PERFORMANCE IN MATHEMATICS OF STUDENTS ENTERING UNIVERSITY IN IRELAND – HAS CURRICULUM REFORM CONTRIBUTED TO A DECLINE IN STANDARDS?

Gerry Shiel*, David Millar and Rachel Cunningham
Educational Research Centre
St Patrick's Campus, Dublin

A series of studies published by staff and recent postgraduates of the University of Limerick show that standards in basic mathematics among university entrants enrolling in degree programmes in science and technology have declined in recent years, as measured by a 40-item Diagnostic test. The studies point to the introduction of Project Maths (the revised mathematics syllabus and associated teaching methods implemented in all post-primary schools from 2010 onwards) and the availability of bonus points for university entry to students taking mathematics at Higher level in the Leaving Certificate since 2012 as key contributing factors. This paper re-examines published data on the performance of First-year undergraduates on the 40-item test and concludes that, while standards on the test have dropped over a number of years, there is difficulty in attributing this to Project Maths. Instead, it is argued that reported performance patterns are most likely to have arisen from a changing mathematical profile among students entering science and technology programmes at UL, and, most recently, from a time-limited realignment of grades arising from the introduction of bonus points.

THE CONTEXT OF PROJECT MATHS

The Project Maths initiative began in 2008, when it was introduced on a phased basis in 24 pilot or 'initial' schools. Prior to this, the most comprehensive reform of post-primary mathematics in Ireland was the introduction of the 'New' or 'Modern' Mathematics curriculum, implemented between 1964 and 1973 (Cunningham, Close & Shiel, 2016). The intention of Project Maths is to elicit 'more student sense-making, problem-solving, engagement in rich learning activities, and conceptual understanding of procedural skill' (NCCA, 2012, p.5).

*Gerry Shiel may be contacted at *gerry.shiel@erc.ie*

The syllabus at Leaving Certificate:

> aims to develop mathematical knowledge, skills and understanding needed for continuing education, life and work. By teaching mathematics in contexts that allow learners to see connections within mathematics, between mathematics and other subjects, and between mathematics and its applications to real life, it is envisaged that learners will develop a flexible, disciplined way of thinking and the enthusiasm to search for creative solutions (DES, 2013, p. 6).

Beginning in 2010, revised syllabi and teaching and assessment methods associated with Project Maths were rolled out, again on a phased basis, in all non-pilot post-primary schools. Students in 2012 (the first national cohort to complete aspects of the Leaving Certificate under Project Maths)[1] were examined on two strands of the new curriculum (Statistics & Probability, Geometry & Trigonometry) and three on the pre-2010 syllabus. The roll out continued until 2015, when all five strands of Project Maths were assessed in full[2].

The Chief Examiner's Report on the Leaving Certificate mathematics examination in 2015 (SEC, 2016) outlined differences between the pre-2010 syllabus and the new syllabus:

> While there is significant overlap between the old and new syllabuses, the new syllabus is different from the previous one both in terms of content and in terms of skills. In terms of content, among the changes at Leaving Certificate are: an increase in the proportion of the syllabus dealing with statistics and probability, the removal of vectors and matrices, and changes to the material on functions and calculus. In terms of skills, the new syllabus has an increased emphasis on problem solving, as well as on the skills of explanation, justification, and communication (p. 3).

The report also noted that the revised syllabus reflects a deliberate attempt to increase the emphasis on higher-order thinking skills, and acknowledges that syllabus expectations are ambitious in this regard at all levels.

A further point to note in considering any effect of Project Maths on student performance is that students taking the Leaving Certificate examination up to

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[1] The 2012 Leaving Certificate cohort comprised two groups: Those who had studied under the pre-2010 syllabus and had taken the optional Transition (Fourth) year and those who had moved directly from Third year to Fifth year in 2010 and had studied under Project Maths.

[2] All five strands were also assessed in 2014, but candidates had a choice at all examination levels between a question on synthetic Geometry and a problem-solving question based on their studies of geometry at Junior Certificate level. The former was more reflective of the previous curriculum. This choice was in place from 2012 to 2014 and was removed from 2015 onwards, when all questions became compulsory.

2014 had studied under Project Maths at Senior Cycle only. Furthermore, the 2015 Leaving Certificate cohort was split between those who had studied Project Maths at Junior and Senior Cycles (students who had not taken Transition year) and those who had studied under Project Maths at Senior Cycle only (students who had taken Transition year). By 2016, all students had been introduced to aspects of the new curriculum throughout their post-primary education. Because of its phased introduction, 2017 is the first year in which at least *some* of the Leaving Certificate cohort (those who did not take Transition year) had studied all strands of Project Maths at both Junior and Senior Cycle while 2018 is the first year for which this will be true for *all* Leaving Certificate students. Hence, care needs to be exercised in drawing inferences about the impact of Project Maths on examination performance, especially in the years prior to 2015.

Concerns about the Impact of Project Maths on Students in Higher Education

Criticism has been directed towards Project Maths since its inception. A report by academics at University College Cork (Grannell, Barry, Cronin, Holland & Hurley, 2011) questioned whether Project Maths could adequately prepare students for the depth and breadth of third-level mathematics courses. The authors raised a number of concerns. For example, they felt there was a strong association between the revised syllabi and the mathematics component of the Programme for International Student Assessment (PISA), organised by the Organisation for Economic Cooperation and Development (OECD), implying that the syllabus was becoming more 'PISA-based'. They argued that the purported benefits of the new curricula were 'exaggerated', e.g., in relation to fostering a more thorough understanding of mathematics. The authors were also critical of the central role given to real-life contexts in the new curricula and called for implementation of a more structured approach to solving problems based on methods associated with the teaching of mathematics in Singapore (Singapore mathematics).

The report argued that reform in mathematics could have been achieved by training teachers on the existing curriculum, rather than, as the report's authors saw it, lowering the standard of material in the curriculum. It called for more intensive training of teachers ('weeks instead of days') and for more involvement of Third-level mathematicians in such in-service training. The authors strongly questioned the absence of certain topics (e.g., vectors, matrices, sequences and series, aspects of calculus) that had been dropped from the Leaving Certificate in the transition to Project Maths, and criticised the ordering of topics in the new syllabi, calling instead for greater integration of strands. They also recommended a reduced emphasis on 'context-constructivist methods' at Senior Cycle.

Kirkland and colleagues (2012) are highly critical of the impact of syllabi issued under Project Maths on the mathematical performance of students intending to study mathematics at university level. In a paper outlining what they describe as 'major flaws' with Project Maths, they argued that the new syllabus was 'completely insufficient and unsuitable by international standards to support engineering, scientific and mathematical education at the highest level' (p. 8). Specific concerns included the emphasis on certain topics such as applied probability with less focus on the areas of calculus (integral and differential) and linear algebra[3]. Kirkland and colleagues objected strongly to the removal of vectors and matrices, arguing that 'their associated rich and powerful theory' is 'ubiquitous throughout engineering, physics, mathematical chemistry, quantitative ecology, computer science, economics and sociology' (p. 5). They also took issue with the volume and nature of the Euclidean Geometry included in the new syllabus, arguing that there is too much content in this area, but also that it is not sufficiently advanced. More generally, they disagreed with the focus on applications, taking the view that there is not enough emphasis on mathematical foundations, and

> ...consequently, students are placed under the unrealistic expectation that they can carefully analyse realistic applications without first acquiring the necessary background knowledge and mathematical ability. The main focus should be on mathematical proficiency, with an occasional application as illustration' (p.2-3).

The paper called for greater collaboration between those involved in curriculum development, those in Third-level institutions (Universities, Institutes of Technology) and the Irish Mathematics Teachers' Association to devise appropriate post-graduate courses for teachers. It also proposed increased differentiation at Leaving Certificate level, where students bound for university courses in mathematics could be offered advanced courses on topics such as calculus, linear algebra and mathematical modelling.

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[3] The report later refers to the 'absence of calculus', which is unclear, since Calculus is a key component of the Functions strand (e.g., DES, 2013). The NCCA (2012) pointed out that, while much of the pre-2010 content in Calculus was retained in the revised syllabus, some predominantly procedural aspects, such as integration by substitution, were dropped at Higher level.

It is noteworthy that these publications were issued at an early stage in the implementation of Project Maths, before graduates of the new programme had entered university courses in mathematics.

