Maths and National Competitiveness

A discussion document submitted to the National Competitiveness Council

By Seán Mc Donagh and Tony Quinlan

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Mathematics and National Competitiveness: An introduction by the National Competitiveness Council

For a long time Irish policymakers, educationalists and employers have been concerned about the performance of Irish students and graduates in mathematics. At regular intervals we have heard calls to improve the mathematical proficiency of students emerging from formal education; we also hear calls to increase the numbers of students studying mathematics at various levels – at Higher Level Leaving Certificate, undergraduate and post graduate levels[1]. Essentially, what is a required is a step change in educational outcomes relating to mathematics. In seeking to enhance performance, however, it is first useful to consider why such a step change in performance is required.

Mathematical literacy drives economic growth. A recent OECD study has highlighted the direct link between student performance in cognitive tests and GDP growth[2]. The findings from this work indicate that even relatively small improvements in the mathematical skills of a nation's labour force can have very large impacts on future economic well-being[3].

At a sectoral level, mathematical literacy is the building block for a vibrant economy. Mathematics underpins many other disciplines such as science, technology, business and finance – all crucial elements of Ireland's economic blueprint and the bedrock for the development of a world-class research and innovation system in Ireland, and the ongoing availability of maths-based skills is a major determinant of Ireland's ability to attract foreign direct investment (see panel opposite). Indeed, recent work by the Expert Group on Future Skills Needs (EGFSN) has found that despite the recession a range of difficult to fill vacancies persist in the Irish labour market - these vacancies are primarily confined to sectors with a large mathematical content such as ICT, engineering, science and finance[4].

From an individual perspective, mathematical skills are essential for enabling people to fully participate and work in a modern society. With the continual growth of the digital society and the pervasiveness of ICT, an

MATHS & ENTERPRISE

Dr. Craig Barrett, former CEO, Intel

"You need to state your goal to be the number 1 in the PISA rankings for maths. Your future relies on a critical mass of maths and science skills. Fix it." [Speaking to the Royal Irish Academy, 8th February 2010]

John Herlihy, Head of Google in Ireland

Ireland is "falling further and further behind in mathematics. First off, I think it is good news that Ireland is investing heavily in technology in third and fourth level. But, while this is positive, the downside is you don't have a stream of good graduates coming through. Lecturers at third level are spending a lot of their time teaching remedial maths..." [Irish Independent 26th September 2008]

Joanne Richardson, Chief executive, American Chamber of Commerce

"Less tuition hours are spent on the key areas of science and maths in Irish schools than OECD/EU averages and this is perhaps reflected in the continuing poor performance of students in these subjects.

If we are to make the smart economy a reality and if we are to retain and grow foreign direct investment we need to ensure a continuous pipeline of graduates with the skills which will drive innovation across all industry sectors such as ICT, pharmaceuticals, engineering, biotech and financial services." [Press Release 18th August 2010]

McKinsey Global Institute

"Demand for deep analytical talent in the United States could be 50 to 60 percent greater than its projected supply by 2018." [Big Data: The Next Frontier for Innovation, Competition, and Productivity]

[1] See for example EGFSN, Raising National Mathematical Achieving, Forfas, November 2008

[2] This is primarily measured through results from the mathematical and scientific literacy segments of the Programme for International Student Assessment. For further information see OECD, The High Cost of Low Educational Performance: The Long-Run Economic Impact of Improving PISA Outcomes, January 2010

[3] A scenario whereby all students are brought up to a minimal skill level (defined here as obtaining a score of 400 on the PISA mathematics and science tests, or one standard deviation below the OECD average) would potentially increase annual GDP growth in Ireland by 0.45 percent in the long term.

[4] EGFSN, National Skills Bulletin 2011, July 2011; EGFSN, Addressing High Level ICT Skills Recruitment Needs, Forfas, January 2012

understanding of mathematics is assuming ever greater importance[5]. From a more material viewpoint, mathematical literacy directly impacts upon an individual's labour market potential. As well as being a prerequisite to gain employment in a whole host of sectors and occupations, proficiency in mathematics also impacts positively upon earnings potential[6].

