2012

How Much Do Our Incoming First Year Students Know?:Diagnostic Testing in Mathematics at Third Level

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Abstract

A continuing cause for concern in higher education institutions is the poor core mathematical skills of incoming students. Many institutions now offer mathematics support services such as drop-in centres, online resources and short "refresher courses" in an attempt to alleviate the problem. The majority of third level institutions in Ireland and internationally now make use of diagnostic testing of incoming first year students that both predict subsequent success and select groups for remediation. This project was developed to explore the issues around diagnostic testing and follow-up support for incoming students in the College of Sciences and Health. A large cohort of first year science students was tested and those who failed to achieve 50% on the test were offered support. This support came in the form of peer-assisted student-led tutorials during which students had the opportunity to revise basic areas of mathematics. On comparison of the scores on the diagnostic test with the end of module results there is a correlation between students who scored poorly on the diagnostic test and students who failed the Semester 1 mathematics module.

Keywords: first year curriculum, mathematics, peer learning

Introduction

Over the past decade comprehensive concerns over student difficulties with mathematics, statistics and general numeracy have been expressed by many governments, employers and higher education providers. Abundant supplies of reports and articles have been produced to highlight these concerns (Hawkes and Savage 2000; Savage 2003; Smith 2004). Furthermore, these issues are not exclusive to the UK and Ireland alone; reports of this kind are being produced worldwide. For example, an Australian article (McGillivray 2008) studied the experiences of first year undergraduate students and attempted to identify the weaknesses in mathematical skills and confidence that act as a barrier for success for many students. This gap between the level of preparedness either expected or required upon entry to third level and the mathematical capabilities acquired at school/college has become known as "the mathematics problem" (Savage 2003).

More recent studies into the changing nature of the mathematical skills which our undergraduates have acquired, have led to many third level institutions organising some form of mathematics support including the provision of drop-in centres, individual consultation and access to special provisions. The main aim is to aid students to overcome their difficulties with mathematics but also to help students with different backgrounds and challenges, such as mature students and students with disabilities, to get an introduction to the mathematical thinking required at third level (Gill, Mac an Bhaird and Ní Fhloinn 2010). Indeed, the Student Maths Learning Centre (SMLC) was established in DIT in 2006, with this purpose in mind.

Diagnostic Testing

Many universities now use diagnostic testing in mathematics as a tool to assess their intake of students, in particular engineering students. Different third level institutions adopt different types of diagnostic tests. An extensive study carried out in 2002 showed that many institutions use multiple-choice questions, either paper-based or computer-based and most tests group questions together under a common heading such as algebra or calculus (LTSN 2002). In Loughborough University, a novel diagnostic test is in use, incorporating a paired question method with the idea that both questions in a pair should test the same topic. Such a structure is believed to allow easy identification and subsequent follow up of topics where the student needs extra help (Lee and Robinson 2004).

Diagnostic testing has helped to show that student performances have declined particularly in the areas of arithmetic and algebra (Atkinson 2004; Gillard, Levi and Wilson 2010). Moreover, the testing has indicated an increase in the variability of results. In terms of practical significance to the teaching and learning of mathematics at third level today, we are faced with the fact that the profiles of students entering mathematics lectures today are not the same as they were (Faulkner 2012). Neither are the mathematical backgrounds of first year undergraduate students as strong as they were as recently as ten years ago.

Ireland has a unique situation in terms of the mathematical homogeneity of its third level students; most students enter via the route of the Leaving Certificate, on completion of 13 years of formal mathematics education. With regards to the transition from second level to third level mathematics, the current complaints of educators at Irish third level institutions, including DIT (Russell 2005; Ni Fhloinn 2006), about the level of mathematical knowledge and skills of incoming students are much the same as those outlined 16 years ago by the London Mathematics Society in the report Tackling the Mathematics Problem (LMS 1995):

1. Students lack reliability and fluency in manipulating and simplifying numerical and algebraic problems

2. There is a marked decline in students' analytical powers when faced with simple two-step or multi-step problems
3. Many students no longer understand or appreciate that mathematics is a precise discipline in which exact, reliable calculation, logical exposition and proof play essential roles.