The NCCA (2012) responded to some of the concerns raised about Project Maths. Its response clarified an important distinction between, on the one hand, PISA, which focuses on assessing mathematical literacy at age 15, and Project Maths, which is concerned with teaching, learning and assessment. It also clarified a distinction between preparing students for mathematics at Third level (a goal often associated with Higher-level mathematics at Leaving Certificate) and a broader effort to ensure that the broad population of students achieve high levels of general mathematical ability. The response explained that the omission of certain topics, especially at Leaving Certificate level, was necessary to ensure that students acquired greater conceptual understanding and problem-solving skills around the content that was included. It also noted that the removal of choice in both the Leaving Certificate syllabi and examinations necessitated a reduction of content. The removal of choice was itself necessitated by the omission of key course topics by some pre-2010 students who, when a choice was available to them, were not adequately prepared for progression to Third-level mathematics.

The NCCA also clarified why matrices and vectors were omitted - explaining that procedures for performing operations tended to be memorised by students, with little application or connection to other areas of mathematics. It was intended that such omissions would allow a 'focus on pedagogical practices that promote the development of skills and conceptual understanding in topics that underpin these areas of mathematics' (2012, p. 14).

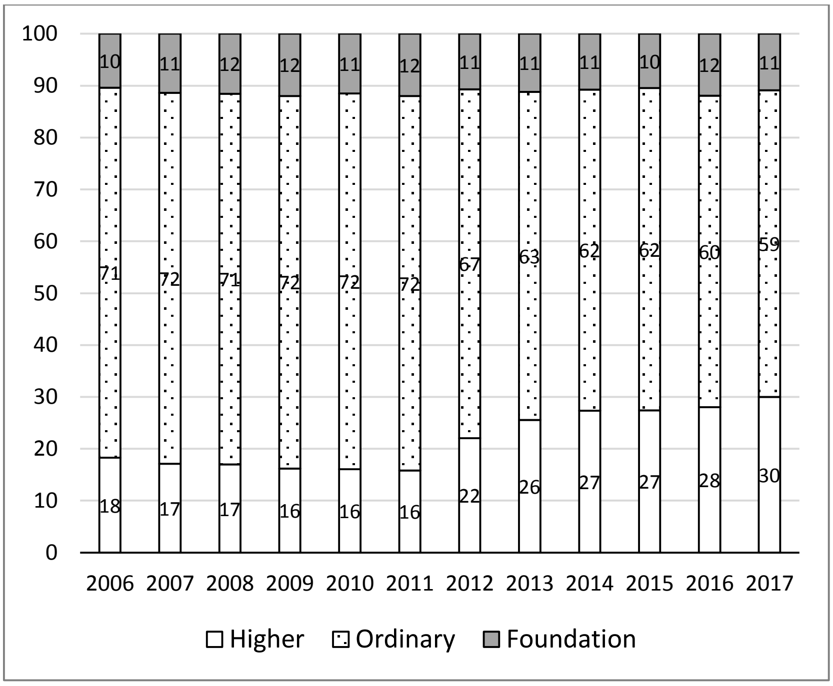
Bonus Points for Leaving Certificate Mathematics

In addition to the implementation of Project Maths, a number of systemic changes to both curriculum and assessment have occurred in recent years. An initiative designed to increase take-up of mathematics at Higher level in the Leaving Certificate examination has been to provide 25 bonus CAO points[4] to students achieving a grade D or higher in Leaving Certificate Higher-level

[4] The paper of the Project Maths Implementation Support Group (DES, 2010) suggests that the uniform bonus (rather than bonus points on a sliding scale) is designed to ensure that students who might otherwise choose to switch from Higher to Ordinary level are incentivised to take the Higher-level examination.

mathematics from 2012.[5] This has contributed to increases in the proportions of students taking Higher-level mathematics at both the Leaving and Junior Certificate, with uptake at Leaving Certificate increasing from 16% in 2011 to 30% in 2017, and uptake at Junior Certificate increasing from 46% to 57% over the same period (SEC, 2011a, b; 2017a, b) (see Figure 1). According to the Department of Education and Skills (2017), the target for take-up of Leaving Certificate Higher-level mathematics is 30% by 2020. Hence, this target has been achieved ahead of schedule.

Figure 1
Proportions of Leaving Certificate Mathematics Candidates taking Higher, Ordinary and Foundation-Level Papers, 2006-2017



[5] From 2017, bonus points are awarded to students achieving grades H1 to H6 (that is, at least 40%) (see http://www.transition.ie/).

A consequence of the timing of the introduction of bonus points is that it is difficult to disentangle their effect on the performance of students in the Leaving Certificate examination from the effects of Project Maths itself. It might also be noted that other changes were underway in the education system during this period. For example, the proportion of students taking Transition Year after completing the Junior Certificate increased substantially between 2005-06 (45.8%) and 2015-16 (67.4%)[6] (Government of Ireland, 2005, 2006; DES, 2015, 2016). An effect of this is that successive cohorts of students taking Leaving Certificate mathematics have had more schooling than their predecessors, and may have benefitted from additional mathematics education offered during Transition Year.

IMPACT OF PROJECT MATHS ON PERFORMANCE AT POST-PRIMARY LEVEL

A number of sources can be drawn on to consider the impact of Project Maths on the performance of students at post-primary level since its introduction. These include evaluations of the impact of Project Maths, performance on international studies of mathematics achievement, performance on examinations, and the report of the Chief Examiner on Leaving Certificate mathematics (SEC, 2016).

NFER Evaluation of Project Maths

The NCCA commissioned the National Foundation for Educational Research (NFER) in the UK to conduct an evaluation of the impact of Project Maths on students' performance and attitudes towards mathematics (see Jeffes et al., 2012, 2013). Separate cohorts of Junior and Senior cycle students with varying levels of experience of Project Maths were assessed in spring 2012 and autumn 2012 using tests based on international studies of mathematics achievement and questionnaire items. The NFER used multi-level modelling to compare performance across time (spring or autumn), across examination entry level (Foundation, Ordinary or Higher) and between genders. Just two content areas – Statistics & Probability, and Geometry & Trigonometry – were factored into the models, since these are the only content areas of the Project Maths syllabi covered by all students in the study.

[6] Percentages were obtained by dividing the numbers of Transition year students in 2005-06 and 2015-16 by the numbers of Third year students enrolled in schools in the previous school years (2004-05 and 2014-15 respectively).

Rather discouragingly, the NFER study reported that 'overall, schools following a greater number of strands, or schools having a greater experience of teaching the revised syllabuses, does not appear to be associated with any improvement in students' achievement or confidence' (Jeffes et al., 2013, p. 5). Examination level was predictive of performance, with students studying Higher level outperforming those studying Ordinary or Foundation levels, though more so on Statistics & Probability than on Geometry & Trigonometry. Females consistently did less well than males. The NFER team did note that their evaluation occurred at a relatively early point in the implementation of Project Maths, and that, over time, there may be a shift from (sometimes new) content to a stronger focus on processes. They also noted a lack of evidence in students' written school work that key processes promoted in Project Maths such as explaining answers were being fully implemented.

Performance in International Studies of Mathematics Achievement

The OECD PISA assessment takes place every three years. Students aged 15 years in over 70 countries completed tests of science, reading literacy and mathematics in the most recent round, which took place in 2015[7]. PISA seeks to assess students' preparedness for the mathematics they will meet in real life and in their future education rather than their performance on school curricula. In Ireland, students in Second year (1.9%), Third year (60.5%), Transition year (26.7%), and Fifth year (10.9%) took part (Shiel, Kelleher, McKeown & Denner, 2016). Hence, PISA provides some information on performance on Senior Cycle mathematics, though a majority of students are in Junior Cycle. Mathematics was a major domain in PISA 2003 and 2012, meaning that more detailed information on performance by content area and process is provided for those years. Figure 2 shows the overall mean scores of students in Ireland and on average across OECD countries for each cycle since 2003. The overall mean score of students in Ireland in 2015 (503.7 score points) was almost identical to the mean score in 2003 (502.8). Moreover, Ireland's overall mean score on PISA mathematics was similar in all cycles except 2009[8]. During the

[7] It should be noted that PISA 2015 was the first year in which all students taking the assessment in Ireland had studied under Project Maths. In 2012, a small minority of students – those in Fifth year and those in Project Maths initial or (pilot) schools – had done so.