It is clear from all of the above, that mathematics is not 'just another subject'. It is fundamental to so much of what we do, both as individuals, and as a country. Improving national mathematical achievement is, therefore, vital for all of us. Like most other interested parties, the Council's concerns relate to both the quality and quantity of available mathematics skills in Ireland. Generally, suggested reforms relate to reforming the mathematics curricula; increasing the time dedicated in the classroom to mathematics; and improving the quality of training for mathematics teachers, issues which are being explicitly addressed by a number of comprehensive and flanking measures by the state.

First and foremost, the Council welcome the publication of the National Strategy to Improve Literacy and Numeracy[7] which was launched in July 2011 following considerable discussion with stakeholders. The Strategy sets out a series of qualitative and quantitative targets for improving literacy and numeracy standards for the period 2011 to 2020, as well as explicitly addressing the time issue raised above.

The ongoing rollout of Project Maths sees the introduction of revised syllabuses for both Junior and Leaving Certificate Mathematics and involves changes to what students learn in mathematics, how they are taught and how they are assessed. Project Maths places greater emphasis on student understanding of mathematical concepts, with increased use of contexts and applications that will enable students to relate mathematics to everyday experience. The initiative will also focus on developing students' problem-solving skills.

Initiatives have also been taken to incentivise the take up on Higher Level mathematics amongst students – the implementation of Bonus Points for Higher Level Mathematics in 2012 by the Universities, DIT, all of the Institutes of Technology and RCSI is particularly welcome in this regard[8].

Reforms to curricula and structures, however, can only go so far in improving educational outcomes. Ultimately, the quality of education is dependent on the quality of teaching. Recent policy initiatives have seen a focus on the issue of teacher quality generally and teacher education specifically. In this regard, the Council is pleased to note the ongoing provision of professional development for teachers. Specifically, the ongoing training of teachers responsible for the delivery of revised Project Maths curricula, and the development of a new post-graduate degree in mathematics to provide unqualified mathematics teachers with the opportunity to upskill their knowledge of mathematics are especially noteworthy developments.

The Council will no doubt return to the theme of improving mathematical attainment in future reports. In the meantime, however, the Council are pleased to publish the following paper by Seán McDonagh and Tony Quinlan which analyses a range of performance metrics and highlights a number of concerns about mathematical achievement. While the research and conclusions contained in the discussion document are solely the responsibility of the authors, we are delighted to circulate this paper as an important and useful contribution to the discussion on improving mathematical attainment in Ireland.

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[5] The growth in data and its implications for societies and economies is explored in a recent paper published by the McKinsey Global Institute. For further information, see Manyika, J., et al, Big Data: The Next Frontier for Innovation, Competition, and Productivity, McKinsey Global Institute, May 2011

[6] A UK study undertaken by the London School of Economics has found that maths based qualifications conferred significant advantages in terms of earnings – comparing income levels and educational backgrounds, the study concluded that having an A-level in maths increased long-term earnings by up to 7-10 percent. The positive association between maths and earnings held regardless of the grades achieved (although there was variation in the scale of the impact). See Dolton, P. and Vignoles, A., The Economic Case for Reforming A Levels, Centre for Economic Performance, London School of Economics, Discussion Paper No' CEPDP0422, April 1999

[7] Department of Education and Skills, Literacy and Numeracy for Learning and Life: The National Strategy to Improve Literacy and Numeracy among Children and Young People 2011-2020, July 2011

[8] Forfás and Expert Group on Future Skills Needs welcome Bonus Points Scheme, Press Release, 12th October 2012

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Note: The research, analysis and conclusions contained herein are solely the responsibility of the authors and do not necessarily represent Forfás or National Competitiveness Council views.

Introduction

1.1 Comparative national Mathematical achievement is an important measure of future national competitiveness. The qualifications necessary for a competitive technology and knowledge based economy in areas such as Applied Sciences, Financial Services, Computing, Engineering, Statistics and Technology are Mathematics based. This note looks at aspects of national Mathematics achievement, at the deep concerns they raise and at some suggestions for immediate improvement.

1.2 In 2011 Leaving Certificate Mathematics at its three levels – Higher, Ordinary and Foundation – had 51,991 entries, the highest individual subject entry. Mathematics is a universal subject and Ireland allocates large teaching resources to it.

