

Incentivising advanced mathematics study at upper secondary level: the case of bonus points in Ireland.

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Secondary level mathematics education in Ireland has recently experienced a period of significant change with the introduction of new curricula and the addition of an incentive to study upper secondary mathematics at the most advanced level (Higher Level). This incentive, typically referred to as ‘bonus points’, appears to have aided a significant increase in the number of students studying upper secondary mathematics at Higher Level. However, thematic analysis of interviews with experienced upper secondary mathematics examiners and exploration of mathematics diagnostic test data outlined in this paper suggest that the difficulty of the Higher Level upper secondary mathematics final examination in Ireland has reduced since the introduction of the bonus points initiative. The sharp increase in students attempting this examination coupled with a policy of maintaining a consistent proportion of students achieving passing grades was identified as a key reason for this possible reduction in standards.

Keywords: mathematics education; incentives; motivation; curriculum change; mathematics examinations.

Introduction

A deficit in the numbers of students completing secondary level education with the skills in mathematics and other STEM subjects desired by employers has been reported in the UK, US, Australia, and Ireland amongst others [1, 2, 3, 4]. Such shortfalls have caused education policy-makers to search for ways to encourage greater participation in the study of secondary mathematics at an advanced level. In Ireland, steps have been taken in recent years in an attempt to address this deficit.

Mathematics is one of three subjects which has been and continues to be treated as a compulsory subject for students in Ireland typically aged 17 or 18 completing their final examinations at secondary level – the Leaving Certificate examinations. While mathematics is not strictly a compulsory subject for the Leaving Certificate examinations, the requirement for students to complete mathematics study at upper secondary level in order to gain access to

tertiary level education ensures that secondary schools treat it as such. Further emphasis has been placed on the subject recently in Ireland as mathematics was assigned a special status in the Leaving Certificate examinations with the introduction in 2012 of 'bonus points' for achieving a passing grade in Leaving Certificate mathematics examinations at Higher Level. These bonus points have been introduced to act as an incentive for students to opt to study the subject at Higher Level and have been made available for mathematics only; thus suggesting the subject has been elevated in importance above the other subjects studied at secondary level in Ireland.

This is a path which other nations are considering, for example Vorderman et al. [5,p.7] suggested that mathematics be given special status as a "subject of critical importance" to improve student performance in the UK. In contrast to Ireland, mathematics study in the UK is not compulsory beyond the age of 16 but recent efforts have been made to achieve the goal that the vast majority of students in England study mathematics up to the age of 18 [6]. It remains to be seen whether or not this can be achieved as most students are opposed to compulsory study of mathematics beyond 16 [6]. Current trends would indicate that reaching such a goal without making mathematics study compulsory is unlikely with lack of confidence, perceived difficulty, dislike of the subject, and perceived lack of relevance being cited by students as the most common reasons for not continuing with mathematics study beyond the age of 16 [6, 7].

Facilitating ways to encourage more students to study mathematics to an advanced level is an important current issue and, consequently, the manner in which the bonus points measure has impacted secondary level mathematics in Ireland should be of particular interest to the international mathematics education community. This study will examine this impact and place particular emphasis on how the introduction of the bonus point initiative has

affected the difficulty of the Higher Level Leaving Certificate mathematics examinations during a period of significant policy and curriculum change.

Mathematics Curriculum Change in Ireland

In Ireland, improving the mathematics capabilities of secondary level students has become a vital aim within the education system. Significant change occurred with the introduction of new mathematics curricula, commonly referred to as 'Project Maths', at Junior Cycle (lower secondary level) and Senior Cycle (upper secondary level). The aim of these new curricula is to encourage a greater focus on problem-solving skills by increasing the use of contexts and real world applications of mathematics while aligning assessment with these revised classroom practices [8, 9]. This change in culture is quite substantial in an Irish context as secondary mathematics education had been dominated by a focus on procedural knowledge since the 1960s [10].

Greater focus has been placed on the study of statistics and probability in Senior Cycle mathematics with a reduction in content in other areas leading to the elimination of topics such as vectors and matrices [11]. Claims that the new mathematics curriculum has resulted in the 'dumbing down' of the syllabus have been rebuffed with the assertion that the renewed focus on problem-solving and real life applications of mathematics instead of the repetition of routine procedures have made classroom activities more "cognitively challenging" [11,p.16]. Criticisms concerning the removal of vectors, matrices, and elements of calculus from the Higher Level Senior Cycle syllabus have been voiced [12]. The key reasons for these changes included the need for a greater focus on depth rather than breadth. In the past, it was recognised that students were capable of applying procedures within these and other aspects of the curriculum but may not have fully understood what they were doing

or how to apply the procedure in different contexts, hence the transition to greater focus on understanding and applications of mathematics [11].

Early analysis would indicate that this aspect of student performance improved as, upon examining samples of student work, it was determined that they appeared to be “successfully drawing together their knowledge across different mathematics topics” [13,p.71]. Further research is needed in this respect, however, to determine whether such a change has been achieved consistently in Irish secondary level mathematics education.

While the changes in curricula and culture have been significant, the way in which students are assessed continues to take the form of high stakes summative examinations. Students sit the Leaving Certificate examinations, typically at age 17 or 18, upon completion of their secondary education. They have the opportunity to study mathematics at one of three levels – Higher, Ordinary, or Foundation. Higher Level mathematics is the most challenging, followed by Ordinary Level and then Foundation Level. With the introduction of the new curricula in 2010, elements of the new Senior Cycle mathematics curriculum were gradually incorporated into the Leaving Certificate mathematics examinations in 2012 and 2013. The first Leaving Certificate mathematics examination to be completely based on the entire new Senior Cycle curriculum in all Irish secondary level schools took place in 2014.

The Bonus Points Initiative

Upon completion of the Leaving Certificate examinations, points are awarded to students based on the grades they achieve in the Leaving Certificate examinations (see Table 1). The number of points achieved by a student is a major factor in determining the courses to which the student may gain entry in tertiary level education. To boost the numbers of students opting to study mathematics at Higher Level at Senior Cycle, 25 bonus points were awarded to students who achieved a grade D3, the lowest passing grade, or above in Higher Level

Leaving Certificate mathematics examinations each year from 2012 onwards. This meant that students could achieve a maximum of 125 points in mathematics at Higher Level in the Leaving Certificate, compared to a maximum of 100 points for all other subjects.