Outline of Project

Diagnostic Testing was carried out for the first time in the College of Sciences and Health in September 2011. Michael Carr in the School of Civil and Building Engineering Services has developed a test over the past number of years and, after discussion with him and consultation with the research, it was decided to use the same test in our own College of Sciences and Health. The test consists of a multiple-choice quiz on webcourses and is based on a large randomised question bank. Students are asked to answer 20 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; they are given a time constraint of 90 minutes.

Students were given immediate results when they submitted their test and any students receiving less than 50% were advised to take part in a revision initiative. This initiative involved student-led tutorials over the first 10 weeks of Semester 1. Two fourth year Mathematical Sciences students facilitated the tutorials and first year students revised basic mathematical concepts in each tutorial using specially prepared revision booklets (prepared by Sigma Centre for Excellence in Mathematics and Statistics support). Students were then asked to retake the Diagnostic Test again during Weeks 11 and 12 of Semester 1.

Evaluation of diagnostic testing

The pilot groups chosen for this study were first year Honours Degree students on eight different programmes in the College of Sciences and Health.

		Leaving Certificate Points*	
Course	**Programme Code**	**Final**	**Mid point**
Mathematical Sciences	DT205/DT220	255	340
Physics Technology	DT222	305	365
Physics with Nanotechnology	DT227	325	375
Clinical Measurement	DT229	410	450
Physics with Bioengineering	DT235	320	390
Optometry	DT224	495	515
Computing	DT211	320	335
Computer Science	DT228	350	370

Table 8.1 Programmes and Leaving Certificate points

Note: In the Irish Leaving Certificate, six subjects are included for the purpose of calculating points. A maximum of 100 points can be attained in any one subject. The final point column shows the lowest points score achieved by an applicant who received an offer of a place on the course. The mid point is the points score of an applicant in the middle of a list of offerees placed in points score order.

Building upon work already carried out in DIT (Michael Carr), the initiative was evaluated using a strategy devised to enhance the way in which the diagnostic test was implemented, and integrated, into programmes. Formative evaluation was also necessary to highlight areas where improvements could be made to the diagnostic test itself and its use within Science programmes. Both quantitative and qualitative research methods were implemented to ascertain the effectiveness of the diagnostic test, the follow-up revision tutorials and to determine where improvements could be made. The methods of data collection are diagnostic test results, attendance at revision tutorials, Leaving Certificate (LC) mathematics mark, diagnostic re-test mark, end of module maths mark and questionnaires.

Across all pilot groups, 329 students were eligible for consideration in the data. Some students had one or more pieces of data with missing values and so were excluded from some comparisons. Reasons for missing data include non-standard entry students, international students and a non-compulsory diagnostic test. Some 26% of students for whom data was collected had taken Higher Level Mathematics at Leaving Certificate and 69% had taken Ordinary Level Mathematics at Leaving Certificate. The response rate for the diagnostic test was 47% (156 responses) giving an overall average mark of 52%.

Programme	No. Eligible Students	Average Mark	Response Rate	Less than 50%
DT205/DT220 – Mathematical Sciences	44	53%	84% (37 responses)	16/37 (43%)
DT222 – Physics Technology	15	58%	52% (8 responses)	4/8 (50%)
DT227 – Physics with Nanotechnology	16	57%	81% (13 students)	4/13 (31%)
DT229 – Clinical Measurement	30	58%	37% (11 students)	4/11 (36%)
DT235 – Physics with Bioengineering	9	50%	67% (6 students)	3/6 (50%)
DT224 – Optometry	30	61%	20% (6 students)	1/6 (17%)
DT211 – Computing	73	42%	34% (25 responses)	16/25 (64%)
DT228 – Computer Science	112	49%	45% (50 students)	26/50 (52%)