[8] Performance in Ireland was significantly below the OECD average in PISA 2009 in both reading literacy and mathematics. Explanations for this include low levels of engagement with the PISA test among students in Ireland in 2009, demographic changes (more students with special education needs), and difficulties with PISA's approach to estimating changes in performance (see Perkins, Cosgrove, Moran & Shiel, 2012, Chapter 9).

same period (2003 to 2015), the average performance across OECD countries dropped from 499.2 to 491.4.[9] Students in Ireland achieved mean scores that were not significantly different from the OECD averages in 2003 and 2006, that were below the OECD average in 2009, but were significantly above the OECD averages in 2012 and 2015. Nevertheless, Ireland continues to lag behind the highest-performing countries in PISA. In 2015, these included Singapore (562.4), Hong Kong (China) (547.9), Japan (532.4), Korea (524.1), Switzerland (521.3) and Estonia (519.5) (Shiel et al., 2016, Table 5.5). Students in Fifth year in Ireland achieved mean scores of 501.6 (SE = 5.48) in 2012 and 495.2 (SE = 5.16) in 2015. The difference of 6.4 score points is not statistically significant (Shiel et al., 2015, e-Appendix Table A8.18). In 2003, students in Ireland in Fifth year (20% of the sample) achieved a mean score of 515.1 (SE = 5.32) (Cosgrove et al., 2005). Again, this is not significantly different form the mean scores of Fifth years in 2012 or 2015, though in 2003, 19.6% of the PISA sample was in Fifth year, compared with 13.2% in 2012, and 10.9% in 2015.

Since Project Maths involved modifications to teaching, learning and assessment of mathematics at both Junior and Senior cycles, stronger overall performance might have been expected in PISA 2015 than in earlier cycles. However, PISA 2015 also saw the introduction of computer-based testing in most participating countries including Ireland. Of the top-30 performing countries on PISA 2012 mathematics, eight had significantly lower mean scores in 2015, including Korea (-29.7), Hong-Kong China (-13.3), Poland (-13.0), Australia (-10.3), and Singapore (-9.3). The average drop in performance was 3.7 on average across OECD countries. The fact that performance did not decline in Ireland suggests that Project Maths may have had a small facilitative effect.

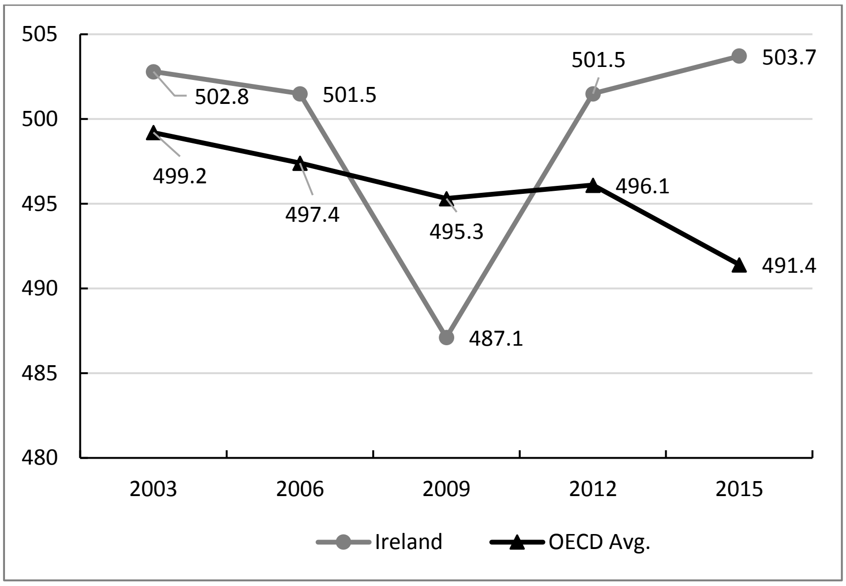
A number of other findings emerge from PISA 2012 and PISA 2015 that are relevant to efforts to raise standards at post-primary level:

- In PISA 2015, 9.8% of students in Ireland achieved scores at the highest proficiency levels (Levels 5-6), compared with 10.7% on average across OECD countries. Since Ireland's mean score on PISA is above the corresponding OECD average, one might expect the proportion of higher achievers to exceed the OECD average as well. In contrast, however, fewer students in Ireland than on average across OECD

[9] The number of OECD countries participating in PISA increased from 29 in 2003 to 35 in 2015.

countries performed at the lowest level of proficiency (Below Level 2) (15.0% and 23.4% respectively).

Figure 2
Mean scores on overall mathematics scale in Ireland and on average across OECD countries, 2003-2015



Source: Shiel et al., 2016, Figure 8.11

- In PISA 2012 (the last cycle for which data on mathematics content areas are available), students in Ireland achieved a mean score of 477.8 on Space & Shape. This is significantly below the corresponding average for OECD countries (489.6). Students in Ireland also underperformed on Space & Shape in PISA 2003.
- In PISA 2015, the gender gap in Ireland in favour of male students on overall mathematics is 16.1 score points, while the corresponding OECD average is 7.9 points; 6.5% of females in Ireland achieved at the highest proficiency levels (Levels 5-6), while 12.9% of male students did so.

- In PISA 2012, male students in Ireland outperformed female students by 24.8 score points on Space and Shape. Gender differences are smaller on other content areas.

Ireland also participated in TIMSS (Trends in International Mathematics and Science study) in 2015. Unlike PISA, which selects an age-based sample, TIMSS uses grade-based samples (Grades 4 and 8, or Fourth class and Second year in Ireland). Second-year students achieved a mean score of 523.5, which is significantly higher than the average of 16 OECD countries that participated in the study (513.2), and the average for all participating countries (481.6) (Clerkin, Perkins & Cunningham, 2016). Just 6.8% of students in Ireland performed at the 'Advanced' TIMSS benchmark, compared with an average of 10.7% across OECD countries in the study, while 6.0% in Ireland compared with 11.2% on average across OECD countries performed below the 'Low' TIMSS benchmark. Relative to their performance on the mathematics test as a whole (523.5), students in Ireland achieved significantly higher mean scores on Number (544.5) and on Data & Chance (533.8), and significantly lower scores on Algebra (501.0) and Geometry (503.0), highlighting these as areas of relative weakness (Clerkin et al., 2016). As Ireland did not participate in TIMSS at Grade 8 (Second year) between 1995 and 2015, it was not possible to examine trends in performance in that study.

Taken together, the outcomes of the recent PISA and TIMSS studies show that, while the average scores of students in Ireland on overall mathematics are higher than the corresponding averages for OECD countries, performance among higher achievers tends to be low. Further, students in Ireland perform less well on Space & Shape (PISA) and Algebra & Geometry (TIMSS) than on other content areas. Indeed, performance on PISA Space & Shape continues to be below the corresponding OECD average score, and female students in particular struggle in this content area.

Performance on the Leaving Certificate Examination

One barometer of performance in mathematics at Senior Cycle in post-primary schools is the Leaving Certificate mathematics examination. Unlike international assessments of mathematics, which include some common test items from cycle to cycle so that trends in performance can be monitored over time, all questions in the Leaving Certificate examination change from year to year, and new scoring schemes are developed for each year. Nevertheless, there is value in examining the distributions of examination grades by year, and ascertaining if any changes have arisen. However, as noted above, the allocation of additional CAO points and increases in the proportions of candidates sitting the Higher-level mathematics papers should be taken into account in interpreting outcomes.

Figure 3 shows the distribution of grades at Higher level in Leaving Certificate mathematics between 2006 and 2016.[10] The figure shows a drop in the proportion of A and B grades awarded from 2012 to 2016 and in the proportion of B grades awarded from 2013 to 2016, compared with earlier years. Thus, for example, while 13.2% achieved an A grade in 2011, just 11.1% did so in 2016. However, in 2011, 1,087 students, achieved an A grade, while in 2016, 3,936 students did so. Hence, in absolute terms, more students achieved Grade A at Higher level after 2011 although they constituted a smaller proportion of all students taking Higher level.

Figure 3 also shows an increase in the percentage of D grades awarded at Higher level from 2013 to 2016 compared with earlier years. In absolute terms, 1308 students achieved Grade D at Higher level in 2011, while in 2016, 3,663 did so. The percentage of all Leaving Certificate candidates who achieved a Grade D at Higher level increased from 2.6% in 2011, to 6.8% in 2017. Some of this increase can be attributed to students who, prior to 2012, might have taken the Ordinary level paper, and, presumably, would have achieved a Grade A or B at that level[11]. However, in addition to migration from Ordinary to Higher level arising from the availability of bonus points, the numbers of students taking the Leaving Certificate mathematics examination have risen. For example, in 2011, 51,991 students sat Leaving Certificate mathematics, while in 2016, 54,225 did so.