Table 1. Points awarded for grades achieved in Leaving Certificate examinations. Note: HA1 represents an A1 grade at Higher Level; OB3 represents a B3 grade at Ordinary Level.

| Grade | Points | Grade | Points |
|--------------|---------------|--------------|---------------|
| HA1 | 100 | OA1 | 60 |
| HA2 | 90 | OA2 | 50 |
| HB1 | 85 | OB1 | 45 |
| HB2 | 80 | OB2 | 40 |
| HB3 | 75 | OB3 | 35 |
| HC1 | 70 | OC1 | 30 |
| HC2 | 65 | OC2 | 25 |
| HC3 | 60 | OC3 | 20 |
| HD1 | 55 | OD1 | 15 |
| HD2 | 50 | OD2 | 10 |
| HD3 | 45 | OD3 | 5 |

The introduction of the bonus points initiative in 2012 appears to have had a noticeable effect on the proportion of students opting to study Higher Level mathematics for the Leaving Certificate examinations. This proportion maintained a consistent level in the years prior to 2012, ranging from 15.8% to 17% in the years 2008 to 2011. It then increased from 15.8% in 2011 to 22.1% in 2012, 25.6% in 2013, 27.3% in 2014, 27.4% in 2015 and 28.5% in 2016 [14].

The overall aim of this initiative is to increase the proportion of students opting to study Higher Level mathematics for the Leaving Certificate examinations to 30% by 2020

[15]. In 2015, Jan O’Sullivan, the Minister for Education in Ireland at the time, indicated that the measure was meeting its objective: “What is positive about the higher level maths paper is that we now have about 27 per cent of students who are taking it and that’s been steadily increasing, no particular increase this year, but I think it has achieved what we wanted.” [16].

Such an increase also appears to have impacted the typical performance of students at this level. The number and proportion of students achieving a C grade or below has, as one would expect, increased significantly during this period [14]. It is thought that this is due to the bonus points initiative as students who would have typically opted for the Ordinary Level paper prior to this initiative are incentivised to attempt the Higher Level paper as there is a possibility of gaining 25 bonus points should they achieve a passing grade [11, 14, 17].

Consider that the maximum number of points a student can achieve through the Ordinary Level examination is 60 for an A1 grade, however a student could obtain 70 points for achieving the lowest passing grade (D3) in the Higher Level examination for mathematics at Leaving Certificate. In such a scenario, they would be awarded 45 points for the D3 grade and the 25 bonus points also, thus giving them a total of 70 points. When one considers the choice these students face, it is not difficult to recognise the reasons for the significant increase in the proportion of students opting for the Higher Level Leaving Certificate mathematics examination and accompanying course of study.

The impact of this phenomenon will be explored in great detail from a range of perspectives within this article and, as such, it is important to consider the conclusions which have been drawn already in relation to the implementation of the bonus points initiative. The Chief Examiner’s Report which examined the impact of the recent changes to secondary mathematics education in Ireland, concluded that the bonus points initiative has been beneficial in that it has ensured that a greater number of candidates have been exposed to a higher level of mathematics [14]. However, concern was raised in this report in relation to

the overall performance of basic mathematical skills in the Higher Level Leaving Certificate examinations. It was indicated that a significant minority of these students had difficulty executing multi-step procedures accurately [14]. Such a concern regarding the execution of basic mathematical skills by these students has also been echoed in recent empirical studies [17, 18].

Treacy & Faulkner [18] examined 6,386 beginning undergraduates' performance of basic mathematical skills in a diagnostic test during the period 2003 to 2013 and concluded that there had been a significant decline in the basic mathematical skills of beginning undergraduates at the University of Limerick (Ireland) as they transitioned from secondary education to tertiary education in Ireland. This noted decline coincided with the introduction of the new secondary mathematics curricula and the bonus points measure.

In a similar study, Treacy et al. [17] concluded that there had been a negative impact in performance of basic mathematical skills among beginning undergraduates that had achieved Higher Level C and D grades in Leaving Certificate mathematics examinations after the introduction of bonus points and the transition to the new mathematics curriculum. Students achieving Higher Level C and D grades in Leaving Certificate mathematics examinations in the period 2012-2014 demonstrated significantly inferior execution of basic mathematical skills in a diagnostic test when compared to similar students from the period 2008-2011. The period 2012-2014 is significant as this was the period during which the new mathematics curriculum was gradually integrated into the Leaving Certificate mathematics examinations. Similarly, the bonus points measure was introduced in 2012 and has been in effect ever since. The significant findings in this study prompted the query as to whether curriculum change, the bonus points initiative, or both had been major factors in the negative impact upon basic mathematical skills among these beginning undergraduates. Exploration of this query will form a central focus of this article.

The introduction of bonus points was intended to act as an incentive for students to study Higher Level mathematics at upper secondary level. As such, the role of incentives in the study of mathematics at secondary level will be considered in depth to offer an insight into the effects measures of this nature have on student motivation. Identifying the means by which student motivation to study mathematics can be effectively enhanced is a challenge with which education systems have grappled [19, 20, 21, 22]. The following brief examination of this field will outline the key concepts and findings which will be utilised to discuss the nature of the bonus points initiative.

Motivation and Incentivising Mathematics Study – An International Perspective

Motivation has been posited as one of the major determinants of students' level of success in school [e.g. 19, 23, 24]. Interestingly, Murayama et al. [20] indicated that student motivation and the learning strategies they employ are the most important factors in students' long term achievement in mathematics. Through their longitudinal study of secondary students in Germany, they concluded that the level of student motivation and the manner in which they study are more important than intelligence when predicting long-term success in mathematics.

Students' prior attainment and self-perceived ability in mathematics as well as availability of a range of appropriate pathways tend to be major influencing factors in students' motivation to study mathematics at secondary level [19, 21, 22]. Similarly, student awareness of the benefits and personal rewards associated with the study of advanced mathematics act as incentives for persisting with study of the subject at secondary level [22].