Table 8.2 Results for diagnostic testing: average mark and response rate

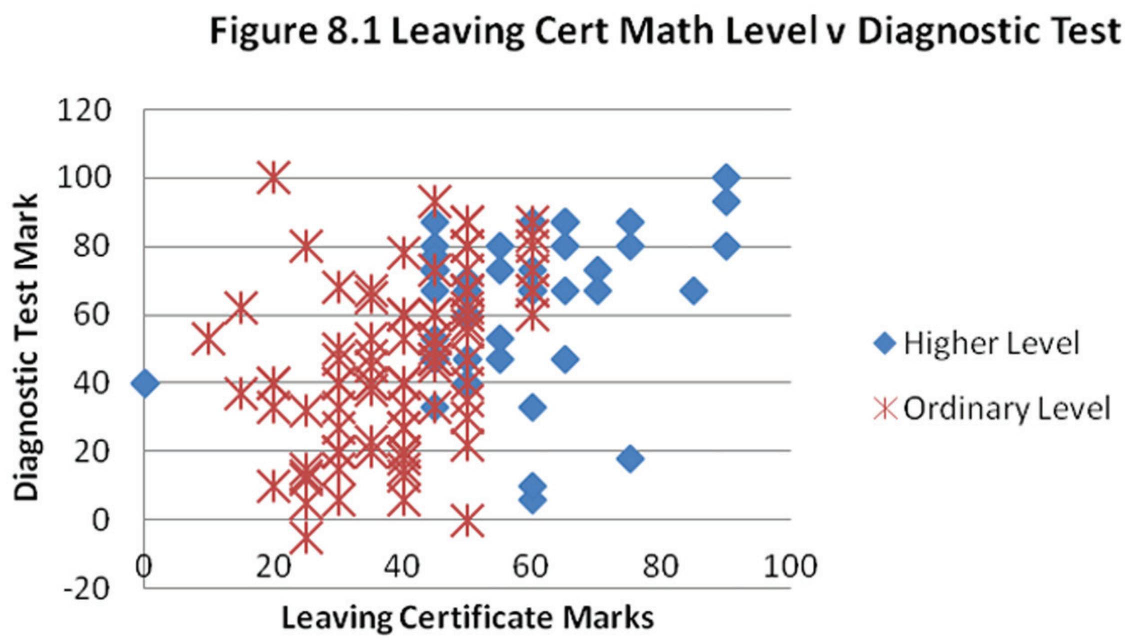


Figure 8.1 is a breakdown of diagnostic test marks versus whether a student sat Higher Level or Ordinary Level Mathematics at Leaving Certificate Level.

As can be seen from Figure 8.1, students who had higher level mathematics were much more likely to get over 50% on the diagnostic test. Some 30% of higher level students failed to achieve 50% on the diagnostic test whereas 56% of ordinary level students failed to achieve over 50% on the same test.

It is worrying that, given that the points requirements to all of the pilot courses are relatively high (to very high in the case of Optometry) and that the basic mathematics requirement is an OB3 (Ordinary Level B3) for all Physics and an OC3 for all Computing programmes, almost half of all respondents (47%) to the diagnostic test failed to achieve more than 50%. In particular, high proportions of students on both computing programmes failed to achieve higher than 50%.

Furthermore, results from the diagnostic test highlighted particular topics about which students had misconceptions or areas where students had little or no prior knowledge on which to base their answers. Algebra and arithmetic were the two main "problem areas" for these students and knowing this in advance of lectures allowed the author to change her style of teaching and allow slightly more time allocation to these topics. Giving the students advance notice and materials to revise these topics and to go over the keywords which they would meet again in lectures, gave the weaker students in particular space to "get their head around the basic concepts" and a direction in which to point themselves mathematically.

Student-assisted tutorials initiative

Students who received less than 50% on the diagnostic test were advised to attend revision tutorials to help them to improve their understanding of basic mathematical concepts. These tutorials were held twice weekly for the first 10 weeks of Semester 1 and were facilitated by two fourth year Mathematical Science students. The average weekly student attendance was 11 students with the majority of attendees being mature students, particularly from the two computing programmes. Attendance was not compulsory nor did it account for any continuous assessment mark and it is for this reason, the author feels, that many students were not motivated enough to attend.

