Project Maths and PISA 2012

Performance in Initial Project Maths Schools and in Non-initial Schools on PISA 2012 Mathematics and Problem-solving and on Junior Certificate Mathematics

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Educational Research Centre

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Abbreviations

BRR	Balanced Repeated Replication
CBA	Computer-Based Assessment
CGI	Cognitively-Guided Instruction
CDP	Continuing Professional Development
DEIS	Delivering Equality of opportunity In Schools
DES	Department of Education and Science, 1997 to 2010
	Department of Education and Skills, 2010 to present
ESCS	Economic, Social, and Cultural Status
ICT	Information and Communications Technology
IMTA	Irish Mathematics Teachers Association
IRT	Item Response Theory
JCPS	Junior Certificate Performance Scale
NCCA	National Council for Curriculum and Assessment
NCE-MSTL	National Centre for Excellence in Mathematics and Science Teaching and Learning
NCTE	National Centre for Technology in Education
NFER	National Foundation for Educational Research
OECD	Organisation for Economic Co-operation and Development
OTL	Opportunity To Learn
PGDE	Post-Graduate Diploma in Education
PISA	Programme for International Student Assessment
PMDT	Project Maths Development Team
PS	Problem-Solving
RDO	Regional Development Officer
RME	Realistic Mathematics Education
SES	Socio-Economic Status
SSP	School Support Programme
TCRP	Test-Curriculum Rating Project

Executive Summary

An initiative to introduce a new approach to teaching and learning mathematics in post-primary schools, called Project Maths, began in 2008 with 24 schools involved initially. All of those schools were selected to participate in the OECD's Programme for International Student Assessment (PISA) in 2012, presenting an opportunity to compare the performance of students in *Initial* schools to those in *Non-initial* schools. The purpose of the comparison was to assess the impact, if any, of Project Maths in the context of the information on demographics and attitudes also collected by PISA. When controlling for factors such as school and student socio-economic status, gender, and attitudes towards mathematics, students in Initial schools scored 10 points higher on PISA mathematics than those in Non-initial schools. There was also evidence of stronger performance on PISA Space & Shape, with female students in Initial schools showing most improvement. Attitudes towards mathematics were more negative among students in Initial schools, which could mask some differences in the direct comparisons of Initial and Non-initial schools where the influence of other variables was not controlled. Evidence of the positive impact of Project Maths at school and classrooms levels was also observed. At junior cycle, the curriculum associated with Project Maths was judged to equip students better for tests requiring the real-world application of mathematical reasoning than the previous curriculum.

Introduction and Methodology

Project Maths is the initiative to introduce a new post-primary mathematics curriculum, implemented initially in 24 schools in 2008, extended to all schools in 2010, and with full national implementation to be completed by 2015. The aims of Project Maths at Junior cycle level are: to develop mathematical knowledge, skills, and understanding; to foster a positive attitude to mathematics; to support the development of literacy and numeracy skills; and to develop the skills of dealing with mathematical concepts in context and applications, as well as in solving problems (DES, 2011a). PISA is an OECD study of the achievement of 15-year-olds in mathematics, reading, and science. The PISA 2012 sample in Ireland included students in all of the Initial Project Maths schools as part of the nationally representative sample.

PISA 2012 is conceptualised in this report as an assessment tool to measure the initial impact of Project Maths as an intervention. A decision was made nationally to administer the PISA 2012 assessment in all Initial schools, as results of the mathematics assessment in these schools are of particular national interest. The groups differed significantly in only one respect: there were significantly more girls in Initial schools (55.0%) than in Non-initial schools (48.9%). For this reason, comparisons by gender are reported. In total, 5,016 students sat the print assessment and a total of 2,396 students participated in the computer-based assessment. The majority (60.5%) of selected students were in Third year at the time of testing, almost a quarter (24.3%) were in Transition year, 13.3% were in Fifth year, and 1.9% were in First or Second year. PISA 2012 included paper- and computer-based assessments of mathematics, computer-based assessment of problem-solving, and questionnaires for students and for principals. For this report, student achievement and student attitudes and behaviours were compared for Initial and Non-initial schools. A multi-level model of achievement was also constructed.

Performance on PISA 2012 Mathematics and Problem-solving

Overall performance on the PISA print mathematics scale was estimated for students in Initial and Non-initial schools. The mean score for students in Initial schools is 505.3, slightly higher than those in Non-initial at 501.3 but not to a statistically significant extent. The pattern of non-significantly higher average scores in Initial schools is repeated for the three process subscales, Formulating, Employing, and Interpreting. Likewise, students in Initial schools have slightly but not significantly higher scores on all four content subscales, Change & Relationships, Space & Shape, Quantity, and Uncertainty & Data. While none of the differences is statistically significant, the largest difference is on Space & Shape, and the performance of Initial students (485.8) is not significantly different from the OECD average of 489.4, whereas the mean for Non-initial students (477.4) is significantly below the OECD average.

No significant differences were observed between male students in Initial and Non-initial schools on the overall print mathematics scale or for the Formulating or Employing subscales, though scores for each were higher among students in Initial schools. There was a significant difference on the Interpreting subscale, with male students in Initial schools scoring 528.6 and males in Non-initial schools scoring 514.6; the average score for male students in Ireland on the Interpreting subscale was above the OECD average for males (501.6). While male students in Initial schools had higher mean scores than males in Non-initial schools across each of the content area subscales, none of the differences was statistically significant. Interestingly, the performance of male students in Initial schools on Space & Shape (496.0) is not significantly different from the OECD average for males (497.2), whereas the average score for male students in Non-initial schools on this subscale, 489.7, is significantly below the OECD average for males.

For female students, the pattern of marginally better performance among those in Initial schools for the overall print mathematics scale and for the process and content subscales is evident again. Performance on the Space & Shape content subscale is significantly better for female students in Initial schools (477.4) than their counterparts in Non-initial schools (464.6), and is not significantly different from the OECD average for female students (481.9), whereas the average score for female students in Non-initial schools is significantly below the OECD average.

In the analysis of the performance of students in Initial and Non-initial schools on computer-based mathematics, no significant differences were observed between male students in the two contexts or between female students. Once again, the pattern of marginally higher performance in Initial schools was observed. Comparing problem-solving achievement in Initial and Non-initial schools, there was no significant difference in overall performance and no difference in the performance of male and female students within Initial and Non-initial schools or between them.

Student Attitudes and Engagement

As part of PISA 2012, students answered a detailed questionnaire on their experiences of learning mathematics and of problem-solving, their attitude to school, and their perception of their mathematics teachers. Significant differences between Initial and Non-initial schools were observed on scales of Intrinsic motivation, Mathematics self-concept, Mathematics anxiety, Self-responsibility for failure in mathematics, Mathematics-related behaviours, Mathematics-related intentions, and Mathematics-related subjective norms. Intrinsic motivation and Mathematics self-concept were higher in Non-initial schools, while Mathematic anxiety was higher in Initial schools, especially among female students. Students in Non-initial schools were more likely to attribute failure to others whereas those in Initial schools were more likely to attribute failure to themselves. Mathematics-related behaviours, intentions, and subjective norms were broadly more positive among students in Non-initial schools than those in Initial schools.

School-related Factors

Indices related to school organisation and resources, school climate, school leadership and management, and teacher behaviour and support for students were compared between Initial and Non-initial schools based on questions on the school and student questionnaires administered as part of PISA 2012. With respect to organisation and resources, the data show no difference between Initial and Non-initial schools in the range of Extra-curricular mathematics activities offered at school, or in the Use of assessment information to inform teaching and learning. Initial schools had significantly higher mean scores than Non-initial schools on School responsibility for curriculum and assessment and on Responsibility for resource allocation, while Non-initial schools had a significantly higher mean score on Quality of schools' educational resources. Computer availability was not significantly different across the school types.

None of differences between mean scores on five school climate scales reached statistical significance and all of the correlations between school climate indices and mathematics achievement are statistically significant. In the case of Initial schools, all of the leadership indices have mean scores below the respective OECD averages. Indeed, the mean scores for Initial schools on the indices of School management – instructional leadership and for Promoting school improvement and professional development are particularly low, though these scales were generic and not specific to mathematics. Correlations between scores on the indices and mathematics achievement are all weak to moderate.

Teacher practices showed a significant difference in favour of Initial schools on the index of Teacher behaviour – student orientation, though mean scores for both Initial and Non-initial schools were well below the OECD average on this index, indicating relatively low levels of orientation. Average scores for two other indices, Teacher behaviour – formative assessment, and Teacher behaviour – teacher directed learning, were also below the corresponding OECD average scores, though the differences were smaller than for Teacher behaviour – student orientation.

Principal teachers in Initial schools tended to be more positive about the expected impact of Project Maths. For example, 88% of students in Initial schools had principal teachers who 'agreed' or 'strongly agreed' that Project Maths would improve mathematics standards in schools, compared with 78% in Non-initial schools. Whereas more students in Initial schools had principal teachers who expected an increase in the proportion of students taking the Junior Certificate examination at Higher level, there was no difference between Initial and Non-initial schools in relation to the Leaving Certificate. Marginally more students attending Initial schools (64%) than Non-initial schools (62%) had principals who believed that students are more engaged since the introduction of Project Maths.

Teaching and Learning in Project Maths

Two questionnaires, one for mathematics teachers, and one for mathematics school co-ordinators, were administered at national level to obtain a reliable, representative and up-to-date profile of mathematics teaching and learning in Irish post-primary schools, and to obtain quantitative and qualitative information on the views of a nationally-representative sample of teachers on the implementation of Project Maths that could be compared across teachers in Initial and Non-initial schools. Three-fifths of surveyed teachers had completed a primary degree that incorporated mathematics up to final year in either three- or four-year programmes, a proportion which was almost identical across Initial and Non-initial schools. Only three percent of teachers overall had completed a primary degree that did not include mathematics as a subject.

There were some significant differences between teachers in Initial and Non-initial schools in the average number of CPD hours undertaken during the three years preceding the survey. Teachers in the Initial schools spent slightly more time than teachers in Non-initial schools attending formal CPD on Project Maths (21.9 vs. 20.1 hours), formal CPD courses designed to address a gap in qualifications (2.9 vs. 1.4 hours) and self-directed CPD (18.2 vs. 14.1 hours). There are substantial differences between the usage of ICT by teachers in Initial schools and Non-initial schools (Figure 6.3): 49.5% of teachers in Initial schools were high users of ICT, compared with 28.9% of teachers in Non-initial schools. Teachers in Initial schools were more likely to report using each form of ICT at least once a week.

Teachers were asked to indicate, overall, whether or not they agreed that Project Maths was having a positive impact on students' learning of mathematics. Close to half of teachers (47.5%) indicated that they did not know if Project Maths was having a positive impact. This indicates, not unexpectedly, that 2012 may have been too early in the implementation of Project Maths for some teachers to have an informed opinion. Teachers were provided with space in the questionnaire to make written comments about their experiences of and views on Project Maths. A large majority of comments (87%) were negative in tone, and the percentages of negative comments were similar in Initial and Non-initial schools. A further 8% were mixed in tone, and just 5% were positive. However, it is possible that teachers may have thought it more important to record reservations than to re-assert positive opinions, which other parts of the questionnaire gave them opportunities to express.

Curriculum Analysis

In a Test-Curriculum Rating Project (TCRP), three independent experts in second-level mathematics education undertook ratings of PISA 2012 items on expected levels of student familiarity with the concept, context, and process of each item. Students studying the Project Maths curriculum at each syllabus level were rated as being more familiar with the concepts, context, and processes underlying PISA items than students studying the pre-2010 curriculum. Given the relatively poorer performance of students in Ireland on the Space & Shape subscale, both in 2003 and 2012 (Perkins et al., 2013), Space & Shape items were a focus of additional attention in the TCRP. Consistent with the overall pattern of familiarity ratings, students studying Project Maths are expected to be more familiar with the Space & Shape items than those studying the previous curriculum.

Raters repeatedly pointed to the literacy demands of PISA items, with the implication that a high level of basic literacy is required to successfully complete PISA mathematics items. Overall, PISA was considered neither to encompass everything in mathematics nor everything in the Irish curriculum. PISA mathematics was also described by the expert raters as linear, with little ambiguity and few opportunities for alternative approaches or lateral reasoning.

Modelling Achievement on PISA 2012 Mathematics and Junior Certificate Mathematics

Two multi-level hierarchical linear regression models were constructed, for print mathematics and for Junior Certificate results. The models attempt to predict a student's score when controlling for a range of school- and student-level demographic and attitudinal variables, including Project Maths status. Project Maths status is a significant predictor of mathematics performance. According to the model, attending an Initial school is associated with a 10-point advantage on print mathematics over students in Non-initial schools when the influence of all the other variables is controlled for. Overall, the model explains 34.1% of the total variance in performance, 81.9% of the between-school variance and 22.8% of the within-school variance. Project Maths status is a small but significant predictor of Junior Certificate mathematics performance, accounting for one-third of a grade difference in scores. The only difference from the PISA model is that mathematics anxiety is not a predictor of Junior Certificate scores.

Conclusions

Overall, students in Initial schools had slightly higher scores on the PISA 2012 print mathematics scale and subscales; significant differences in favour of students in Initial schools were observed on the Interpreting process for males and on the Space & Shape subscale for females. Attitudes and behaviours were generally more negative among students in Initial schools, though the relationship between attitudes and performance is a complex one whereby anxiety had a significant negative association with PISA mathematics, but no significant association in the model of Junior Certificate mathematics.

Implementation of Project Maths placed additional pressures and demands on students and on teachers, evident in some of negative attitudes observed in the current study. For example, there were high levels of reported anxiety among girls in Initial schools, and it remains to be seen whether these attitudes can be attributed to the transition itself or are down to issues in the teaching, learning, and assessment of Project Maths. The transition period was characterised by increased scrutiny that may have contributed to anxiety among teachers and parents, which in turn could have contributed to higher levels of anxiety among students. The same attitudes may not persist following full implementation.

Given Ireland's history of relatively weak performance on PISA Space & Shape, it was the focus of particular attention in this report. There was a significant advantage for female students in Initial schools, bringing them in line with the OECD average, with the effect that the mean score for all students in Initial schools was not significantly different from the OECD average. Continuing to improve performance on Space & Shape in PISA could require changes in the primary mathematics curriculum, such as inclusion of more transformational geometry topics and higher order geometric thinking, and more practical work in geometry and measure. The theoretical emphasis in the Project Maths Geometry and trigonometry strand may also need to be examined in terms of its impact on students' spatial reasoning and visualisation.

Concerns were repeatedly raised in the present study about the literacy demands of Project Maths, with teachers in Initial schools particularly conscious of the challenge. In order to achieve the aim of situating questions in a real-world context, it is necessary to include a narrative description of the context. A relatively high level of verbal literacy appears to be necessary to successfully complete real-life mathematics items. For students with limited literacy skills, the additional information could act as a barrier to understanding rather than a facilitator. To address this and provide a stronger sense of balance, some context-free, abstract items could be used in teaching alongside some with narrative, while teacher modelling of mathematical language, and student engagement in group work and in explaining their mathematical reasoning are also highly relevant.

1. Introduction and Context

Project Maths is the initiative to introduce a new post-primary mathematics curriculum, implemented initially in 24 schools in 2008, extended to all schools in 2010, and 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 sample in Ireland included students in all of the Initial Project Maths schools as part of the nationally representative sample. PISA 2012 presented an opportunity to compare the achievement of students in *Initial* schools to those in *Non-initial* schools. This chapter gives a brief description of the background to Project Maths and an overview of PISA 2012. A brief review of literature on Project Maths and on curriculum reform more generally is also presented as well as a brief description of some of the public discourse surrounding Project Maths. The final section outlines the structure of the rest of the report.

1.1 The Pre-history of Project Maths

The version of the Junior Certificate mathematics curriculum that preceded Project Maths was introduced in 2000 (Department of Education and Science [DES], 2000) and the Leaving Certificate curriculum was previously revised in 1992 (see National Council for Curriculum and Assessment [NCCA], 2005). By 2005, there was already discussion on the need to reform mathematics curricula (Conway & Sloane, 2006). One element contributing to this was the results of PISA 2003 (Cosgrove, Shiel, Sofroniou, Zastrutzki, & Shortt, 2005), which saw Ireland achieve an overall mean score that was not significantly different from the OECD average, an overall ranking of 17th among 29 OECD countries, and a mean score that was well below the OECD average on Space & Shape. Another related to the Leaving Certificate Mathematics Examination, which, in 2005, included a low proportion of students taking the Higher level paper, a sizeable proportion of students at Ordinary level achieving a Grade E or lower, and a substantial gender difference in favour of females (Conway & Sloane, 2006; NCCA, 2005). Some of the concerns arose in the context of establishing policies aimed at developing a knowledge-based economy, which might be undermined by poor achievement in mathematics leading to lower capacity for certain third-level courses (NCCA, 2005). A number of initiatives sought to identify the issues and possible solutions. Conway and Sloane (2006) reported for the NCCA on international trends in post-primary mathematics education. The NCCA itself published the results of its consultation with interest groups in mathematics education in 2006.

Shortly after the introduction of the 2000 curriculum, Smyth and Hannon (2002) examined trends in students' selection of examination levels and their performance at Junior Certificate and Leaving Certificate. Significantly more male than female students studied mathematics at Higher level in the Junior Certificate, and there were related differences in school sector and gender. A major factor in selection and performance was the availability of instruction at Higher level: Some schools, for example, did not have the resources to stream a small, separate Higher level class, with the results that some students had no option but to take the Ordinary level paper. There was also a connection between the examination level taken by students at Junior Certificate and Leaving Certificate, with students more likely to move down rather than up a level, rendering the selection of examination level at Junior Certificate all the more important.

Conway and Sloane (2006) outlined five challenges facing proposed reforms in mathematics education: defining a vision, changing examinations and assessment practices, addressing the tension between excellence and equity, teacher education and continuing professional development, and scaling any change from pilot to national implementation. The first step towards defining a vision was the consultation undertaken by the NCCA (2006). It invited contributions from students and parents, teachers and principals, employers, and third-level mathematics lecturers. Both Conway and Sloane (2006) and NCCA (2006) referred to the examination and assessment practices being narrow in their style and content and being predictable. These issues were a major focus of attention in the reform process.

Conway and Sloane's (2006) report reviewed five initiatives in mathematics education: Mathematics in Context (MiC), a programme using RME-inspired (Realistic Mathematics Education) curriculum materials; 'Coaching' as a model for Continuing Professional Development in mathematics education (West and Staub, 2004); ICT (Information and Communication Technology) and mathematics education; Cognitively Guided Instruction (CGI); and the IEA First Teacher Education Study: The education of mathematics teachers (Schwille & Tatto, 2004 cited in Conway & Sloane, 2006; lead countries: USA and Australia). Most of the research reviewed was at the level of classroom intervention rather than curricular change and the evaluation methods reflected the scale of the intervention. CGI, for example, is based on research in cognitive science and developmental psychology and emphasises active participation in lessons building on what students already know and how they think. The intervention, which involved a one-month summer training course for teachers, was associated with better student performance on measures of recall and problem-solving. Compared to a control group in which attention to students' answers received greater emphasis, teachers who had completed the training course paid more attention to the processes students used to solve problems. Research in the area has continued to produce similar results. In an intervention using student-focused teacher practices, achievement scores and attitudes were improved and the negative impact of socio-economic status (SES) was reduced (Boaler, 2006). Another intervention based on motivation theory was observed to support student self-regulation in mathematics classes, which in turn has been associated with higher PISA achievement scores (Perels, Dignath, & Schmitz, 2009). Overall, there is evidence that various forms of intervention can have an impact at the classroom level in small studies where teachers received extensive training and support. Evaluations of system-level interventions are fewer.

Realistic Mathematics Education (RME) is a constructivist stance that values learning mathematics through problem-solving and modelling in relevant and interesting contexts (NCCA, 2005). RME is central to the framework for PISA (OECD, 2013a; Shiel, Perkins, Close, & Oldham, 2007) and its influence on the reform of the primary school curriculum (DES, 1999) can be seen in references to "real-life situations" (p. 4) and "real-life examples" (p. 8). The recent history of mathematics education in Ireland, however, has been strongly influenced by the modern mathematics revolution in the 1960s which emphasised abstraction, rigorous logical argument, and precise use of terminology (Conway & Sloane, 2005). In practice, pedagogy was observed to rely on memorising and routine performance, with exposition by the teacher using the textbook followed by individual repetition by students, rather than on logic, creativity or relational understanding (NCCA, 2005). Lyons, Lynch, Close, Sheerin, and Boland (2003) identified teacher practices in 10 case studies involving demonstration by the teacher before practice by the students, with the vast majority of interaction (96%) initiated by the teacher. The culture of teaching and learning in Ireland might not fit well with the exploratory, open-ended style of the constructivist approach.

The NCCA's (2006) consultation identified cultural attitudes towards teaching and learning as an important part of reform of the curriculum. The other main concerns had to do with the emphasis on procedural skills rather than understanding, poor application in real-world contexts, low uptake of Higher level mathematics and low grades at Ordinary level, and gender differences in both uptake and achievement. Addressing any of these was deemed to require changes in the attitudes of teachers, students, and parents. Practical changes such as increased use of problem-solving and of ICT and the inclusion of continuous assessment likewise could only take place if there were changes in the philosophy and attitudes of teachers, according to the respondents. The main contributors to the consultation were teachers themselves, which suggests that there was an appetite for change at least among some teachers, as well as a considerable need for Continuing Professional Development (CPD). The extent of teachers' content knowledge of mathematics was also identified as an issue, with no formal provision for CPD in that area at the time (NCCA, 2005).

1.2 Implementation of Curriculum Change

Curriculum implementation has to do with what happens in practice, rather than what the curriculum intends. Implementation is a process that involves teachers learning to do something new, and changing their beliefs and behaviours (Fullan, 1992). Elsewhere, Fullan (1998) describes the processes of "unlearning" and "relearning" (p. 218). Like any change, implementation of a new curriculum involves "loss, anxiety, and struggle" (Marris, 1975 cited in Fullan 2001). Indeed, according to Fullan (1992), implementation cannot happen without teachers and teacher development, while successful implementation depends on leadership, resources, and teachers' ownership of the new curriculum. For teachers, change occurs in the materials they use, their pedagogy, and their beliefs.

Fullan (2001) sets out three phases in the process educational change: Initiation, Implementation, and Continuation. Applying this framework to Project Maths, the Initiation phase covers the period of development up to the beginning of the pilot, marking the start of the Implementation. At present, Project Maths is somewhere between Implementation and Continuation as the national implementation is almost complete and the Project Maths curriculum is the only mathematics curriculum. Central to sustaining change, Fullan (2001) argues, is infrastructure but he further specifies that "reculturing" and not just "restructuring" is required. Fullan also warns of "implementation dip" (p. 25), that is, a decrease in performance immediately after change, followed by recovery and then improvement.

The indicative timescale provided by Fullan (2001) is 3 to 5 years for moderate change and 5 to 10 years for large-scale reform. In a previous iteration of the model, Fullan (1998) wrote about a fourth phase: Outcomes; it is reasonable to suggest that Project Maths has yet to reach the Outcomes phase. As for the measurement of the impact of curriculum change, Fullan's work is more concerned with the degree of implementation in classrooms, whether low, medium, or high, than with the impact on students' achievement. The other ingredient in sustaining change is ownership by teachers, which involves clarity, skill, and commitment (Fullan, 1998, 2001).

It is worth briefly describing the context in which the Project Maths initiative took place with respect to pedagogy and teacher practices. Lyons et al. (2003) present a detailed analysis of teachers' practices in 10 case studies. They observed that mathematics was taught as an abstract, fixed body of knowledge, comprising discrete elements that had to be demonstrated rather than explained. Lessons were characterised by emphasis on examination technique, clear identification of 'hard' and 'easy' questions, and finding the 'right' answer rather than solving the problem (Lyons et al., 2003). Even reserving judgement on whether this is the optimal approach to teaching mathematics, it is clearly different from the approach outlined in the Project Maths curricula. In this context, the magnitude of change in teachers' beliefs and pedagogy required to implement Project Maths as intended is large.

Continuing Professional Development support for mathematics teachers in Initial schools consisted of summer courses, school visits from a Regional Development Officer (RDO), 10 workshops that focused on changing classroom practice and evening courses on mathematics content delivered by the Project Maths Development Team (PMDT) through the network of Education Centres, and courses on ICT from the National Centre for Technology in Education (NCTE). Teachers in Initial schools were supported by the RDOs through meetings, seminars, and online resources (Lynch, Kelly, & Linney, 2014). Each RDO was responsible for three or four schools with school visits arranged as required by the teachers (R. Linney, personal communication, 10th June 2014). A new Professional Diploma in Mathematics for Teaching, which is aimed at 'out-of-field' teachers of mathematics was initiated in 2012 at the National Centre for Excellence in Mathematics and Science Teaching and Learning (NCE-MSTL) based in the University of Limerick with 390 places available each year on a regional basis in collaboration with other agencies.