It must be noted, however, that intrinsic motivation to study mathematics has been determined to have superior effects when compared to extrinsic motivation. Intrinsic motivation relies upon a student's interest to undertake a task as well as the accompanying

pleasure and satisfaction derived from the task, while extrinsic motivation relates to engagement with a task for external reasons [25]. Opting to study mathematics at Higher Level for Senior Cycle in order to achieve bonus points is an example of extrinsic motivation in action.

Students who develop their value and enjoyment of mathematics tend to display greater confidence and persistence while also enhancing their levels of achievement – this is typically achieved through consistent, high-quality instructional practices through which students develop a strong understanding of the fundamental concepts [21, 26, 27]. Extrinsic motivation can have an immediate effect on academic achievement but this tends to be short-lived, while intrinsic motivation tends to have a greater effect on long-term learning [20]. This has led to recommendations for teachers to implement effective strategies to enhance intrinsic motivation among students while also avoiding strategies which focus on increasing extrinsic motivation [28, 29].

Zhu & Leung [29] used Trends in International Mathematics and Science Studies (TIMSS) data from 2003 to determine how pleasure-oriented (intrinsic-related) and productivity-oriented (extrinsic-related) motivation affect eighth-grade (typically 14-15 years old) students' mathematics performances in East Asia education systems compared with education systems in Western countries (US, England, The Netherlands, Australia). Pleasure-oriented motivation referred to the value they placed on mathematics and the enjoyment they derive from studying mathematics. Productivity-oriented motivation referred to the need to learn for utilitarian purposes, e.g. needing mathematics to get into university or to get a job. They found that both types of motivation aided East Asian students but discovered that increased levels of extrinsic-related motivation appeared to have either no effect or, more often, a negative effect on student learning in Western countries within the study. Students with higher levels of pleasure-oriented motivation tended to demonstrate

significantly superior achievement in mathematics in all regions [29]. This further highlights the need to focus on developing students' intrinsic motivation to study mathematics at secondary level rather than promoting measures which aim to enhance extrinsic motivation, especially in Western cultures.

Nevertheless, extrinsic motivation in the form of various rewards to incentivise the study of advanced secondary level mathematics are in evidence internationally. Bonus point schemes for mathematics, similar to that which is being implemented in Ireland, exist in Australia but measures are also in place for a range of other subjects and the number of points awarded changes depending on the university and the course to which a student applies [30, 31, 32]. In 2015, Israel awarded 25 bonus points to students who passed the highest level mathematics examination at secondary level, known as the five point examination. This incentive is being increased to 35 bonus points as part of a range of measures aimed at doubling the number of students opting for the five point examination in Israel by 2019 [33, 34]. Initial reports indicate that this bonus points measure is aiding an increase in the number of students opting for the five point mathematics examination but this has yet to be officially confirmed or extensively researched [34].

Incentives of this nature and their effects on student motivation form an important element of the results and subsequent discussion sections in this article. The means by which data was gathered to inform these results and discussion will be explored in the next section.

Methodology

The aim of this study was to determine the effects that the bonus points initiative had on the difficulty of the Higher Level Leaving Certificate mathematics examinations upon the introduction and continued implementation of this initiative. This study took the form of ex post facto research as the possible cause for the decrease in performance of basic

mathematical skills displayed by beginning undergraduates in Ireland as reported by Treacy et al. [17] was explored after the fact [35]. Motivation for this investigation developed from the observation of a significant reduction in performance of basic mathematical skills among beginning undergraduates that had achieved Higher Level C and D grades in Leaving Certificate mathematics examinations after the introduction of the bonus points initiative and the transition to the new mathematics curriculum [17]. As such, these and other possible factors will be explored to determine the reasons for the noted reduction in basic mathematical skills of beginning undergraduates in Ireland.

A mixed methods approach was applied to gather the relevant data. Within this study the quantitative data gathered and explored prompted the author to investigate further, thus qualitative data was gathered to produce more complete knowledge which was necessary to inform understanding with regard to the relevant phenomena. Data related to the performance by 1,648 beginning undergraduates at an Irish university (University of Limerick) in a diagnostic test which examined their basic mathematical skills in the period from 2008 to 2014 were examined. This provided the author with a means to track the basic mathematical skills of those who had achieved at particular grade levels in the Higher Level Leaving Certificate mathematics examinations after the introduction of bonus points and the transition to the new mathematics curriculum. Data on the overall performance of students in the Higher Level Leaving Certificate mathematics examinations from 2008 to 2016 sourced from the State Examinations Commission [14] were also examined to determine trends in grades awarded during those years. Interviews were conducted with experienced examiners of the Higher Level Leaving Certificate mathematics examination to aid with interpretation of the quantitative data outlined and provide a rich insight into the effects of the transformation which has taken place in secondary level mathematics education in Ireland.

Diagnostic Tests

Quantitative data used in this study were derived from two sources: analysis of student performance of a diagnostic test which examined beginning undergraduates' basic mathematical skills and statistics from the State Examinations Commission [14] outlining Leaving Certificate mathematics grades awarded to students. Since 1998, beginning undergraduates have been given a 40-question mathematics diagnostic test without prior notification during their first assigned lecture in service mathematics modules for science-based and technology-based undergraduate degree courses at the University of Limerick (UL). This diagnostic test, which poses the same 40 questions each year, is assigned to these students with the intention of assessing their performance of basic mathematical skills in particular mathematical topics. These topics can be broadly grouped as arithmetic (13 questions), algebra (8 questions), geometry (11 questions), calculus (7 questions), and modelling (1 question). See Appendix 1 for examples of these questions.

Students who score 18/40 or less are considered to be 'at risk' which indicates that they are mathematically under-prepared for the challenges they will face within their service mathematics module. This cut-off point of 18/40 was objectively proved to be accurate for determining whether or not a student is 'at risk' based on retrospective data. In the period 1998–2008, 84.4% of students who attained a mark of 18 or less in the UL diagnostic test went on to fail their end-of-term examination [36]. Test questions within the UL diagnostic are set to match the basic mathematical skills required of students in the targeted UL service mathematics modules. This test was compared with the Irish Junior Certificate mathematics syllabus, the Irish Leaving Certificate mathematics syllabus, the European Society for Engineering Education (SEFI) Core Level Zero syllabus for engineers, and further diagnostic tests as well as being piloted in Irish secondary schools to ensure the validity of this research

tool [37]. Both Irish syllabi quoted here are the versions which were in place before the introduction the new mathematics syllabi.

