than 60%. Given that these students volunteered to do the test, there may be significantly more students in final year who still lack many core mathematical skills.

4. Conclusion and Future Work

4.1 Conclusion

By the completion of the core skills initiative, thirty out of thirty-four students in the pilot group had achieved a score of over 90% in the assessment, with some students showing a substantial improvement over the course of the project. Some of this improvement was due to students becoming more used to this type of examination, but there is undoubtedly an underlying improvement in their ability to perform basic mathematical tasks. Furthermore, this pilot was performed with the strongest cohort of Ordinary degree students in the DIT [6] in their third year, which suggests that there are many more engineering students who are limping through earlier years and other courses with similar or worse problems, not to mention those who have already dropped out.

The results of the small group of final year Honours degree students who took the assessment have shown that there may be a significant number of students who struggle with basic mathematical concepts throughout their entire degree. Such problems are clearly endemic and will persist if not tackled in a consistent manner. The core skills assessment is one such way to encourage students to seek help to address these deficiencies, and it is extremely important that this work be rolled out across all first year courses in engineering.

None of the students surveyed in this pilot used the MLC to assist them with their core mathematics. This may demonstrate that if students do not get into the habit of attending the MLC in early years, they will not attend in third year. Also, the DIT is split over several campuses, and funding has been significantly reduced, so the MLC is only open in the Engineering Faculty twice a week, at times which may not suit all students.

4.2 Future work

The core skills assessment will now be introduced to several first year classes, with a view to making it compulsory for all first year engineering programmes over the next few years. We intend to extend the number of questions within the assessment and to develop more advanced core exercises for later years which reinforce basic concepts covered at an earlier stage. Currently a practice test is being developed, which would be always available to students. This test will direct students to pre-existing resources targeted at their individual weaknesses.

While the 90% pass mark was effective for third-year students, a sliding scale of marks would be more appropriate for first-years: for example, less than 70% does not gain any marks for the student, but 70-79% counts for four marks, 80-89% for six marks and greater than 90% is a full ten marks.

A portion of the current pilot group of Ordinary Degree students will continue into final two years of the Honours Degree programme. It is intended to re-test these students when they are in the final year of the Honours degree to investigate depth of learning from the core skills assessment. Interviews will be conducted with six of these students to gain a deeper insight into how problems with core mathematical skills can affect students throughout their studies. In addition, all fourth year Honours degree students will sit the Mathematics Diagnostic Test to give a fuller picture of the core skills problems which remain when students are about to complete their studies.

In addition to conducting a survey of all students who partake in the assessment, we will also carry out in-depth interviews with a selection of students across several courses.

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