The Project Maths curriculum has five inter-connected strands: Statistics and probability, Geometry and trigonometry, Number, Algebra, and Functions (NCCA, 2011). The Syllabus Strands match the content areas in earlier curricula quite closely with Sets and Number from the pre-2010 curriculum being combined. Similarly, Geometry and Trigonometry are combined, while the content of Applied arithmetic and measure is distributed among a number of the Project Maths strands (Table 1.1). The aims and objectives of Project Maths are similar in spirit to those of the 1992 Leaving Certificate and the 2000 Junior Certificate. The alignment of the aims and objectives and of the syllabus strands in both the primary curriculum and Project Maths is intended to emphasise the continuity of the curricula. The NCCA (nda) has also published bridging documents that track the continuity of syllabus strands from Primary to Post-Primary, and a Common Introductory Course (ndb) for First year mathematics, before students opt for Higher, Ordinary, or Foundation level. The aims of Project Maths at Junior cycle level are: to develop mathematical knowledge, skills, and understanding; to foster a positive attitude to mathematics; to support the development of literacy and numeracy

Table 1.1
Pre-2010 Mathematics Content Areas and Project Maths Syllabus Strands

Pre-2010 Content Area	Project Maths Syllabus Strand
Sets Number	3 Number
Applied arithmetic and measure	-
Algebra	4 Algebra
Statistics	1 Statistics and probability
Geometry Trigonometry	2 Geometry and trigonometry
Functions	5 Functions

skills; and to develop the skills of dealing with mathematical concepts in context and applications, as well as in solving problems (DES, 2011a).

September 2008 saw the introduction of Strand 1, Statistics and probability, and Strand 2, Geometry and trigonometry, for First year and Fifth year students in Initial schools, so their examinations in Junior Certificate 2011 and Leaving Certificate 2010 included some questions from the Project Maths curriculum. In September 2009, Strand 3, Number, and Strand 4, Algebra, were introduced, and questions on these content areas were added to the Junior Certificate examinations in 2012 and Leaving Certificate in 2011 for students in Initial schools. Strand 5, Functions, was introduced in September 2010 for examination at Junior Certificate 2013 and Leaving Certificate 2012. Non-initial schools followed each of these steps two years later so the Junior Certificate in 2015 will include the entire Project Maths curriculum for all students.

1.3 Research on Project Maths

As part of the implementation of Project Maths, the NCCA commissioned the National Foundation for Educational Research (NFER) to conduct 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 eight Initial and eight Non-initial schools. Students in Third year of the Junior cycle and Sixth year of the senior cycle took part. Jeffes et al. (2013) provided limited details on the achievement scales used, which were comprised of released items from TIMSS and sample items from PISA. Comparisons to international results are made but, on the authors' admission, not to a high level of precision. Jeffes et al. also had to account for age- and grade-range differences when adapting for Leaving Certificate students items drawn from Trends in International Mathematics and Science (TIMSS) for Grade 8 and PISA for 15-year-olds. Overall, few differences were observed between the performance of students in Initial and Non-initial schools or between their teachers' approaches, at least as indicated by students' written work. In the survey of students, those in Initial schools did report frequently using certain of the new processes and activities of Project Maths: using real-life situations, making links between mathematics 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). There is some discrepancy too between what students and teachers report to be doing in class and the samples of written work analysed. Where the surveys strongly indicate the use of collaboration and of ICT in Initial schools, the written work had little evidence of these practices and mainly showed the use of mathematical procedures, rather than reasoning, communication, and connections to other topics. Other aspects of the implementation of Project Maths were less successful and, for example, Jeffes et al. (2013) reported an over-reliance on textbooks.

Turning to the achievement scores based on items taken from earlier international studies of mathematics achievement, tests were taken at two time points, allowing limited longitudinal comparison. For Leaving Certificate students, there was no difference between Initial and Non-initial schools on test items based on Strand 1 content (Statistics and probability) or on Strand 2 (Geometry and trigonometry). Also among Leaving Certificate students, there were no significant differences in the levels of confidence of Initial and Non-initial students on four of the strands but Initial students were significantly more confident about Strand 5 (Functions). There was no significant link, however, between confidence and achievement.

With regard to aspirations and intentions, more students in Initial schools intended to take the Higher level Junior Certificate examination (81%) than students in Non-initial schools (66%) and Higher level students in Initial schools were also more ambitious for the future than those in Non-initial schools. Overall, the majority of students recognised the importance of mathematics for daily life, for studying other subjects, and for their prospects for further study and employment (Jeffes et al., 2013). Students in all schools had high levels of awareness of the importance of mathematics for careers such as engineering, information technology, and science but lower levels of awareness for medical professions (Jeffes et al., 2013).

As part of PISA 2012, Cosgrove, Perkins, Shiel, Fish, and McGuinness (2012) surveyed teachers in Initial and Non-initial schools. They noted some important differences, such as more frequent use of ICT in Initial schools and more positive changes in learning and assessment among teachers in such schools since the implementation of Project Maths, though teachers in Initial schools were also less confident in their teaching. This can be attributed to some extent to the phased implementation of Project Maths over a short timeframe and the time required for teachers to become familiar and comfortable with the new curriculum, two of the main challenges listed by Cosgrove et al. (2012). The third challenge was the literacy demands of Project Maths in that the problems presented to students in both classroom and examination contexts contained more text and greater linguistic complexity than was the case prior to Project Maths.

It should be noted that the research studies implemented by the NFER and the ERC, as well as the current report, document the early stages of the implementation of Project Maths. Project Maths can be considered a large-scale reform, in which case the timescale for its full impact is five to ten years, according to Fullan (2001). The first cohort who will have studied Project Maths from First to Sixth year in all schools will be the Leaving Certificate class of 2018. In the period of initial implementation, a range of views were expressed and debates initiated, all of which are important elements of the context for these studies.

1.4 Project Maths Discourse

The introduction of Project Maths has not been achieved without some controversy. Several stakeholders have published their positions on the new curriculum and on its implementation. A central point of discussion has been what Conway and Sloane (2006) termed the excellence-equity tension and whether the aims and objectives of Project Maths make it more accessible to students at the expense of preparing them well for careers in mathematics. On the other hand, the less abstract approach may demand greater literacy skills, making mathematics harder still for some students.

The Irish Mathematics Teachers Association (IMTA; 2012) made detailed comments on aspects of Project Maths ranging from syllabus content to teaching methodology to assessment. Some of their concerns were about details of the syllabus, for example, whether certain strands are too long or certain topics over- or under-represented. There were also more fundamental points relating to the pedagogical direction of Project Maths: It was seen as moving from a deductive paradigm to an inductive one, dissipating the “perception of mathematics as an abstract subject” (p. 5). A disadvantage of peer-led learning was also identified in that the pace could be set by the least able student, in which case more able students may not be well served (IMTA, 2012). A final major concern for the IMTA was over the literacy demands of Project Maths, with unnecessarily difficult or elaborate language used in curriculum materials and exams.

An independent analysis of Project Maths (Lubienski, 2011) makes several points similar to those of the IMTA about the practical matters of text books and examination papers, as well as several additional substantive points. Firstly, Lubienski notes the tension between an explicit emphasis on problem-solving in Project Maths, which her respondents linked to Realistic Mathematics Education, and teacher practice which favours demonstration. Secondly, Lubienski points to external pressure to implement Project Maths reforms faster than might have been preferred and simultaneously at First and Fifth year. It should also be noted that Lubienski (2011) was very positive about the successful implementation in the Initial schools, praising in particular the professionalism of teachers and schools.

The perspective of third-level teachers was put forward by Grannell, Barry, Cronin, Holland, and Hurley (2011). They expressed concern about whether students who would study mathematics at third level were prepared by Project Maths for the depth and breadth of third-level mathematics courses. Some of their concerns, such as the availability of textbooks and preparation of teachers, can be seen as consequences of implementation. More serious is the criticism of the assumption by Project Maths that better understanding is associated with the reform approach, including Realistic Mathematics Education. Grannell et al. (2011) propose that improvements in teacher training could yield similar benefits without lowering the standard of material in the curriculum, which they suggest Project Maths does. Their detailed strand-by-strand critique is moot since the national implementation of Project Maths is now almost complete but it demonstrates the real concern they had about the impact of Project Maths on their work as mathematical science teachers at third level, including the absence of some key topics at Leaving Certificate level.

The NCCA itself entered the debate in 2012 with a response to certain points of criticism. The NCCA describes Project Maths as an important attempt to address the culture and history of mathematics education in Ireland. The response is critical of the high-stakes examinations which dominate teacher and student behaviour, resulting in teaching by transmission, with limited use of formative assessment. The vision for teaching underlying Project Maths is a “non-linear dialogue in which meanings and connections are explored, misunderstandings are recognised, made explicit and students learn from them” (NCCA, 2012, p. 10), and this places the onus for the success of Project Maths on teachers’ ability to adapt to the new curriculum. To this end, the NCCA cites the range of opportunities for professional development made available to teachers by the DES.

1.5 Report Outline

Chapter 2 details the methodology of the present study, with descriptions of the PISA frameworks for mathematics and problem-solving, details of the sampling approach, a comparison of the demographic and school characteristics of the Initial and Non-initial schools, and an outline of how the results were analysed. Chapter 3 compares the performance of students in Initial and Non-initial schools on the PISA scales of mathematics and problem-solving, including comparisons by student gender and Chapter 4 presents the same analysis for a range of variables on students’ attitudes towards mathematics. Chapter 5 covers the comparison between schools on factors such as resources and policies as well as PISA indices of school climate. Chapter 6 focuses on the experience of teachers in Initial and Non-initial schools with respect to the implementation of Project Maths.

The alignment of the pre-2010 content areas and the Project Maths syllabus strands in Table 1.1 is an approximation based on the initial conceptualisation. Chapter 7 extends this with a curriculum analysis in which PISA items are examined and their coverage by the two versions of the mathematics curriculum rated. The main purpose of the analysis of Chapter 7 is the rating of students' expected familiarity with PISA items based on the pre-2010 and Project Maths curricula. Drawing on the analyses comparing Initial and Non-initial schools, Chapter 8 presents a model of mathematics achievement which focuses on the impact of Project Maths and factors associated with this. Separate models are presented for PISA mathematics and for Junior Certificate mathematics results. Finally, Chapter 9 sets out the conclusions of the present study and recommendations for the future implementation of Project Maths.

1.5 Conclusion

It is possible to identify three major issues that shaped the development of Project Maths. Firstly, a culture of mathematics teaching, learning, and examination that has neither engaged students sufficiently nor adequately developed their mathematical knowledge and skills was identified. Secondly, a philosophical shift to constructivist and problem-solving approaches was informed by international experience and by criticisms of the pre-2010 curricula. Thirdly, evidence from other countries' experience of PISA and other examples of interventions in mathematics teaching and learning presented options for the new curriculum.

The research evidence to date suggests that teachers have been slow to move to the teaching and assessment style demanded under the Project Maths initiative, and this may be due in part to the anxiety caused by the implementation process. It is interesting to note the apparent connection between student confidence and performance reported by Jeffes et al. (2013), and also in evidence in PISA, where students in Ireland had significantly higher levels of mathematics-related anxiety than on average across OECD countries as well as lower mathematical self-concept, while achieving a level of performance just above the OECD average.

At a practical level, there has been some understandable resistance from teachers for whom difficulties have been created by the speed of implementation of Project Maths at both junior and senior cycles, despite efforts to consult them on the process and to provide additional CPD. Many of the issues raised can be considered transitional and, once implementation is complete, should no longer cause the same level of concern or anxiety. The philosophical questions and criticisms of Project Maths are more profound, even if the argument is reduced to whether or not the Project Maths initiative has 'dumbed-down' mathematics or is less-challenging than earlier syllabi.

2. Methodology

PISA 2012 is conceptualised in this report as an assessment tool to measure the initial impact of Project Maths as an intervention. As indicated in Chapter 1, the focus is on comparisons of students in Initial and Non-initial schools in terms of their achievement in mathematics and problem-solving, their attitudes towards education and towards mathematics in particular, and their educational environment as described by their principals. Achievement in problem-solving is compared on the basis of its explicit inclusion among the aims of Project Maths (DES, 2011a). This chapter describes the PISA 2012 frameworks for mathematics and problem-solving, giving details of the scales and subscales and of the composition of the tests, as well as the sampling process for PISA 2012 in Ireland. Essential to the comparison of students in Initial and Non-initial schools is to determine whether the two groups of schools differ systematically with respect to student demographics or school characteristics; as detailed below, the schools were observed to be similar enough to make valid comparisons in the rest of the report.

2.1 The PISA 2012 Mathematics Framework

In PISA 2012, mathematical literacy is defined 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).

This definition emphasises the view of students as active problem-solvers and explicitly states the mathematical processes (formulating, employing, and interpreting) in which students engage as active problem-solvers. Central to the PISA definition of mathematical literacy is the notion of mathematical modelling, referred to as mathematising in earlier PISA frameworks (Figure 2.1). Mathematical modelling refers to the stages that individuals progress through as they use mathematics and mathematical tools to solve problems set in real-life contexts.

Figure 2.1 illustrates the model of PISA mathematical literacy in practice. Mathematical literacy starts with a problem situated in real-life context, characterised in the framework in terms of the mathematical content that underlies the challenge and the real-world context in which it arises. In order for the problem to be solved, mathematical thought and action must be applied to the challenge. This is operationalised in three ways in the framework: by drawing upon a variety of mathematical *concepts, knowledge, and skills*; by making use of fundamental mathematical *capabilities*; and by engaging in different mathematical *processes*. The mathematical modelling process is illustrated in the inner-most box of Figure 2.1. The cycle starts with a problem situated in a meaningful context. The problem-solver identifies the relevant mathematics in the problem situation and then *formulates* the situation mathematically according to mathematical concepts and relationships identified, thus transforming the problem so that it is amenable to mathematical treatment. The problem-solver then employs mathematical capabilities and processes to obtain mathematical results. The mathematical results must then be interpreted and evaluated in terms of

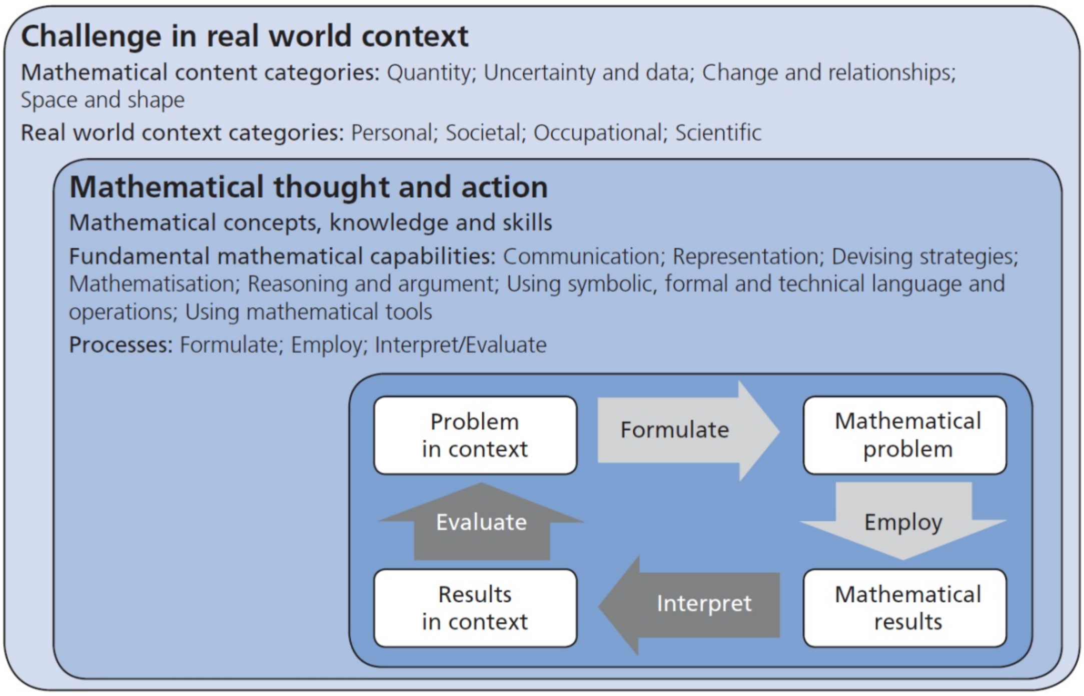


Figure 2.1
A Model of PISA Mathematical Literacy in Practice (OECD, 2013a).

the original contextual problem. Depending on the nature of the mathematical problem to be solved, it may not be necessary to engage in all stages of the modelling cycle, and many PISA items involve only parts of the cycle.

For the purposes of assessment, the PISA 2012 definition of mathematical literacy is conceptualised in terms of three interrelated aspects which work together to ensure broad coverage of the domain:

- The mathematical *content* assessed;
- The mathematical *processes* that describe what students do to connect the context of the problem with mathematics in solving the problem, and the capabilities that underlie those processes; and
- The *contexts* in which mathematical problems are located.

2.1.1 Mathematical Content Knowledge

The PISA framework specifies four content categories, which exemplify the range of mathematical content that is central to the discipline:

- Change & Relationships;
- Space & Shape;
- Quantity; and
- Uncertainty & Data.

It is argued that these categories "meet the requirements of historical development, coverage of the domain of mathematics and the underlying phenomena which motivate its development, and reflection of the major strands of school curricula" (OECD, 2013a, p. 33). The four content areas are not intended to be mutually exclusive.

Change & Relationships

Mathematical literacy in the Change & Relationships subdomain involves understanding types of change and recognising when they occur in order to use suitable mathematical models to describe and predict change. In mathematical terms, this means modelling the change and relationships with appropriate functions and equations, as well as creating, interpreting, and translating among symbolic and graphical representations of relationships. Tasks in this content area also require an understanding of aspects of functions and algebra (such as algebraic expressions, equations and inequalities, tables, and graphical representations), statistical representations of data, and descriptions of relationships, geometric phenomena (e.g. the relationships among lengths of the sides of triangles), and the basics of number.

Space & Shape

Space & Shape covers a wide range of phenomena, including patterns, properties of objects, positions and orientations, representations of objects, decoding and encoding of visual information, navigation, and dynamic interaction with real shapes as well as with representations. Mathematical literacy in this subdomain involves understanding a set of core concepts and skills, for example understanding perspective, creating and reading maps, transforming shapes with and without technology, interpreting views of three-dimensional scenes from various perspectives, and constructing representations of shapes (OECD, 2013a). While geometry is central to Space & Shape, this subdomain also draws on aspects of other content areas such as spatial visualisation, measurement, number and algebra.

Quantity

The PISA framework suggests that Quantity “may be the most pervasive and essential mathematical aspect of engaging with, and functioning in, our world” (OECD, 2013a, p. 34). It incorporates quantification of the world (e.g. understanding measurements, counts, indicators, relative size, and numerical trends and patterns) and quantitative reasoning (e.g. number sense, multiple representations of numbers, elegance in computation, mental calculation, estimation, and assessment of reasonableness of results). Literacy in this subdomain entails the application of knowledge of number and number operations in a wide variety of settings, and is a prerequisite for engagement with the other content areas. This content area lends itself strongly to the application of tools such as calculators and spreadsheets.

Uncertainty & Data

Literacy in the Uncertainty & Data content area includes knowledge of variation in processes, uncertainty and error in measurement, and chance. It also includes forming, interpreting, and evaluating conclusions drawn in circumstances where there is uncertainty. Key concepts in this category are presentation and interpretation of data. An understanding of probability and statistics provides a means for describing, modelling, and interpreting phenomena involving uncertainty, and for making inferences. Literacy in this area also requires knowledge of number and of aspects of algebra, such as graphs and symbolic representation.

The PISA mathematics assessment aims to be reflective of the mathematics that 15-year-old students are likely to have had the opportunity to learn and therefore includes a range of content topics, including: functions; algebraic expressions; equations and inequalities; co-ordinate systems;

relationships within and among geometrical objects in two and three dimensions; measurement; numbers and units; arithmetic operations; percentages, ratios and proportions; counting principles; estimation; data collection; data variability and its description; samples and sampling; and chance and probability. The four content categories outlined in PISA serve as the foundation for identifying this range of content; however, there is no one-to-one mapping of content topics to these categories (OECD, 2013a).

2.1.2 Mathematical Processes and the Underlying Mathematical Capabilities

The PISA 2012 definition of mathematical literacy refers to three processes that correspond to the different stages of the mathematical modelling cycle. These are:

- *Formulating* situations mathematically;
- *Employing* mathematical concepts, facts, procedures, and reasoning; and
- *Interpreting*, applying, and evaluating mathematical outcomes.

Seven fundamental mathematical abilities are identified as underpinning these processes: communication; mathematising; representation; reasoning and argument; devising strategies for solving problems; using symbolic, formal and technical language and operations; and using mathematical tools (OECD, 2013a).

Formulating Situations Mathematically

This process involves recognising and identifying opportunities to use mathematics in real-world contexts, and translating the problem into formal mathematical language.

Employing Mathematical Concepts, Facts, Procedures, and Reasoning

This process refers to performing the mathematical procedures that are required to find a mathematical solution to the problem, such as performing arithmetic computations, solving equations, making logical deductions from mathematical assumptions, performing symbolic manipulations, extracting mathematical information from tables and graphs, representing and manipulating shapes in space, and analysing data.

Interpreting, Applying, and Evaluating Mathematical Outcomes

This mathematical process includes both the ‘interpret’ and ‘evaluate’ arrows displayed in the innermost box of Figure 2.1. Interpreting, applying and evaluating mathematical outcomes refers to a student’s ability to reflect on mathematical solutions, results, or conclusions and interpret them in the context of real-life problems. This process involves translating mathematical solutions back in to the original problem context and evaluating whether the solution makes sense.

2.1.3 Mathematical Contexts

The manner in which mathematical thinking is applied to a problem often depends on the setting in which it is encountered and therefore the ability to engage with mathematical problems in a variety of contexts is central to how PISA defines mathematical literacy. Four context categories are outlined in the PISA framework: personal, occupational, societal, and scientific. The major purpose of the context categories is to ensure that the selection of assessment items reflects a broad range of settings.

2.1.4 Format

PISA 2012 items use one of four question formats. Simple multiple-choice items are where there is one correct response to be selected from a number of alternatives, while complex multiple-choice items require students to choose between a number of possible responses to a series of statements. Open constructed-response items require a somewhat extended written response from a student. Finally, closed constructed-response items allow for a more structured response that can be easily judged to be either correct or incorrect; in mathematics the closed constructed-response is often a number.

2.1.5 Computer-based Assessment of Mathematics

There is an increasing interdependency between mathematical literacy and the use of computer technology in the workplace (OECD, 2014a). An optional computer-based assessment of mathematics in which Ireland participated was included for the first time in PISA 2012 to explore this relationship. The computer-based assessment of mathematics is underpinned by the same framework as the print mathematics assessment.

The computer-based assessment of mathematics aims to ensure that the demands that relate to the test environment, such as ICT skills and item format, are significantly lower than the demands associated with the mathematics. In order to ensure this, three aspects of each item are described:

1. The mathematical competencies being tested, i.e. the aspects of mathematical literacy that are present in all environments, not just computer environments. These are tested in every computer-based mathematics item.
2. Competencies that cover aspects of mathematics and ICT, such as: making a chart from data; producing graphs of functions and using the graphs to answer questions about functions; sorting information and planning efficient sorting strategies; using hand-held or on-screen calculators; using virtual instruments such as an on-screen ruler or protractor; and transforming images using a dialog box or mouse to rotate, reflect or translate the image. These are assessed in some items only, in an effort to isolate the effects of this type of item format on performance.
3. ICT skills, i.e. the fundamental skills needed to work with a computer, including basic knowledge of hardware (e.g. keyboard and mouse) and of conventions (e.g. arrows to move forward and specific buttons to execute commands). Items were designed to keep the need for such skills to a minimum core level.

2.1.6 PISA 2012 Mathematics Test Characteristics

The print mathematics test consists of 110 items, while the computer-based mathematics assessment contains 41 items. The PISA 2012 mathematics test items are classified according to the main elements of the framework as outlined above (Table 2.1). With regard to the mathematical processes, about half of items belong to the process *employing mathematical concepts, facts, procedures, and reasoning,* while the remainder of the items are split approximately evenly between the two processes that involve *formulating situations mathematically* and *interpreting, applying, and evaluating mathematical outcomes*. Items are distributed approximately evenly across the content and context categories.

Table 2.1
Distribution of 2012 Mathematics Items by Process, Content, and Context

Process	%	Content	%	Context	%
Print-based Assessment					
Formulating situations mathematically	29.3	Change & Relationships	26.6	Personal	19.3
Employing mathematical concepts, facts, procedures, and reasoning	45.9	Space & Shape	24.8	Occupational	22.0
Interpreting, applying and evaluating mathematical outcomes	24.8	Quantity	25.7	Societal	33.0
		Uncertainty & Data	22.9	Scientific	25.7
Computer-based Assessment					
Formulating situations mathematically	22.0	Change & Relationships	26.8	Personal	31.7
Employing mathematical concepts, facts, procedures, and reasoning	53.6	Space & Shape	29.2	Occupational	22.0
Interpreting, applying and evaluating mathematical outcomes	24.4	Quantity	22.0	Societal	26.8
		Uncertainty & Data	22.0	Scientific	19.5

Of the print mathematics items, approximately 41% of which are multiple-choice or complex multiple-choice, 30% require a short written response, and 28% require a longer written response. Approximately 29% of computer-based mathematics items are classified as multiple-choice or complex multiple-choice, 61% as short constructed-response, and 10% as open constructed-response.

2.2 Problem-solving Framework

Problem-solving was included as an additional assessment domain in PISA 2012. It is the second time that problem-solving has been assessed in PISA; however, the assessment has been significantly revised since it was last administered, in PISA 2003. The assessment has moved to a computer-based platform, making the students' interaction with the problem a central feature of the assessment. Furthermore, the computer delivery of the assessment makes it possible to capture information on the problem-solving process.

