Project Maths and PISA: Comparing the coverage of PISA mathematics items by the Project Maths and pre-Project Maths curricula

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Project Maths (PM) is a new activity-based post-primary mathematics curriculum. Implementation began in 2008 in 24 initial schools and has now extended to all post-primary schools in Ireland. The Irish sample for PISA 2012 included students in all of the Initial Project Maths (IPM) schools, as well as students in the regular PISA sample, most of whom had not studied the PM curriculum at all (NPM). This paper provides the background to a project that compares the performance of students at IPM and NPM schools on PISA 2012 mathematics scales and subscales, and builds a model of student performance that includes PM status. First, the paper sets out the background to Project Maths and the framework of PISA mathematics. Drawing on a test-curriculum rating process, it then notes similarities and differences between the PISA mathematics framework and both the PM and pre-PM curricula. Three mathematics experts rated the likely familiarity of students with the concept, the context, and the main process underlying PISA 2012 trend mathematics item. Across all syllabus levels, students studying the Project Maths curriculum were expected to be more familiar with the PISA items than students studying the pre-PM curriculum. The curriculum analysis was a precursor to analysis of the performance of students at IPM and NPM on overall PISA mathematics, on the four content scales (Change & Relationships, Space & Shape, Quantity, and Uncertainty & Data), and on the three process subscales (Formulating, Employing, and Interpreting). The responses of students in IPM and NPM schools are also compared on several measures of attitudes towards mathematics, including intrinsic motivation to learn mathematics, mathematics self-concept and mathematics anxiety. A multi-level model (school, student levels) examines the effects of a range of variables on overall PISA mathematics performance, including student gender, socio-economic status, attitudes towards mathematics, mathematics intentions, grade level, and school PM status. The purpose of the model is to gain a clearer insight into the range of school and student factors operating on performance in PISA mathematics, including the effects of studying under the PM curriculum (see www.erc.ie/pisa for the full report). The outcomes of the study will be discussed with reference to published research on the implementation of Project Maths in schools, and the actions that are needed to support teachers in implementing PM in schools.

INTRODUCTION

Project Maths is the new post-primary mathematics curriculum. It focuses on developing students' understanding of mathematical concepts and their mathematical skills using meaningful examples from everyday life (NCCA, 2011). Project Maths also aims to foster students' enthusiasm for mathematics and to encourage students to think creatively about the ways mathematics can be used and applied (Jeffes *et al.*, 2012). It is underpinned by Realistic Maths Education, a pedagogy which emphasises dialogue, exploring connections, and learning from experimentation and misunderstanding (Lubienski, 2011, NCCA, 2005). Both the Junior Certificate and

Leaving Certificate PM curricula are divided into five strands: Statistics & Probability, Geometry & Trigonometry, Number, Algebra, and Functions. Project Maths was introduced in 24 pilot schools in 2008 with full, national implementation to be completed by 2015.

The Programme for International Student Assessment (PISA) is an OECD study of the achievement of 15-year-olds in mathematics, reading, and science. The PISA 2012 mathematics framework defines mathematical literacy as:

> An individual's capacity to formulate, employ and interpret mathematics in a variety of contexts. It includes reasoning mathematically and using mathematics concepts, procedures, facts and tools to describe, explain and predict phenomena. It assists individuals to recognise the role that mathematics plays in the world and to make the well-founded judgments and decisions needed by constructive, engaged and reflective citizens (OECD, 2013a, p. 25).

For the purposes of assessment, the PISA 2012 definition of mathematical literacy is conceptualised in terms of three interrelated aspects:

- The mathematical content assessed in the areas of Change & Relationships, Space & Shape, Quantity, and Uncertainty & Data;
- The mathematical processes used by students in solving problems, categorised as *Formulating* situations mathematically; *Employing* mathematical concepts, facts, procedures, and reasoning; and *Interpreting*, applying, and evaluating mathematical outcomes; and
- The contexts in which mathematical problems are located, whether personal, occupational, societal, and scientific.

In addition to the assessments of mathematical literacy, PISA collects background information from questionnaires on students' family life, attitudes towards mathematics and education, learning behaviours, educational career, and ICT familiarity. Ireland has participated in PISA since the first cycle in 2000 and in PISA 2012, students in Ireland scored significantly above the OECD average on scales of mathematics, reading, and science (Perkins *et al.*, 2013).

In 2012 and in previous PISA cycles, however, students in Ireland scored below the OECD average on the Space & Shape mathematics subscale (Cosgrove *et al.*, 2005; Perkins *et al.*, 2010). Performance in PISA has been cited along with failure rates in Leaving Certificate mathematics among the factors which prompted the debate on reform of the mathematics curricula and the development of Project Maths (Conway & Sloane, 2005). PISA 2012 presented an opportunity to compare the achievements of students in Initial Project Maths (IPM) schools to those in Non-initial Project Maths schools (NPM) so the PISA sample included students in all of the IPM schools as part of the nationally representative sample. For the purposes of this paper, PISA mathematics can be conceptualised as an assessment tool to measure the impact of Project Maths as an intervention. The PISA mathematics test also provides a benchmark against which to compare the performance of students who have studied under the Project Maths curriculum and those who have studied under its predecessor.