1.3 The following are some of the levels achieved by the 51,991 entries:

- 6,656 (12.8%) achieved an Honours grade (i.e. A/B/C) on the Higher Level, the smallest proportion by far of all the subjects. These were eligible to apply for Higher Education (HE) courses requiring an Honours in Mathematics;
- 7,982 (15.4%) passed Higher Level;
- 4,280 (8.2%) achieved an A grade at Ordinary level the highest such figure for any subject;
- 33,795 (65.0%) passed Ordinary level so that 41,777 (80.4%) achieved eligibility for Higher Education courses requiring an Ordinary D3 pass for entry including, for example, entry to Primary Teacher Training;
- At Foundation level 2,766 (5.3%) achieved A/B grades;
- In 2011, 15.8 percent of all Mathematics entries were at Honours level or 18.0 percent of those who took Higher or Ordinary Level. This proportion sharply contrasts with the average of 70 percent of entries taking the Higher Level in all subjects excluding Irish and Mathematics. 275 fewer students took Higher Level Mathematics in 2011 than in 2008;

1.4 National Mathematics achievement – a vital strategic measure of competitiveness – is entirely in our own hands. National decisions can improve that achievement immediately and in the intermediate term. This note suggests some immediate steps towards improvement. Some international comparisons are now made.

International Comparisons

2.1 One important comparative measure is the triennial PISA (Programme for International Student Assessment) Mathematics tests for 15 year-olds. The same tests are applied in all 65 participating countries. The Canadian longitudinal study of the 30,000 Canadians who did these tests in 2000 established PISA tests as good predictors of University entry, persistence and success[9].

2.2 The work of Hanuchek, Woessman, and others on PISA tests and their predecessor standardized tests over 50 years establish convincingly the following two claims[10],[11]:

- Comparative national economic progress is correlated to national performance in these tests (measured, say, by average performance).
- Independently of this, comparative national economic progress is correlated to the proportion of high achievers in such tests.

By both these measures in PISA Mathematics – overall performance and the proportion of high achievers – Ireland should have serious concerns about its future competitiveness.

2.3 In PISA Mathematics in 2009, Ireland ranked 32nd amongst 65 participating countries and was below the OECD average. Ireland's performance has declined since 2003 with a stronger decline at the upper end of achievement. Ireland's decline since 2003 was the second largest amongst 2003 participants.

2.4 The performance at the highest levels raises deep cause for concern about Mathematics teaching at primary and lower second level. At the top PISA level, Level 6, Ireland's 0.9 percent lags behind the OECD average of 3.1 percent and way behind the top performing countries. Six countries achieved more than 8 percent at Level 6.

Table 1: High Achievers Level 6 and 5: PISA Mathematics. 2009

	OECD Average	*Ireland*
Level 6	3.1%	0.9%
Level 5	9.6%	5.8%
Total 6/5	12.7%	6.7%
		Source: ERC

At Levels 5 and 6 Ireland achieved 6.7 percent as opposed to an OECD average of 12.7 percent. The 6.7 percent contrasts with the 11.4 percent achieved by Ireland in 2003. Ireland was below the OECD average for top performers in Mathematics in 2006 also. Finland had 20+ percent at Levels 5/6.

Ireland aspires to producing the highest quality graduates and the most innovative postgraduates. The figures for PISA high Mathematics achievement questions whether the foundations are being properly laid in the school system for potential high achievers.

2.5 Mathematics distinguishes itself from other disciplines in that mature capacities can be developed at an earlier age - Professional Mathematicians frequently do their most innovative work at a young age. This makes the Irish PISA Mathematics performance all the more serious. It also questions whether the discontinuity in Mathematics development and effort caused by the Transition Year is advisable for some talented young people.

[9] OECD, Pathways to Success – How Knowledge and Skills Shape Future Lives in Canada, 2010

[10] Hanushek, E., Woessman, L., The High Cost of Low Educational Performance, OECD, 2010

[11] Hanushek, E., Woessman, L., The Role of School Improvement in Economic Development, NBER, 2007

2.6 It is worth noting the 10 top performing countries in PISA Mathematics 2009. They are – in order – Shanghai, Singapore, Hong-Kong, Korea, Taipei, Finland, Liechtenstein, Switzerland, Japan, and Canada.