The aim of the assessment of problem-solving in PISA 2012 is to measure the cognitive processes fundamental to problem-solving so the assessment expressly excludes problems requiring expert knowledge of substantive areas for their solution. According to the assessment framework (OECD, 2013a), this also distinguishes the assessment from problem-solving tasks in the other PISA domains of reading, mathematics and science.

For the purposes of PISA 2012, problem-solving competency is defined as:

> An individual's capacity to engage in cognitive processing to understand and resolve problem situations where a method of solution is not immediately obvious. It includes the willingness to engage with such situations in order to achieve one's potential as a constructive and reflective citizen (OECD, 2013a, p. 122).

The PISA 2012 problem-solving framework is organised around three key elements: the problem context, the nature of the problem situation, and the problem-solving processes.

2.2.1 Problem Context

To ensure the assessment contains items from a range of contexts, items are classified according to two dimensions: the setting (i.e. whether it involves technology or not) and the focus (personal or social). Problems set in a *technology* context have the functionality of a technological device as their basis (e.g. mobile phones, remote controls for appliances, ticket vending machines). Problems that occur in other settings are classified as having *non-technology* contexts (e.g. route-planning, task-scheduling, decision-making). *Personal* contexts include those that relate to the self, family and peer groups, while *social* contexts refer to the community or society in general.

2.2.2 Nature of the Problem Situation

Problem-solving items are also classified according to the nature of the problem situation (i.e. whether the problem situation is static or interactive). A *static* problem situation is one where the information provided to the problem-solver at the outset is complete, while an *interactive* problem situation is one where the student needs to explore the problem situation to uncover additional relevant information. Examples of interactive problem situations include encountering technological devices like mobile phones and ticket vending machines for the first time.

2.2.4 Problem-solving Processes

The assessment framework specifies four processes involved in problem-solving: exploring and understanding; representing and formulating; planning and executing; and monitoring and reflecting.

Exploring and understanding

This process involves building mental representations of each of the pieces of information presented in the problem, including exploring the problem situation (observing it, interacting with it, searching for information, and finding limitations and obstacles), and understanding information presented from the outset and information discovered while interacting with the problem situation.

Representing and formulating

This process refers to building a mental model of the problem situation by selecting relevant information, organising it mentally, and integrating it with relevant prior knowledge. This may involve representing the problem through tabular, graphical, symbolic, or verbal representations, and shifting between these representational formats, formulating hypotheses by identifying the relevant factors in the problem and their interrelationships, or organising and critically evaluating information.

Planning and executing

This process consists of goal-setting (including clarifying the overall goal, setting sub-goals, where necessary), devising the steps in a plan or strategy to reach the goal, and executing the plan.

Monitoring and reflecting

This process includes monitoring progress towards the goal at each stage of the problem-solving process (such as checking intermediate and final results, detecting unexpected events, and taking remedial action when required) as well as reflecting on solutions from different perspectives, critically evaluating assumptions and alternative solutions, identifying the need for additional information or clarification, and communicating progress in a suitable manner (OECD, 2013a).

Each of the problem-solving processes requires the use of reasoning skills such as deductive, inductive, quantitative, correlational, analogical, combinatorial, and multidimensional reasoning (OECD, 2013a). A broad mix of reasoning skills is sampled across assessment items, as the complexity and types of reasoning involved affect item difficulty.

2.2.5 PISA 2012 Problem-solving Test Characteristics

The computer-based assessment of problem-solving consists of 42 items distributed over 16 units and all items are classified according to the main elements of the framework outline above (Table 2.2). In terms of the problem setting, there is an even split of items presented in technology and non-technology settings. Just over half of items are presented in a personal setting, with the remainder presented in a social setting. Almost two-thirds of items are considered to be interactive, with just over a third considered to be static. About a fifth of items are ‘representing and formulating’ tasks, while just under a quarter are ‘exploring and understanding’ tasks. Approximately 38% of items mainly involve ‘planning and executing’ and the remaining 17% are classified as ‘monitoring and reflecting’ tasks.

2.3 PISA Context Questionnaires

As well as measuring student achievement, PISA collects background information from student and school questionnaires. The data gathered from these questionnaires are used to contextualise the results, by exploring relationships between students’ background characteristics and their outcomes. The information collected as part of PISA is conceptualised at four levels: variables that relate to individual students, to classrooms, to schools, and to the country’s educational system as a whole (OECD, 2013a), as set out in Table 2.3.

Countries are given the opportunity to add a small number of questions of national interest to the PISA questionnaires. In Ireland, a number of nationally relevant questions were added to the context questionnaires, including questions relating to involvement in paid work, early school-leaving intent, immigration and integration, interaction with parents, and enjoyment of reading in the student questionnaire, and integration of migrant students, opinions on Project Maths, and ability grouping

Table 2.2
Distribution of 2012 Problem-solving Items by Context (Setting and Focus), Nature of Problem Situation, and Problem-solving Process

Context	%	Context	%	Nature of problem situation	%	Problem-solving process	%
Technology	50.0	Social	45.2	Static	35.7	Exploring & understanding	23.8
Non-technology	50.0	Personal	54.8	Interactive	64.3	Representing & formulating	21.4
						Planning & executing	38.1
						Monitoring & reflecting	16.7

Table 2.3
Coverage of PISA Context Questionnaires

Student information	Grade
	Gender
	Socio-economic background
	Immigrant and language status
	Family support
School information	Community size
	Resources
	Qualifications of teaching staff
School-level processes	Decision-making
	Admission policies
	Assessment and evaluation policies
	Teacher professional development
	Teacher engagement and morale
	Teacher-student relations
	Parental involvement
Student outcomes	Truancy
	Educational expectations
	Motivation and learning engagement
	Sense of belonging
Mathematics-related outcomes	Strategies and metacognition
	Mathematics-related attitudes and behaviour
	Mathematics self-concept
	Opportunity to learn
	Instructional quality
	System- and school-level support
Educational Career	Pre-school education
ICT familiarity	Use of ICT at home and at schools

for mathematics in the school questionnaire. Ireland also opted to administer two additional student questionnaire modules offered as part of PISA, one on students' educational careers and the other on ICT familiarity. While an international teacher questionnaire was not part of PISA 2012, a national teacher questionnaire that was targeted at all mathematics teachers in participating schools was developed and administered in Ireland in conjunction with the assessment. In addition, a national questionnaire was also administered to mathematics school co-ordinators in Ireland. Data from the teacher questionnaire are presented in Chapter 6 of this report.

2.4 Sampling and weighting

The 24 Initial schools were selected from 225 volunteer schools to be broadly representative of the national population of schools. One of the original 24 amalgamated with another school so further reference in this report is to the remaining 23 Initial schools. With the agreement of the international PISA consortium, a decision was made nationally to administer the PISA 2012 assessment in all 23 Initial schools, as results of the mathematics assessment in these schools are of particular national interest. It should be noted that the inclusion of all Initial schools in the sample for Ireland results in an over-sampling of such schools. The sample weights, however, take account of this over-sampling.

The sampling process took place in two stages: school level and student level. Samples for each country were drawn by the international PISA consortium (OECD, in press). Sampling at the school level involved first categorising schools into 11 distinct groups, or explicit strata, based on relevant school-level characteristics. The approach taken to stratifying schools in Ireland differed from earlier PISA cycles in two major respects. Firstly, an explicit stratum was created for Initial schools, in order to accommodate the administration of the assessment in all 23 of such schools. In addition, an explicit stratum was created for non-aided schools (these had been excluded from the sampling frame in previous cycles of PISA). The remaining schools (i.e. DES-funded, Non-initial schools) were then divided into nine further explicit strata derived from all possible combinations of two school-level variables (school size and sector), each containing three levels (small, medium, or large, and community and comprehensive, secondary, or vocational). Within each explicit stratum, schools were ordered by two implicit stratification variables: socio-economic status and school gender composition. Schools were categorised according to which quartile they occupied with regard to the school DEIS[1] score for the former and the percentage of students who were female for the latter. As Initial schools occupied their own explicit stratum, they were implicitly stratified by school size and type, in addition to school socio-economic status (i.e. DEIS score) and gender composition. Non-aided schools were not stratified by the implicit variables, as information on the characteristics of these schools was not available. The number of schools sampled within each explicit stratum is based on the number of students in that stratum in the population and the number in the expected sample. The probability of a school being selected is proportional to the number of students in the target population in the school. Overall, 188 schools were sampled to participate. Of these, 183 schools took part, including one replacement school. This gives a weighted school-level response rate of 97.3% after replacement. Six participating schools were Irish-medium. As in previous cycles of PISA, these schools were provided with both English and Irish versions of all print materials. Students chose on an individual basis which version of the assessment and questionnaire they would prefer, on the day of testing. Irish medium schools were also offered computer-based materials in either English or Irish.

The second stage of sampling involved selecting students within schools that had agreed to participate. In schools with 35 or fewer students who met the age criteria, all students were selected; in schools with more than 35 such students, 35 were randomly sampled. From the 35 (or fewer) students selected to complete the assessment, a subset of up to 18 were randomly selected to participate in the computer-based test.

Of the 6,318 students who were sampled to participate in the print assessment, 70 (1.1%) were ineligible. Of this 1.1%, 14 (0.2% overall) did not meet the age requirement, and 56 (0.9%) were no longer enrolled in the school. There was a within-school exclusion rate of 4.3% (271 students). These students were deemed by school principals to be unable to participate due to either limited experience of the language of the assessment or special educational needs, as outlined in PISA guidelines. This left 5,977 students eligible to complete the assessment. In total, 5,016 students sat the print assessment, yielding a weighted response rate of 84.1%. Absenteeism accounted for the majority of cases of non-participation (749 students, or 12.5% of eligible students), with student or parent refusals accounting for the remaining 212 students (3.5%). Response rates in Ireland at both school and student level met international PISA standards (85% and 80%, respectively; OECD, in press). The majority (60.5%) of selected students were in Third year at the time of testing, almost a quarter (24.3%) were in Transition year, 13.3% were in Fifth year, and 1.9% were in First or Second year. A total of 2,396 students participated in the computer-based assessment, which was 67% of students sampled to participate.

[1] DEIS, Delivering Equality of Opportunity in Schools, provides additional, targeted resources to primary and post-primary schools that have high concentrations of disadvantage, under the School Support Programme (SSP) (DES, 2005).

2.5 Student and School Characteristics

The purpose of this report is to compare the performance of students in the 23 Initial schools with those in Non-initial schools on the PISA mathematics and problem-solving assessments. Before comparing performance in these schools, the demographics of students attending Initial and Non-initial schools were compared to determine whether the samples differ in any way that could have an impact on the comparison of achievement results in Chapter 3. Very few demographic differences were observed between the two samples (Table 2.4 lists the variables on which no significant differences were observed and the percentages for Initial and Non-initial students are reported in Appendix A2). The groups differed significantly in only one respect: there were significantly more girls in Initial schools (55.0%) than in Non-initial schools (48.9%). For this reason, comparisons by gender are reported after the Initial-Non-initial tests of difference in Chapters 3 and 4 and gender is included as a predictor in the models in Chapter 8.

Significant differences were observed between the two samples on DEIS status and fee-paying status. However, there were only two Initial schools that are also DEIS schools. Fee-paying status can be explained by school mean Economic, Social, and Cultural Status (ESCS), the OECD's measure of socio-economic status which is a continuous variable and so is of greater value in specifying the source of variation. The school characteristics on which there were no differences are in Table 2.4 and tables of results for all variables are in Appendix A2. The only school-level comparison in subsequent chapters is between Initial and Non-initial schools and the models in Chapter 8 include school mean ESCS and school sector as these are the characteristics of schools for which efforts can be made to address any observed discrepancies.

2.6 Analyses

Student achievement on PISA was scaled using a one-parameter Item Response Theory (IRT) model (specifically, a mixed coefficient multinomial logit model), which uses estimates of item difficulty to predict the probability that a student will answer a question correctly (assuming items behave the same way across countries). In PISA, the procedure was applied in three steps: national calibrations, international scaling, and student score generation. IRT places item difficulty and student ability on the same metric, meaning that student ability at a specific level can be described in terms of task characteristics of items associated with that level.

Table 2.4
Student and School Characteristics on which No Differences between Initial and Non-initial Schools were Observed

Student characteristics	School characteristics
Economic, Social, and Cultural Status (ESCS)	School mean ESCS
Family structure	Sector
Immigrant status	Gender composition
Language status	Rurality
Traveller status	Proximity of other schools
Time spent in paid work during term time	
Duration of pre-school attendance	
Grade level	
Early school-leaving risk	
Frequency of skipping school	
Frequency of arriving later for school	

In order to generate unbiased estimates of group scores, student achievement estimates were imputed using five plausible values. Plausible values are random numbers which are drawn from the distribution of scale scores that could be reasonably assigned to a student. Plausible values contain random error variance components and are not optimal for reporting scores at the level of the individual student. However, when combined, plausible values can be used to describe the performance of groups of students. In PISA, five plausible values are assigned to each student for each overall scale (print mathematics, computer-based mathematics, print reading, digital reading, science, and problem-solving) and for each print mathematics subscale (Formulate, Employ, Interpret, Change & Relationships, Space & Shape, Quantity, and Uncertainty & Data). Plausible values were produced from country-by-country regressions, based on principal components analyses of dummy-coded student questionnaire variables and student gender, grade, and parental occupation status. This scaling process essentially produces student-level achievement estimates which are, in theory, unbiased estimates that can be used to compare the performance of students across countries participating in PISA, as well as to compare the performance of sub-groups of students within and across countries. Full details on the development of achievement scales in PISA 2012 can be found in the PISA 2012 Technical Report (OECD, in press).

For this report, student achievement was compared for Initial and Non-initial schools using *t*-tests. The level of statistical significance applied to the tests was $\alpha = .05$ and significant differences are reported in bold face in tables. *T*-tests include the standard error of the mean and the relatively small sample of students from Initial schools makes for a higher threshold for significance in the magnitude of the difference. Further detail on the method used for multi-level modelling is provided in Chapter 8.

2.8 Conclusion

The PISA 2012 mathematics and problem-solving frameworks describe many of the skills and capacities covered by the Irish mathematics curriculum, both under the Project Maths initiative and the previous curriculum. The independence of PISA makes it a suitable means to compare student performance in Initial and Non-initial schools, with the mathematics subscales offering an additional detailed view of aspects of student achievement, assuming that there is some commonality between the goals of PISA mathematics and Junior Certificate mathematics. Twenty-three Initial schools were sampled for PISA 2012 and performance in these schools can be compared to that of Non-initial schools selected. Analyses of student demographics and school characteristics indicate few systematic differences between Initial and Non-initial schools; however, a significant gender difference was observed. On the basis of this chapter, then, any differences observed in student achievement on PISA scales and subscales can be attributed, at least to some extent, to students' learning experiences arising from the Project Maths initiative.

Inset 2.1. How to Interpret the Analyses in this Report

OECD average

Throughout this report reference is made to the OECD average. This is the arithmetic mean of all OECD countries that have valid data on the indicator in question. Where references are made to 'OECD' in tables and figures, this always refers to the OECD average. Also in this report, 'mean' and 'average' are used interchangeably.

Comparing mean scores

Because PISA assesses samples of students, and students attempt only a subset of PISA items, achievement estimates are prone to uncertainty arising from sampling and measurement error. The precision of these estimates is measured using the standard error, which is an estimate of the degree to which a statistic, such as a country mean, may be expected to vary about the true (but unknown) population mean. Assuming a normal distribution, a 95% confidence interval can be created around a mean using the following formula: *Statistic ± 1.96 standard errors.* The confidence interval is the range in which the population estimate is expected to fall 95% of the time using different samples. The standard errors associated with mean achievement scores in PISA were computed in a way that takes account of the two-stage, stratified sampling technique used in PISA. The approach used for calculating sampling variances for PISA estimates is known as Fay's Balanced Repeated Replication (BRR), or balanced half-samples, which takes into account the clustered nature of the sample. Using this method, half of the sample is weighted by a K factor, which must be between 0 and 1 (set at 0.5 for PISA analyses), while the other half is weighted by 2 - K. Graphs of mean scores include error bars to illustrate ± 1.96 standard errors.

Statistical significance

Statistical significance indicates that a difference between estimates has not occurred by chance and would probably occur again if the survey was repeated (i.e. for significance at the 5% level, the observed difference would most likely be observed again 95 times out of 100). In this report, mean scores are sometimes compared for countries or groups of students. When it is noted that these scores differ significantly from one another (i.e. $p < .05$), the reader can infer that the difference is *statistically* significant.

Standard deviation

The standard deviation is a measure of the spread of scores for a particular group. The smaller the standard deviation, the less dispersed the scores are. The standard deviation provides a useful way of interpreting the difference in mean scores between groups, since it corresponds to percentages of a normally distributed population, i.e. 68% of students in a population have an achievement score that is within one standard deviation of the mean and 95% have a score that is within two standard deviations of the mean. In PISA 2012, Ireland achieved a mean problem-solving score of 498 and the standard deviation was 93. Therefore, 68% of students in Ireland are estimated to have obtained an achievement score between 405 and 591 (498 ± 93 * 1), while 95% of students are estimated to have obtained an achievement score between 312 and 684 (498 ± 93 * 1.96).

Proficiency levels

In PISA, student performance and the level of difficulty of assessment items are placed on a single scale for each domain assessed. Using this approach means that each scale can be divided into proficiency levels and the skills and competencies of students within each proficiency level can be described. In 2012, six proficiency levels are described for the paper-based assessment of mathematics and for the computer-based assessments of mathematics and problem-solving. Level 2 is considered the basic level of proficiency needed to participate effectively and productively in society and in future learning (OECD, 2013a). Within a level, all students are expected to answer at least half of the items at that level correctly (and fewer than half of the items at a higher level). A student scoring at the bottom of a proficiency level has a .62 probability of answering the easiest items at that level correctly, and a .42 probability of answering the most difficult items correctly. A student scoring at the top of a level has a .62 probability of getting the most difficult items right, and a .78 probability of getting the easiest items right.

Correlations

Correlation coefficients describe the strength of a relationship between two variables (e.g. the relationship between socio-economic status and mathematics achievement). However, a correlation does not imply a causal relationship. The value of a correlation (i.e. the r value) can range from -1 to +1. A value of 0 indicates that there is no relationship between variables, while the closer a value is to ±1, the stronger the relationship. For the present study, a correlation is considered moderate-to-strong with values in the range $r = \pm .41$ to $r = \pm .55$, moderate in the range $r = \pm .26$ to $r = \pm 0.40$, and weak-to-moderate in the range $r = \pm .11$ to $r = \pm .25$. A negative correlation (e.g. -.26) means that as one variable increases, the other decreases; a positive correlation (e.g. .26) means that both either increase or decrease together.

3. Performance on PISA 2012 Mathematics and Problem-solving

As detailed in Chapter 2, students in all 23 Initial schools participated in PISA 2012. This chapter compares their results to the other students in PISA 2012 (i.e. students in Non-initial schools). The first section reports results on the print mathematics scale and its associated process and content subscales, including performance at the proficiency levels described in PISA 2012. In the second section, comparisons by gender are made for each of the print mathematics scales and subscales. Mathematics was also tested in a computer-based format and comparison of these results is reported in the third section, along with comparisons by gender. The final section compares performance between students in Initial and Non-initial schools on the computer-based problem-solving assessment in PISA 2012.

3.1 Print mathematics

Overall performance on the PISA print mathematics scale was estimated for students in Initial and Non-initial schools. The mean score for students in Initial schools is 505.3, slightly higher than those in Non-initial at 501.3 but not to a statistically significant extent. The pattern of non-significantly higher average scores in Initial schools is repeated for the three process subscales, Formulating, Employing, and Interpreting (Figure 3.1). Likewise, students in Initial schools have slightly but not significantly higher scores on all four content subscales, Change & Relationships, Space & Shape, Quantity, and Uncertainty & Data (Figure 3.2). While none of the differences is statistically significant, the largest difference is on Space & Shape, and the performance of Initial students (485.8) is not significantly different from the OECD average of 489.4, whereas the mean for Non-initial students (477.4) is significantly below the OECD average.

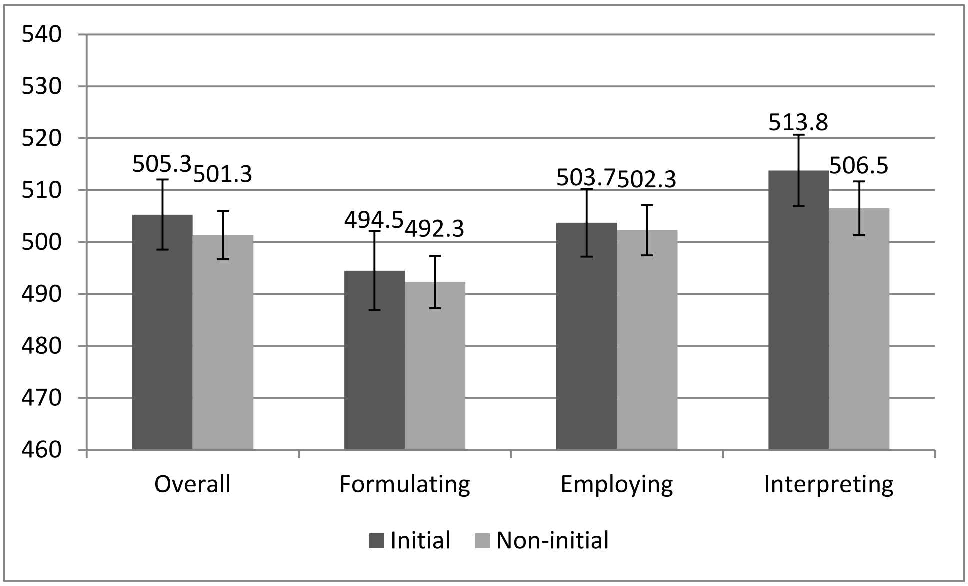


Figure 3.1. Mean Scores on Overall Print Mathematics and Process Subscales of Students in Initial and Non-initial Schools.

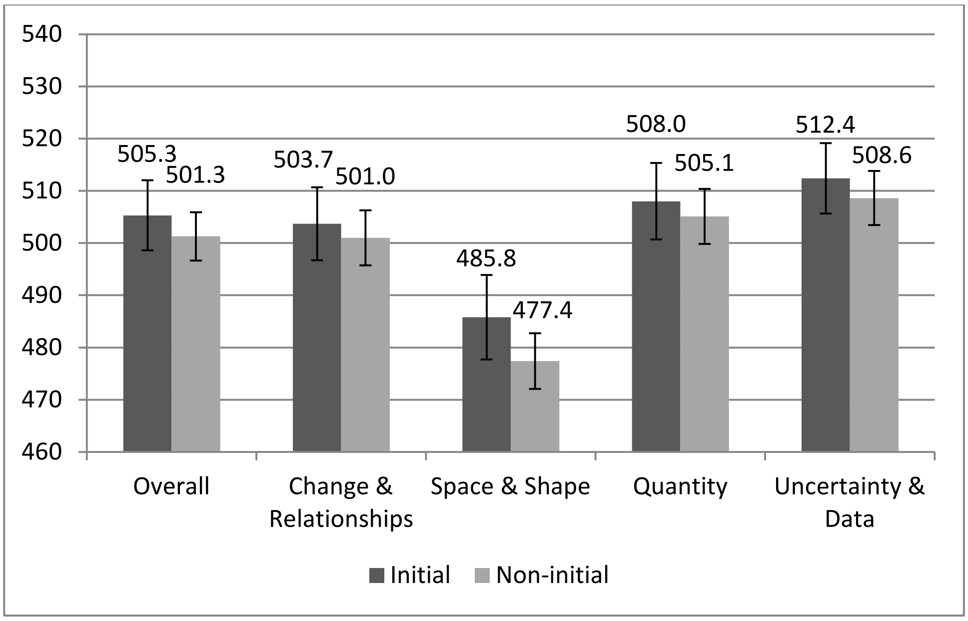


Figure 3.2. Mean Scores on Overall Print Mathematics Content Subscales of Students in Initial and Non-initial Schools.

Performance at Print Mathematics Proficiency Levels

Scores on the mathematics scale and subscales are grouped into levels of proficiency at which particular skills and abilities are likely to be demonstrated by students (see Inset 2.1). For example, students at Level 1 are likely to answer questions which provide all relevant information in a familiar context correctly, while those at Level 6 are likely to succeed on items that require them to creatively investigate and model complex problem situations in the most difficult PISA items (see Table 3.1). Level 2 is considered the minimal level of proficiency required to participate fully in society and future learning (OECD, 2013a). For the purposes of this report, two sub-groups of students are considered in detail: those scoring below proficiency Level 2 (i.e. low-achieving students) and those scoring at Level 5 or above (i.e. high-achieving students).

While there were no significant differences in the proportions of students from Initial and Non-initial schools achieving the same levels on the proficiency scales, a consistent pattern was observed, reflecting the differences in overall performance. There are fewer students from Initial schools scoring below Level 2 on the overall print mathematics scale and on the three process subscales. The proportion of higher-achieving students on the overall print mathematics scale and each of the process subscales is very similar in the Initial and Non-initial schools, with the exception of the Interpreting subscale (Figure 3.3). Looking to the content subscales (Figure 3.4), the pattern is similar, with fewer low-achieving students and marginally more high-achieving students in Initial schools.