It must be noted that the questions which make up this diagnostic test were created to determine whether students possess the basic mathematical skills to succeed in their chosen tertiary level mathematics module. As such, students who progressed from a secondary mathematics education system which placed emphasis on procedural fluency may have been well placed to succeed in this diagnostic test. Students who completed their secondary education before the mathematics curriculum change may have had an advantage in that respect when comparing them to students who completed their secondary education during the phased or full implementation of the new mathematics curriculum. The shift in emphasis from a focus on procedural skills to problem solving skills and applications of mathematics needs to be factored into any analysis of the data arising from these diagnostic tests. Having stated that, the skills which were tested through the diagnostic test are skills which students were expected to master in both the old and the new mathematics curricula.

UL diagnostic test data were gathered each year from 1998 to 2014 and recorded for each student within the UL database. Direct comparisons in basic mathematical competency levels can be reliably made when comparing each cohort as the same diagnostic test was used in each of these years. This paper will focus on data from 2008 to 2014 so that the impact of the introduction and continued provision of bonus points for achieving a passing grade in Higher Level Leaving Certificate mathematics examinations can be observed.

Interviews

Semi-structured interviews were carried out with five experienced examiners of the Higher Level Leaving Certificate mathematics examinations. The interview questions were piloted with one other interviewee. Examiners interviewed are referred to using the letter E and a

number to differentiate each interviewee and maintain their anonymity, e.g. E1, E2, E3.

Criteria set out by the author beforehand required that these examiners would have all had experience correcting Higher Level Leaving Certificate mathematics examinations during the implementation of the old curriculum (examinations before 2012) as well as during the phased and eventual full implementation of the new mathematics curriculum (examinations from 2012 onwards). These criteria were established so that these examiners would have an in-depth perspective of the Higher Level Leaving Certificate mathematics examinations before, during, and after the stated period of transition. This data was gathered to provide a rich insight into any potential changes in the perceived difficulty of the Higher Level Leaving Certificate mathematics examinations since the change in curriculum and corresponding introduction of the bonus points initiative.

The participants were contacted through the Irish Mathematics Teachers' Association (IMTA). In order to ensure that each interviewee met the criteria outlined, purposive sampling was employed. While this approach is more susceptible to potential bias, such potential was recognised and accounted for. Allied to that, using purposive sampling ensured that the data collected would provide a stronger understanding of phenomena explored. Nine individuals who satisfied the criteria were identified, five agreed to participate and were interviewed by the author during the period of March 2016 to May 2016. Each had at least seven years of experience correcting Higher Level Leaving Certificate mathematics examination scripts and all had been active in such a role during at least the previous seven years. One of the interviewees was an acquaintance of the author; the author had not previously known any of the other interviewees. The interviews were completed in order to achieve an in-depth insight into the perceived difficulty of the relevant examinations, comparing their views on the examinations which students completed before and after the

transition to the new mathematics curricula and the accompanying implementation of the bonus points initiative.

A set list of open-ended questions were used during the semi-structured interviews as such an approach offered a number of advantages including flexibility to follow an unanticipated line of discussion; making better informed assessments of what the respondent really believes; and encouraging freedom of expression from respondents [35]. The resulting data were recorded and transcribed fully to facilitate analysis. It must also be noted at this point that, due to funding constraints, the author completed interviewee recruitment with the assistance of the IMTA and he completed all qualitative data collection and analysis. While this was beneficial in gaining an in-depth understanding of the data, it may be considered a limitation due to the potential for bias at any point during these processes.

Thematic analysis of this qualitative data was carried out to form a rich understanding of the participants' experiences and opinions related to the changes which have taken place in secondary level mathematics education in Ireland. This understanding was derived inductively through analysis, examination, and reflection on the relevant phenomena that emerged during repeated engagement with the data [38]. The qualitative data were coded using the computer program Nvivo (version 10) to determine the key features of the data. A total of 16 codes were initially generated and then modified as the analysis progressed. This process developed as a result of listening, transcribing, reading, and re-reading of the data as well as reference to the relevant literature discussed previously in this article. The identified codes were then checked and rechecked against the audio versions of the interviews to determine any new codes and links between codes. At this point, there was an identification of four definitional codes and seven explanatory codes, each of which had two or more subcodes. Once coding was complete, the four key themes discussed later in this article were identified and named. Written analysis of the data was constructed using these themes and

informed by the coding completed previously. Quantitative data were used to complement the rich understanding gained from the thematic analysis of the qualitative data. This process aimed to achieve triangulation and thus strengthen the basis for conclusions drawn through this study.

Results

The data gathered, both qualitative and quantitative, will be outlined according to the themes which emerged during analysis of the quantitative data. First, the effect of the bonus points initiative on the uptake of Higher Level mathematics for Senior Cycle will be examined to offer further insight into the effects on grade allocation and the effects on student motivation to study Senior Cycle mathematics at Higher Level.

Bonus Points effect on the uptake of Higher Level mathematics for Senior Cycle

With the introduction of bonus points and the gradual integration of the new mathematics curricula into the Leaving Certificate examinations in 2012, the combined number of students sitting the Leaving Certificate mathematics examinations at Higher Level and Ordinary Level remained relatively steady at between 45,047 and 47,957 in the years 2008-2016 [14].

However, as alluded to previously, there was a steady increase in the proportion of students opting for the Higher Level paper instead of the Ordinary Level paper from 2012 onwards – a time period which coincided with the introduction and continued provision of bonus points.