Figure 4 shows the distribution of performance at Leaving Certificate Ordinary level. Here, we see a reduction in the proportion of students achieving Grade A, down from 11.4% of Ordinary level students in 2011 to 6.8% in 2016. In absolute terms, this represents a drop from 4,276 students in 2011 (8.2% of all Leaving Certificate mathematics candidates) to 2,213 students in 2016 (4.1%). Interestingly, the proportion achieving Grade B at Ordinary level remained fairly stable from 2011 (30.4%) to 2016 (28.8%). In absolute terms, the number achieving Grade B at this level declined from

[10] Data for 2017 are not reported here, as a new grading system was introduced in that year.

[11] According to the pre-2017 CAO points conversion system, a C2 at Higher level was regarded as being equivalent to an A1 at Ordinary Level in terms of points allocated (60 points). Similarly, a D2 at Higher level was deemed to correspond to an A2 at Ordinary level (55 points), and a D3 at Higher level to a B1 at Ordinary level (50 points). Since the same conversion system is used across all subjects, it is unclear if it suits some subjects more than others.

11,402 (21.9% of all Leaving Certificate mathematics candidates in 2011) to 9,374 in 2016 (17.3%).

The distribution of C and D grades at Ordinary level has been relatively less settled, though the underlying trends are upwards – from 27.8% at Grade C in 2011 to 32.8% in 2016, and from 20.6% at Grade D in 2011 to 22.6% in 2016. According to the Chief Examiner for Mathematics (SEC, 2015):

> The candidates whose choice of level is least certain are those near the overlap of standards between the levels – they are among the lower-achieving candidates at Higher level, and the higher-achieving candidates at Ordinary level. When the proportion of such candidates opting for Higher level increases, an increase can be expected in the percentage of low grades awarded at Higher level, along with a decrease in the percentage of high grades awarded at Ordinary level (p. 9).

Regarding the proportions of students achieving Grade E or lower at Higher level (up from 3.1% in 2011 to 4.5% in 2016), the Chief Examiner noted that, while those who achieve Grade D (or higher) will have benefitted from taking Higher level, 'not all those who opt for Higher level are necessarily making the optimum choice' (p. 27).

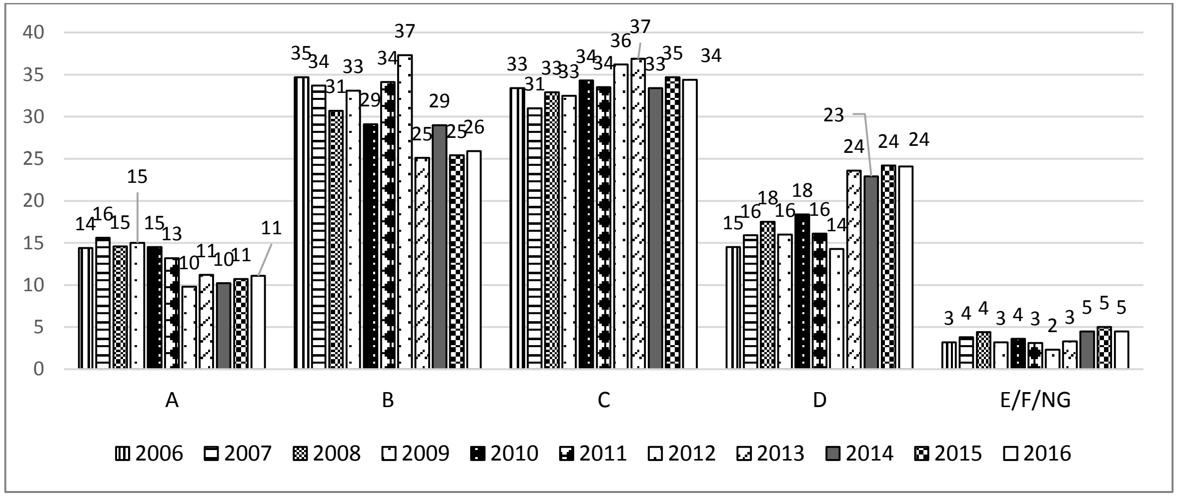
Chief Examiner's Report - 2015 - Leaving Certificate Examination

The Chief Examiner's Report on the 2015 Leaving Certificate examination in mathematics provides useful additional information on the strengths and weaknesses of students at the end of their second-level schooling, including those likely to progress to the study of mathematics at Third level (SEC, 2016). While much of the commentary in the report focuses on the performance of random samples of students on specific items that appeared in the 2015 examinations at Higher, Ordinary and Foundation levels, the report also includes some broad generalisations about standards:

- The overall performance of some Higher-level candidates with respect to their ability to apply basic skills appropriately and accurately is a cause of concern. . . The proportion of candidates for whom this was a significant difficulty has risen since 2011, and a significant minority of candidates now struggle to complete multi-step problems accurately (p. 27)

Figure 3

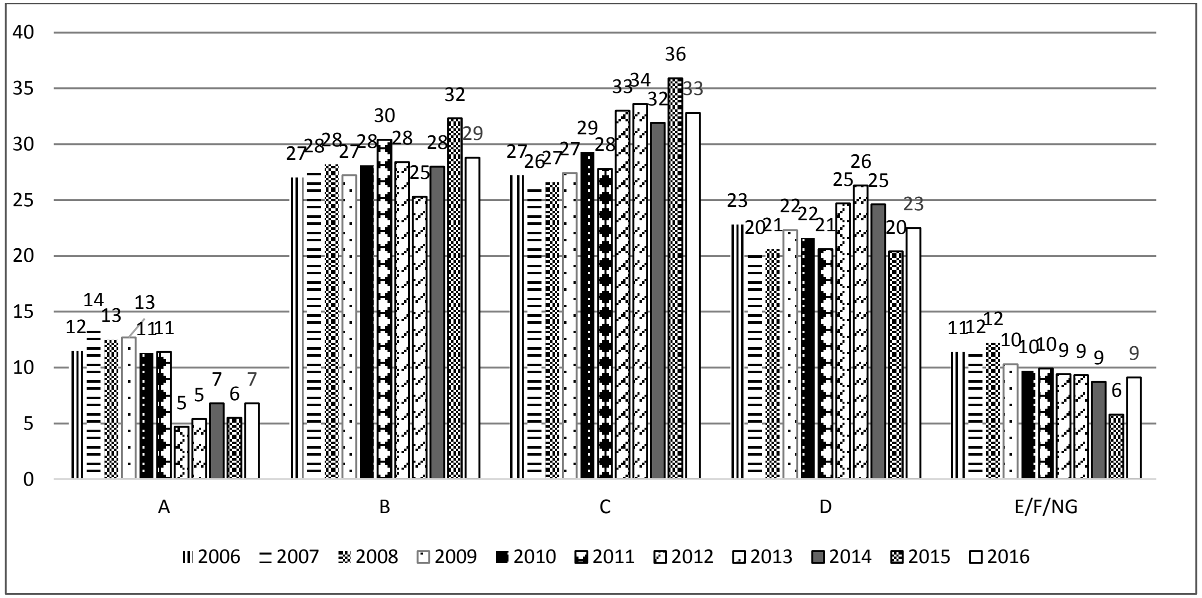
Distribution of Grades by Leaving Certificate Higher-Level Mathematics (2006-2016)



Source: State Examinations Commission Website - https://www.examinations.ie/statistics/

Figure 4

Distribution of Grades by Leaving Certificate Ordinary-Level Mathematics (2006-2016)



Source: State Examinations Commission Website - https://www.examinations.ie/statistics/

- At Ordinary level, many candidates display a lack of knowledge of standard procedures, a lack of basic competence in Algebra (and in algebraic manipulation in particular) and a lack of perseverance. An appropriate balance needs to be struck between developing and consolidating candidates' skills, on the one hand, and developing their capacity to apply, mathematize and reason in less-familiar contexts on the other (p. 27-28)
- Many candidates at Ordinary level also had difficulty working with functions. . . the idea of functions cuts across all of the syllabus strands and might be profitably approached in an integrated way, rather than as a stand-alone strand in itself (p. 28)
- Candidates who cannot complete basic arithmetical and algebraic procedures are unlikely to make much progress on questions where they first have to mathematise the problem . . . The majority of these skills and functions should be acquired in Junior Cycle, and should be consolidated and improved as students move through Senior Cycle (p. 28)
- Candidates at all levels had more difficulty with questions which required them to draw on multiple strands of the syllabus at once, so there is clearly a sense in which their knowledge and skills are compartmentalised (p. 28)
- In many instances, candidates showed an improvement over preceding years in their answers to questions that required an explanation or justification. This is. . . a very positive development (p. 28).