Each tutorial had a separate revision booklet prepared for it with each booklet covering a different basic mathematical topic; for example Booklet 3 – Algebra, Booklet 5 – Factorising. Students were seated in small groups and were given a short introduction to the topic by the tutors. Each group was then given time to work on and discuss some questions together and their solutions were checked by the tutors. If a question was consistently incorrectly answered, the tutors worked through this on the board. Booklets also contained extra questions and worked solutions for students to work through after each tutorial. The group work aspect of the tutorials allowed students to work together on problems and also to meet other learners in the same situation as themselves.

Student feedback about the initiative was very positive. More than 50% of original respondents (regardless of their mark on the diagnostic test) attended some revision tutorials.

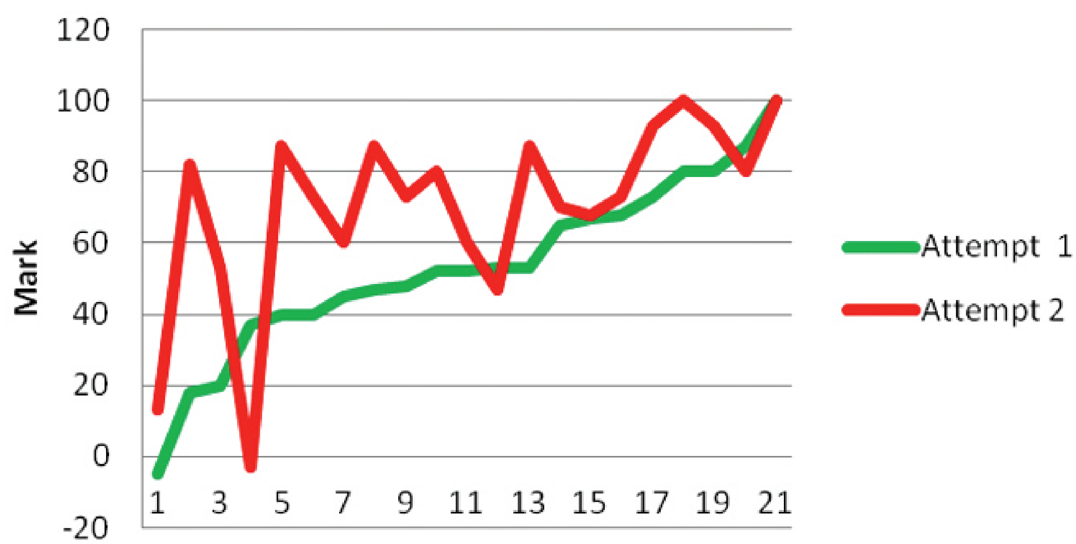
Percentage Agreement	**Response**
87%	Revision booklets were well-structured with good examples.
75%	Revision tutorials had improved their knowledge of basic mathematics.
88%	Revision tutorials had greatly improved their confidence with mathematics

Table 8.3 Student feedback about the initiative

Re-test

The diagnostic test was made available again during Weeks 11 and 12 of Semester 1 and students were reminded to attempt the test. 13% of students re-sat the test and again this figure may have been influenced by the non-compulsory nature of the initiative, coupled with a lack of motivation shown by many of the (especially weaker) students. The results however were more reassuring with 86% of respondents increasing their marks. The average increase in results was 62% which shows a significant improvement in understanding and competency in basic mathematical questions. These results also helped to improve students' confidence in their mathematical ability and keep them focused on the maths module.