As part of the implementation of Project Maths, the Department of Education and Skills commissioned an independent evaluation of the impact of Project Maths on student achievement, learning, and motivation (Jeffes *et al.*, 2012, 2013). The

evaluation included a standardised assessment of student achievement, a survey of attitudes, analysis of students' work, and case studies in selected IPM and NPM schools. Students in Second and Third years of the Junior Cycle and in Fifth and Sixth years of the Senior Cycle took part. Overall, few differences were identified between the performance of IPM and NPM students, with IPM students in the Senior Cycle scoring better on Strand 2, Geometry & Trigonometry, for example. Likewise teachers' approaches appeared to be similar, at least as indicated by students' written work. In the survey of students, those in IPM schools did report more frequent use of certain of the new processes and activities associated with Project Maths: using real-life situations, making links between maths topics, working in small groups, and using computers (Jeffes *et al.*, 2013). However, this was often alongside more transmissive activities like reading from textbooks and copying from the board (Jeffes *et al.*, 2013). Other aspects of Project Maths were less successful and students reported discomfort with multiple interpretations, which is perhaps understandable since the students had been taught since Primary School to find the single right answer (Jeffes *et al.*, 2013). In conjunction with PISA, Cosgrove *et al.* (2012) surveyed teachers in IPM and NPM schools. Those in IPM reported positive changes in teaching and learning practices, though this was perhaps at the expense of teacher confidence in some areas of teaching and assessment.

Neither the old Junior Cert mathematics curriculum nor the new Project Maths curriculum is directly based on PISA processes and content areas, though it is instructive to note the extent to which each version of the curriculum corresponds to the PISA mathematics framework. As part of the Project Maths report, a PISA Test-Curriculum Rating Project (TCRP) was undertaken in 2014, building on a similar project following PISA 2003 when mathematics was last the major domain (Close, 2006). It aims to compare the coverage of PISA test items by the Project Maths curriculum and the previous curriculum.

METHOD

Three independent experts in second-level mathematics education undertook ratings of PISA 2015 trend items, reviewing a total of 40 units containing 71 items. The items were evenly distributed among the four PISA content subscales: Change & Relationships (23.9%), Space & Shape (23.9%), Quantity (26.8%), and Uncertainty & Data (25.4%). First, ratings were given on the process and content area or syllabus strand that best corresponded to each PISA item (Table 1). Next, the raters considered the expected familiarity of students under the Project Maths curriculum and the old curriculum with the concept, context, and process of each PISA item on a three-point scale of *Not familiar*, *Somewhat familiar*, and *Very familiar*, and gave separate ratings for students working towards taking a Higher, Ordinary, or Foundation Level Junior Certificate Maths exam. After they had undertaken independent ratings, the raters met to discuss items on which there was disagreement, as well as wider issues in the implementation of Project Maths. On the basis of the meeting, ratings for each item were finalised and the coverage of PISA items in the two versions of the curriculum was determined. There was also extended discussion of the performance of students in Ireland on the Space & Shape subscale.

Table 1: Processes, pre-PM content areas, and Project Maths syllabus strands used in the TCRP

Process	Pre-PM Content Area	PM Syllabus Strand
Recall	Sets	Statistics & probability
Implement procedures	Number systems	Geometry & trigonometry
Connect	Applied arithmetic & measure	Number
Reason mathematically	Algebra	Algebra
Solve problems	Statistics	Functions
	Geometry	
	Trigonometry	
	Functions & graphs	

CURRICULUM ANALYSIS RESULTS

Students studying the Project Maths curriculum were rated as being more familiar with the concepts, content, and processes the PISA underlying items at all syllabus levels than students studying the pre-PM curriculum (Table 2). Even on areas where students of the pre-PM curriculum were rated as *Very Familiar* on average, familiarity ratings were higher for the Project Maths curriculum. Higher level Project Maths students are expected to be at least *Somewhat familiar* with every item and *Very familiar* with more than 80% of them; by contrast, students studying the pre-PM curriculum at Higher level were expected to be *Very familiar* with fewer than 55% of items. For Foundation level students, 25.4% of items were judged to be unfamiliar under the Project Maths curriculum compared to more than half (60.6%) under the previous curriculum. For some items, students were expected to be familiar with the process or with the content area in the given context of the PISA item even if not with the details of the item itself.

Almost all of the items were deemed to be covered by both curricula, 91.5% by the pre-PM curriculum and 97.2% by Project Maths. The most common process underlying the PISA items was Implement procedures (36.6%), followed by Connect (26.8%). Just a few items drew on the skills of Recall (7%) or Solving problems (8.5%). More than a quarter of the PISA items were on Statistics and Probability (28.2%) and more than a third were on Number (38%, corresponding to Number systems and Applied arithmetic and measure in the pre-PM content areas). Just 8.5% of items were rated under Geometry & Trigonometry, suggesting that many of the PISA items on the Space & Shape subscale require knowledge of areas beyond Geometry and Trigonometry.