In addressing performance across mathematics processes, the Chief Examiner's report noted that, while students taking the Higher-level examination were able to tackle non-routine questions with varying degrees of success (thereby demonstrating some level of strategic competence), the majority of students taking Ordinary level were 'unable to deal with problems presented in an unfamiliar context, even when the questions were relatively easy to solve if the candidates had attempted them' (p. 23).

The report repeatedly raised the question of students' difficulties in applying skills and knowledge from one strand to another, and argued that 'mathematics is not a list of discrete rules and definitions to be learned but rather a series of interconnected principles that can be understood and then applied in a variety of contexts' (p. 30). It acknowledged that, while compartmentalising knowledge (i.e., organising teaching and learning by strand) is useful from an organisational perspective, it restricts students' ability to cope with unfamiliar questions, especially those requiring knowledge from several strands.

PERFORMANCE ON THE DIAGNOSTIC TEST OF MATHEMATICS AT THE UNIVERSITY OF LIMERICK

A number of studies published by faculty and graduates of the University of Limerick (UL) in recent years have focused on the 'maths problem' – that is, low standards in mathematics among students taking mathematics servicecourses when they study science or engineering in institutions of higher education. Since 1998, UL has administered a voluntary Diagnostic test, with 40 items, to incoming First Year students enrolled in science-based or technology-based courses. Students who do not meet the cut-off score are deemed to be at risk[12], and are advised to attend support services provided by the university (Faulkner, Hannigan & Gill, 2010). The test comprises 13 questions on Arithmetic, 8 on Algebra, 4 on Geometry, 3 on trigonometry, 4 on Co-ordinate Geometry, 2 on Complex Numbers, 3 on Differentiation, 2 on Integration and 1 on Modelling. According to Faulkner et al. (2010), the majority of questions are aimed at the Ordinary level Leaving Certificate mathematics standard, with the exception of six that are covered at Higher level (2 on Integration, 2 on Logarithms in the arithmetic section, and 2 on Differentiation). The test has not changed since it was first administered in 1998. Students are not notified of the test in advance and they are not allowed to use a calculator. Space on the test booklet is provided for rough work.

Treacy, Faulkner and Prendergast (2016) discussed the internal consistency of the Diagnostic test, but do not report any statistical evidence. They also acknowledged that the Diagnostic test may no longer reflect the revised (Project Maths) Leaving certificate examination in that it was designed with reference to the pre-Project Maths syllabus.

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[12] Originally, students scoring 19 or below were considered to be 'at risk' (e.g. Faulkner et al., 2010). However, Treacy and Faulkner (2015) and Treacy et al. (2016) cite evidence that a score of 18 or below is more predictive of future difficulties.

Four articles examining performance on the Diagnostic test between 1998 and 2014 are considered here. Drawing on data in two of the articles (Faulkner et al., 2010, Table 2; Treacy & Faulkner, 2015, Table 2) , it was possible to examine performance in the period 1998 to 2013 (see Figure 5). Faulkner et al. describe performance between 1998 and 2008, while Treacy and Faulkner cover the period from 2003 to 2013. Figure 5 shows that performance on the Diagnostic test has fallen over time. The mean score on the Diagnostic test in 1998 was 23.7, while it was 19.0 in 2013. A key feature of Figure 5 is the gradual and sustained decline in performance between these years. In other words, a pattern of declining performance had been evident even before Project Maths or bonus CAO points for achieving Grade D3 or higher on the Higher level Leaving Certificate mathematics examination had been implemented.

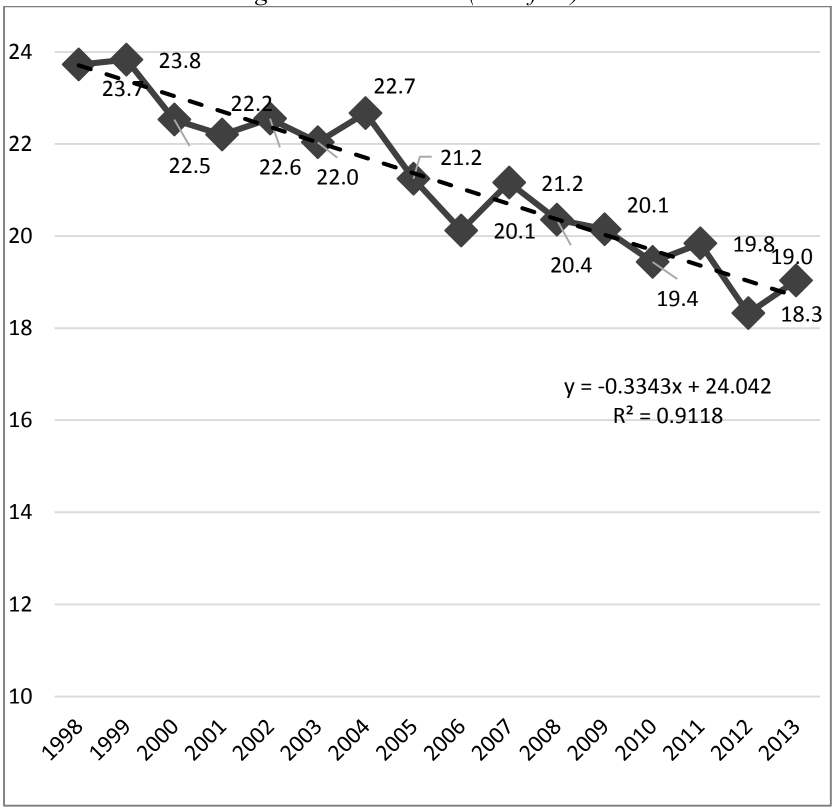
In interpreting these findings, it is important to note that the number of students taking the Diagnostic test each year has also varied. In 1998, 507 students took the test, while in 2013, 645 did so. The highest number taking the test is 793 in 2012, while the lowest is 337 in 2003. Participation by students in the assessment has also varied. According to Treacy et al. (2016), it has ranged from 80.4% to 92.7%. These authors do not provide a breakdown of participation by year. Nor is it clear if the inclusion of the missing students would have altered the outcomes.

Faulkner, Hannigan and Gill (2010)

The analysis by Faulkner et al., (2010) of overall performance in the period from 1998 to 2008 acknowledged the statistically significant decline in performance on the Diagnostic test across this period. In addition, these researchers benchmarked performance against the Leaving Certificate mathematics grades achieved by students taking the Diagnostic test. Five grade points were examined, C1 on the Higher-level paper and A1, A2, B1 and B3 on the Ordinary-level paper. While the numbers achieving each grade were relatively small (for example, 35 achieved a C1 at Higher level in 1998 while 36 did so in 2008), nonetheless, aside from minor fluctuations, students at each of these grade points performed at about the same level on the Diagnostic test from year to year. Furthermore, there was only minor overlap in performance on the Diagnostic test across the grade points examined. This is to be expected, since the authors did not compare performance across grades with equivalent CAO point values (for example, Higher C3 and Ordinary A1 are both worth 60 points on the pre-2017 CAO scale).

Figure 5

Mean Mathematics Diagnostic Test Scores (out of 40) 1998-2013



Sources: Table 2, Treacy and Faulkner (2015) and Table 2, Faulkner et al., (2010).

A further set of analyses looked at changes in performance among science and technology students on items on the Diagnostic test that measured Arithmetic (13 items) and Algebra (8). Here, consistent with the overall decline in performance between 1998 and 2008, performance on each of these item clusters is statistically significantly lower between these years for students taking degrees in science and in technology. Increases in variability on a year-by-year basis were also observed.

In discussing their findings, Faulkner et al. noted that the decline in overall performance on the Diagnostic test could not be linked to changes in the performance of students at each of the studied grade bands on the Leaving Certificate mathematics examination i.e., there was no evidence of 'grade dilution'. Rather, they identified an increase in the proportion of entrants to UL science and technology courses taking the Leaving certificate examination at Ordinary level and increased numbers of non-traditional students as the main reasons underlying observed changes. For example, in the case of science students, the proportion taking Ordinary level increased from 43.1% in 1998 to 55.0% in 2008 (Faulkner et al., Table 6). Furthermore, the number taking Ordinary level increased from 87 to 166. The proportion of non-traditional students increased from 1.5% to 7% during the same period. Hence, Faulkner et al. attribute changes in performance primarily to changes in the student intake.