Table 3.1
Descriptions of Six Levels of Proficiency on the Overall Print Mathematics Scale and Percentages of Students Achieving each Level in Initial and Non-initial schools

Level *(Range)*	**Students at this level are capable of:**	**Initial**		**Non-initial**	
		%	***SE***	**%**	***SE***
6 *(669 and above)*	Conceptualising, generalising and using information based on their investigations and modelling of complex problem situations; using knowledge in relatively non-standard contexts; linking different information sources and representations and moving flexibly among them; applying their insight and understanding, along with mastery of symbolic and formal mathematical operations and relationships, to develop new approaches and strategies for addressing novel situations; reflecting on their actions and formulating and precisely communicating their actions and reflections regarding their findings, interpretations and arguments, and explaining why they were applied to the original situation. Students at this level are able to successfully complete the most difficult PISA items.	1.7	(0.72)	2.2	(0.24)
5 *(607 to less than 669)*	Developing and working with models of complex situations, including identifying constraints and specifying assumptions; selecting, comparing and evaluating appropriate problem-solving strategies for dealing with complex problems related to these models; working strategically using broad, well-developed thinking and reasoning skills, appropriate linked representations, symbolic and formal characterisations and insights pertaining to these situations; beginning to reflect on their work and formulating and communicating their interpretations and reasoning.	9.1	(1.43)	8.5	(0.53)
4 *(545 to less than 607)*	Working effectively with explicit models of complex, concrete situations that may involve constraints or making assumptions; selecting and integrating different representations (including symbolic representations) and linking them directly to aspects of real-world situations; using their limited range of skills and reasoning with some insight in straightforward contexts; constructing and communicating explanations and arguments based on their interpretations, arguments and actions.	22.2	(1.82)	20.2	(0.79)
3 *(482 to less than 545)*	Executing clearly described procedures (including those that require sequential decisions); making sufficiently sound interpretations to be able to build simple models or select and applying simple problem-solving strategies; interpreting and using representations based on different information sources and reasoning directly from them; handling percentages, fractions and decimal numbers and working with proportional relationships; engaging in basic interpretation and reasoning.	26.7	(2.47)	28.3	(0.89)
2 *(420 to less than 482)*	Interpreting and recognising situations in contexts that require no more than direct inference; extracting relevant information from a single source and making use of a single representational mode; employing basic algorithms, formulae, procedures or conventions to solve problems involving whole numbers; making literal interpretations of results. Level 2 is considered the baseline level of mathematical proficiency that is required to participate fully in modern society.	25.0	(2.08)	23.9	(0.73)
1 *(358 to less than 420)*	Answering questions involving familiar contexts where all relevant information is present and the questions are clearly defined; identifying information and carrying out routine procedures according to direct instructions in explicit situations; performing actions that are almost always obvious and follow immediately from the given stimuli.	11.2	(1.45)	12.1	(0.74)
Below Level 1 *(below 358)*	Performing very direct and straightforward mathematical tasks, such as reading a single value from a well-labelled chart or table where the labels on the chart match the words in the stimulus and question, so that the selection criteria are clear and the relationship between the chart and the aspects of the contexts depicted are evident; performing arithmetic calculations with whole numbers by following clear and well-defined instructions.	4.1	(0.81)	4.8	(0.57)

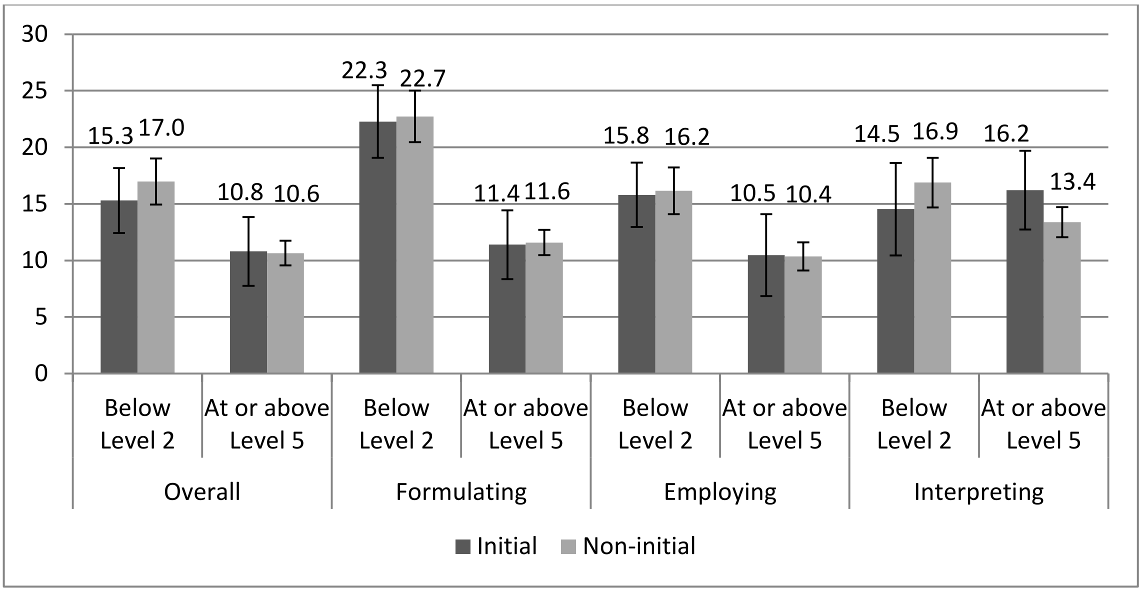


Figure 3.3. Percentages of Students Performing Below Level 2 and At or Above Level 5 on Print Mathematics Scale and Process Subscales among Students in Initial and Non-initial schools.

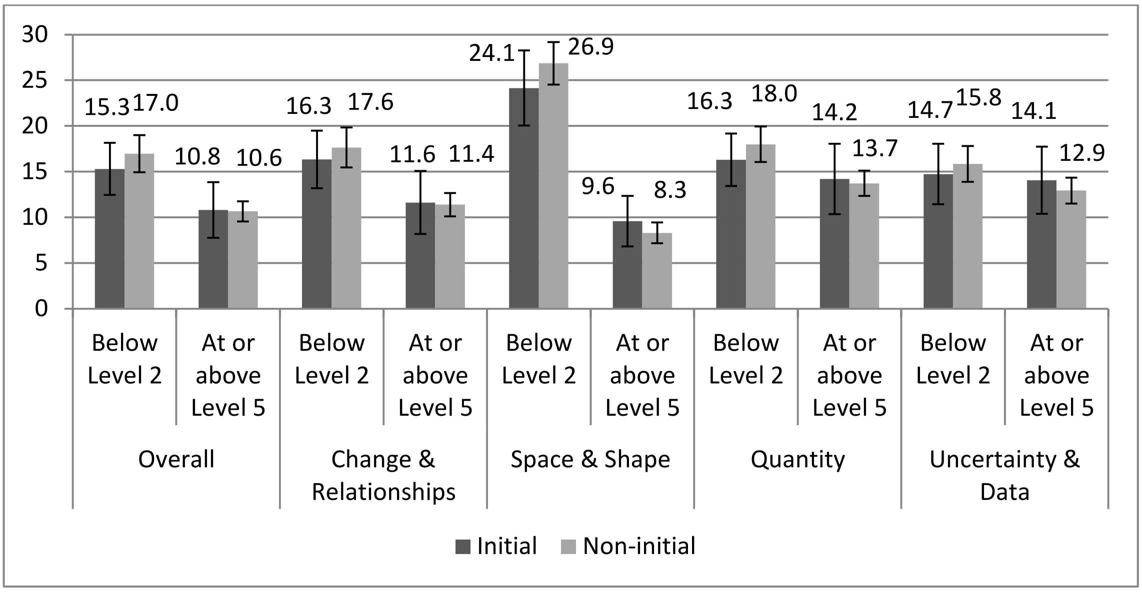


Figure 3.4. Percentages of Students Performing Below Level 2 and At or Above Level 5 on Content Subscales among Students in Initial and Non-initial Schools.

3.2 Gender Differences in Print Mathematics Performance

In the national report on the performance of students in Ireland on PISA 2012 (Perkins et al., 2013) significant gender differences were identified: Male students significantly out-performed female students on the overall print mathematics scale, on the three process scales, and on the four content scales. In the present study, the gender gap on the print mathematics scale was 15.3 points for Non-initial schools, while in Initial schools it was slightly higher at 18.0 points; both differences are statistically significant and in favour of male students. In the remaining analyses, performance comparisons are reported between Initial and Non-initial schools for each gender.

No significant differences were observed between male students in Initial and Non-initial schools on the overall print mathematics scale or for the Formulating or Employing subscales, though scores for each were higher among students in Initial schools (Figure 3.5). There was a significant difference on the Interpreting subscale, with male students in Initial schools scoring 528.6 and males in Non-initial schools scoring 514.6; the average score for male students in Ireland on the Interpreting subscale was above the OECD average for males (501.6). While male students in Initial schools had higher mean scores than males in Non-initial schools across each of the content area subscales (Figure 3.6), none of the differences was statistically significant. Interestingly, the performance of male students in Initial schools on Space & Shape (496.0) is not significantly different from the OECD average for males (497.2), whereas the average score for male students in Non-initial schools on this subscale, 489.7, is significantly below the OECD average for males.

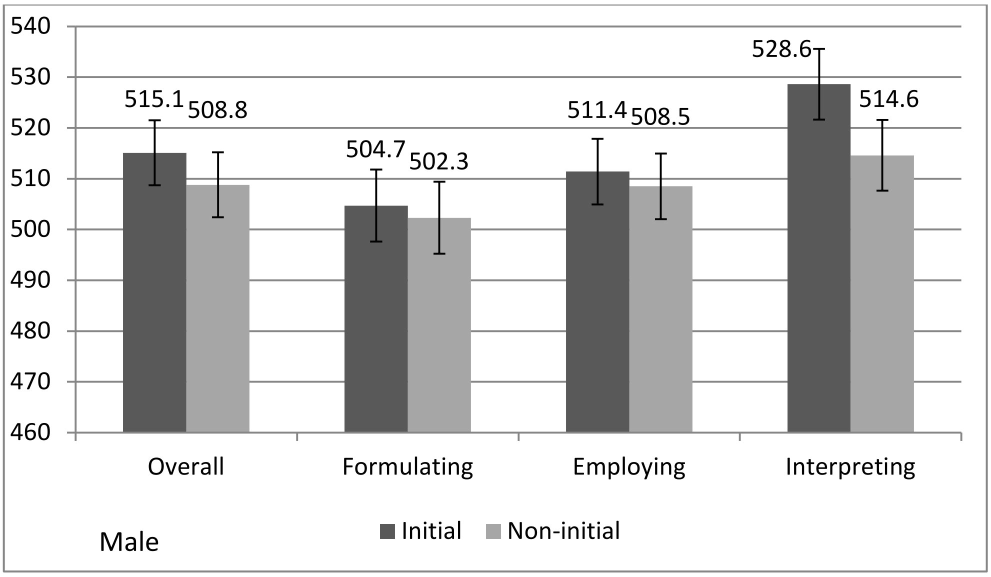


Figure 3.5. Mean Scores of Male Students on Overall Print Mathematics and Process Subscales in Initial and Non-initial Schools.

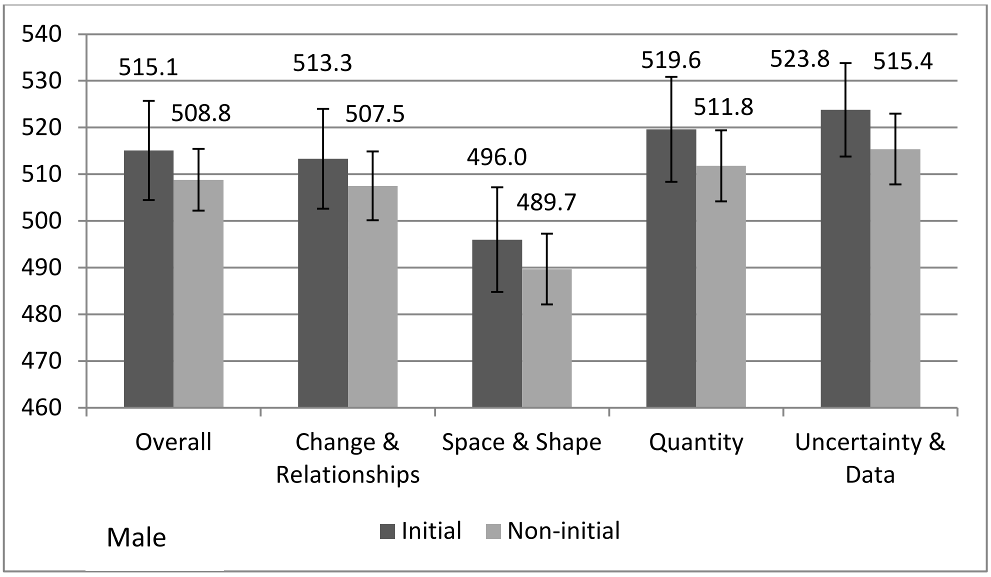


Figure 3.6. Means Scores of Male Students on Overall Print Mathematics Content Subscales in Initial and Non-initial Schools.

For female students, the pattern of marginally better performance among those in Initial schools for the overall print mathematics scale and for the process (Figure 3.7) and content (Figure 3.8) subscales is evident again. Performance on the Space & Shape content subscale is significantly better for female students in Initial schools (477.4) than their counterparts in Non-initial schools (464.6), and is not significantly different from the OECD average for female students (481.9), whereas the average score for female students in Non-initial schools is significantly below the OECD average.

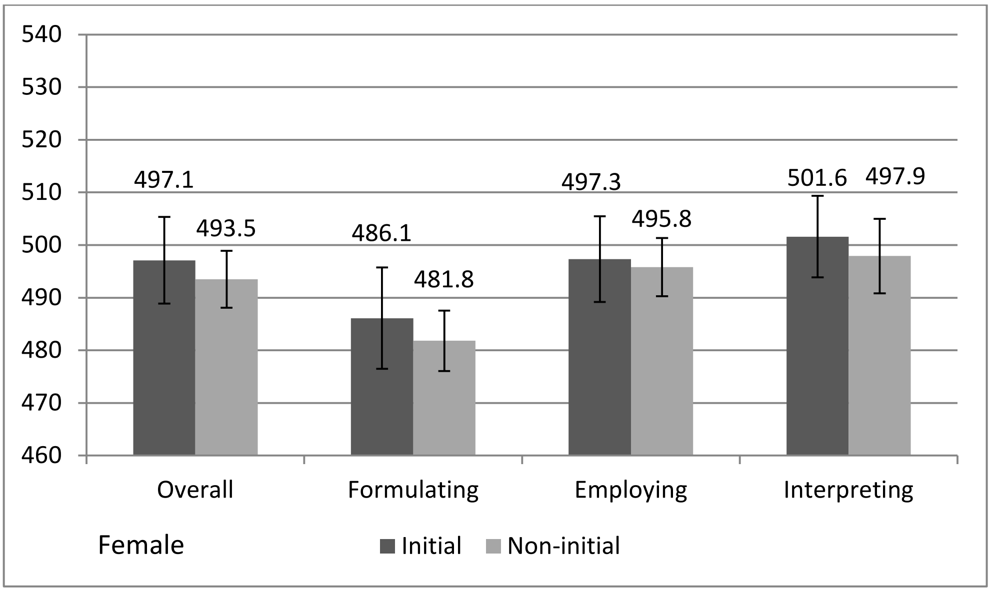


Figure 3.7. Mean Scores of Female Students on Overall Print Mathematics and Process Subscales in Initial and Non-initial Schools.

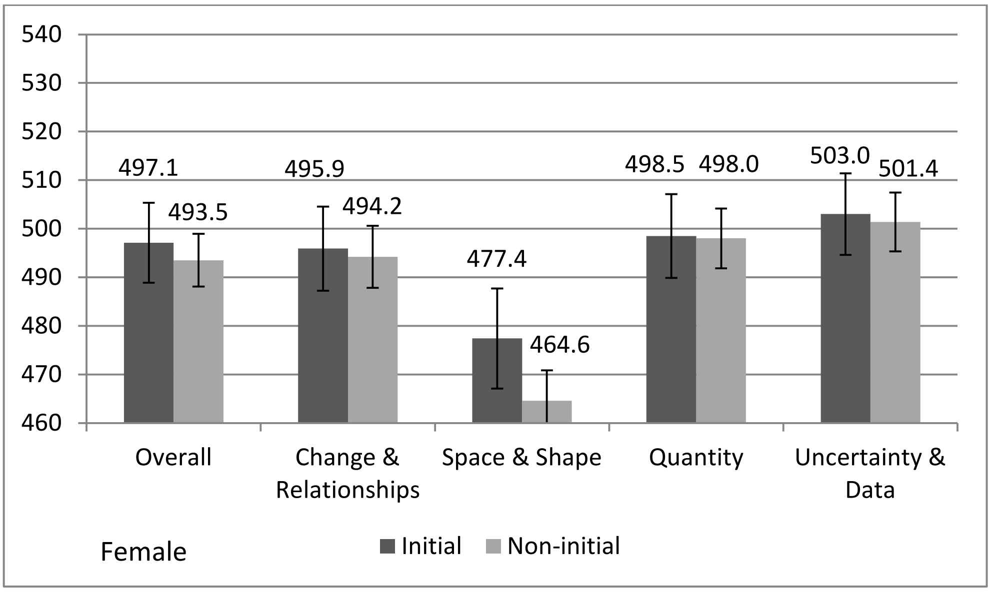


Figure 3.8. Mean Scores of Female Students on Overall Print Mathematics Content Subscales in Initial and Non-initial Schools.

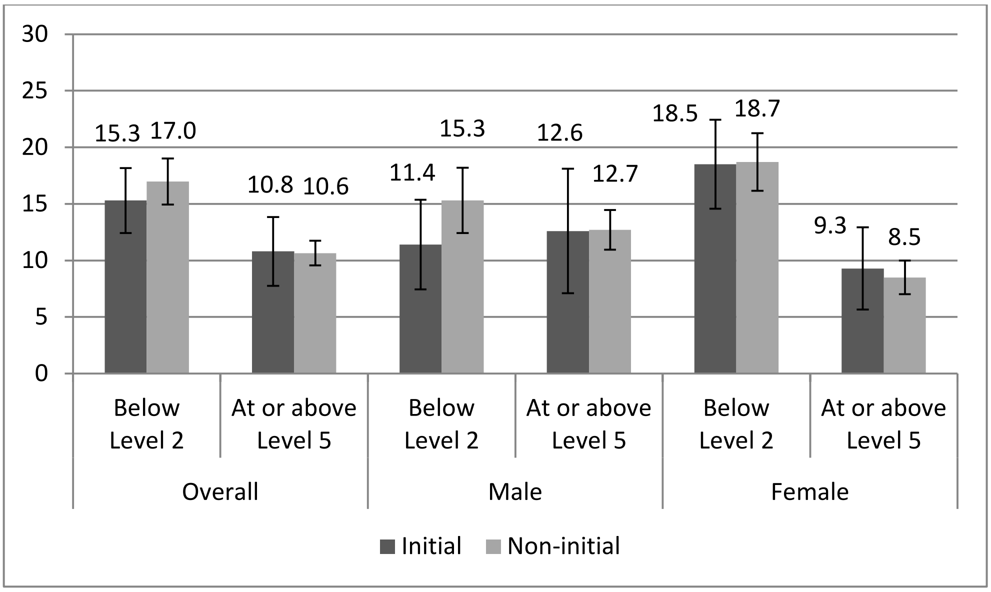


Figure 3.9. Percentages of Males and Females Performing Below Level 2 and At or Above Level 5 on Print Mathematics in Initial and Non-initial Schools.

As noted above, there were slightly fewer students below proficiency Level 2 in Initial schools, as well as marginally more at Level 5 or above. Figure 3.9 gives a breakdown by gender and suggests that most of the differences at the lower levels are attributable to the better performance of lower-achieving male students than female students in Initial schools.

The analysis of differences in print mathematics achievement between students in Initial and Non-initial schools shows a consistent pattern of higher achievement in Initial schools, though few of the differences are statistically significant and to some extent this can be attributed to the relatively small sample in Initial schools. The significant differences are in the Interpreting process area for males and the Shape & Space content area for females, both of which are closely aligned to the aims of Project Maths.

3.3 Computer-based Mathematics

In Ireland, a subsample of students in all schools also participated in a computer-based assessment of mathematics, which is underpinned by the same framework as the print assessment, though performance is not reported by process or content area subscales. As noted in the main report on PISA 2012, the performance of students in Ireland on computer-based mathematics did not differ significantly from the 23-country OECD average[2] (Perkins et al., 2013). The performance of male students is not significantly different from the 23-country OECD average for male students while female students performed significantly below the OECD average for females.

In the analysis of the performance of students in Initial and Non-initial schools on computer-based mathematics, no significant differences were observed between male students in the two contexts or between female students (Figure 3.10). Once again, the pattern of marginally higher performance in Initial schools was observed. Within the school categories, gender differences were significant with a slightly larger gender gap in Initial (23.6 points) than Non-initial schools (18.4).

[2] Thirty-two countries, including 23 OECD countries, participated in the optional computer-based assessment of mathematics.

With respect to proficiency levels, the same thresholds applied to computer-based mathematics as applied to print mathematics (Table 3.1). No significant differences were observed in the proportion of students at each proficiency level in Initial and Non-initial schools. The pattern of fewer low-achieving students (i.e. below Level 2) in Initial schools is again apparent, though only among male students, while there are more high-achieving male and female students in Initial schools (Figure 3.11).

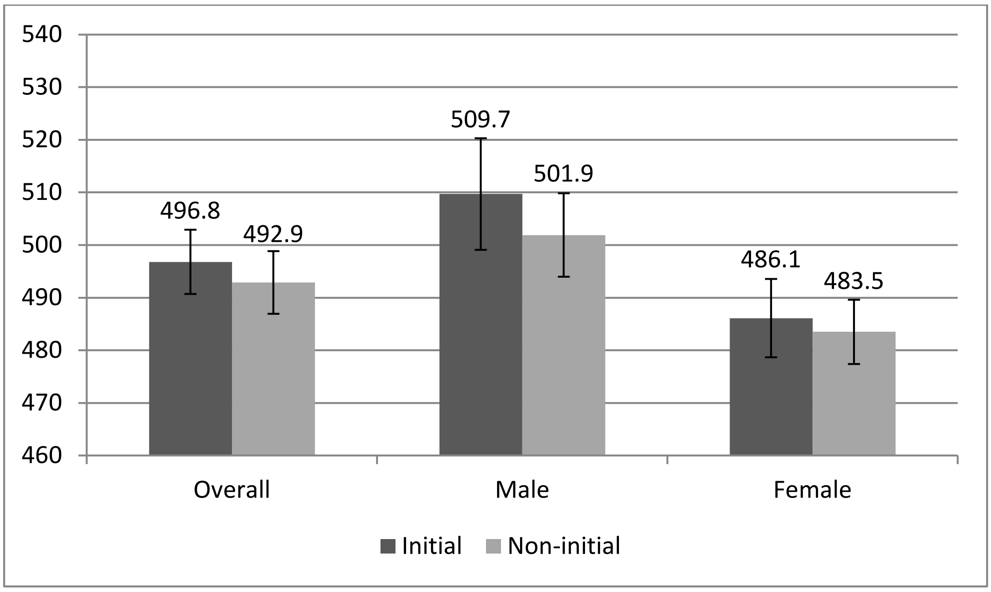


Figure 3.10. Mean Scores on Computer-based Mathematics and for Male and Female Students in Initial and Non-initial Schools.

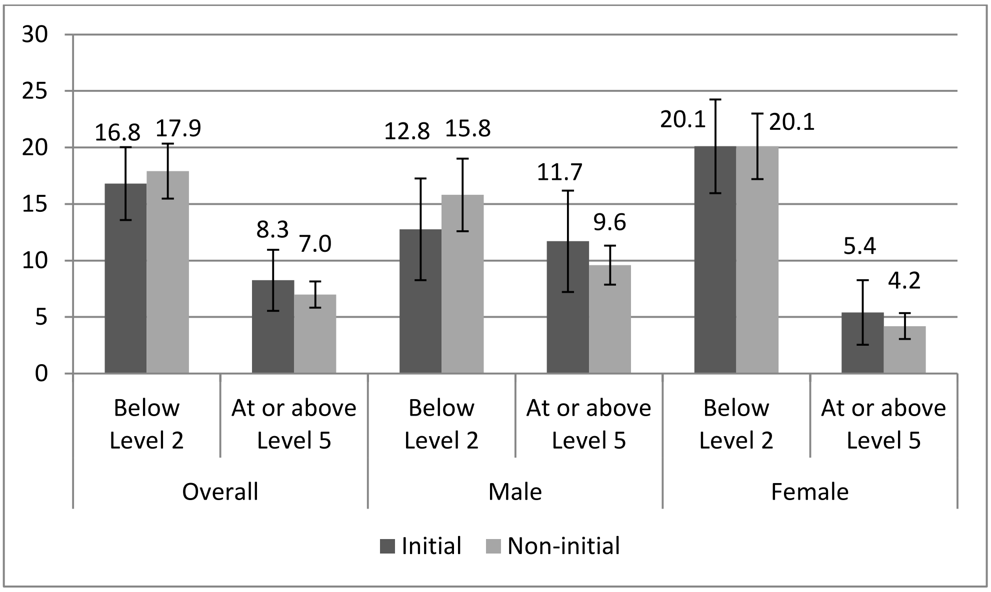


Figure 3.11. Percentage of Students Performing Below Level 2 and At or Above Level 5 on Computer-based Mathematics and for Male and Female Students in Initial and Non-initial Schools.