Table 2: Expected student familiarity ratings for 71 PISA items in the areas of concept, context and process, by Junior Cycle syllabus level for the Pre-PM and PM curricula

	Students Studying Pre-PM Curriculum			Students Studying PM Curriculum		
	Not familiar %	Somewhat familiar %	Very familiar %	Not familiar %	Somewhat familiar %	Very familiar %
Concept – Higher	12.7	32.7	54.9	0.0	18.3	81.7
Concept – Ordinary	19.7	46.5	33.8	7.0	25.4	67.6
Concept – Foundation	52.1	36.6	11.3	25.4	32.4	42.2
Context – Higher	18.3	47.9	33.8	0.0	15.5	84.5
Context – Ordinary	36.6	43.7	19.7	2.8	19.7	77.5
Context – Foundation	59.1	28.2	12.7	8.4	25.4	66.2
Process – Higher	7.1	38.0	54.9	0.0	4.2	95.8
Process – Ordinary	22.5	45.1	32.4	1.4	28.2	70.4
Process – Foundation	60.6	23.9	15.5	12.7	16.9	70.4

Several content areas that are not covered by the PISA items reviewed were also identified: equations, functions, sets, both formal and co-ordinate geometry, trigonometry, and property of number. On the other hand, applied arithmetic and measure and statistics were deemed to be over-represented in PISA. Overall, PISA was considered neither to encompass everything in mathematics nor everything in the Irish curriculum. PISA was also described by the expert raters as linear, with little ambiguity and few opportunities for alternative approaches or lateral reasoning.

Only a small number of the PISA items were deemed not to be covered by the Project Maths curriculum at any level, including items concerning 2-D or 3-D rotation of objects and dealing with links between information on a table and information on a map or chart. There were other examples where information in a narrative description could be used to determine the correct formula to apply in answering the question; students in Ireland are likely to be familiar with the use of the formula but not with the narrative description. Project Maths was considered to have minimal coverage of data tables and the skills associated with interpreting tables.

Raters repeatedly pointed to the literacy demands of PISA items, with the implication that a high level of basic literacy is required to successfully attempt the items. The old curriculum was less reliant on written text than Project Maths and only information and data that were directly relevant to answering the question were provided. No information could be shown on a diagram that was not in the written description. On the other hand, Project Maths is more like PISA in its presentation of information.

The extent to which students might be able to apply skills learned in other subjects to PISA was also considered. Items involving maps and charts might be easier for students who had covered similar material in geography, for example, and students of technical graphics are likely to have a major advantage on PISA Shape & Space items. Similarly, subjects like woodwork, metalwork, and construction studies develop skills that are useful in Space & Shape. However, there are other subjects

whose lessons can be applied to PISA items, such as business studies and science and the overlap between mathematics and other subjects was considered bi-directional.

CONCLUSIONS

Overall, the analysis presented here indicates that Project Maths at Junior Cycle level is closer in its conceptualisation to PISA mathematics literacy than the previous curriculum, suggesting that students in IPM schools might be better equipped for the PISA test. Project Maths, then, does show the potential to address some of the long-standing issues in the teaching and learning of mathematics in Ireland, such as teaching by transmission, and moving towards RME.

With respect to the OECD average score and comparison to other countries, concerns had been raised over Ireland's relatively poor performance on Space & Shape, which was significantly below the OECD average in both 2003 and 2012 (Perkins *et al.*, 2013). The same issue was identified across a number of English-speaking countries (OECD, 2013b), and points related to the teaching of geometry and trigonometry were also raised. The curriculum ratings indicate that the Project Maths curriculum may go some way to addressing the historic problem with PISA Space & Shape; the expert raters identified spatial relations and rotational geometry as examples of areas that are likely to improve under Project Maths. However, the complexity of PISA items also means that students are challenged to cross the boundaries between content areas and processes and to think creatively.

The research evidence (Jeffes *et al.*, 2012, 2013; Cosgrove *et al.*, 2012) suggests that teachers have been slow to move to the teaching and assessment style demanded under Project Maths, and this may be due in part to the anxiety caused by the implementation process that is still underway. Professional development workshops were discussed by the three experts in the context of the Shape & Space items but the issues are likely to affect other parts of the curriculum. An emphasis on practical pedagogy was apparent in the workshops with use of manipulables by teachers and of small-group discussion encouraged, for example. However, any of these approaches requires comfort on the part of teachers with using demonstration objects in class and with facilitating group discussion, neither of which can be taken for granted. Changes to how teachers approach mathematics require changes in teachers' and students' expectations of their roles.

For the full report on *Project Maths and PISA* and for further information on PISA 2012, see www.erc.ie/pisa

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