2.7 Higher Leaving Certificate Mathematics is the highest level in the school system. Higher Level subjects can be ranked by their number of entries in 2011. Tables 2 and 3 do that for males and females who have quite different subject preferences. These tables also contain for comparison the ranked entries for A-level across the UK and for Scottish Highers. Although not a like-for-like comparison, it is a valid and interesting one.

Table 2: Male Choice 2011: Higher Leaving/UK A-Level/Scottish Highers

Scottish Higher *Male*	*UK A-Level* *Male*	*Ranking*	*Irish Higher Leaving* *Male*
English	**Mathematics**	**1**	English
Mathematics	Biology	**2**	Geography
Physics	English	**3**	Biology
Chemistry	Physics	**4**	Construction
PE	Chemistry	**5**	Bus. Studies
History	History	**6**	French
Geography	Gen Studies	**7**	Irish
Biology	Bus Studies	**8**	**Mathematics**
Modern studies	Geography	**9**	History
Bus. Management	Economics	**10**	Engineering
			Sources: JCQ, UCAS, SEC

2.8 Mathematics is the top ranked A-level male subject choice and is in second place in Scotland. It ranks 8th in the Irish Higher Leaving male choice. Those interested in Irish competitiveness will notice the high ranking of Physical sciences – Physics and Chemistry – in the UK and Scottish male choices. These subjects are not in the Irish male top 10. Increasing Higher Mathematics uptake has to be the first step in promoting these subjects.

Table 3: Female Choice 2011: Higher Leaving/UK A-Level/Scottish Highers

Scottish Higher Female	*UK A-Level Female*	*Ranking*	*Irish Higher Leaving Female*
English	English	**1**	English
Mathematics	Psychology	**2**	Biology
Biology	Biology	**3**	Geography
Art/Design	Art/Design	**4**	Irish
History	**Mathematics**	**5**	French
Chemistry	History	**6**	Home Econ
Modern Stud	Sociology	**7**	Bus. Studies
Bus management	Chemistry	**8**	Art
Geography	Gen. Studies	**9**	**Mathematics**
French	Media/TV	**10**	Music
			Sources: JCQ, UCAS, SEC

2.9 Amongst females, Mathematics is second again in Scotland and in the top 5 in the UK. It ranks in 9th place here.

2.10 These comparisons suggest that Ireland's competitiveness would be significantly improved by raising Higher Mathematics to a top 5 ranking. This requires an additional 5,000+ entries.

Mathematics: Just another Subject?

3.1 There is a widespread, false and dangerous view that Mathematics is just another subject. Indeed until recently, the Points System unintentionally supported that view, in that it awarded Mathematics the same points as any other subject. This view in the past informed decisions to reduce time for Mathematics at primary and lower second level to make time for other subjects.

3.2 Mathematics is a double examination subject (i.e. students sit two examination papers) - a fact that gets no recognition in the Points system (so too is English, also unrecognized). As mentioned above about 16 percent do Higher Level Mathematics in contrast to the 70 percent, on average, of other subject students who do the Higher course (excluding Math and Irish). Mathematics develops vital intellectual capabilities and enhances generic skills such as logical analytical reasoning and problem solving skills. It requires student application and develops self learning skills. It is a prerequisite and enabler of other disciplines.

3.3 Entry to primary teacher training, undergraduate and graduate, goes a step further. It places Mathematics in its minimum entry standards at a lower level than other subjects. Entrants require an Honours grade (A/B/C) in Irish. In English a pass at Higher or an Ordinary C3 grade suffices. In Mathematics, which all primary teachers teach, all that is required is Ordinary D3. Numeracy, this long standing arrangement loudly proclaims, is less important than literacy. Of those entering all undergraduate teacher-training. 95 percent have Honours in English and 35 percent have Honours in Mathematics. In at least one Teacher Training College Mathematics is consistently the "academic" subject least chosen.

3.4 In choosing whether to take Leaving Certificate Mathematics at Higher or other level, many students, well capable of Higher Level, choose the Ordinary course. Table 4 contrasts the 18,291 who achieved Honours (A/B/C) at Junior level in 2009 with the 6,656 who obtained Honours (A/B/C) in the Leaving Certificate of 2011.