All examiners agreed that this measure has had a significant effect on the typical profile of the students attempting the Leaving Certificate mathematics examinations at Higher Level:

“...it does definitely encourage people to stay in. There’s no question about that. It encouraged people to stay in right along the spectrum. But it definitely gets the

[students] that think ‘I’ve a chance of getting a D3 here’ and if he gets a D3 it’s worth the same as a C1 in another subject.” (E5)

“Even if you just look at the figures alone, you have about 8,000 sitting it (Higher Level Leaving Certificate mathematics examination) in 2008 or 2009 while now you have about 14,000 students opting for it so there’s a tail there now which couldn’t possibly match up with the people who did the previous paper in terms of ability, in terms of pure mathematical ability, ignoring the course changes and so on, those cohorts would certainly not match their counterparts from previous years.” (E3)

The author analysed the cohorts of all students that attempted the Leaving Certificate mathematics examinations at either Higher or Ordinary Level as this group would typically be comparable year on year. Analysing the cohorts of students opting for the Higher Level paper alone would not have yielded a similar consistency as the aforementioned migration of students from Ordinary Level to Higher Level from 2012 onwards has adjusted the make-up of this group considerably. One would expect that the vast majority of the extra students opting for the Higher Level paper would typically have opted for the Ordinary Level paper if the bonus points incentive had not been in place. As such, those students would not be expected to achieve the highest grades but may be expected to achieve C, D, E, or F grades. As can be observed in Figure 1, the proportion of students achieving Higher Level C grades and D grades increased significantly but the proportion that failed the examination (E and F grades) only increased marginally (see Fig. 1). The proportion achieving A grades increased slightly, while for B grades, the increase was noticeable.

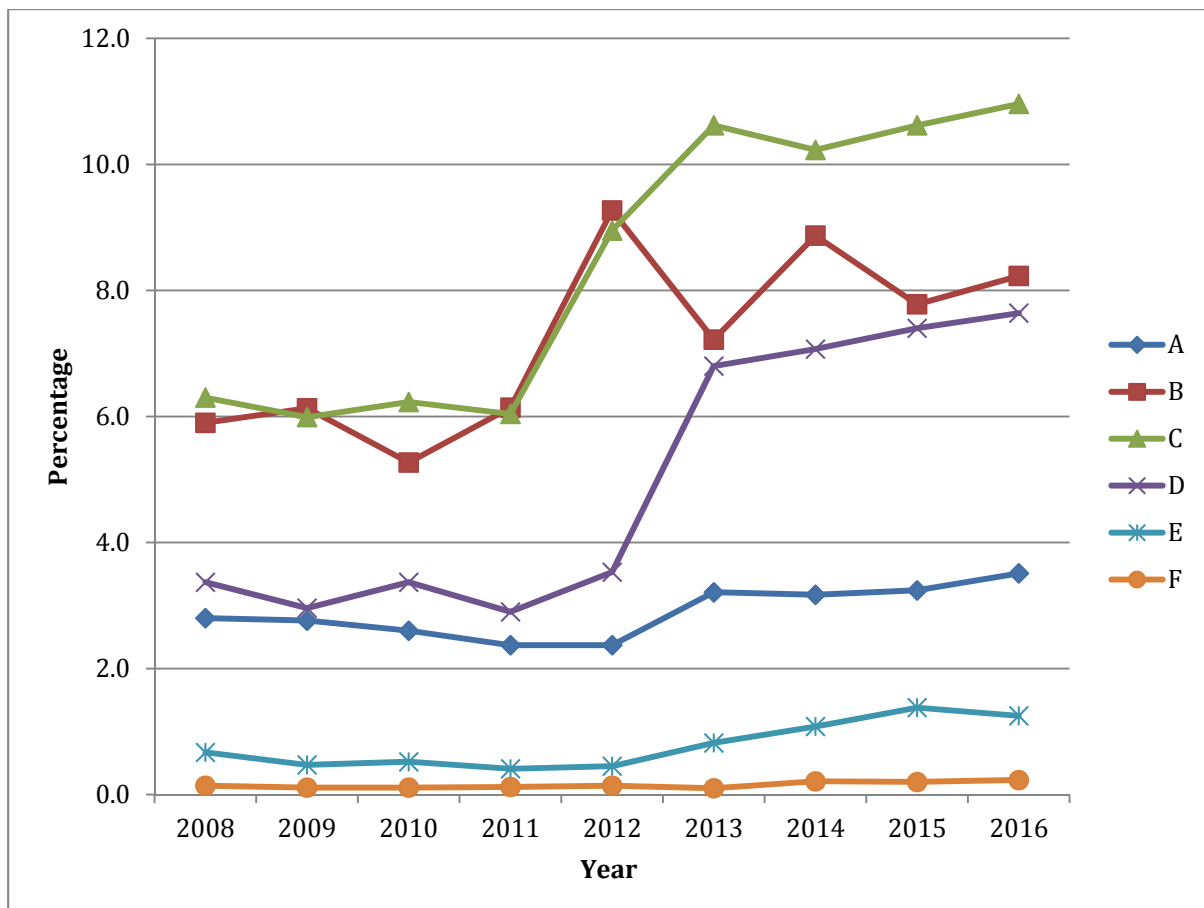


Figure 1. Percentage of students that attempted the Leaving Certificate mathematics examination at either Higher or Ordinary Level that achieved the given grades at Higher Level. Source of data: SEC [14].

Bonus Points effect on the difficulty of achieving a passing grade in Higher Level Leaving Certificate mathematics examinations

The examiners interviewed all agreed that since 2012, the Higher Level Leaving Certificate mathematics examination has been easier to pass. For example:

“...maybe you have students that aren’t so good at maths, they want the extra 25 points that’s available so they are sticking it out as long as they can. I can see it in the classroom – it has a huge impact there as well. At the end of the day, you have to cater for these students if you’re trying to encourage them to stay and do honours level then you don’t want to have all of them failing and I think the papers have reflected that. The standard of questions being asked of students at higher level has been very, very easy.”