Treacy and Faulkner (2015)

Treacy and Faulkner (2015) published a second paper on trends on the UL Diagnostic test in 2015. This one examined trends in overall performance in the period from 2003 to 2013, and hence overlaps with the earlier analysis by Faulkner et al. in that both analyses include the period from 2003 to 2008. The key argument is that changes in performance (as per Figure 5, where the mean score on the Diagnostic test was 22.0 in 2003 and 19.0 in 2013) arise because of changes in the standard at different Leaving Certificate grade points, especially in 2012 and 2013, following the introduction of bonus points. It is also asserted that the introduction of Project Maths curricula coincides with the observed declines in performance. Further analyses provided in the paper include comparisons between the proportions of students at different Leaving Certificate grades who are deemed at risk[13] (of failing mathematics in the first year of Third level). The grades considered are Higher B, C, D and Ordinary A, B, C. Increases in the proportions of at-risk students are apparent for Higher C and D, and for Ordinary A and B, but not for Ordinary C. The authors also replicate the analysis of performance on the Diagnostic test by grade band between 2003 and 2013, though, unlike Faulkner et al. (2010), they look at eight Leaving Certificate grade points (Higher C1, C2, C3, and Ordinary A1, A2, B1, B2 and B3. It is unclear how many students there are at each of these grade points, though in the case of the Higher level grade points, the numbers

[13] The updated cut-off score of 18 or below is used in this study.

are likely to be low in some years (Faulkner et al. reported a range of 23 to 37 Higher C1 students between 2003 and 2008). Treacy and Faulkner (2015) report statistically significant declines in performance on the Diagnostic test for students on all grade bands that were examined, except Ordinary B3. However, the statistical tests used are not reported, and it is unclear whether corrective measures for multiple comparisons were applied. No information is given on trends at Higher level Grades D1 to D3. In the conclusion to the paper, the authors noted that 'these findings indicate that the transition to these new [Project Maths] curricula has coincided with a decline in the performance of the basic mathematical skills that are required for students to be fully prepared for service mathematics studied in higher education' (p. 14).

There are a number of additional points that need to be taken into account in interpreting the findings and conclusions in Treacy and Faulkner's paper:

- In general, tests of statistical significance compare the years 2003 and 2013. However, the data in Figure 5 in this paper shows an almost linear decline in performance since 1998. Faulkner et al. attributed declines between 1998 and 2008 to changes in the profile of students entering mathematics service courses. Treacy and Faulkner (2015) offer an alternative narrative – that recent changes can be attributed to a decline in standards in the Leaving Certificate examination linked to availability of bonus CAO points and to the impact of Project Maths or both.
- Since the proportion of Leaving Certificate mathematics candidates nationally increased from 16% to 26% between 2011 and 2013 (see Figure 1, this paper), it is not surprising that the proportion of UL entrants in science and technology courses taking the Leaving Certificate examination at Higher level also increased. Looking at Figure 7 in Treacy and Faulkner (2015), there are clear downward trends on the Diagnostic test at almost all grade points examined between 2011 and 2012. It is possible that some adjustments were made by the State Examinations Commission in 2012 and 2013 to accommodate the movement of additional students to the Higher-level examination[14]. Given subsequent data (including Tables 2-5 in Treacy

[14] The State Examination Commission openly states that such adjustments, though perhaps not on such a scale, are a standard part of the process of marking the State Examinations (see, for example, SEC, n.d).

et al., 2016), it appears that, after 2012, performance on the Diagnostic test has, for the most part, levelled off again, albeit at lower levels than before.

- Students taking the Leaving Certificate mathematics examination in 2012 and 2013 had not studied under Project Maths at Junior Cycle. Furthermore, the 2012 cohort had studied just two (of five) mathematics strands under Project Maths, while the 2013 cohort had studied four of five strands (Strand 5, Functions, was not examined for the first time at Leaving Certificate level until 2014). These observations weaken inferences that are made about the effect of Project Maths on performance on the Diagnostic test. Indeed, Treacy and Faulkner (2015) may have over-estimated the effects of Project Maths on Diagnostic test performance, as they incorrectly state that elements of Project Maths were incorporated into the Leaving Certificate examination in 2011 (rather than 2012). Only students in the 24 initial schools involved in piloting Project Maths were assessed on aspects of the Project Maths syllabi in the 2011 Leaving Certificate examination.
- It is regrettable that Diagnostic test performance at Grades D1 to D3 at Higher level was not examined by Treacy and Faulkner, as performance at these grade points would have been expected to be most affected by the increases in the proportions of students taking mathematics at Higher level (see Figure 2, this paper). However, Treacy et al. (2016) report that the number of students with D grades between 2008 and 2013 ranged between 37 and 68, so numbers may have been too small to conduct a detailed analysis at multiple grade points within the D grade band.
- It is unclear what proportions of the 2012 and 2013 cohorts (that is, those who had studied under Project Maths at Senior Cycle) were absent when the Diagnostic test was administered to incoming First year students. The absence of higher-achieving students (who perhaps felt that they did not need to take the test) may have skewed the overall results and the percentages failing to reach criterion in these and other years.

In the pre-2017 CAO conversion table, a Higher-level C3 is deemed to equate to A1 at Ordinary level, while a Higher-level D2 is deemed to have the same value as an Ordinary Level A2 (D 1 falls midway between Ordinary A1 and A2). Similarly, a Higher D3 is deemed to be equivalent to an Ordinary B1. This scheme operated across all subject areas.[15] However, the data in Faulkner et al. (2010, Figures 2 and 3), and in Treacy and Faulkner (2015, Figure 7) suggest that, for the most part, such overlap did not occur in practice, either prior to or after implementation of Project Maths. This would seem to question the validity of the CAO's application of the same points values to grades in mathematics that may not be equivalent in terms of the skills that students have acquired. It also, perhaps, explains why the State Examinations Commission had to adjust grades in 2012 to accommodate the large increase in the proportion of students taking the Higher-level examination. However, the size of the adjustment made in 2012 may be exaggerated in the Faulkner et al. and Treacy and Faulkner papers in that overall performance on the Diagnostic test in UL dropped by 1.5 score points between 2011 and 2012 (see Figure 5, this paper). This can't be attributed to the availability of bonus CAO points, or to the ongoing implementation of Project Maths. Rather, it seems to be part of a longer-term trend of declining scores on the Diagnostic test. Indeed, across the years for which we were able to obtain data or estimate overall scores on the Diagnostic test, performance was lowest (at 18.3 out of 40) in 2012.

Treacy, Faulkner and Prendergast (2016)

The third article focused on changes in performance on the Diagnostic test between 2008 and 2014. This article further promoted the view that the introduction of Project Maths impacted negatively on the performance of science and technology students entering UL. Indeed, the title of the article implies a correlation between Project Maths and under-graduate students' performance on the Diagnostic test.

The article extended earlier analyses in two ways. First, it looked at performance on the Diagnostic test for subsets of items dealing with Arithmetic, Algebra, Geometry, Calculus and Modelling at three grade points – Higher level B, C and D. Second, it included data for 2014 – the first year in which all five strands taught under Project Maths were assessed in the Leaving Certificate examination.

An effect of transitioning to grades (B, C, D) from grade points (B1, B2, B3 etc.), in the context of the analyses performed by Treacy et al. is that the

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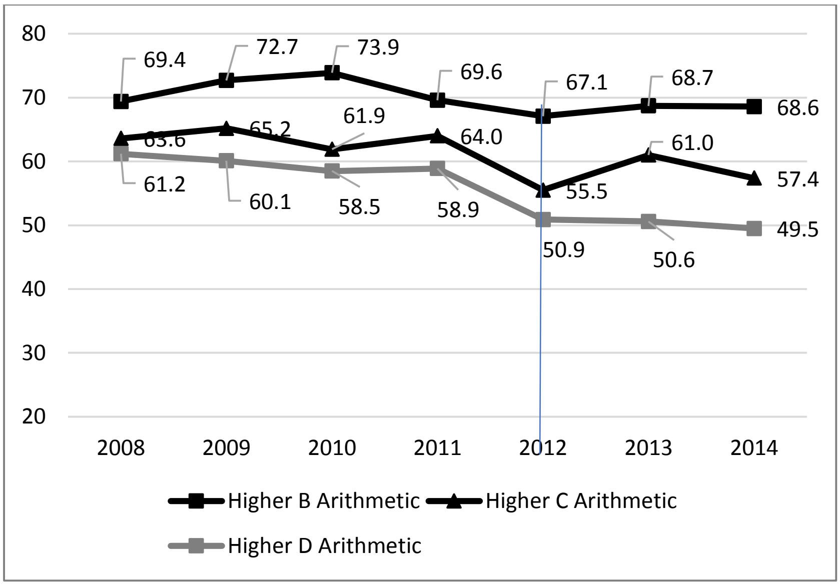
[15] The new (2017) CAO scheme makes similar assumptions, with, for example, H5 (50-60% at Higher level) deemed to be the same as O1 (90-10% at Ordinary level). Again, this scheme operates across all subject areas, including mathematics.

numbers of students in each cluster are greater and performance looks more stable than if intermediate grade points had been used. Drawing on data in Tables 2-4 in Treacy et al. (2016), we constructed a series of charts to illustrate patterns in performance for each content area between 2008 and 2014 (see Figures 6.1 to 6.5). Following on from Treacy et al., percent correct scores are used.