3.5 Problem-solving

The overall performance of students in Ireland on computer-based problem-solving in PISA 2012 (498.3) is not significantly different from the OECD average of 500.1 (Perkins & Shiel, 2014). The performance of students in Ireland is similar to the 23-country OECD average for problems classified as Exploring & Understanding and Representing & Formulating, the so-called knowledge-acquisition processes. Turning to higher-level problem-solving processes, students in Ireland are less likely to be successful on Planning & Executing items than the average of students across the 23-participating OECD countries, while they are more likely to be successful on the Monitoring & Reflecting items. Performance on interactive items, which are slightly harder than static items, was stronger than expected in Ireland (OECD, 2014b). The OECD report suggests that high-achieving students are open to novelty, are tolerant of doubt and uncertainty, and can use intuition to solve a problem.

Comparing Initial and Non-initial schools, there was no significant difference in overall performance and no difference in the performance of male and female students within Initial and Non-initial schools or between them (Figure 3.12). In contrast, on average across OECD countries, boys had significantly higher scores than girls (OECD, 2014b). In the present study, female students in Initial schools had slightly higher scores than their male counterparts, while male students had higher scores than female students in Non-initial schools, though, as noted above, these differences were not statistically significant. With respect to proficiency levels, there were no significant differences between students in Initial and Non-initial schools (Figure 3.13). Again, the gender gap is minimal in Ireland whereas on average across OECD countries there are more boys than girls scoring at or above Level 5 and below Level 2.

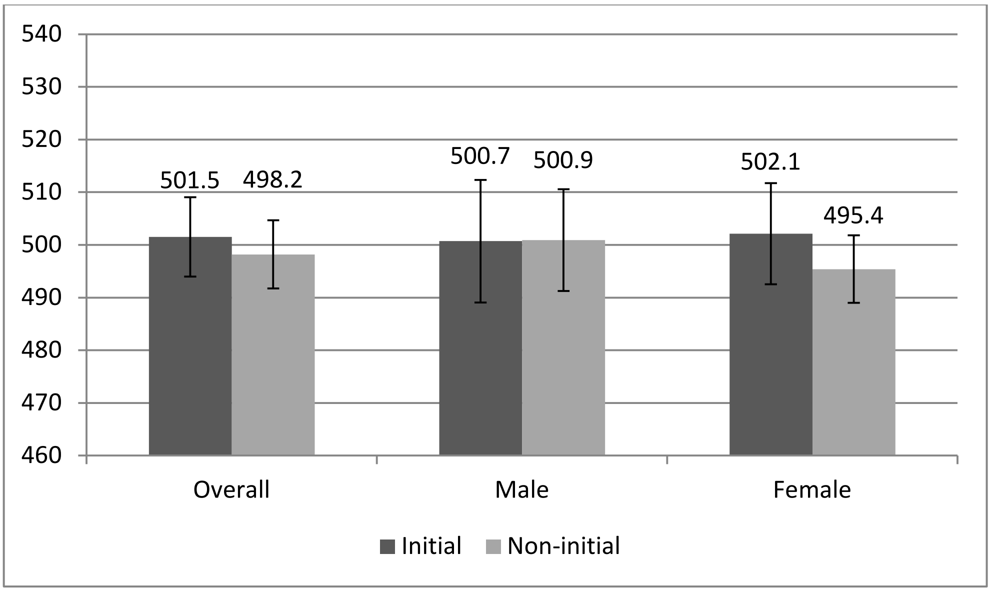


Figure 3.12. Mean Scores on Problem-solving and for Male and Female Students in Initial and Non-initial Schools.

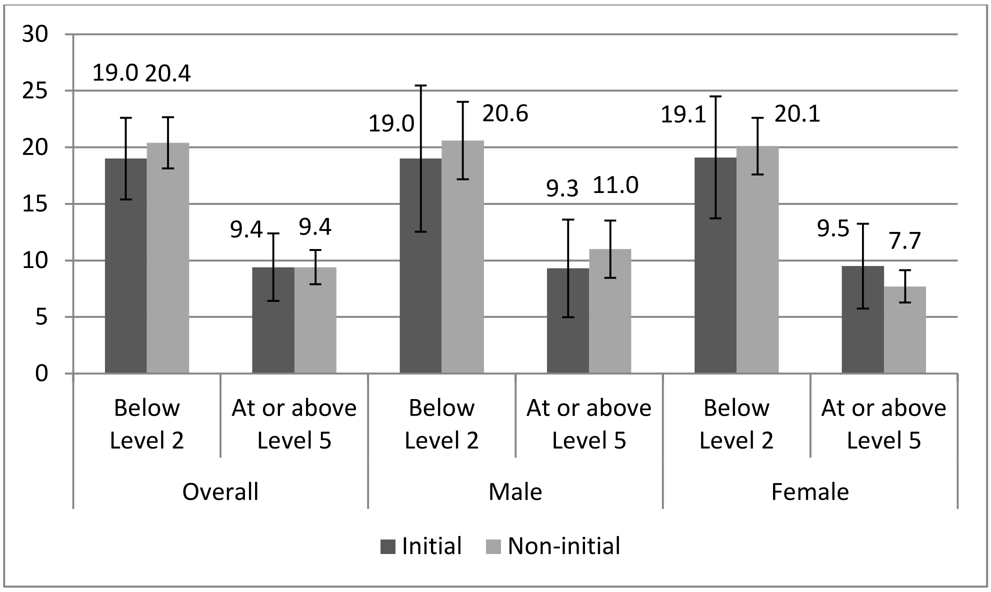


Figure 3.13. Percentage of Students Performing Below Level 2 and At or Above Level 5 on Problem-solving and for Male and Female Students in Initial and Non-initial Schools.

3.6 Conclusion

Comparison of the performance of students in Initial and Non-initial schools showed few significant differences on the print mathematics, computer-based mathematics, or computer-based problem-solving scales. There was a consistent pattern of results on the mathematics scales that showed small advantages in favour of students in Initial schools. In the comparison of male and female performance, two significant differences were observed: male students at Initial schools had higher scores than those at Non-initial schools on the Interpreting process subscale; and female students at Initial schools had higher scores than those at Non-initial school on the Shape & Space content subscale.

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, where performance was significantly below the OECD average in both 2003 and 2012 (Perkins et al., 2013). Similar issues were identified across a number of English-speaking countries on Space & Shape as well as other subscales, and points related to the teaching of geometry and trigonometry were also raised. In the comparison of Initial and Non-initial students reported here, those in Initial schools performed slightly better than those in Non-initial schools and achieved a mean score that was not significantly different from the OECD average. The pattern was apparent for both male and female students, with the largest gains observed for female students in Initial schools. Owing to the small numbers in the Initial schools, the results should be interpreted cautiously but they indicate that Project Maths may go some way to addressing the historic problem with PISA Space & Shape.

A general trend was observed in the results such that students in Initial schools had slightly higher scores, and this was usually manifest in fewer low-achieving students and more high-achieving students. However, the proportions of low-achieving female students are almost identical in Initial and Non-initial schools on the mathematics scales and subscales, indicating that the small differences that were observed in favour of Initial schools can be attributed to stronger performance among males.

4. Student Attitudes and Engagement

PISA 2012 included questions on students' attitudes towards and engagement with school, and with mathematics in particular. Since one of the aims of Project Maths is to improve student engagement with mathematics, this chapter examines the respective attitudes of students in Initial and Non-initial schools to identify any differences, and reports the correlations with performance on print mathematics, computer-based mathematics, and problem-solving for both school categories. For scales on which differences were identified, an item-by-item analysis explores the precise points on which students' attitudes differed. Gender differences are also reported, both within and between Initial and Non-initial schools.

4.1 Scale Scores and Correlations with Achievement

As part of PISA 2012, students answered a detailed questionnaire on their experiences of learning mathematics and of problem-solving, their attitude to school, and their perception of their mathematics teachers. Based on their responses, 14 scales of attitudes and behaviour were generated (Table 4.1). The questions used to compose each scale are listed throughout the chapter in tables indicating how Initial and Non-initial students responded. The average score for each scale across OECD countries is 0.0 and the standard deviation is 1.0.

Perkins et al. (2013) report the scale means for Ireland and on average across OECD countries. Table 4.1 gives the mean scores and standard errors for Initial and Non-initial schools; the Non-initial mean is close to the national mean in most cases since students in Non-initial schools account for the majority of the national sample. Significant differences between Initial and Non-initial schools are indicated in Table 4.1, along with correlations between scale scores and achievement on print mathematics, computer-based mathematics, and problem-solving. The rest of this chapter looks at the items which comprise each of the scales of behaviour and attitudes to identify any underlying differences between Initial and Non-initial students.

As the focus of this report is on differences between Initial and Non-initial schools, only scales on which results are significantly different are considered in detail while the others are reported in Appendix A4. There are seven scales on which students in Initial and Non-initial schools differed significantly, with no immediately obvious pattern in the differences: for some variables, one group is above the OECD average and the other below and vice versa. Inspection of the correlations suggests that none of these variables is very strongly associated with achievement on print mathematics, computer-based mathematics, or problem-solving but there are several correlations in the moderate-to-strong and moderate ranges. Some correlations in the weak-to-moderate range are also statistically significant. The magnitude and direction of the correlations are also similar in Initial and Non-initial schools.

4.2 Intrinsic motivation

Students in Initial schools were significantly below the average across OECD countries on the intrinsic motivation scale while students in Non-initial schools were significantly above it. Students were asked about their intrinsic motivation towards mathematics, with questions on their interest and enjoyment (Table 4.2). For both Initial and Non-initial students, there are slightly higher levels of

Table 4.1

Scales of Attitudes and Behaviour: Mean Scores and Correlations with Achievement in Initial and Non-initial Schools

	Initial				Non-initial				Initial-Non-initial
	M (*SE*)	Maths *r*	CBA Maths *r*	PS *r*	*M* (*SE*)	Maths *r*	CBA Maths *r*	PS *r*	*M* (*SE*)
Attitudes, activities	0.22 (0.05)	.04	-.01	-.01	0.20 (0.02)	***.10****	***.10****	***.11****	0.02 (0.05)
Attitudes, outcomes	0.16 (0.05)	.08	.04	.08	0.11 (0.02)	***.08****	***.12****	***.12****	0.05 (0.05)
Belonging	0.08 (0.06)	-.01	-.03	.04	-0.03 (0.02)	.01	.01	.03	0.11 (0.06)
Intrinsic motivation	-0.11 (0.05)	***.24****	***.18****	***.16****	**0.06*** (0.02)	***.24****	***.21****	***.21****	**-0.17*** (0.05)
Instrumental motivation	0.08 (0.05)	***.18****	.10	***.16****	0.13 (0.02)	***.14****	***.13****	***.15****	-0.05 (0.05)
Perseverance	0.05 (0.02)	***.32****	***.26****	***.30****	0.15 (0.02)	***.26****	***.21****	***.25****	-0.10 (0.03)
Mathematics self-efficacy	-0.06 (0.04)	***.53****	***.41****	***.42****	0.02 (0.02)	***.55****	***.47****	***.47****	-0.08 (0.04)
Mathematics self-concept	-0.17 (0.06)	***.47****	***.39****	***.33****	**-0.04*** (0.02)	***.40****	***.34****	***.33****	**-0.13*** (0.06)
Mathematics anxiety	**0.23*** (0.05)	***-.41****	***-.33****	***-.27****	0.10 (0.05)	***-.38****	***-.31****	***-.31****	**0.13*** (0.07)
Self-responsibility for failure	**0.05*** (0.05)	***-.30****	***-.26****	***-.29****	-0.11 (0.02)	***-.19****	***-.16****	***-.16****	**0.16*** (0.05)
Openness to problem-solving	0.00 (0.05)	***.42****	***.36****	***.36****	-0.02 (0.02)	***.40****	***.36****	***.31****	0.02 (0.05)
Mathematics-related behaviours	-0.55 (0.05)	***.21****	***.14****	***.19****	**-0.42*** (0.02)	***.14****	***.13****	***.16****	**-0.13*** (0.05)
Mathematics-related intentions	-0.30 (0.05)	.11	.07	.01	**-0.11*** (0.02)	***.07****	.03	.03	**-0.19*** (0.05)
Mathematics-related subjective norms	0.04 (0.02)	.09	.05	.01	**0.13*** (0.02)	.00	.04	-.01	**-0.09*** (0.03)

Note. Significantly higher mean scores in bold. Significant correlations in bold italics.

Table 4.2

Percentages of Students who Agree or Disagree with various Statements about their Intrinsic Motivation to Learn Mathematics in Initial and Non-initial Schools

	Initial		Non-initial	
	% Strongly agree/Agree (SE)	*% Strongly disagree/Disagree (SE)*	*% Strongly agree/Agree (SE)*	*% Strongly disagree/Disagree (SE)*
I enjoy reading about mathematics	27.6 (2.22)	72.4 (2.22)	**33.6*** (0.87)	66.4 (0.87)
I look forward to my mathematics lessons	31.6 (2.36)	68.4 (2.36)	**40.6*** (1.17)	59.4 (1.17)
I do mathematics because I enjoy it	27.9 (1.99)	72.1 (1.99)	**37.4*** (1.05)	62.6 (1.05)
I am interested in the things I learn in mathematics	44.7 (2.61)	55.3 (2.61)	49.8 (1.09)	50.2 (1.09)

Note. Significantly higher mean scores in bold.

disagreement with statements on reading about mathematics, enjoying mathematics, and being interested in learning about mathematics with students in Initial schools demonstrating lower levels of agreement. It is arguable that responses to any of these questions were greatly influenced by whether or not students were taking Project Maths, but the question on looking forward to mathematics lessons is of particular note. Fewer than one third of students in Initial schools agree with the statement compared to just over two-fifths in Non-initial schools. There is no difference between the ratings of male and female students within the Initial or Non-initial groups (Table A4.1) but the difference between Initial and Non-initial schools is apparent for both boys and girls. Overall, this scale has a weak-to-moderate association with achievement (Table 4.1).

4.3 Mathematics Self-concept

Students in Ireland had similar levels of confidence in their mathematical abilities to the average across OECD countries, and this is reflected in the score for students in Non-initial schools, which is the same as the national average. However, ratings of mathematics self-concept among students in Initial schools are significantly lower than among students in Non-initial schools and Table 4.3 shows where the differences lie. A majority of students in both school groups disagree with the first statement, about not being good at mathematics, but most students in both groups show broadly negative attitudes on the other items. Students in Initial schools are significantly less likely to agree that they get good grades in mathematics and that they understand the most difficult work. Male students have a significantly higher mean score for mathematics self-concept than female students in both Initial (-0.01 for males and -0.30 for females) and Non-initial schools (0.09 for males and -0.17 for females) (see Table A4.1 in Appendix A4).

4.4 Mathematics Anxiety

Mathematics anxiety usually has to do with the impact of intrusive negative thoughts on working memory while completing tasks in mathematics (Ashcraft & Kirk, 2001), but the PISA anxiety scale also includes items on more general feelings of worry and concern related to mathematics. Levels of mathematics anxiety among students in Ireland were significantly higher than on average across OECD countries, and the Non-initial group had similarly high levels. The ratings of students in Initial

Table 4.3

Percentages of Students who Agree or Disagree with various Statements about their Mathematics Self-concept in Initial and Non-initial Schools

	Initial		Non-initial	
	Strongly agree/ Agree % (SE)	*% Strongly disagree/Disagree (SE)*	*% Strongly agree/Agree (SE)*	*% Strongly disagree/Disagree (SE)*
I am just not good at mathematics	43.6 (2.95)	56.4 (2.95)	39.8 (1.00)	60.2 (1.00)
I get good grades in mathematics	54.5 (2.90)	45.5 (2.90)	**61.7*** (1.04)	38.3 (1.04)
I learn mathematics quickly	45.6 (2.76)	54.4 (2.76)	46.5 (1.01)	53.5 (1.01)
I have always believed that mathematics is one of my best subjects	29.7 (2.42)	70.3 (2.42)	34.4 (0.96)	65.6 (0.96)
In my mathematics class, I understand even the most difficult work	29.4 (2.22)	70.6 (2.22)	**34.4*** (0.81)	65.6 (0.81)

Note. Significantly higher mean scores in bold.

Table 4.4
Percentages of Students who Agree or Disagree with various Statements about their Mathematics Anxiety in Initial and Non-initial Schools

	Initial		Non-initial	
	Strongly agree/ Agree % (SE)	*% Strongly disagree/Disagree (SE)*	*% Strongly agree/Agree (SE)*	*% Strongly disagree/Disagree (SE)*
I often worry that it will be difficult for me in mathematics classes	72.5 (2.55)	27.5 (2.55)	69.6 (0.91)	30.4 (0.91)
I get very tense when I have to do mathematics homework	**43.3*** (2.13)	56.7 (2.13)	35.7 (1.03)	64.3 (1.03)
I get very nervous doing mathematics problems	**37.5*** (2.66)	62.5 (2.66)	29.4 (0.93)	70.6 (0.93)
I feel helpless when doing a mathematics problem	32.3 (2.44)	67.7 (2.44)	27.9 (0.88)	72.1 (0.88)
I worry that I will get poor grades in mathematics	**68.6*** (2.51)	31.4 (2.51)	61.8 (1.03)	38.2 (1.03)

Note. Significantly higher mean scores in bold.

schools were significantly higher still than those at the Non-initial schools and the differences were apparent on three of the scale items (Table 4.4). Two of those items referred to the conventional understanding of mathematics anxiety impinging on performance, when doing homework or when working on mathematics problems. The third item was at the more general level of worrying about grades and presents a contrast to the mathematics self-concept item where the majority of students believe they get good grades in mathematics. As with the national average, mathematics anxiety scores were significantly higher for female students than for males in both the Initial (-0.002 for males and 0.43 for females) and Non-initial schools (-0.05 for males and 0.27 for females). Notably, female students in Initial schools had a significantly higher mean score (0.43) than those in Non-initial schools (0.27) while scores for male students did not differ across school category (see Table A4.1 in Appendix A4). As highlighted in Table 4.1, mathematics anxiety was significantly negatively correlated with performance on both computer- and paper-based mathematics and on problem-solving.

4.5 Self-responsibility for Failure in Mathematics

The scale on perceived self-responsibility for failure in mathematics is based on a vignette about mathematics tests: “Each week your mathematics teacher gives a short quiz. Recently you have done badly on these quizzes. Today you are trying to figure out why”. Table 4.5 sets out the likelihood of students’ feelings in the situation described. On the scale reported in Table 4.1, higher scores indicate that students attribute failure to their own ability or effort while lower scores indicate attribution to other factors, including their teacher, the course material, and luck. Students in Non-initial schools (-0.11) were significantly more likely to attribute failure to others than students on average in OECD countries (0.00). Students in Initial schools were more likely to attribute failure to themselves (0.05). There were significant group differences on three of the items. More Non-initial students thought it was *Not at all likely* that the course material was too hard or that the teacher failed to inspire students’ interest while more Initial students thought it was *Likely* that they made bad guesses. There were significant gender differences in both the Initial and Non-initial groups, such that females had higher rates of self-attribution of responsibility for failure (see Table

Table 4.5
Percentages of Students' Ratings of the Likelihood of Statements about Responsibility for Failure in Mathematics in Initial and Non-initial Schools

	Initial				Non-initial			
	Very likely % (*SE*)	Likely % (*SE*)	Slightly likely % (*SE*)	Not at all likely % (*SE*)	Very likely % (*SE*)	Likely % (*SE*)	Slightly likely % (*SE*)	Not at all likely % (*SE*)
I'm not very good at solving mathematics problems	18.6	37.0	32.0	12.4	15.12	38.7	32.1	14.1
	(1.92)	(2.22)	(2.54)	(1.82)	(0.65)	(1.01)	(0.93)	(0.56)
My teacher did not explain the concepts well this week	18.5	30.1	33.1	18.3	14.6	30.7	32.9	21.8
	(1.82)	(2.52)	(2.33)	(1.97)	(0.73)	(0.93)	(0.89)	(0.87)
This week I made bad guesses on the test	7.8	**39.5***	31.5	21.2	8.1	32.7	35.2	24.0
	(1.50)	(2.69)	(2.77)	(1.98)	(0.51)	(0.77)	(0.94)	(0.91)
Sometimes the course material is too hard	33.6	43.0	18.7	4.7	30.4	41.3	21.2	**7.1***
	(2.30)	(2.52)	(1.70)	(1.09)	(0.91)	(0.94)	(0.69)	(0.50)
The teacher did not get students interested in the material	25.9	28.3	32.3	13.5	21.8	29.1	29.1	**20.0***
	(2.16)	(2.23)	(2.45)	(1.96)	(0.81)	(1.01)	(0.92)	(0.77)
Sometimes I am just unlucky	10.9	27.9	29.8	31.4	12.4	25.2	32.1	30.3
	(1.74)	(2.30)	(2.25)	(2.53)	(0.58)	(0.79)	(0.97)	(0.91)

Note. Significantly higher mean scores in bold.

A4.1 in Appendix A4). Furthermore, female students in Initial schools had higher average scores than females in Non-initial schools.

4.6 Mathematics-related Behaviours

Students were asked about the frequency with which they engage in mathematics-related activities, including formal participation in mathematics clubs or competitions and informal talking to friends about mathematics problems. Ireland was significantly below the OECD average on the scale of mathematics behaviours, and the Non-initial schools had a similar score to the national average (-0.42) while students in Initial schools were significantly lower still (-0.55). Table 4.6 shows the eight behaviours in question and there was no significant difference between Initial and Non-initial schools on any of them, though this is mainly due to the low rates of participation overall: Fewer than 10% of students are 'often' or 'almost always' involved in six of the eight activities with between 10% and 20% taking part in the other two. Looking at the difference between Initial and Non-initial schools, there is a consistent pattern of slightly lower engagement in Initial schools and this may have contributed to the significant scale score difference. The low variation in scores was also apparent in the gender comparisons, with similar results for boys and girls overall. However, female students in Initial schools (-0.59) have significantly lower mathematics-related behaviour scores than female students in Non-initial schools (-0.44) (see Table A4.1 in Appendix A4).

4.7 Mathematics-related Intentions

PISA is concerned with students' future study and work plans and higher scores on the intentions scale show preferences for mathematics courses and careers over courses and careers in English or Science. Students in Ireland had significantly lower mathematics-related intentions than on average across OECD countries; as with the other scales, the average score in Non-initial schools (-0.11) is close to the national average. Students in Initial schools had significantly lower scores (-0.30) than those Non-initial schools. In general, the preferences expressed were not in favour of mathematics

Table 4.6
Percentages of Students who Agree or Disagree with various Statements about their Mathematics-related Behaviours in Initial and Non-initial Schools

	Initial		Non-initial	
	Always or almost always/Often % (SE)	*Sometimes/Rarely or never % (SE)*	*Always or almost always/Often % (SE)*	*Sometimes/Rarely or never % (SE)*
I talk about mathematics problems with my friends	7.6 (1.51)	92.4 (1.51)	10.3 (0.67)	89.7 (0.67)
I help my friends with mathematics	18.5 (2.01)	81.5 (2.01)	19.1 (0.83)	80.9 (0.83)
I do mathematics as an extracurricular activity	4.2 (1.04)	95.8 (1.04)	5.6 (0.38)	94.4 (0.38
I take part in mathematics competitions	1.5 (0.57)	98.5 (0.57)	2.4 (0.28)	97.6 (0.28)
I do mathematics more than 2 hours a day outside of school	2.7 (0.75)	97.3 (0.75)	4.3 (0.35)	95.7 (0.35)
I play chess	7.8 (1.11)	92.2 (1.11)	9.8 (0.61)	90.2 (0.61)
I programme computers	11.8 (1.78)	88.2 (1.78)	12.5 (0.65)	87.5 (0.65)
I participate in a mathematics club	0.7 (0.43)	99.3 (0.43)	0.9 (0.20)	99.1 (0.20)

Note. Significantly higher mean scores in bo.ld

courses or careers, except on the item about being willing to work harder in class than required; a majority of students in both school groups would work harder in mathematics class than English class but the majority was larger in Non-initial schools (Table 4.7); a possible interpretation here is that students in Initial schools are already working as hard as they can. The other three items on which Initial and Non-initial differed significantly saw Initial students select science skills, classes, and careers over mathematics. There was a significant gender gap in Non-initial schools, with boys

Table 4.7
Percentages of students who Intend to take Additional Mathematics- or English-related Actions in Initial and Non-initial Schools

	Initial		Non-initial	
	% (SE)	*% (SE)*	*% (SE)*	*% (SE)*
	Maths courses	*English courses*	*Maths courses*	*English courses*
Intend to take additional courses after school finishes	43.9 (2.31)	56.1 (2.31)	47.4 (1.04)	52.6 (1.04)
	Maths skills	Science skills	Maths skills	Science skills
Major in a subject in college that requires particular skills	29.3 (2.56)	70.7 (2.56)	**38.6*** (1.06)	61.4 (1.06)
	Maths class	English class	Maths class	English class
Are willing to study harder in class than is required	52.7 (2.52)	47.3 (2.52)	**59.2*** (0.84)	40.8 (0.84)
	Maths classes	Science classes	Maths classes	Science classes
Plan on taking as many particular classes as possible during my education	45.0 (2.95)	55.0 (2.95)	**52.8*** (1.15)	47.2 (1.15)
	Maths	Science	Maths	Science
Plan to pursue a career that involves a lot of…	33.3 (2.73)	66.7 (2.73)	**39.6*** (1.03)	60.4 (1.03)

Note. Significantly higher mean scores in bold.

having higher mathematics-related intentions (see Table A4.1 in Appendix A4). The gender difference was not significant in Initial schools with very low scores for both genders.