(E1)

While not all interviewed suggested that the difficulty of the questions for Higher Level Leaving Certificate mathematics examinations has become 'very, very easy', all have indicated that the level of mathematical ability required to pass the examination has been reduced:

"Some students that are passing the higher level maths paper are not necessarily at the standard that they should be to pass it. Some that are passing it shouldn't actually be passing it." (E2)

The impact of the results in the initial years of the new mathematics curriculum at Senior Cycle and the bonus points initiative have also been highlighted, particularly the low rates of failure:

"They do look at results from previous years and see that it is relatively easy to pass the paper; not to get the high grades but then again, they're not really that interested in that." (E3)

One aspect which also aided the relatively consistent pass rate, even though there was a large surge in numbers taking the Higher Level examination, was the policy of maintaining consistency in the proportion of grades awarded each year and especially maintaining a relative consistency in the proportion of students who fail the examination. All of the examiners interviewed referred to this idea of the grade allocation fitting the 'bell curve' which alludes to the process of 'attainment referencing', which will be discussed in brief here and in detail later in this article. Each year, a sample of scripts are marked and then analysed to ascertain whether adjustments are required for the marking scheme so that the aforementioned consistency of grades awarded can be maintained year on year. Those interviewed had reservations regarding the suitability of this process, especially given the sharp rise in students opting for the Higher Level Leaving Certificate mathematics paper:

"I feel that there is some attempt to keep the bell curve in the right fit. So there is some attempt to keep 4, 5, 6 percent fail rate. So if you're keeping a 5% fail rate and that

includes 3,000 kids that previously wouldn't have done it because they weren't going to pass then in order to keep the failure rate at 5% and accommodate those 3,000 students then I think there possibly is a certain pressure every year - if you want to stick to that statistic - to make it slightly easier to get the D3. The ability of the student that's getting the D3 and the D2 wouldn't have passed probably before the bonus points went in." (E5)

The overall effect of this surge in students attempting the Higher Level Leaving Certificate mathematics paper that previously may not have opted to attempt the paper, coupled with a policy of maintaining a similar proportion of failures year on year has appeared to have had some negative effects:

"Obviously there's more people taking the Leaving [Certificate] maths (at Higher Level) which is obviously a nice thing ... some of them are passing with a low grade but I think they're getting a false sense of security because they're passing with low partial understanding and then they come into college and they're drowning in the maths that they are being shown. So the numbers are increasing and all that, which is nice, but I think the standard isn't increasing in the same way." (E2)

"The introduction of bonus points means a lot more students are staying there (opting to study at Higher Level) and at the end of the day you want your bell curve to reflect as it always has but I think the mathematical ability of those students is quite poor." (E1)

Bonus Points effect on the difficulty of achieving A or B grades in Higher Level mathematics at Leaving Certificate

Examiners had somewhat mixed views on whether or not it was easier to achieve an A grade or a B grade in the Higher Level Leaving Certificate Examinations since the introduction of bonus points and the new mathematics curriculum. Most believed that the level of difficulty to achieve these grades had been maintained, for example:

"Those people at the lower end of the scale, I would question their ability, their mathematical ability. Certainly not at the top end of the scale – I think it's every bit as difficult to achieve that A grade as it would have been in the past so I wouldn't have any

worry about the A or B candidates – they would have a pretty good grasp of the subject. It's just those at the other end, I would question their abilities.” (E3)

“I feel that if you get an A, you're well worth an A. If you get a B, you're well worth a B. If you get a D, I feel... I would worry about the ability of someone getting a D1 or a D2 or a D3.” (E5)

Others have indicated that it may be slightly easier to achieve on the upper end of the grade scale due to an adjustment in the difficulty of questions to compensate for those that may be struggling to pass the examination:

“It's touch and go I suppose. Some papers do seem easier than others. There's definitely some questions that I marked in last year's paper (2015) that were challenging enough but what I find with that at times is those might be only worth 5 marks while the easier question could be worth 15 marks...so that does mean that the knock on effect to that is people are potentially getting As and Bs a bit easier than in the past.” (E2)

Overall, those interviewed tended to believe that achieving A grades and B grades were as difficult since the introduction of the revised mathematics curriculum and the bonus points initiative as they were prior to their introduction. Although there were some instances, such as the one above, in which examiners felt the difficulty in achieving these grades was impacted somewhat. When the cohorts of all students who sat the Leaving Certificate mathematics examinations at Higher or Ordinary Level are examined, the proportion of students awarded Higher Level A grades was largely maintained (see Figure 1). Upon examining these statistics, it is noticeable that the proportion of Higher Level B grades awarded increased from a range of 5.3%-6.1% in the period 2008-2011 to 7.2%-9.3% in the period 2012-2016.

Examiners' overall opinions of the bonus points initiative

Overall, only one of the five examiners interviewed believed that the bonus points initiative should be maintained in its current form but this endorsement was tentative: “I would think

[the bonus points] are justified on the amount of time you put into [studying Senior Cycle mathematics at Higher Level] but they're getting people doing it that shouldn't be doing it" (E4). All other examiners rejected the initiative in its current format – some suggested adjustments such as a sliding scale of bonus points related to the grade that the student achieves; while others suggested that the initiative should be abolished completely. The reasons given for questioning the bonus points initiative typically revolved around how this approach affected students' motivation to study mathematics at Higher Level for Senior Cycle:

“It's not the best way to encourage people to do it because I feel that students are doing it for the wrong reason. It's not for any great love of mathematics that they are doing it. You would wonder when they go onto third level and there are certain mathematical requirements for the courses, are these students really at that level?” (E3)

Diagnostic Tests

Performance by beginning undergraduates in the UL diagnostic test changed significantly in 2012 with the proportion of students failing the test (i.e. scoring less than 18 out of 40) increasing from 44.8% in 2011 to 53.7% in 2012. This failure rate reduced in 2013 (48.7%) and 2014 (48.6%) but remained markedly above the failure rate recorded in 2011 and the years prior to 2011 [18]. This drop in performance of basic mathematical skills coincided with a marked increase in the proportion of students who had studied mathematics at Higher Level in the Leaving Certificate examinations [17, 18]. This unexpected result led the author to explore student performance in the UL diagnostic test in accordance with their performance in the Higher Level Leaving Certificate Mathematics examinations.