Table 4: Mathematics: Higher Leaving 2011 and Junior Cert 2009

	Male	*Female*	*Total*
Higher A/B/C Junior Cert 2009	8,959	9,332	**18,291**
Higher Leaving A/B/C 2011	3,558	3,098	**6,656**
Difference	-5,401 (60.3%)	-6,234 (66.8%)	**-11,635 (63.6%)**
			Source: SEC

The difference is 11,635 or 63.6 percent less – the female decline is deeper. Getting, for instance, one in three of those "dropping down" to remain successfully at Higher studies would transform national Mathematical achievement. The decision to "drop down" is made by intelligent young people, advised by schools and parents. The incentive to drop down needs to be replaced with an incentive to remain at Higher Level Mathematical studies.

3.5 Underachievement in Mathematics may have a variety of causes – inadequate teaching, lack of student application, poorly qualified teachers, school policies, poor guidance, student choice and the unintended incentivisation of lower achievement by the Points System. Where underachievement is not caused by any defect of the curriculum it may be that it will not be remedied by curriculum change! Causes should be addressed directly.

Mathematics and Higher Education

4.1 Mathematical achievement is one of the best predictors of persistence and success in Higher Education (HE). Improving Mathematical achievement improves preparedness for higher studies and the quality of higher qualifications and skills. Table 5 gives the non persistence rates to year two in HE by points gained from Mathematics from the HEA Student Progression Report on the intake to full-time HE in 2007. The final column gives the cumulative numbers of those achieving those points in 2011.

Table 5: Mathematics Points and Persistence Predictions

Math Grades	*Points*	*Non persistence*	*Cumulative total 2011*	
H:A1	100	3%	470	
H:A2	90	5%	1,084	
H:B1	85	6%	1,921	
H:B2	80	6%	2,871	
H:B3	75	6%	3,891	
H:C1	70	6%	4,857	
H:C2	65	5%	5,923	
H:C3 + O:A1	60	7%	8,204	**15.8%**
H:D1	55	11%	8,815	
H:D2 + O:A2	50	10%	11,955	
H:D3 + O:B1	45	12%	15,775	
O:B2	40	13%	19,668	
O:B3	35	16%	23,642	
O:C1	30	17%	27,375	**52.7%**
O:C2	25	21%	30,859	
O:C3	20	28%	34,057	
O:D1	15	29%	36,880	
O:D2	10	35%	39,263	
O:D3	05	39%	41,777	**80.4%**
				Sources: HEA, SEC

The 8,204 (15.8%) who gain 60 or more points from Mathematics have an expectation of high persistence rates. Mathematics confers preparedness for success. The 19,171 (36.9%) who gain 30-55 points have a higher expectation of non-persistence. Below 30 points, non-persistence to year 2 risks increasing to high levels. The preparedness for Higher Education is more questionable.

It is clear from Table 5 that the quality and effectiveness of Irish Higher Education would be transformed by increasing the Higher Level Mathematics participation by 4,000/5,000 and by raising the performance of 10,000 others by one grade. This should be an immediate national objective.

4.2 Table 5 brings into question the minimum Mathematics entry standard to some courses. It suggests that raising minimum standards from Ordinary D3 to, say, Ordinary C2 would have a major effect on preparedness, persistence and quality.

4.3 The national ambition for a 72 percent entry rate of the school leaving cohort to HE is not now matched by a national Mathematical achievement and preparedness that would ensure persistence and success for such a large entry. Irish competitiveness depends on the quality of its qualifications.

Mathematics and the Points System

5.1 The Point System for selection for HE may unintentionally be having a serious perverse effect on the mathematical achievement of some school leavers. Table 4 illustrates a major drop down from Higher Level Mathematics in Senior cycle.

5.2 Mathematics is a double examination subject, as is English (i.e. students sit two examination papers in both subjects). These representing the highest level of numeracy and literacy in the school system, get no Points recognition for this.

5.3 Perversely, for some students, the Points System may encourage lower achievement in Mathematics when it is an eligibility subject. Some students may aim at getting the minimum Ordinary D3 required in Mathematics and then at gaining the points for selection in their other 6 "easier" subjects. This may contribute to the drop down after Junior Certificate. Where Mathematics is a required subject it is more logical that it should be included in the 6 subjects contributing points for selection.