Figure 8.2 Test Mark vs Retest Mark



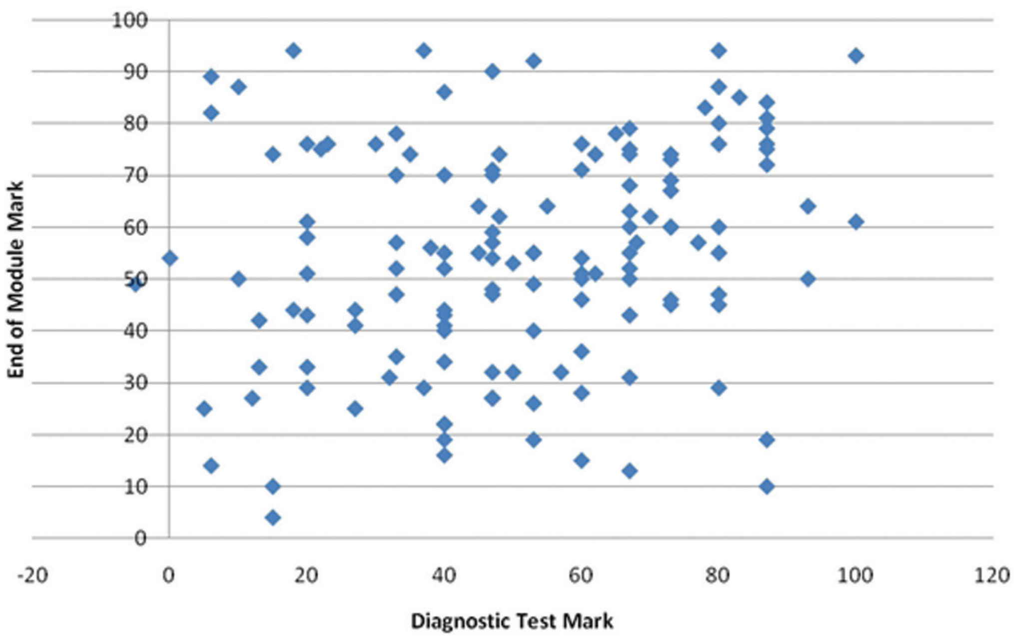
Correlation Analysis

To measure the strength of association (if any) between the diagnostic test mark and the end of module exam mark, we used the correlation coefficient. Any respondents who had either not taken the diagnostic test and/or had not taken the end of module exam mark were omitted from the analysis, leaving us with a sample size of 155. A non-compulsory submission of the diagnostic test was a major contributory factor to such omissions as well as students dropping out of their programme before the end of the semester.

Analysis of the data shows that there is a positive correlation between the diagnostic test mark and the end of module mark (r = .390) which is statistically significant (p = 0.000). This tells us that those students who achieved a poor score on the diagnostic test tended to also obtain a poor end of module mark.

A scatter diagram (see Figure 8.3) of the data shows a linear relationship between the variables.

Figure 8.3 Scatter Diagram of Diagnostic Test Mark vs End of Maths Module Mark



The regression equation is as follows:

End of Maths Module mark = 16.67 + 0.833 *(Diagnostic Test)*

In conclusion, diagnostic testing provided a positive approach to a situation. For our students it provided a constructive method which led to ongoing support and for the author as an academic interested in this research, it provided an indication of "what is needed" in terms of teaching and possible changes in the curriculum. There was a systematic improvement in the basic mathematical skills of students who participated in the initiative and this is evident from the results on the re-test and also from student feedback. We hope that this initiative will become an integral part of mathematical education for first year students, as the number of students sitting the diagnostic test increases in future years.

Future Work

The diagnostic test will be introduced to additional cohorts of students from 2013. To ensure a better initial response rate, each group will now be given a dedicated time slot in a computer lab during their induction schedule. This will help to collect and analyse results in advance of the students beginning their first year mathematics modules and will allow discussion of how and where students can avail of maths support early in the semester.

Due to financial constraints, it is unlikely that the student-led revision tutorials will run again. In their place, an online resource will be made available to all students. This resource will be updated each week with a new tutorial. The revision booklets will again play a major role along with video links and dedicated quizzes for each topic.

This mathematics support initiative will feature in an upcoming edition of The Irish Mathematics Learning Support Network newsletter and it is hoped that there will be collaboration with other institutions running similar initiatives over the coming years so that recommendations can be discussed and improvements can be made.

Recommendations to DIT

1. Diagnostic Testing in mathematics should be extended to all incoming first year students in the College of Science and Health. Compulsory submission of the diagnostic test should be enforced by all first year maths lecturers as the results of the test can then inform how teaching strategies may need to be adapted.

2. A higher level of the first year maths diagnostic test should be developed for administration in the third year of degree programmes. Many of the degrees in the College of Sciences and Health require a Statistics module to be completed by students in their second or third year and so this higher level test should contain a mixture of numerical and statistical type questions.

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