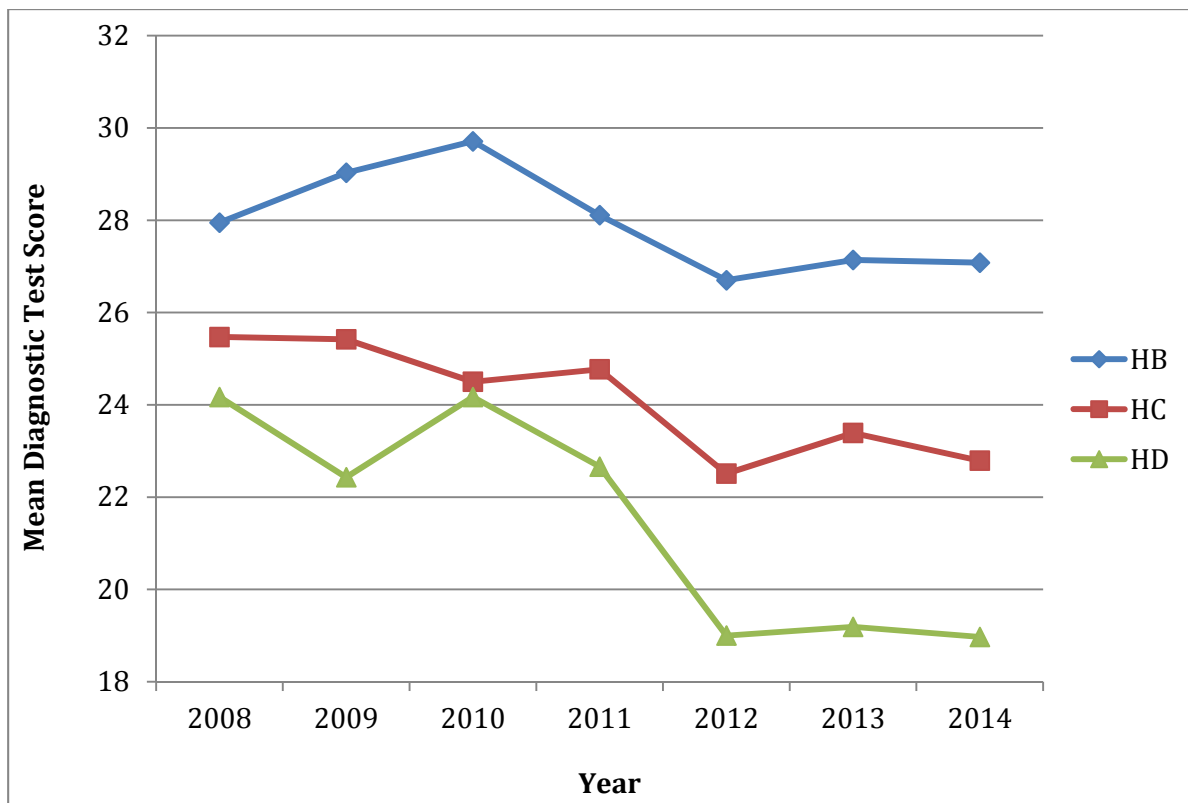


Figure 2. Mean score in the diagnostic test of students that achieved a given Leaving Certificate mathematics grade between 2008 and 2014.

Mean student performance in the diagnostic test according to the Higher Level Leaving Certificate Mathematics grade achieved was relatively consistent between 2008 and 2011 at Higher Level B, C, and D grades. This is in line with the findings of Faulkner, Hannigan, & Gill [39] as they stated that students entering UL with particular Leaving Certificate mathematics grades performed to a similar level in the UL diagnostic test between 1998 and 2008. In 2012, there is a clear reduction in the mean score of students that achieved each of these grades, this change was significant for C and D grades ($p < 0.01$) and just outside the threshold for significance when considering B grades ($p = 0.052$). The mean scores for these grades in 2013 and 2014 were similar to those recorded in 2012.

Discussion

The decrease in mean diagnostic test scores of students who achieved Higher Level Leaving Certificate mathematics grades B, C, and D in 2012 coincides with the introduction of two significant changes – the initial phased integration of the new mathematics curriculum material into the examinations and the introduction of the bonus points initiative.

The change in curriculum for students completing their Leaving Certificate mathematics examination in 2012 was relatively minor. These students had largely experienced the previous curricula during their secondary school lives with only two out of five strands of the new mathematics curricula introduced to their mathematics instruction and their Leaving Certificate mathematics examination. The two strands introduced were ‘Geometry and Trigonometry’ and ‘Statistics and Probability’. While such a change could be expected to affect student performance somewhat, it is questionable whether the significant changes in performance according to Leaving Certificate grade (see figure 2) could be adequately explained by a change in curriculum alone.

The second significant change which affected Leaving Certificate Higher Level mathematics in 2012, the introduction of bonus points, appeared to have a more immediate impact. The proportion of students opting for the Higher Level paper at Leaving Certificate increased from 15.8% in 2011 to 22.1% in 2012 [14] - a 39.8% increase in the proportion of students opting to attempt the Higher Level Leaving Certificate mathematics examination. This measure, while successful in attracting more students to study mathematics at a more advanced level, may have ultimately led to a reduction in standards.

Observations from experienced examiners interviewed alluded to the adjustment in marks awarded and difficulty of questions set from 2012 onwards to ensure that a relatively consistent failure rate is maintained. The increase in students opting to sit the Higher Level Leaving Certificate examination due to the introduction of the bonus points initiative seemed

to create a need to make such adjustments if the consistent failure rate was to be maintained. Consideration of the cohorts of all students that attempted the Leaving Certificate mathematics examination at either Higher or Ordinary Level (see Fig. 1) provides further insight into this phenomenon. The large increase in the proportions that were awarded Higher Level C and D grades coupled with only a slight increase in the proportions awarded failing grades (E or F) from 2012 onwards was referenced by the experienced examiners interviewed through this research:

“The only thing now is you have more people doing them so you have more people failing them. But that’s only a percentage – the percentage has gone up but probably not in ratio to the number of [students] coming in. I think the number of failures should be more.” (E4)

With the increase in students opting for the Higher Level paper in order to achieve the 25 bonus points on offer, it may have been that some of these students did not have the mathematical capabilities required to perform at the level expected of Higher Level mathematics students at Leaving Certificate. Thus, examiners may have been faced with the choice – award failing grades to a greater proportion of students than in previous years or reduce the mathematical standards required to achieve passing grades in the Higher Level Leaving Certificate mathematics examination. As the proportion of students who failed this examination in 2012 (2.3%) was actually below the typical failure rate in previous years (3%) [14], it is reasonable to question why this would occur given that the proportion of students attempting the Higher Level paper had increased so significantly. Allied to that, the results outlined above (see figure 2) indicate a statistically significant decrease ($p < 0.01$) in mean score in the diagnostic test of students that achieved a Higher Level Leaving Certificate mathematics grade C or D when 2011 and 2012 are compared. Consideration of the processes in place for correcting this examination should aid in determining reasons for these anomalies.