4.8 Subjective Norms

Mathematics-related subjective norms have to do with the attitudes towards mathematics of students' peers and parents, and higher scores indicate a perception by students of more positive attitudes. Compared to the average across OECD countries, students in Ireland reported significantly more positive attitudes, which is also reflected in the Non-initial average scale score (0.13). Students in Initial schools had lower scores (0.05) than those in Non-initial schools but were still significantly above the OECD average. Only one of the scale items showed a significantly different pattern of responses such that more students in Non-initial schools indicated that their friends enjoy taking mathematics tests than students in Initial schools, though the percentages were low for both groups (Table 4.8). There were no significant gender differences within or between Initial and Non-initial schools (see Table A4.1 in Appendix A4).

4.9 Conclusion

The aim of this chapter was to identify aspects of students' behaviour and attitudes towards mathematics that differ between Initial and Non-initial schools. While there were some significant differences between the school groups and between male and female students, these generally indicated more negative attitudes among students in Initial schools. However, close attention should be paid to a number of other factors when interpreting these differences. There may be interactions between some of the variables, such as the complex relationship between mathematics self-concept, anxiety, performance, and gender. These issues are explored further in the models of achievement in Chapter 8 which includes four of the attitude scales reported here on the basis of significant differences between Initial and Non-initial schools and moderate correlations with achievement. The four scales are: Intrinsic motivation, Mathematics self-concept, Mathematics anxiety, and Self-responsibility for failure.

Table 4.8

Percentages of Students who Agree or Disagree with various Statements about their Mathematics-related Subjective Norms in Initial and Non-initial Schools

	Initial		Non-initial	
	Strongly agree/ Agree % (SE)	*% Strongly disagree/Disagree (SE)*	*% Strongly agree/Agree (SE)*	*% Strongly disagree/Disagree (SE)*
Most of my friends do well in mathematics	67.1 (2.51)	32.9 (2.51)	67.6 (1.21)	32.4 (1.21)
Most of my friends work hard at mathematics	61.9 (2.52)	38.1 (2.52)	63.2 (1.06)	36.8 (1.06)
My friends enjoy taking mathematics tests	6.5 (1.23)	93.5 (1.23)	**9.8*** (0.55)	90.2 (0.55)
My parents believe it's important for me to study mathematics	93.8 (1.13)	6.2 (1.13)	94.9 (0.45)	5.1 (0.45)
My parents believe that mathematics is important for my career	81.8 (2.00)	18.2 (2.00)	82.7 (0.81)	17.3 (0.81)
My parents like mathematics	57.8 (2.35)	42.2 (2.35)	62.4 (1.02)	37.6 (1.02)

Note. Significantly higher mean scores in bold.

The first attitudinal variable on which a difference was observed was Intrinsic motivation. Non-initial schools were above the OECD average while Initial schools were below it. For Mathematics self-concept, both school groups were below the OECD average but Initial schools had an even lower mean score; a similar pattern emerged for anxiety with Non-initial schools significantly above the OECD average and Initial schools higher still. On the scale of Self-responsibility for failure in mathematics, Initial students were more likely to attribute responsibility for failure in mathematics to their own ability or effort. Both groups scored low on Mathematics-related behaviours and intentions to work in or study mathematics, again with students in Initial schools lower still on average. Finally, the subjective norms of students in Non-initial schools were more positive than those of students in Initial schools.

There is some evidence here of more negative attitudes towards mathematics among students in Initial schools, with the high levels of anxiety a possible cause of concern. Students in Initial schools are less likely to report enjoying mathematics and are less likely to choose mathematics courses or careers. Project Maths is intended to improve students' attitudes and interest in mathematics so the results here may be somewhat surprising. On the other hand, these students were among the first to adopt the Project Maths curriculum and their attitudes may reflect some of the challenges and uncertainties in that transition.

5. School-related Factors

In this chapter, mean scores on a range of indices related to school organisation and resources, school climate, school leadership and management, and teacher behaviour and support for students were compared between Initial and Non-initial schools. The scales, which are based on questions on the school and student questionnaires administered as part of PISA 2012, can provide insights into how school-related factors are associated with student performance. The chapter concludes with a summary of principals' views on the effects of Project Maths on teaching and learning, and a description of initiatives other than Project Maths that were being implemented in schools in Ireland around the time that PISA 2012 took place.

Although mathematics was the major assessment domain in PISA 2012, many questions underlying the scales described in this chapter do not relate specifically to mathematics. Hence, care should be exercised in interpreting associations between scale scores and mathematics performance, which might have been different had the questions underpinning the scales been more closely related to mathematics. For example, the school leadership scale is based in part on the frequency with which principal teachers report that they use student performance results to develop the school's educational goals and make sure that teachers' professional development activities are in accordance with the teaching goals of the school. Though these do not relate specifically to mathematics, they may still be relevant for promoting mathematics at school level and may be associated with mathematics performance. It should also be noted that, where questionnaire items are based on the responses of principal teachers, those responses are applied to all PISA students in the school. Hence, the resulting indices are computed at the student level, even if based on responses provided by principals.

5.1 School Organisation and Resources

The indices associated with school organisation and resources are described below:

- *Extracurricular mathematics activities at school*. This index was derived from school principals' reports on whether their schools offered each of four extracurricular activities in mathematics to students' in the modal grade for 15-year olds (third year in Ireland). These were mathematics club, mathematics competitions, computer clubs and extra lessons. This index was developed by summing up the number of activities that a school offers.[3]
- *Use of assessment information*. School principals indicated whether students' assessments are used for a range of purposes such as to inform parents about their child's progress and make decisions about students' retention or promotion. The index was derived by adding up the number of "yes" responses to these questions.
- *School responsibility for curriculum and assessment*. School principals indicated whether "principals", "teachers", "school governing board", "regional or local education authority", or "national education authority" had a considerable responsibility for tasks such as

[3] For "additional mathematics lessons", one point was allocated if principals responded with "enrichment mathematics only", "remedial mathematics only" or "without differentiation depending on the prior achievement level of the students"; and two points were allocated if school principals responded "both enrichment and remedial mathematics".

establishing student assessment policies, choosing which textbooks are used, determining course content, and deciding which courses are offered. The index is based on the ratio of the number of responsibilities that “principals” and/or “teachers” have for these four items to the number of responsibilities that “regional or local education authority” and/or “national education authority” have. This index has an OECD mean of 0.0 and a standard deviation of 1.0. Positive values on this index indicate relatively more responsibility for schools than for local, regional or national education authorities.

- *School responsibility for resource allocation*. School principals were asked to report whether “principals”, “teachers”, “school governing board”, “regional or local education authority” or “national education authority” have a considerable responsibility for such tasks as selecting teachers for hire, dismissing teachers and formulating the school budget. The resulting index is based on the ratio of the number of responsibilities that “principals” and/or “teachers” have for these six items to the number of responsibilities that “regional or local education authority” and/or “national education authority” have. Positive values on this index indicate relatively more responsibility for schools than for local, regional or national education authorities. This index has an OECD mean of 0.0 and a standard deviation of 1.0.
- *School educational resources*. School principals reported on their perceptions of the extent to which six factors hinder instruction at their school, including a shortage or inadequacy of science laboratory equipment and a shortage or inadequacy of computer software for instruction. Positive values on this scale indicate relatively better resources. The OECD average is 0.0 and the standard deviation is 1.0.
- *Computer availability*. The index was derived by dividing the number of computers available for educational purposes to students in the modal grade for 15-year-olds (Third year in Ireland) by the number of students in the modal grade for 15-year-olds.

Table 5.1 provides data on these indices for Initial and Non-initial schools, and gives correlations with the overall performance on PISA mathematics for students in the two school categories. The data show no difference between Initial and Non-initial schools in the range of Extra-curricular mathematics activities offered at school, or in the Use of assessment information to inform teaching and learning. Initial schools had significantly higher mean scores than Non-initial schools on School responsibility for curriculum and assessment and on Responsibility for resource allocation, while Non-initial schools had a significantly higher mean score on Quality of schools’ educational resources. Computer availability was not significantly different across the school types. Correlation coefficients between scores on the indices and student performance were weak and none reached statistical significance for either school group.

Scores for schools in Ireland were low on some of the indicators which are comparable across OECD countries. For example, mean scores of -0.35 (Initial schools) and -0.42 (Non-initial schools) on the index for Responsibility for resource allocation were well below the OECD average of 0.0. An additional index relating to school organisation and resources – *Ability grouping in mathematics classes* – was derived from two items based of school principals’ reports on whether their school organises mathematics instruction differently in the modal grade (Third year in Ireland) for student with differing abilities. This index has three categories: (1) no mathematic classes study at different levels of difficulty or study different content; (2) some mathematics classes study at different levels

Table 5.1

Mean Scores, Standard Errors, and Correlations with Mathematics Achievement on Indices of School Organisation and Resources in Initial and Non-initial Schools

	Initial			Non-initial		
	M	*SE*	*r*	*M*	*SE*	*r*
Extra-curricular maths activities at school	1.80	0.11	-.03	1.80	0.11	.06
Use of assessment information	4.29	0.03	-.11	4.91	0.11	-.07
School responsibility for curriculum and assessment	**0.35**	0.02	-.08	0.09	0.06	.01
Responsibility for resource allocation	**-0.37**	0.01	.15	-0.43	0.02	.04
Quality of schools' educational resources	**-0.22**	0.01	.08	0.13	0.08	.06
Computer availability	0.71	0.01	.07	0.64	0.04	-.06

Note. Where mean scores are in bold, they are significantly higher (or lower) in Initial than in Non-initial schools. Significant correlation coefficients are in bold italics. Significance of correlation was evaluated by computing t-values (coefficients over their standard errors) and assessing significance using 80 degrees of freedom (the number of variance strata in the BRR variance estimation method) at the .05 level.

of difficulty or study different content; and (3) all mathematics classes study at different levels of difficulty or study different content. In Ireland, 59% of students in both Initial and Non-initial schools had principal teachers who indicated that all mathematics classes study at different levels of difficulty or different content, while the remainder were in schools whose principals said that some mathematics classes study at different levels of difficulty or content. No principals in either school type indicated that no mathematics classes study at different levels of difficulty. Hence, based on the information in this index, there are no differences in broad arrangements for grouping students for mathematics instruction across Initial and Non-initial schools.

5.2 School Climate

Variables associated with school climate in PISA are based on the assumption that learning requires an orderly and cooperative environment inside and outside the classroom (OECD, 2013b). Five indices, each with an OECD average of 0.0, and a standard deviation of 1.0, are considered:

- *Teacher-student relations.* This index is based on students' responses to questions on whether and to what extent they agree with statements on their relationship with their teachers at school, including whether they get on with their teachers, whether teachers are interested in their personal well-being, whether teachers take the student seriously, and whether teachers are a source of support to students. High values on the index indicate a more positive perception of student-teacher relations.
- *Disciplinary climate in mathematics classes.* This index is based on students' reports of the frequency with which interruptions occurred in mathematics lessons. These include the frequency with which students don't listen to what the teacher says, there is noise and disorder, students cannot work well, and students don't start working for a long time after the lesson begins. Negative behaviours were reverse-coded so that higher values on the index indicate that students perceive the disciplinary climate in the classroom to be relatively better.
- *Student-related factors affecting school climate.* Principal teachers indicated the extent to which they believed learning in their school was hindered by a number of factors, including student truancy, students skipping classes, students arriving late for school, students not

attending compulsory school events or excursions, and students lacking respect for teachers. Higher values on this index indicate that principals believe that student behaviour hinders learning to a lesser extent, and negative values indicate that student behaviour hinders learning to a greater extent, compared to the OECD average.

- *Teacher-related factors affecting school climate*. Principal teachers reported on the extent to which they believed learning in their school was hindered by such factors as students not being encouraged to reach their full potential, poor teacher-student relations and teachers' low expectations of students. Positive responses on the resulting index reflect principals' perceptions these issues affect learning to a lesser extent, and negative values to a greater extent, compared with the OECD average.
- *Teacher morale. S*chool principals indicated their level of agreement with statements such as 'the morale of teachers in this school is high', 'teachers work with enthusiasm', and 'teachers value academic achievement'. Positive values on the resulting scale indicate that principals believe that teacher morale is higher than the OECD average, and negative values indicate that it is lower.

Table 5.2 shows the mean scores and correlations with overall PISA mathematics achievement for students in Initial and Non-initial schools. None of differences between mean scores reached statistical significance. It is notable that the mean scores on Teacher morale for both Initial and Non-initial schools are well above the OECD average of 0.0. On the other hand, both school types record negative mean scores on the index of Student-related factors affecting school climate. In Non-initial schools, all of the correlations between school climate indices and mathematics achievement are statistically significant, with weak to moderate correlations with mathematics achievement for Disciplinary climate (both school types) and Student-related factors affecting school climate (Non-initial schools). For Initial schools, there are significant positive correlations for three scales: Teacher Student Relations, Disciplinary Climate, and School-related factors affecting disciplinary climate.

5.3 School Leadership and Management

A third cluster of indices relate to school leadership and management. Each index has an OECD mean of 0.0 and a standard deviation of 1.0, and each is based on the frequency with which the principal engaged in certain activities during the previous school year. The indices are:

Table 5.2
Mean Scores, Standard Errors, and Correlations with Mathematics Achievement on Indices of School Climate in Initial and Non-initial Schools

	Initial			Non-initial		
	M	*SE*	*r*	*M*	*SE*	*r*
Teacher Student Relations	0.03	0.05	***.15***	0.10	0.02	***.07***
Disciplinary Climate	0.06	0.06	***.24***	0.13	0.03	***.26***
Student-related Factors Affecting School Climate	-0.14	0.02	***.12***	-0.08	0.07	***.22***
Teacher-related Factors Affecting School Climate	-0.01	0.02	.05	0.11	0.08	***.13***
Teacher Morale	0.43	0.01	.02	0.50	0.08	***.07***

Note. Where mean scores are in bold, they are significantly higher (or lower) in Initial than in Non-initial schools. Significant correlation coefficients are in bold italics.

- *Framing and communicating schools' goals and curricular development.* This index was derived from school principals' responses about the frequency with which they were involved in activities such as using student performance results to develop the school's educational goals and ensuring that professional development activities of teachers are in accordance with the teaching goals of the school.
- *School management – Instructional leadership.* This index was derived from school principals' responses about the frequency with which they were involved in such activities as promoting teaching practices based on recent educational research and praising teachers whose students are actively participating in learning. A higher score indicates greater involvement in management-related instructional leadership activities.
- *Promoting school leadership and professional development*. This index was derived from principal teachers' responses to questions that asked about the frequency with which they engaged in such activities as taking the initiative to discuss matters when a teacher has a problem in his/her classroom, and paying attention to disruptive behaviours in classrooms. Higher scores indicate greater involvement in such leadership activities.
- *School management – Teacher participation.* This index is based on the frequency with which principal teachers reported involvement in activities such as providing school staff with opportunities to participate in school decision making, and building a school culture of continuous improvement.

Table 5.3 shows the mean scores and correlations with overall PISA mathematics achievement for students in Initial and Non-initial schools on the school leadership indices. In the case of Initial schools, all of the leadership indices have negative mean scores. Indeed, the mean scores for Initial schools on the indices of School management – instructional leadership and for Promoting school improvement and professional development are particularly low, though these scales were generic and not specific to mathematics. Correlations between scores on the indices and mathematics achievement are all weak to moderate. In the case of School management – instructional leadership and Promoting school improvement and professional development, the correlation coefficients for Initial schools are significant and negative.

Table 5.3
Mean Scores, Standard Errors, and Correlations with Mathematics Achievement on Indices of School Leadership in Initial and Non-initial Schools

	Initial Schools			Non-initial Schools		
	M	*SE*	*r*	*M*	*SE*	*r*
Framing and communicating schools' goals and curricular development	-0.08	0.02	***.14***	-0.07	0.09	.02
School management – instructional leadership	**-0.29**	0.02	.06	0.08	0.09	.00
Promoting school improvement and professional development	**-0.15**	0.01	.02	0.06	0.09	***-.11***
School management: teacher participation	-0.09	0.01	***.14***	0.10	0.10	-.05

Note. Where mean scores are in bold, they are significantly higher (or lower) in Initial than in Non-initial schools. Significant correlation coefficients are in bold italics.

5.4 Teacher Practices and Support for Students in Mathematics

The fourth cluster of behaviours considered here relates to teacher practices and support for students. All have an OECD average of zero and a standard deviation of one. All of the indices in this cluster refer specifically to teacher practices in mathematics lessons.

- *Teacher behaviour – Formative assessment*. This index is based on the frequency (every lesson, most lessons, some lessons, hardly ever or never) with which students in PISA 2012 reported that their teacher give them feedback on how well they are doing in mathematics classes, on their strengths and weaknesses in mathematics, and on what they need to do to become better at mathematics.
- *Teacher behaviour – Student orientation*. This index is based on students' reports on the frequency with which the teacher gives different work to classmates who have difficulties learning and/or to those who can advance faster, the teacher assigns projects that require at least one week to complete, the teacher has students work in small groups to come up with a joint solution to a problem or task, and the teacher asks students to help plan classroom activities or topics.
- *Teacher behaviour – Teacher-directed instruction*. This index is based on students' reports of the frequency with which teachers engage in such practices as asking students to present their thinking or reasoning at some length, asking questions as to whether students understood what was taught, and telling students what they have to learn.
- *Teacher support* for students. This index is based on the frequency with which students reported that teachers engage in such practices as providing extra help when needed, continuing teaching until students understand, and showing interest in every student's learning.

Table 5.4 summarises the outcomes. There was a significant difference in favour of Initial schools on the index of Teacher behaviour – student orientation, though mean scores for both Initial and Non-initial schools were well below the OECD average on this index, indicating relatively low levels of orientation. Average scores for two other indices, Teacher behaviour – formative assessment, and Teacher behaviour – teacher-directed learning, were also below the corresponding OECD average scores, though the differences were smaller than for Teacher behaviour – student orientation. For Non-initial schools, correlations between the indices of Teacher behaviour – formative assessment,

Table 5.4
Mean Scores, Standard Errors, and Correlations with Mathematics Achievement on Indices of Teacher Practices and Support for Students in Initial and Non-initial Schools

	Initial			Non-initial		
	M	*SE*	*r*	*M*	*SE*	*r*
Teacher behaviour – Formative assessment	-0.11	0.04	-.09	-0.07	0.02	***-.14***
Teacher behaviour – student orientation	**-0.46**	0.04	-.10	-0.58	0.03	***-.22***
Teacher behaviour – Teacher-directed Instruction	-0.14	0.05	.00	-0.08	0.02	***-.06***
Teacher support for students	0.03	0.05	.09	0.08	0.02	.03

Note. Where mean scores are in bold, they are significantly higher (or lower) in Initial than in Non-initial schools. Significant correlation coefficients are in bold italics.

Teacher-behaviour – student orientation, and Teacher behaviour – teacher-directed instruction were all negative and significant.

5.5 Principal Teachers' Perceptions of the Effects of Project Maths

The school questionnaire in Ireland included eight statements designed to tap into principals' perceptions of the possible effects of Project Maths. These are compared for Initial and Non-initial schools (Table 5.5). Care should be exercised in interpreting differences between mean scores since these can be quite small, yet statistically significant.

Principal teachers in Initial schools tended to be more positive about the expected impact of Project Maths. For example, 88% of students in Initial schools had principal teachers who 'agreed' or 'strongly agreed' that Project Maths would improve mathematics standards in schools, compared with 78% in Non-initial schools. Whereas more students in Initial schools had principal teachers who expected an increase in the proportion of students taking the Junior Certificate examination at Higher level, there was no difference between Initial and Non-initial schools in relation to the Leaving Certificate. Marginally more students attending Initial schools (64%) than Non-initial schools (62%) had principals who believed that students are more engaged since the introduction of Project Maths.

More students in Non-initial schools (83%) than Initial schools (70%) had principal teachers who believed that their school was well resourced to implement Project Maths, and the difference in mean scores was statistically significant. However, fewer students in Non-initial schools (69%) than in Initial schools (83%) had principals who believed that teachers in their school were enthusiastic about Project Maths. In the same vein, fewer students in Non-initial schools (74%) than in Initial

Table 5.5
Percentages of Principals who 'Strongly agree' or 'Agree' with Statements about Project Maths and Mean Scores in Initial and Non-initial Schools

	Percent Strongly Agree or Agree		Mean Score (*SE*) on Scale	
Variable	Initial	Non-initial	Initial	Non-initial
School well-resourced to implement PM	70.2	82.6	**3.06** (0.01)	3.21 (0.03)
PM will improve maths standards in school	87.8	77.8	**3.14** (0.00)	2.91 (0.03)
PM will lead to more students in this school taking Higher level maths at JC Exam	85.5	77.5	**3.00** (0.0)	2.83 (0.03)
PM will lead to more students in this school taking Higher level maths at LC Exam	66.2	66.4	2.81 (0.01)	2.78 (0.03)
The support that maths teachers receive enables them to teach PM effectively	72.2	83.5	**2.88** (0.01)	3.00 (0.03)
Project Maths has been well-received by students in this school	68.6	77.1	2.80 (0.00)	2.84 (0.02)
No discernible change in scores since Project Maths was introduced	61.1	65.3	**2.56** (0.00)	2.66 (0.02)
Maths teachers in this school are enthusiastic about Project Maths	83.1	68.7	**2.93** (0.00)	2.76 (0.03)
Students are more engaged since the introduction of Project Maths	64.1	62.3	**2.74** (0.00)	2.66 (0.03)
Project maths will improve the effectiveness of maths teachers in this school	94.9	73.8	**3.12** (0.00)	2.80 (0.03)

Note. Where mean scores are in bold, they are significantly higher (or lower) in Initial than in Non-initial schools. Responses are on a four-point scale: Strongly agree, Agree, Disagree, and Strongly disagree.

schools (95%) had principals who believed that Project Maths would improve the effectiveness of mathematics teachers in their school, and again, the mean score for Non-initial schools was significantly lower than for Initial schools. On balance, students in Initial schools had principal teachers who were more positively disposed towards Project Maths, in terms of its effects on students and their teachers, compared with principals in Non-initial schools.

5.5.1 Implementation of Other Initiatives to Improve Mathematics in Schools

Principal teachers were asked to identify any other initiatives besides Project Maths that were being implemented in their school in the 2011-12 school year, with the purpose of improving performance on mathematics. Principal teachers of 36% of students in Non-initial schools identified at least one additional initiative. No principals in Initial school identified one other than Project Maths. The mean PISA mathematics score of students in Non-initial schools in which an initiative other than Project Maths was implemented was 491.6 (*SE* = 3.04), while that of students in Non-initial schools in which no initiative was being implemented was 508.0 (*SE* = 1.38). The difference was statistically significant, 95% CI [9.76, 23.04], suggesting that schools with lower-achieving students are more likely to implement additional measures to improve mathematics than schools with high achievers.

The initiatives identified by principal teachers varied in their scope. Some, such as learning support, might be expected to be widely available and hence may not constitute an initiative at all. The full list of initiatives included:

- Small group instruction after school to support students likely to need support to 'pass' mathematics and support for those who might struggle to stay at Higher level;
- Maths competitions and Maths Week;
- Maths Camp – a revision course over Easter for Third year students taking mathematics at Higher level;
- Implementation of National Strategy to Improve Literacy and Numeracy, including staff development with a numeracy focus;
- Revision of basic primary skills in first year;
- Mathematics quizzes;
- A student numeracy committee;
- Homework club and special classes;
- Participation in Mathematical Olympiad by students in Transition year;
- Collaboration with local university;
- Learning support in mathematics.

5.6 Conclusion

Comparisons across Initial and Non-initial schools on a number of scales dealing with school organisation and resources revealed differences for school responsibility for curriculum and assessment and responsibility for resource allocation (both marginally higher in Initial schools) and on quality of schools' educational resources (lower in Initial schools). Mean scores for both Initial and Non-initial schools were low, compared with the corresponding OECD averages, on the indices of responsibility for resource allocation, and for quality of schools' educational resources. Correlations between the indices of school organisation and resources and mathematics achievement were generally weak.

There were no significant differences between the mean scores of students in Initial and Non-initial schools on five measures of school climate, including students' perceptions of Disciplinary climate in mathematics lessons (the only one of the indices that was specific to mathematics) and their perceptions of their relations with their teachers. Of the five indices, the highest in both school categories was Teacher morale (as perceived by school principals), while scores on Disciplinary climate were also above the OECD average in both school categories. The strongest correlations with PISA mathematics were observed for Disciplinary climate and for Teacher-related factors affecting school climate (as perceived by school principals) in both school types.

Students attending Initial schools had lower average scores than students attending Non-initial schools on School management – instructional leadership and Promoting school improvement and professional development, and the average scores on these indices for Initial schools were well below the corresponding OECD country averages, suggesting that principals in such schools engaged less frequently in activities that might be expected to promote enhanced teaching and learning (though not necessarily in mathematics). The lower average scores for Initial schools might also suggest that principal teachers of such schools were more aware of activities they could implement to impact on teaching and learning (perhaps through their involvement in Project Maths), but also recognised the complexity of implementing such activities well.