Figure 6.1 shows that, for students achieving a Grade B, performance on the Arithmetic component of the Diagnostic test was marginally lower in 2014 (68.6%) than in 2008 (69.4%). There were larger declines at Grades C (from 63.6% to 57.4%), and D (61.2% to 49.5%). The Figure also shows that the largest declines occurred between 2011 (the last year in which bonus points were not available) and 2012.

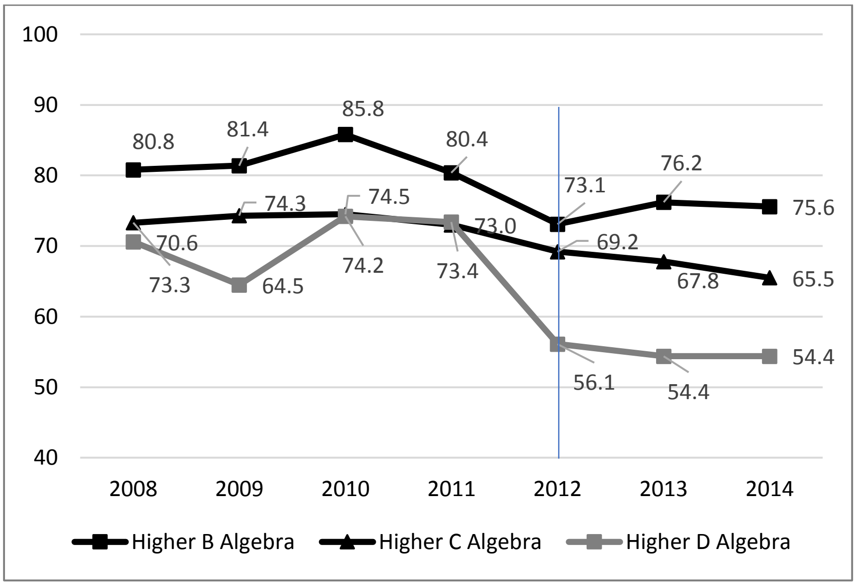
Figure 6.1
Percent Correct Scores on Arithmetic Items at Higher-Level Grades B, C and D, 2008-2014



Source: Treacy et al., 2016, Tables 3-5.

For example, at Grade D, performance dropped from 58.9% in 2011 to 50.9% in 2012, before apparently settling at around this level in subsequent years. Again, it seems unlikely that the drop between 2011 and 2012 can be attributed to Project Maths, since Number (the syllabus strand most closely linked to Arithmetic on the Diagnostic test) was not assessed under Project Maths until 2013.

Figure 6.2
Percent Correct Scores on Algebra Items at Higher-Level Grades B, C and D, 2008-2014



Source: Treacy et al., 2016, Tables 3-5.

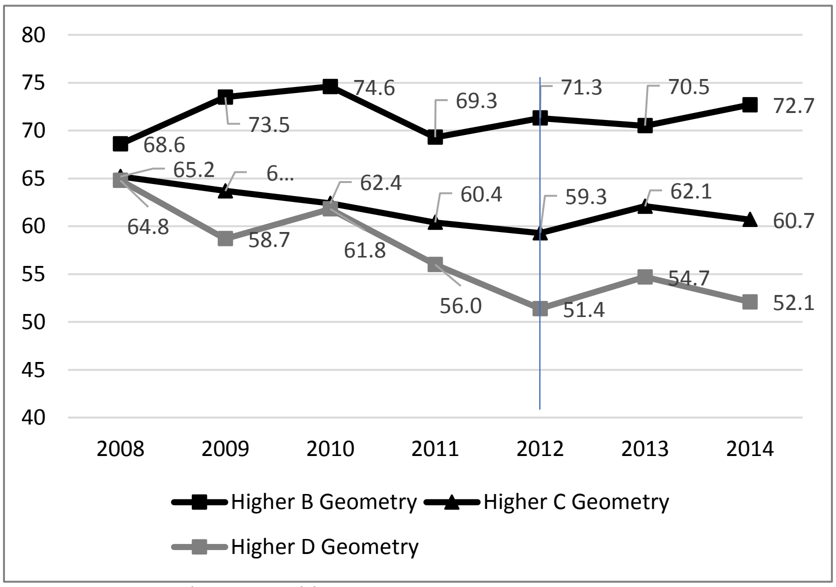
We see a similar pattern of results for Algebra (Figure 6.2). Here, performance dropped from 80.8% in 2008 to 75.6% in 2014 for students who achieved a Higher-level Grade B in the Leaving Certificate examination. There was a larger drop between 2008 (73.3%) and 2014 (54.4%) for students achieving a Higher-level Grade D. The decline between 2011 and 2012 for students who achieved Grade D is particularly noticeable (from 73.4% to 56.1%). However, this can hardly be attributed to Project Maths since Algebra under Project Maths was not assessed for the first time until 2013, and in that year performance on Algebra was similar to 2012 – that is, performance had levelled off after the adjustment in 2012.

Figure 6.3 shows the percent correct scores on Calculus items. Again, performance dropped from 59.0% to 45.5% for those achieving Higher-level Grade B between 2008 and 2014, with a drop of over 10 percentage points between 2011 and 2012. It might be noted that changes to Calculus (Differentiation and Integration) in the Leaving Certificate examination did not occur until 2014 as Functions, which incorporates Differentiation and Integration, was not examined for the first time until that year. However, there are only relatively minor changes in performance on the Calculus cluster within the Diagnostic test between 2013 and 2014. Indeed, students entering UL in 2014 who had achieved a Higher-level Grade D at Leaving Certificate had a higher percent correct score on Calculus (25.5%) compared with those who entered in 2013 (23.7%). It is unclear why performance on Calculus among First year students dropped from 47.1% in 2010 to 33.5% in 2011 among students achieving a Grade D, as neither bonus points nor Project Maths were in place for students taking the Leaving Certificate examination in 2011, while overall scores on the Diagnostic test remained constant for 2010 and 2011 (19.4 and 19.8 score points, respectively). The sharp drop on Calculus could have been a consequence of both a small number of test items (5) and a small number of students.

Figure 6.4 shows performance on Geometry items on the Diagnostic test, by year. Here, a drop between 2011 and 2012 is evident at Higher-level Grade D only, where the average percent correct score fell from 56.0 to 51.4. Perhaps greater stability is evident as, along with Statistics & Probability, Geometry & Trigonometry under Project Maths was assessed in the 2012 Leaving Certificate examination.

Figure 6.5 indicates that performance on modelling (based on one item on the Diagnostic test) dropped by almost 10 percentage points between 2011 and 2012 for students achieving a Higher-level Grade C in the Leaving Certificate examination, and by 7.5 points for students achieving a Higher-level D grade. From 2012 onwards, however, performance increased steadily for students achieving Grades B, C and D at Higher level. The item, which could be solved by applying algebraic skills, required students to provide a formula for calculating a monthly bill, given the standard charge and cost per unit used. This item is, perhaps, more closely linked to Project Maths than any of the other items on the Diagnostic test (of which 31 appear in an appendix to Faulkner et al., 2010).