The State Examinations Commission (SEC) in Ireland have processes in place to maintain standards year on year within high-stakes national examinations, using practices similar to other examination systems around the world [40]. Examiners of the Leaving Certificate mathematics Higher Level examinations are tasked with correcting a sample of scripts according to the initial marking scheme. These are then collected and analysed by the chief examiner and senior examining team, with changes made to the marking scheme so that candidates achieve the grade that is believed to be deserved. The SEC [40,p.2] indicate that any adjustments made “will be based on a combination of statistical information and experts’ judgements of the standards” to ensure that grades do not fluctuate widely from year to year. They refer to this as the process of ‘attainment-referencing’.

While such a system ensures that the grades awarded each year are largely maintained, it is questionable whether such a system maintained the standards of performance by students in the Higher Level Leaving Certificate mathematics examinations after the introduction of the bonus points initiative. From 2011 to 2012, there was a 39.8% increase in the proportion of students opting to attempt the Higher Level Leaving Certificate mathematics examination which greatly impacted upon the make-up of a typical cohort attempting this examination. Thus, maintaining consistency of grades awarded between these two years would not appear to be a practice which would maintain the same standards of difficulty in achieving the assigned grades. Even though the ‘attainment-referencing’ practice is commonly used for high-stakes national assessments in various education systems, in this instance it may not have been the best approach given the significant change in the make-up of the cohort of students attempting the Higher Level Leaving Certificate mathematics examination.

Observations of the effects that the bonus points initiative has had on students’ motivation to study mathematics at an advanced level in secondary education provide some important lessons. While significantly more students have been exposed to studying Higher

Level mathematics at Senior Cycle secondary education in Ireland since the introduction of the bonus points initiative, it is questionable whether the overall mathematical capabilities of these students have improved as a result when compared to previous cohorts. Upon the transition to the new mathematics curricula and the introduction of the bonus points initiative, basic mathematical skills, as measured by the UL diagnostic test, of students who achieved Higher Level C and D grades have decreased. Similarly, experienced Leaving Certificate Higher Level mathematics examiners have questioned the difficulty of passing the examination since these measures were put in place. Introducing an extrinsically motivating factor such as bonus points must therefore be questioned.

Perhaps greater focus on effective strategies to enhance intrinsic motivation among students would produce better long term outcomes as previous studies have indicated [20, 28, 29]. Having stated that, the special status that mathematics has been given in upper secondary national examinations through the bonus points initiative may yield a positive outcome. Similarly, the increased use of contexts and real world applications of mathematics through the new curricula may render the subject more appealing to students, thus boosting intrinsic motivation. The passing of time may allow for an enhanced perspective through further research of these issues.

Conclusion

The new mathematics curriculum and the bonus points measure were both introduced to the Higher Level Leaving Certificate mathematics examinations in 2012. In this year, beginning undergraduate students' execution of basic mathematical skills decreased noticeably.

Students who achieved Higher Level C and D grades performed at a level statistically significantly below their counterparts the previous year [17]. Taking into account that only two out five strands from the new Senior Cycle mathematics curriculum had been introduced,

the impact of this change would not appear to be the key factor in such a reduction in mean performance. The introduction of bonus points increased the proportion of students opting to attempt the Higher Level Leaving Certificate mathematics examination by 39.8% in 2012. This may have meant that students who were not mathematically capable of performing up to the standard required were opting for the Higher Level paper.

Experienced Higher Level Leaving Certificate mathematics examiners indicated that the difficulty of this examination has been adjusted in the years since the introduction of bonus points and the revised mathematics curriculum. Similarly, they indicated that the manner in which these examinations were marked have been adjusted to ensure the proportion of students passing the examination is maintained at a consistent level. This commonly implemented practice of ‘attainment referencing’ may not have been suitable in this instance given the significant changes to the make-up of the typical cohort attempting the Higher Level Leaving Certificate mathematics examination. While this bonus points initiative has significantly increased the number of students studying mathematics at Higher Level, the possible impact it has had on the difficulty of the accompanying Leaving Certificate examination would cause one to question whether this measure has had a positive effect.

Intrinsic motivation has been shown to have superior impacts upon students’ success in mathematics when compared to extrinsic motivation, especially in Western cultures [20, 28, 29]. Secondary level mathematics education in Ireland must take this into account and place greater emphasis on developing student interest and affection for mathematics rather than offering rewards such as bonus points for studying the subject at an advanced level. Other nations and education systems should recognise this also and adjust accordingly so that sustained meaningful improvement is achieved in mathematics education rather than implementing measures which may just result in questionable short term gains.

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Appendix 1. Sample of questions from the UL Diagnostic Test

ROUGHWORK

12. Express 0.01234 in Scientific Notation.

Ans _____ Don't know

13. Divide 30 in the ratio 3:2

Ans _____ Don't know

ALGEBRA Q14 - Q21

14. Solve for h : $V = \pi r^2 h$

Ans _____ Don't know

15. Evaluate $ab + 2bc - 3ac$ when $a = 3$, $b = -2$ and $c = 4$.

Ans _____ Don't know

16. Solve the equation: $3(x + 2) - 24 = 0$

Ans _____ Don't know

17. Solve for x : $x^2 + x - 6 = 0$

Ans _____ Don't know

18. Solve the set of equations:

$$2x + y = 7$$

$$x + 2y = 5$$

Ans _____ Don't know

19. Write out $(x + 3y)(a - 2b)$ in an equivalent form without brackets.

Ans _____ Don't know

20. Solve for x : $3 - 6x < 21$

Ans _____ Don't know

21. Simplify $\frac{1}{x-1} - \frac{2}{x+1}$

Ans _____ Don't know