The mean score of students in Initial school was higher than for students in Non-initial schools on just one of the indices of teacher practices and support for students in mathematics, viz. Teacher behaviour – student orientation. However, the mean scores for both school categories were below the OECD average. The negative correlations between this index and PISA mathematics suggests that teachers provide most support to the weakest students, though it should be noted that significance was reached only in the case of Non-initial schools.

Students in Initial schools had principal teachers who were more positive about the expected impact of Project Maths than their counterparts in Non-initial schools, about the proportion of students likely to take Higher level on the Junior Certificate mathematics examination, and about student engagement in mathematics. Surprisingly, none of the principal teachers of students in Initial schools reported that they had implemented an additional initiative to improve mathematic teaching and learning, side-by-side with Project Maths. In contrast, 36% of students in Non-initial schools had principals who reported at least one additional initiative. However, some initiatives that were reported might be expected to be found in all schools. In Chapter 4, students in both Initial and Non-initial schools were reported to have had low average scores (compared with the corresponding OECD average) on an index of participation in activities that might be expected to promote students' interest in mathematics as well as their mathematical achievement. This would suggest scope for schools to increase the number of extra-curricular activities in mathematics such as mathematics clubs and competitions in which students could engage.

6. Teaching and Learning in Project Maths

This chapter reports on a survey of mathematics teachers and mathematics school co-ordinators that was administered in Ireland in conjunction with PISA 2012.

6.1 Aims of the Survey and Content of Questionnaires

Two questionnaires, one for mathematics teachers, and one for mathematics school co-ordinators[4], were administered at national level.[5] These questionnaires were national instruments, administered only in Ireland. The aims of administering the questionnaires were:

1. To obtain a reliable, representative and up-to-date profile of mathematics teaching and learning in Irish post-primary schools;
2. To obtain quantitative (numeric) and qualitative (narrative) information on the views of a nationally-representative sample of teachers on the implementation of Project Maths that could be compared across teachers in Initial and Non-initial schools.

With respect to the second aim, since Project Maths was implemented in an earlier timeframe in the 23 Initial schools, comparisons between Initial and Non-initial schools could provide some indication of any issues or changes to do with the implementation of Project Maths in initial and later stages, though it should be borne in mind that national roll-out of Project Maths was informed by the experiences of the Initial schools.

The mathematics teacher questionnaire included the following sections:

- Background information (gender, teaching experience, employment status, qualifications, teaching hours, participation in CPD)
- Views on the nature of mathematics and teaching mathematics
- Teaching and learning of students with differing levels of ability
- Views on Project Maths.

The mathematics school co-ordinator questionnaire was considerably shorter than the teacher questionnaire and asked about the following:

- Organisation of base and mathematics classes for instruction
- Distribution of students across mathematics syllabus levels.

It should be noted that, since a majority of students taking part in PISA are in Junior cycle, many of the questionnaire items on Project Maths were targeted specifically to Junior cycle; there is no equivalent, specific focus on teachers' views at senior cycle.

6.2 Demographic and Background Characteristics of Mathematics Teachers and School Co-ordinators

Table 6.1 show some of the characteristics of the teachers and mathematics school co-ordinators who participated in the survey. Since these data are weighted, they represent a profile of

[4] Mathematics school co-ordinators may also be referred to as 'mathematics subject heads' or 'mathematics department heads'.

[5] The mathematics teacher and school-coordinator questionnaires also included items dealing with mathematics in transition year. See Moran et al. (2013) for questionnaire outcomes relating to transition year.

mathematics teachers in schools in general, rather than survey participants.[6] Overall, 80.3% of selected teachers returned a questionnaire, and 93.4% of school co-ordinators did so. Sixty-five percent of mathematics teachers were female (Table 6.1). About three-tenths of teachers indicated having 21 or more years of experience, 47.2% had between six and 20 years of experience, 15.7% between three and five years, and 6.3% reported having fewer than two years of teaching experience. Two-thirds of teachers (66.0%) were permanently employed; of the remaining respondents, similar proportions of teachers were on fixed-term contracts of more than a year (15.6%) and on fixed-term contracts of less than a year (18.4%).

A quarter of teachers were in vocational schools, 22.6% in girls' secondary schools, 18.8% in mixed secondary schools, 17.1% in boys' secondary schools, and 16.6% in community and comprehensive schools. One-fifth of teachers (21.2%) were in DEIS (SSP) schools and 4% of teachers were working in Project Maths Initial schools. Just under a tenth of teachers were based in fee-paying schools. Most schools (64.4%) had student enrolments of between 401 and 800 students, one fifth of schools were small (< 400) and the remaining 14.7% were very large schools of over 800 students.

Three-fifths of surveyed teachers had completed a primary degree that incorporated mathematics up to final year in either three- or four-year programmes, a proportion which was almost identical across Initial and Non-initial schools (Table 6.2). Only three percent of teachers overall had completed a primary degree that did not include mathematics as a subject. The remainder (35.4%) had completed a primary degree with mathematics in first year or first and second year only. The characteristics of mathematics co-ordinators were broadly similar to those of teachers.

The most common postgraduate qualification, held by 56.3% of teachers, was a Higher or Postgraduate Diploma in Education (HDip/PGDE) that included a specific focus on mathematics education. The percentage of teachers with this qualification was slightly lower in Initial schools than Non-initial schools, though Initial schools also had a slightly higher percentage of teachers with a HDip/PGDE without a specific focus on mathematics education (29.1% vs. 22.1%). Ten percent of

Table 6.1
Demographic Characteristics of Teachers Participating in the PISA 2012 Mathematics Teacher Survey

Characteristic	*N*	%
Gender		
Female	844	65.2
Male	451	34.8
Years Teaching Experience		
One to two	83	6.3
Three to five	207	15.7
Six to ten	287	21.8
Eleven to twenty	334	25.4
Twenty one or more	405	30.8
Employment Status		
Permanent	852	66.0
Fixed term > 1 year	201	15.6
Fixed term < 1 year	238	18.4

Note. Data are weighted to reflect the population of teachers.

[6] See the technical appendix in Cosgrove et al. (2012) for details of the sampling weights.

Table 6.2
Percentage of Teachers who Hold Primary Degrees with Varying Quantities of Mathematics Content: Overall, and in Initial and Non-initial Schools

Degree Content	Overall	Initial Schools	Non-initial Schools
Primary degree with mathematics up to final year	60.0	60.2	60.0
Primary degree with mathematics in first and second year	20.1	15.4	20.3
Primary degree with mathematics in first year only	15.3	21.5	15.0
Primary degree that did not include mathematics as a subject	3.3	1.3	3.4
None of the above	1.2	1.8	1.2

teachers reported having no postgraduate qualification in mathematics education. Of these, three-quarters indicated that they had a primary degree which included mathematics for two years or more. Overall, 76.3% of mathematics teachers reported that they had studied mathematics teaching methods at some point in their pre-service teacher preparation.

6.3 Teaching and Classroom Activities

Teachers were asked to indicate how much emphasis they placed on various teaching and classroom activities in a typical week in teaching mathematics to Third year students. The response options were none, low, medium, or high emphasis. Teachers in both Initial and Non-initial schools placed highest emphasis on whole class teaching. However, across other teaching/classroom activities, teachers in Initial and Non-initial schools had slightly different profiles. More teachers in Non-initial than in Initial schools placed little or no emphasis on student group learning activities (52.0% vs. 44.5% respectively) and assessment of student learning (12.2% vs. 5.9%).

Figure 6.1 shows teaching and classroom activities on which teachers placed high emphasis in Initial and Non-initial schools. More teachers in Initial than Non-initial schools reported placing a high emphasis on individual student learning (a difference of 5%), and on group learning activities (11.3%). Teachers in Initial schools placed lower emphasis than teachers in Non-initial schools on keeping order in the classroom (a difference of 7.3%) and on administrative tasks (4.6%).

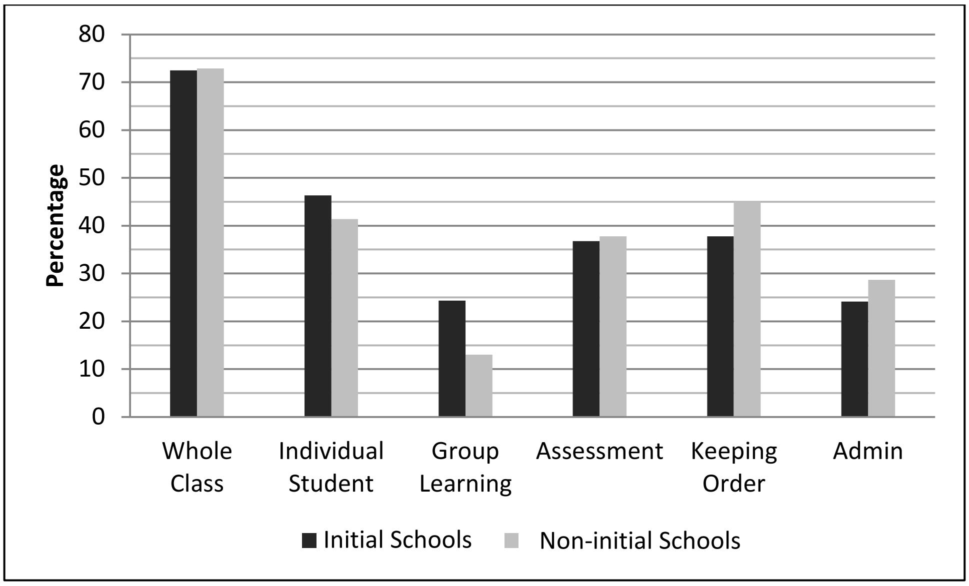


Figure 6.1. Percentages of Teachers Who Reported Placing a High Emphasis on various Teaching and Classroom Activities when Teaching Mathematics to Third Year Students in Initial and Non-initial Schools

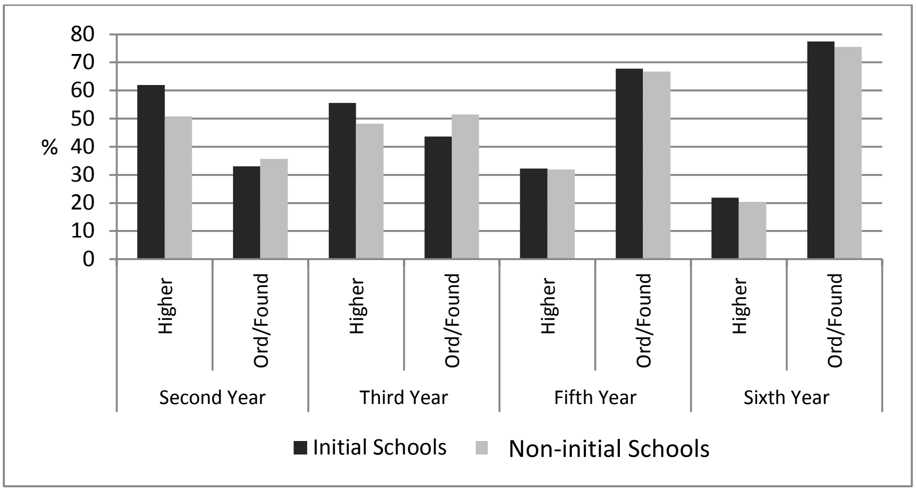
6.4 Patterns of Mathematics Syllabus Uptake and Grouping for Instruction

Mathematics co-ordinators were asked to estimate the percentage of students in their schools studying mathematics at each syllabus level during the 2011-2012 school year. For Higher level, these ranged from 51.2% in Second year to 20.3% in Sixth year, while the percentages taking Ordinary/Foundation level mathematics ranged from 35.5% in Second year to 75.6% by Sixth year. Of note is the drop in the percentage of students studying Higher level mathematics between Fifth and Sixth years, from 31.9% to 20.3%, implying that about a third of students who begin senior cycle studying mathematics at Higher level end up taking Ordinary or Foundation level. First years tend to study mathematics at Common level (in line with the implementation of the Common Introductory Course), though 10.6% were reported to be taking Higher level and 5% taking Ordinary or Foundation level.

As noted in Chapter 1, one objective of the Project Maths initiative is to increase uptake of Higher level mathematics for both the Junior and Leaving Certificates. Patterns of syllabus level uptake in Initial and Non-initial schools (again as estimated by mathematics school co-ordinators) are shown in Figure 6.2. For clarity, the graph only displays Higher and Ordinary/Foundation levels (i.e. excludes Common level). A general pattern of slightly more frequent Higher level and slightly lower Ordinary/Foundation level uptake in Initial and Non-initial schools emerges. Though differences are slight in most years, the pattern is more pronounced in Second and Third years. The only statistically significant difference in Higher level uptake is at Second year level.

6.5 Continuing Professional Development (CPD)

Teachers were asked to indicate the number of hours of CPD relating to mathematics in which they had engaged, how much of this was outside school time, and what obstacles they had encountered in attending CPD related to mathematics education. When answering these questions, teachers



Note. The difference is statistically significant for Higher level uptake in Second Year.

Figure 6.2. Percentages of Students Studying Mathematics at each Syllabus Level by Grade (Mathematics School Co-ordinators' Estimates) in Initial and Non-initial Schools

were advised that CPD was intended to cover both formal and informal activities. It should also be noted that the model of support for teachers in Initial schools was different from that for teachers in Non-initial schools, with workshops delivered in a shorter space of time, and in-school support available from a designated RDO.

Table 6.3 shows the average number of hours of participation in different kinds of CPD in the last three years for all mathematics teachers, as well as the averages for teachers in Initial and Non-initial schools. Overall, the highest levels of participation were for formal CPD on Project Maths (20.2 hours) and self-directed CPD (study of Project Maths materials; books or journals on mathematics education etc.) (14.2 hours). The least time was spent on formal courses designed to address a gap in qualifications to teach mathematics (1.5 hours), formal postgraduate study that included mathematics or mathematics education (1.6 hours) and formal CPD relating to the Junior Certificate mathematics syllabus (other than Project Maths) (1.8 hours).

There were some significant differences between teachers in Initial and Non-initial schools in the average number of CPD hours undertaken during the three years preceding the survey. Teachers in the Initial schools spent slightly more time than teachers in Non-initial schools attending formal CPD on Project Maths (21.9 vs. 20.1 hours), formal CPD courses designed to address a gap in qualifications (2.9 vs. 1.4 hours) and self-directed CPD (18.2 vs. 14.1 hours). The largest differences observed between teachers in Initial and Non-initial schools were in the amount of in-school professional development activities relating to mathematics (7.2 vs. 2.8 hours) and the total number of CPD hours (57.9 vs. 44.7), with teachers in Initial schools engaging in more hours than their counterparts in Non-initial schools for both categories. This may reflect the more widespread provision and encouragement of CPD in schools in which Project Maths was introduced earlier.

Table 6.3

Hours of CPD participation in the last three years: Overall, and in Initial and Non-initial schools

Type of CPD	All			Initial Schools			Non-initial Schools		
	M	*SE*	*SD*	*M*	*SE*	*SD*	*M*	*SE*	*SD*
Formal CPD on Project Maths	20.2	0.34	9.6	21.9	0.74	9.6	20.1	0.35	9.6
Formal CPD on the Junior Certificate mathematics syllabus other than Project Maths	1.8	0.18	5.2	1.9	0.34	4.8	1.8	0.19	5.2
A formal CPD course designed to address a gap in your qualifications to teach mathematics	1.5	0.19	5.7	2.9	0.56	7.9	1.4	0.20	5.6
In-school professional development activities relating to mathematics	3.0	0.23	5.7	7.2	1.41	9.1	2.8	0.23	5.4
Self-directed CPD, e.g. study of Project Maths materials; of books or journals on mathematics education	14.2	0.34	11.4	18.2	1.74	11.5	14.1	0.34	11.4
External meetings relating to mathematics, e.g. the Irish Maths Teachers Association	2.9	0.23	5.9	3.7	0.65	6.3	2.9	0.24	5.9
Formal postgraduate study that included mathematics or mathematics education (e.g. M.A., M.Ed.)	1.6	0.19	6.3	2.1	1.62	7.4	1.6	0.19	6.3
Total CPD Hours	45.2	0.87	25.9	57.9	4.92	29.4	44.7	0.87	25.6

Note. Grey shading indicates a statistically significant difference ($p < .05$*).*

Teachers in the Initial and Non-initial schools identified broadly similar obstacles to CPD attendance. Teachers in Initial schools, however, were less likely (a difference of 5% or more) to indicate that not being informed of courses and a lack of time outside of school hours had affected their participation in CPD attendance, and more likely than teachers in Non-initial schools to indicate that location of courses had prevented CPD participation.

6.6 Use of ICT in the Teaching and Learning of Mathematics

Teachers were asked to indicate the frequency with which they used six ICT resources during their mathematics classes – PC/Laptop, data projector[7], internet, general software (e.g. PowerPoint, Word), mathematics software (e.g. Geometer's Sketchpad, GeoGebra, Logo, Scratch) and spreadsheets (e.g. Excel). The most commonly-used resources were a PC/laptop and a data projector/whiteboard, with 60% or more of teachers using these at least once a week. Spreadsheet packages were used much less frequently (48.9% of teachers never used these), and use of internet sites, general software, and mathematics-specific software was intermediate.

Just over 5% of teachers reported using all six resources at least once a week, and a further 24.5% of teachers reported using four or five of them with this frequency. These 29.7% of teachers may be regarded as *high users of ICT* during mathematics classes. At the other extreme, 6.0% of teachers indicated that they never or hardly ever used any of the six resources. A further 7.3% hardly ever or never used four or five of these resources, and these 13.3% may be regarded as *low users of ICT* during mathematics classes. Other teachers can be categorised as medium ICT users.

There are substantial differences between the usage of ICT by teachers in Initial schools and Non-initial schools (Figure 6.3): 49.5% of teachers in Initial schools were high users of ICT, compared with 28.9% of teachers in Non-initial schools. Teachers in Initial schools were more likely to report using each form of ICT at least once a week. In particular, teachers in Initial schools were more likely to report using mathematics-specific software at least once a week than teachers in Non-initial schools (42.5% vs. 24.2%) and they were more likely to report using general software at least once a week (50.3% vs. 36.7%). Use of spreadsheets was quite low in both groups (Figure 6.4).

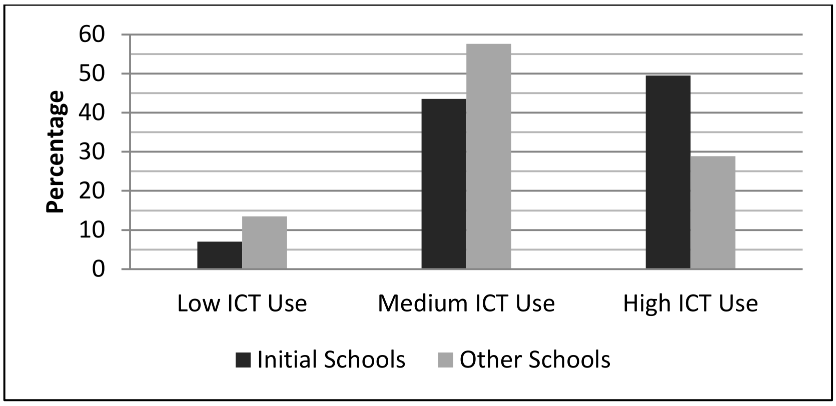


Figure 6.3. Percentages of Teachers who Report Low, Medium, and High Use of ICT during Mathematics Classes in Initial and Non-initial Schools

[7] Note that although 'data projector' did not explicitly refer to an interactive whiteboard, it is reasonable to assume that some teachers would have included use of an interactive whiteboard under this category.

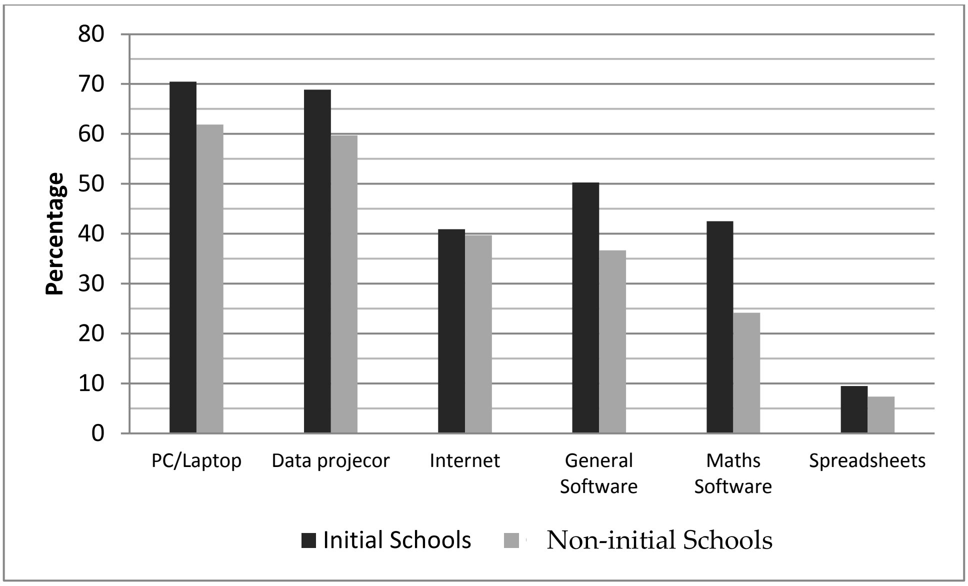


Figure 6.4. Percentages of Teachers who Report Using Various ICT at Least Once a Week During Mathematics Classes in Initial and Non-initial schools

6.7 Use of Differentiated Teaching Practices

Teachers were asked how they provide different teaching and learning experiences for students of differing ability levels *within* their Third year mathematics classes. In interpreting the data, it should be noted that class groups may already reflect ability grouping between classes, and hence, there may be more limited opportunity or need for differentiated approaches. Two-thirds of teachers (65.5%) indicated that they taught Third years at the time of completing the questionnaire, and the responses reported here are based on these teachers only.

The four most commonly-used strategies (with 55-70% of teachers reporting using these sometimes or often) were providing different class materials or activities, having students work in mixed-ability pairs or groups, providing different homework tasks, and providing planned or structured (one-to-one) instruction (Figure 6.5). Team teaching was used considerably less frequently (with 61.1% never using this), as was working with a Special Needs Assistant (54.4% reported never using this). The use of these latter two approaches may be partly related to the availability of other staff to support their implementation. Two remaining strategies, organising students by ability for teaching and learning, and assigning grades on the basis of differing criteria, were used with moderate frequency.

A comparison of the extent to which teachers in Initial schools and Non-initial schools used each of these strategies indicates that, in general, teachers use them with similar levels of frequency. However, there are two exceptions. Figure 6.5 shows that teachers in Initial schools were more likely to report having students work in mixed-ability groups or pairs sometimes or often (81.0%) when compared to teachers in Non-initial schools (66.6%) and those in Non-initial schools were more likely to report working with an SNA sometimes or often (34.2%) than teachers in Initial schools (26.0%).

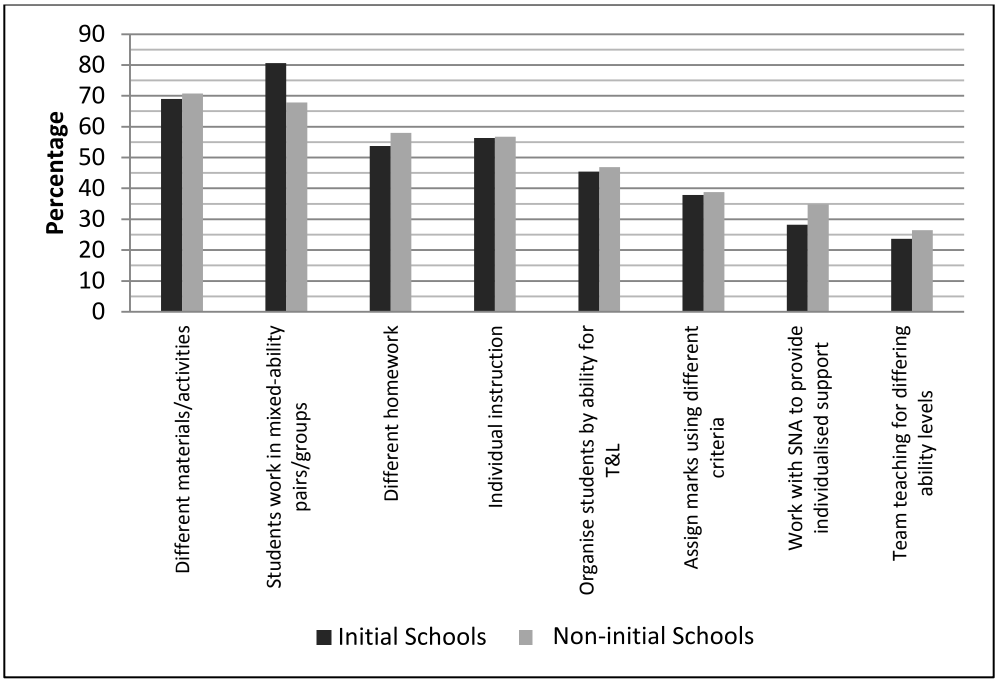


Figure 6.5 Percentages of Teachers using Differentiated Teaching and Learning Approaches 'Sometimes' or 'Often' in Third Year Mathematics Classes in Initial and Non-initial Schools

6.8 General Views on the Implementation of Project Maths

About half (50.2%) of respondents indicated that they had been teaching Project Maths at junior cycle for one year, 45.3% for two years, and a small minority (4.6%) for longer than two years, reflecting the phased implementation. Teachers were asked to indicate, overall, whether or not they agreed that Project Maths was having a positive impact on students' learning of mathematics (Table 6.6). What is striking about the results is that close to half of teachers (47.5%) indicated that they did not know if Project Maths was having a positive impact. This indicates, not unexpectedly, that 2012 may have been too early in the implementation of Project Maths for some teachers to have an informed opinion.