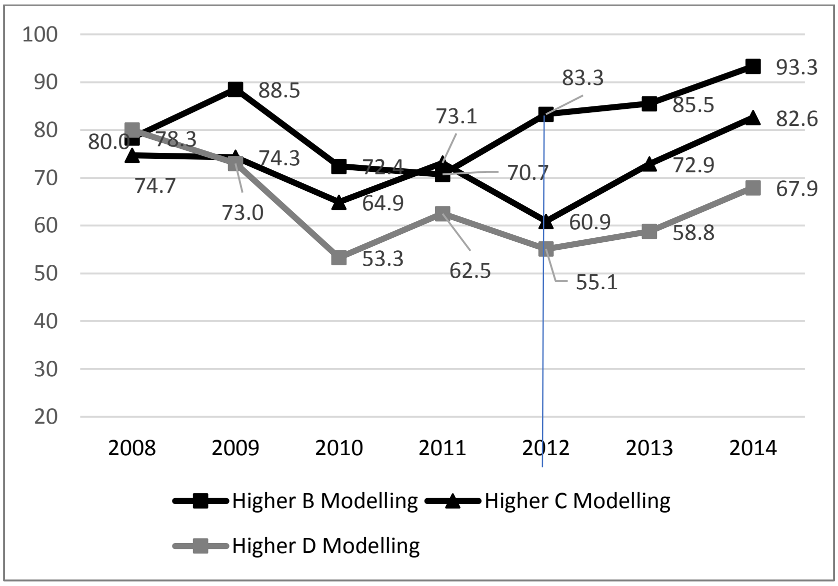
Figure 6.4
Percent Correct Scores on Geometry Items at Higher-Level Grades B, C and D, 2008-2014



Source: Treacy et al., 2016, Tables 3-5.

In discussing their findings, Treacy et al. (2016) hypothesise that the decline in the performance of students in UL on the diagnostic test can be attributed to the reallocation of time originally given to teaching basic skills to teaching applications. This, in turn is linked to a decline in basic skills, as measured by the Diagnostic test, between 2008 and 2014. However, it is evident from the data in Figure 5 (this paper) and elsewhere that performance on the Diagnostic test had been declining steadily since 1998. The idea that there is a dichotomy between, on the one hand, teaching basic skills, and, on the other, applying skills to solve problems needs to be challenged. The current mathematics syllabi at Junior and Senior cycles (e.g., DES, 2013) refer to five key processes that students should employ in their mathematics: conceptual understanding, procedural fluency, strategic competence, adaptive reasoning and productive disposition.[16] If students are to progress, as envisioned by the syllabus, attention needs to be paid to all of these processes, and not just procedural fluency, so that students understand the relevance of the procedures they are acquiring and begin to reflect on how these might be used.

Figure 6.5
Percent Correct Scores on Modelling Item at Higher-Level Grades B, C and D, 2008-2014



Source: Treacy et al., 2016, Tables 3-5.

[16] The Chief Examiner's Report (SEC, 2015) analysed students' responses to Leaving Certificate mathematics examination questions using this framework.

Treacy (2017)

As part of a broader analysis of the effects of bonus CAO points on mathematics performance, Treacy (2017) looked at the Diagnostic test scores of UL students taking science or engineering in First year who had achieved Higher-level grades B, C and D in the Leaving Certificate mathematics examinations between 2008 and 2014.[17] While mean overall scores on the Diagnostic test were found to have dropped at each of these grade bands between 2008 and 2014, the greatest declines occurred between 2011 and 2012. However, performance also dropped at all three grade bands between 2010 and 2011, and there is no clear reason why this occurred. Interestingly, Treacy acknowledged that the drop in performance in 2012 was unlikely to have arisen because of curriculum change (setting aside the inference made in earlier papers) and attributes much of it to the availability of bonus CAO points in 2012, and an assumption that the State Examinations Commission worked to avoid an increase in the proportion of students achieving below Grade D3 at Higher level.

CONCLUSION

First, it is clear that the entry-level mathematical performance of students taking science and engineering courses at the UL has declined between the years for which data on overall performance are available – 1998 to 2014. Moreover, the decline has been linear (as per Figure 5, this paper). However, much of the decline occurred prior to the availability of CAO bonus points on Leaving Certificate performance and before implementation of Project Maths had begun. Hence, attributing the decline to either of these factors, without considering changes to the profile of students entering mathematics service courses at the university, is problematic.

It is also clear that the State Examinations Commission realigned Leaving Certificate mathematics grades to some extent in 2012 and after, in order to accommodate a large increase in the proportion of students taking the Higher-level examination. However, this, in and of itself, cannot be held responsible for the documented declines on the Diagnostic test. The realignment, which was probably necessary because of a lack of congruence between grades at Higher and Ordinary levels, can be viewed as a time-limited adjustment, and doesn't necessarily reflect a change in overall standards, even though sharp falls in content cluster scores on the Diagnostic test were observed at some

[17] For this analysis, Grades B1, B2 and B3 were categorised as Grade B, Grades C1, C2 and C3 as Grade C, and D1, D2 and D3 as Grade D. No rationale was given for treating the data in this way.

grades at Higher level. Indeed, the relative stability in performance, both nationally on Leaving Certificate grades (as per Figures 3-4, this paper) and on the Diagnostic test in the years immediately after 2012 is notable, at a time when the proportion of students sitting the Leaving Certificate mathematics examinations nationally at Higher level, and the number of entrants to science and technology courses at UL, continued to rise.

While it is acknowledged that the realignment of grades in 2012 had an impact on the distribution of content-area scores on the Diagnostic test in 2012 and subsequent years, there is no evidence that this, in and of itself, was responsible for a decline in the basic mathematics skills of students entering UL. However, it might be argued that students who would have taken the Ordinary level mathematics course in 2012 were attracted to Higher level by the possibility of extra CAO points, and that they would have performed better on the Diagnostic test if they had studied the Ordinary level course. This was considered to an extent by Treacy and Faulkner (2015) when they compared mean scores on the Diagnostic test across selected grade points between 2003 and 2013. Figure 7 in their report shows minimal evidence of overlap between grade points, either before 2012, or immediately after it. However, as noted earlier, they did not include Grades D1, D2 or D3 in their analyses, apparently because relatively few UL students achieved those grades.

Both Treacy and Faulkner (2015) and Treacy et al. (2016) raised the possibility that the decline in mean scores on the Diagnostic test might be linked to the implementation of Project Maths. We can find little evidence to support this view. Data from PISA suggest that performance in mathematics at age 15 has improved marginally since the introduction of Project Maths, though it is acknowledged that the interpretation of this is complicated by the transition to computer-based assessment in PISA. Admittedly, PISA does not include students in Sixth year. However, as of 2014 (the last year covered by Treacy et al., 2016 and Treacy, 2017), Project Maths had not been implemented sufficiently extensively to justify any firm conclusions about its effects. In contrast to his stance in earlier papers, Treacy (2017) acknowledged that Project Maths had not been implemented or assessed to any great extent by 2012, and hence a decline in performance on the UL Diagnostic test could not be attributed to curriculum change. This is in line with our own view that changes brought about by the implementation of Project Maths cannot have impacted on performance on the UL Diagnostic test as early as 2012. However, this does not mean that we are not concerned by declining standards of basic skills among new entrants to UL science and technology courses (and, presumably, similar courses in other Third-level institutions). We believe that there are a number of ways in which standards might be raised. One is to look at the criteria for admission to courses, and whether these are adequate, given the standard of mathematics expected of students in their first and subsequent years. Another is to work towards raising standards nationally (which, we believe, is the intent of the articles we reviewed). Elsewhere (Shiel & Kelleher, 2017), we have outlined areas of weakness in students' performance at Junior Cycle, including low performance on aspects of spatial reasoning, problem solving and algebra, and suggested that these might be addressed in the current development of specifications for mathematics at that level. The Chief Examiner's report on Leaving Certificate mathematics outlines some issues that need to be addressed in teaching and learning mathematics at Senior Cycle which may ultimately feed into curriculum revision at that level. Further research could be conducted at Senior Cycle to get a clearer understanding of areas of specific weakness among students and how these might be addressed.

Finally, while we think it is useful for UL to administer the same Diagnostic test over multiple years, we also wonder if the test should now be revised to bring it into line with the current Leaving Certificate syllabus. This would be fairer to students in terms of identifying their strengths and weaknesses, and their need for further intervention. We also wonder if lack of access to calculators might be a factor in the low scores achieved by some students, and whether their performance and, ultimately, their ability to solve problems, might improve if they had access to the tools they used at post-primary level.

We also believe that there would be value in gathering some background information on students taking the Diagnostic test (e.g., gender, socioeconomic status, study of mathematics in Transition Year) so that these can be considered in interpreting changes in average performance from year to year. Finally, there would be value in examining whether students who would have studied science or technology at UL in the past are now more likely to study in other areas (e.g., computer science), resulting in a somewhat different cohort of students seeking entry into science and technology courses.

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