5.4 The example of Irish is instructive. Honours in Irish is required for entry to Primary Teacher Training. Entry is largely female. Higher Irish has a much higher female proportion than other languages as bright females and their schools wishing to keep career options open continue with Higher Irish. Mathematics can learn from this.

5.5 There are three types of HE courses (in terms of Mathematics entry requirement):

- Some courses require Honours in Mathematics. These may not be so affected by a bonus for Higher Mathematics as all eligible applicants earn the same bonus
- Some require Ordinary level Mathematics for eligibility – usually a D3. To stop the Points System incentivising low Mathematics achievement, as argued above, these courses should insist on Mathematics being one of the 6 subjects contributing points for selection. Table 5 above supports a further step - making Ordinary C1 or C2 the minimum Mathematics entry standard.
- Some courses do not require Mathematics. The persistence figures in Table 5 are across all courses and Mathematics promotes generic skills of wide application.

Conclusions

Ireland has one advantage in that Mathematics is a universal subject at Senior Cycle. What is urgently needed is to improve significantly national Mathematical achievement and to use more effectively the resource allocated to it. Furthermore a deeper national understanding of the importance of Mathematics to national competitiveness, Higher Education success and future careers needs to be promoted.

- A national target of 4,000 more successfully completing Higher Level Mathematics and a further raising of 10,000 others by at least one grade should be set for the Leaving Certificate of 2014. The cooperation of school and HE authorities, young people, parents and the Mathematics Teachers Association should be sought in achieving this target. Each school should have its Mathematics policy and goals.
- Mathematics is a double examination subject with a requirement for student application. This should be recognized in the Points System for HE admission
- Where Mathematics is a required subject for a course, it should count as one of the 6 subjects contributing points for selection from 2014 onwards. This should promote both greater achievement in the Senior Cycle starting 2012 and success in HE.
- Where Ordinary level D3 is now a requirement for a course this should be raised in 2014 to C2 Ordinary. This also will promote persistence and success. For those excluded by this, rigorous FE courses allowing for earned progression should be available. The above steps should help to stop the present "drop down" from Junior Cycle to Senior Cycle Mathematics.

- The Mathematical entry requirement for Teacher Training should be the same as the English requirement and appropriately high. From 2014, Mathematics should be included in the 6 subjects earning points for selection. This should improve Mathematics at secondary now and at primary later.
- Selection methods for graduate entry to Teacher Training should give a strong transparent priority to numerate degrees.
- A major programme of Continuous Professional Development in Mathematics teaching should continue to 2014 and be compulsory for underachieving or under qualified teachers.
- The possibility of having some of the best Mathematics teachers teaching topics from the school Mathematics curriculum on line and accessible at any time to all should be explored. This would enable widespread access to the best teaching. A pilot scheme covering topics from the Higher Leaving course should be available to the 2012-2014 senior cycle.
- To promote high achievement, an annual national senior and junior Olympiad of Mathematics with an emphasis on imagination, talent and fun should be held with its annual finale coinciding with the Young Scientist exhibition.
- Underachievement in Mathematics has many causes - uninspiring teaching, lack of application, disincentivisation by the Points System, school policy and guidance and student choice. These causes should be addressed directly. Curriculum change may not solve underachievement not caused by the curriculum.
- National decisions need to be made now to affect the Senior Cycle entrants in 2012 and HE entrants of 2014. The above recommendations cost little but rather should contribute considerably to the future cost effectiveness, output and quality of HE. They also should enhance Irish future competitiveness.

Bibliography

1. www.examinations.ie
2. www.jcq.org.uk
3. www.ucas.com
4. PISA 2009: The Performance and Progress of 15-year-olds in Ireland, 2011, ERC
5. PISA 2009 Results: What Students know and can do – Vol. 1, 2010, OECD
6. A Study of Progression in Irish Higher Education, 2010, HEA
7. Pathways to Success – How Knowledge and Skills Shape Future Lives in Canada, 2010, OECD
8. Hanushek, E., Woessman, L., 2010, The High Cost of Low Educational Performance, OECD
9. Hanushek, E., Woessman, L., 2007, The Role of School Improvement in Economic Development, NBER
10. EGFSN, 2008, Raising National Mathematical Achievement, Forfás