Across all schools, slightly fewer teachers disagreed or strongly disagreed (22.8%) than agreed or strongly agreed (29.7%) with the statement. A comparison of the responses of teachers in Initial and Non-initial schools indicates that more teachers in Initial schools were inclined to agree with the statement, and fewer teachers in Initial schools indicated that they didn't know.

Table 6.6

Responses of Teachers to the Statement 'Overall, Project Maths is having a positive impact on students' learning of mathematics' in Initial and Non-initial Schools

	All %	Initial %	Non-initial %
Strongly disagree	7.5	4.0	7.6
Disagree	15.3	12.5	15.4
Don't know	47.5	38.4	48.0
Agree	23.3	35.0	22.7
Strongly agree	6.4	10.1	6.3

Note. 8.4% of respondents were missing data on this question.

Teachers were asked to indicate, for a set of 19 statements relating to students' learning of mathematics, whether they perceived that there had been a change, ranging from a large negative one, to a large positive one, with the implementation of Project Maths (see Cosgrove et al. 2012). Generally, teachers in Initial schools reported larger positive changes than teachers in Non-initial schools. Differences are statistically significant on the following items, with teachers in Initial schools recording more positive changes on all of them: use of collaborative group work; students explaining how they solved a problem; students trying different strategies; their grasp of fundamental concepts and principles; and the sense of challenge experienced by higher achievers.

Teachers indicated the level of challenge for 12 aspects associated with the implementation of Project Maths in their schools. Figure 6.6 compares the percentages of teachers in Initial and Non-initial schools who indicated that each of the 12 aspects was, in their view, a major challenge. Responses diverge considerably between the two groups (by 10 percentage points or more) on eight of the items. In all eight cases, teachers in Initial schools were more inclined than teachers in Non-initial schools to rate them as a major challenge. These were: the assessment materials available at the time of the survey (72.6% compared with 40.3%), parents' reactions (32.0% vs. 9.7%), students' reactions (38.4% vs. 21.2%), time available (71.4% compared with 59.3%), resources available (39.8% vs. 28.4%), teaching materials (42.1% compared with 31.1%), CPD available or attended (22.8% vs. 12.1%), and the literacy demands of the new courses (59.8% compared with 49.2%).

Across both groups, however, three aspects of the implementation of Project Maths emerged as significant challenges (appearing among the top four in terms of the percentages rated as being a major challenge). These were the time available, the phased implementation of Project Maths, and the literacy demands of the new courses. Also, both groups shared the view that the following four aspects of Project Maths posed less of a challenge in its implementation: parents' reactions, CPD available/attended, their own views on what should be taught, and their views on how it should be taught.

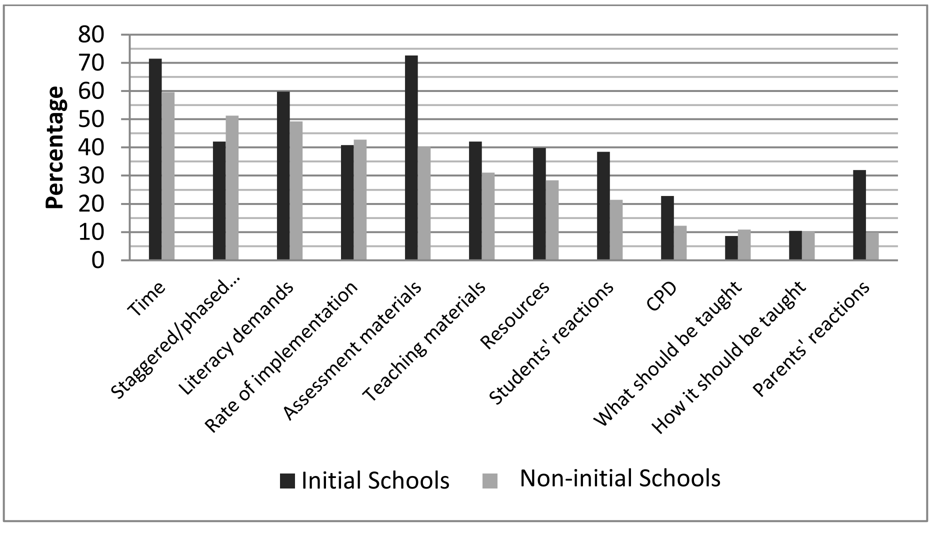


Figure 6.6. Percentages of Teachers Indicating that each of 12 Aspects of the Implementation of Project Maths is 'A major challenge' (junior cycle only) in Initial and Non-initial schools.

6.9 Teachers' Comments on Project Maths

Teachers were provided with space in the questionnaire to make written comments about their experiences of and views on Project Maths. The question was pitched at a general level (i.e. *please make any further comments on Project Maths in your work as a teacher in the space below, if you wish*). Of all respondents, 34.5% wrote comments. About the same percentages of teachers in Initial schools and Non-initial schools made written comments (35.7% and 34.7%, respectively). Comments were subjected to a detailed content analysis, and classified along three dimensions:

1. Overall tone of the comment: positive, negative, or mixed[8];
2. Whether the comment referred to the junior cycle, the senior cycle, or both;
3. The content of the comment itself: eight themes were identified. These are described in detail in the next section. Some of these themes overlap with one another. In addition, 5.6% of comments were classified under 'other' as they did not readily fit under the main themes.

The content analysis was conducted initially by one researcher, and then validated by a second. In a small number of cases, comments were reclassified.

A large majority of comments (87%) were negative in tone, and the percentages of negative comments were similar in Initial and Non-initial schools. A further 8% were mixed in tone, and just 5% were positive. However, it is possible that teachers may have thought it more important to record reservations than to re-assert positive opinions, which other parts of the questionnaire gave them opportunities to express.

A majority of comments (81%) covered both junior and senior cycles. Teachers in Non-initial schools were slightly more inclined than teachers in Initial schools to comment on senior cycle or junior cycle separately. The themes around which teachers' comments were grouped were: Syllabus and Assessment (with syllabus, time and exams as subthemes); Phased Implementation (with textbooks, professional development and resources as subthemes); Literacy and Ability; Methodology; Change; Communication; General Comments; and Other.

To a large extent, the distribution of comments across content areas was similar for teachers in Initial and Non-initial schools, with two exceptions. Teachers in Non-initial schools were more inclined to make comments on the *phased implementatio*n of Project Maths, while those in Initial schools tended to comment more frequently on *examinations*. These differences can be related to the fact that the Initial schools were ahead of Non-initial schools in their experiences of Project Maths.

The most commonly-occurring themes/subthemes were *phased implementation, literacy and ability, syllabus, time* and *examinations*. These are discussed below.

Phased Implementation

Over one-quarter (26.8%) of all comments referred to the *phased nature of the implementation of Project Maths*, that is, both the phased introduction of strands and the simultaneous introduction at First and Fifth year. Comments on implementation were more prevalent among teachers in Non-initial schools (28.2%) compared with teachers in Initial schools (19.3%). Most teachers who made

[8] Example of a general, positive comment: *I like the concept of Project Maths. I see how children learn from one another;* example of a general, negative comment: *Introducing this change on top of dealing with very large classes is ridiculous;* example of a general, mixed comment: *There is a good understanding of the concepts but it is difficult to prepare for the Junior Certificate examination.*

comments on implementation disagreed with Project Maths being implemented in a phased manner. Teachers viewed implementation in this way as being unfair on senior cycle students who may not have acquired the knowledge or skills needed for the new course during junior cycle. Teachers generally felt it would have been better to introduce Project Maths initially to First years (and implement it upwards from there).

> The way in which Project Math is being introduced is proving to be a major challenge. If it had been introduced in First year only, it would have been more manageable, as it would give the students the chance to use the terminology from the beginning.

Literacy and Ability

About one in eight of the comments (13.1%) raised the issue of literacy levels and differences in students' ability more generally. Some teachers expressed concerns about the use of language in the revised curriculum. Teachers felt that weaker students, students with special needs and non-native English speakers were struggling with comprehension of the material and the wordy nature of some of the examination questions. They were of the view that Project Maths was a good approach for students of higher ability; however, they felt that some higher-ability mathematics students were now struggling as they also needed good literacy skills in order to read, understand and answer examination questions. Some teachers perceived a neglect of Foundation level in the development of syllabus and CPD materials and resources.

> The language used when phrasing a question poses a major difficulty for students whose literacy skills would be weak, they can therefore not answer a question they are mathematically capable of doing! This is a major issue. It is something which needs to be addressed if students are to be examined fairly.

Syllabus

One-eighth (12.2%) of teachers commented on aspects of the revised syllabus, and 92.4% of these comments were negative in tone. A number of teachers felt the course was too long, with too much content, and reported difficulty in being able to cover the syllabus[9]. Some teachers felt that Statistics and probability posed a challenge for students, especially in senior cycle; others felt there was a reduction in level of difficulty in the revised curriculum compared to the one previously in place. This theme overlaps with the *examinations* theme insofar as teachers felt more pressure to cover the entire course with choice removed from the examinations.

> If the goal was to provide time to allow teachers and students to explore topics in greater depth and detail, then Project Maths will not succeed. The curriculum is too overloaded for this. Some topics have doubled in size. Teachers are intimidated by the amount of new material and the methods recommended.

Time

Nine percent of teachers' comments mentioned time being an issue for the successful implementation of Project Maths, and again these comments were mostly (92.9%) negative. From the comments received, it can be inferred that teachers were referring both to instructional time,

[9] It may be borne in mind that, at the time of the survey, most teachers were dealing with the implementation of part of the new syllabus, while maintaining part of the old syllabus.

and time outside of teaching hours. Many teachers who commented on time felt they did not have enough time to cover the course. Some teachers reported spending evenings and weekends doing extra work in order to prepare students. They also felt this extra work had resulted in other subjects suffering.

Examinations

Comments that came under the theme of examinations (8.5% of all comments) covered the structure, content, and layout of examination papers and marking schemes. Comments on examinations were more prevalent among teachers in Initial schools compared with teachers in Non-initial schools. Teachers were generally unhappy with the removal of question choice from the examination papers. Some even felt it may discourage students from taking the examination at Higher level. Others commented that the removal of choice resulted in them being under too much pressure to cover the course and adequately prepare students. Some felt that the layout and structure of the sample papers and marking schemes lacked clarity. Teachers also voiced dissatisfaction with the lack of availability of sample papers and marking schemes, and were of the view that aspects of the examination (including the marking) were aiding the 'dumbing-down' of mathematics. A few teachers noted a discrepancy between the problem-solving and group work approach of Project Maths and the prescribed nature of the Leaving Certificate examination.

> I would question the notion of 'no choice' of Leaving Certificate papers. This will discourage some students from pursuing Higher level course; instead, they will pick a perceived 'easy subject' with choice on paper.

6.10 Conclusion

This chapter reports on the outcomes of a questionnaire to teachers that were administered as part of PISA 2012 in Ireland. The analyses of both quantitative and qualitative data focused on identifying differences between the response patterns of teachers in Initial and Non-initial schools, and, where relevant, more general patterns in teacher responses. Over 80% of selected teachers of students taking part in PISA 2012 returned a questionnaire. The analyses found that:

- Teachers in Initial schools had similar qualifications for teaching mathematics as their counterparts in Non-initial schools.
- Teachers in Initial schools placed a high emphasis on individual student learning and on student group learning activities, and less emphasis on keeping order in the classroom and on completing administrative tasks, compared with teachers in Non-initial schools.
- In the context of CPD, the largest differences reported by teachers in Initial and Non-initial schools were in the amount of in-school professional development activities relating to mathematics in the previous three years (7.2 vs. 2.8 hours) and the total number of CPD hours (57.9 vs. 44.7).
- Teachers in Initial schools were more likely to report using mathematics-specific software at least once a week than teachers in Non-initial schools, who were more likely to report using general software. Use of spreadsheets was quite low in both Initial and Non-initial schools.
- Teachers in Initial schools were more likely than their counterparts in Non-initial schools to report having students work in mixed ability pairs or groups sometimes or often, as an approach to differentiating instruction.

- More teachers in Initial than in Non-initial schools agreed or strongly agreed that, overall, Project Maths had a positive impact on students' learning of mathematics, though between 38% and 48% of teachers across school types reported that they did not know of the impact of Project Maths at the time of the survey.
- More teachers in Initial schools reported large positive changes in their students' learning arising from implementation of Project Maths in five areas: use of collaborative group work; students explaining how they solved a problem; students trying different strategies; their grasp of fundamental concepts and principles; and the sense of challenge experienced by higher achievers.
- More teachers in Initial schools than in Non-initial schools reported that availability of assessment materials, parents' reactions to Project Maths, resources available, CPD available or attended, and the literacy demands of Project Maths presented major challenges to effective implementation.
- In their comments on Project Maths, teachers in Initial and Non-initial schools raised a number of concerns about phased implementation, literacy and ability, syllabus content and structure, lack of time to complete the syllabus, and examinations.

7. Curriculum Analysis

Neither the pre-2010 Junior Certificate mathematics curriculum nor the new Project Maths curriculum is directly based on processes and content areas assessed in PISA mathematics. However, it is useful to consider the extent of overlap, if any, between each version of the syllabus and PISA. As part of this study, a national-level PISA Test-Curriculum Rating Project (TCRP) was undertaken, building on a similar project following PISA 2003 when mathematics was last the major domain (Cosgrove et al., 2005). This chapter describes the method used in the comparison, presents the overall results, and illustrates the ratings with some sample PISA items.

Several earlier international studies of mathematics have included measures of curricular coverage, traditionally termed measures of Opportunity To Learn (OTL) (Husén, 1967). This information is typically gathered by asking teachers of assessed students or curriculum specialists to examine each assessment item and judge whether students would have had an opportunity to learn the topic represented by the item. Other studies have also included comparative analyses of textbooks and curriculum documents.

The outcomes of a curriculum analysis allow for an examination of the effects of curriculum coverage on student achievement, as measured by assessments such as PISA, both at the individual item level and at student level. This type of information also allows countries to make comparisons between their curriculum and those of other countries, which can yield useful information about the differences between countries in terms of the inclusion and depth of coverage of a topic, the time at which a topic is first introduced, or how a topic is taught. PISA, however, does not include any such measures as its focus moves away from school-based learning towards knowledge and skills needed by adults in society. It is of great interest to Ireland, from both policy and research perspectives, to develop national measures of curricular coverage to inform interpretation of student outcomes on PISA. Furthermore, the on-going transition to Project Maths renders a curriculum analysis more important as it includes a comparison of the Project Maths-based syllabus and pre-2010 syllabus.

The aim of the original Curriculum Rating Project was to develop and implement a set of rating scales which are reliable, valid, and capable of capturing the extent and type of similarities and differences between PISA items and questions posed to students in Third year of the junior cycle. After meetings with curriculum experts in September 2000, pilot scales were developed and tested. The scales were refined following analysis and discussion of the pilot ratings and comments. The project was repeated following PISA 2003, when mathematics was first a major domain in PISA (Cosgrove et al., 2005).

The PISA Test-Curriculum Rating scales differ from traditional OTL measures as they are multidimensional, taking into account different aspects of the items as well as different levels of the syllabus. The three-point rating scale used also differs from traditional OTL measures in that rather than having the *estimated proportion of students exposed to a topic* (all/some/none) or the *perceived appropriateness of each item* (highly appropriate/acceptable/not appropriate) as its points, it has the *expected familiarity level of a typical student* (very/somewhat/not) with various aspects of the question. Table 7.1 gives a broad overview of the framework on which the scales are based. The framework comprises a 3 x 3 matrix whereby the three aspects or dimensions of an item which are examined (Concept, Context, and Process) are rated on expected familiarity to a typical

Table 7.1
Matrix of Ratings of Concept, Context, and Process by Syllabus Level used in the TCRP

	Higher	Ordinary	Foundation
Concept	Not familiar	Not familiar	Not familiar
	Somewhat familiar	Somewhat familiar	Somewhat familiar
	Very familiar	Very familiar	Very familiar
Context	Not familiar	Not familiar	Not familiar
	Somewhat familiar	Somewhat familiar	Somewhat familiar
	Very familiar	Very familiar	Very familiar
Process	Not familiar	Not familiar	Not familiar
	Somewhat familiar	Somewhat familiar	Somewhat familiar
	Very familiar	Very familiar	Very familiar

student at the three syllabus levels; the Project Maths and pre-2010 curricula were rated separately. In this way, each item receives nine ratings and the multi-dimensional nature of both the items and the Irish education system is taken into account. Although there is no separate Foundation level syllabus in the Project Maths curriculum, there is a separate examination so the Foundation level rating was retained. This also allows for more complete comparisons between the two curricula. Each aspect of the scales is described below in some detail. There is also a brief description of the content areas, processes, contexts, and item formats included in the PISA mathematics framework.

7.2 Methodology

Three independent experts in second-level mathematics education undertook ratings of PISA 2012 items that were identified by the consortium that developed the PISA tests on behalf of the OECD as items that may be used again in the future to track trends in mathematics performance. In all, there were 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%).

Although PISA specified three broad clusters of mathematical processes relating to formulating, employing and interpreting, these PISA processes are not the focus of the ratings in this exercise. The pre-2010 syllabus provides some insights into the processes that students can be expected to employ, including recalling basic facts, instrumental understanding (implementing procedures), application, relational understanding, analysis, and communication. The Project Maths syllabi are perhaps less detailed in terms of explicating mathematical processes, though these can be inferred from reading the descriptions of the various strand units. For example, the following types of understanding are identified in the contexts of statistics and probability: representing, describing and interpreting numerical data, formulating a question, and drawing conclusions.

For each PISA item, raters identified the underlying process, content area on the pre-2010 Junior Certificate mathematics syllabus, and syllabus strand in the Project Maths syllabus examined in Initial schools in 2012 (Table 7.2). The processes considered in the TCRP are defined as follows:

- Recall – recall and understand mathematical terminology, facts, definitions, and formulae;
- Implement procedures – implement suitable standard and non-standard procedures with a variety of tools ;
- Connect – make connections within mathematics itself (for example, link a table and a graph) and in applications of mathematics in practical everyday contexts;

Table 7.2
Processes, Pre-2010 Content Areas, and Project Maths Syllabus Strands used in the TCRP

Process	Pre-2010 Content Area	Project Maths Syllabus Strand
Recall	Sets	Statistics and probability
Implement procedures	Number systems	Geometry and trigonometry
Connect	Applied arithmetic and measure	Number
Reason mathematically	Algebra	Algebra
Solve problems	Statistics	Functions
	Geometry	
	Trigonometry	
	Functions and graphs	

- Reason mathematically – reason, investigate, and hypothesise with patterns and relationships in mathematics;
- Solve problems – apply mathematical concepts and processes, and plan and implement solutions to problems, in a variety of contexts.

Next, the raters considered familiarity with the Concept, Context, and Process of the PISA item, each on a three-point scale of *Not familiar*, *Somewhat familiar*, and *Very familiar*, and gave separate ratings for Higher, Ordinary, and Foundation level students. For each rating, responses across markers were compared and averaged, and, where at least two of the experts agreed, the rating was accepted; in cases of disagreement, the item was opened to discussion. It should be noted that the concept, context, and process ratings are not linked to those of the PISA framework described in Chapter 2, since the focus was on categorising PISA items with reference to national curricula. The Process scale requires raters to consider the main process underlying the item. For this rating, the following processes, as defined earlier, can be considered: Recall, Implement procedures, Connect, Reason mathematically, and Solve problems.

The Concept scale requires raters to read through the text of the question and rate how familiar they would expect the *typical Third year student* studying for Junior Certificate mathematics to be with the *concept underlying the question*. 'Concept' here means a mathematical principle in its abstract form; this is in contrast to the demonstration of understanding, i.e. the application of a mathematical principle in a specific instance. Thus, for the Concept scale raters are asked to identify the abstract mathematical concept underlying the item and not to concern themselves with its application, though it is recognised that conceptual understanding may not be sufficient to enable a student to arrive at a correct answer on a PISA item.

The Context scale requires raters to consider the stimulus text, in which the information needed to respond to questions is embedded, and the question, rating how familiar they would expect the typical Third year student to be with *applying the concept underlying the question* in the type of *context* suggested by the question and stimulus text. 'Context' can be defined in a number of different ways, but the focus here is at a fairly general level, i.e. whether students are familiar with the mathematical concept being contexualised as specified, and whether the contextualisation of the question would be likely, based on the syllabus or Junior Certificate examinations, to guide them to (or distract them from) the successful application of the concept.

The final stage of the analysis involved a meeting of the expert group to discuss contentious items. 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 an extended discussion of the performance of students in Ireland on the Space & Shape subscale.

7.3 TCRP Results

7.3.1 Alignment

The frequency with which PISA items were categorised by process, pre-2010 content area, and Project Maths syllabus strand are reported Tables 7.3, 7.4, and 7.5. Almost all of the items were deemed to be covered by both curricula, 91.5% by the pre-2010 curriculum and 97.2% by Project Maths. Table 7.3 shows that almost three-fifths of the PISA items (56%) were judged to require higher-level processes such as connecting, reasoning mathematically, and solving problems. The remainder called on more basic processes such as recall and implement procedures.

Table 7.4 shows that over one-quarter of PISA trend items assessed statistics, as defined in the pre-2010 syllabus, while approximately one-in-five items assessed knowledge of number systems. Just over one-in-ten items (11.3%) assessed algebra. Geometry, trigonometry, and functions and graphs were also relatively under-represented.

Table 7.5 confirms the relatively strong focus on Number in PISA, with 38% of items categorised in this way. It also shows a relative increase in the proportion of items categorised as Algebra, with over one-fifth of items now categorised in this way. This arises, in part, because of a redistribution of

Table 7.3
*Frequency of Process Ratings Applied to PISA mathematics items (*n *= 71)*

Process	Frequency	%
Recall	5	7.0
Implement procedures	26	36.6
Connect	19	26.8
Reason mathematically	15	21.1
Solve problems	6	8.5

Table 7.4
*Frequency of Pre-2010 Content Areas Applied to PISA mathematics items (*n *= 71)*

Pre-2010 Content Area	Frequency	%
Sets	1	1.4
Number systems	15	21.1
Applied arithmetic and measure	12	16.9
Algebra	8	11.3
Statistics	20	28.2
Geometry	6	8.5
Trigonometry	1	1.4
Functions and graphs	2	2.8
Not covered	6	8.5

Table 7.5

*Frequency of Project Maths syllabus strands Applied to PISA mathematics items (*n *= 71)*

Project Maths Syllabus Strand	Frequency	%
Statistics and probability	20	28.2
Geometry and trigonometry	6	8.5
Number	27	38.0
Algebra	16	22.5
Functions	0	0.0
Not covered	2	2.8

Applied arithmetic and measure items, which are now spread across other content strands. For example, ten items that were categorised as Applied arithmetic and measure in the pre-2010 curriculum have transferred to Number under Project Maths.

7.3.2 Familiarity

Familiarity ratings for each PISA item are reported here under the four PISA subscales: Change & Relationships, Space & Shape, Quantity, and Uncertainty & Data. Before considering the PISA content areas separately, the overall familiarity ratings are presented (Table 7.6). Students studying the Project Maths curriculum at each syllabus level were rated as being more familiar with the concepts, context, and processes underlying PISA items than students studying the pre-2010 curriculum. Even on areas where students of the pre-2010 curriculum were rated as *Very Familiar* on average (mode = 3), 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*

Table 7.6

*Percentage of Items with which Students Are Expected to Show varying Degrees of Familiarity, for Concept, Context, and Process of PISA mathematics items (*n *= 71)*

	Pre-2010			Project Maths			Difference PM-Pre-2010
	Not familiar	Somewhat familiar	Very familiar	Not familiar	Somewhat familiar	Very familiar	Very familiar
Concept – Higher	12.7	32.7	54.9	0.0	18.3	81.7	26.8
Concept – Ordinary	19.7	46.5	33.8	7.0	25.4	67.6	33.8
Concept – Foundation	52.1	36.6	11.3	25.4	32.4	42.2	30.9
Context – Higher	18.3	47.9	33.8	0.0	15.5	84.5	50.7
Context – Ordinary	36.6	43.7	19.7	2.8	19.7	77.5	57.8
Context – Foundation	59.1	28.2	12.7	8.4	25.4	66.2	53.5
Process – Higher	7.1	38.0	54.9	0.0	4.2	95.8	40.9
Process – Ordinary	22.5	45.1	32.4	1.4	28.2	70.4	38.0
Process – Foundation	60.6	23.9	15.5	12.7	16.9	70.4	54.9

familiar with more than 80% of them; by contrast, students studying the pre-2010 curriculum at Higher level are expected to be *Very familiar* with fewer than 55% of items. For students taking the Foundation level examination for Junior Certificate, 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.

In some cases, ratings for Ordinary and Foundation levels were the same as no distinction is made between them in the syllabus. However, raters took into account the likelihood that in practice students at Foundation level were unlikely to study all aspects of the syllabus so there were also items with different ratings for Ordinary and Foundation level students

7.3.1 Change & Relationships

Among the items reviewed, 17 were from the Change & Relationships subscale cluster. For these items, the pattern of expected familiarity was similar to the overall percentages. Based on the Pre-2010 curriculum, students were expected to *Very familiar* with the concept, context, and process of relatively few items while Project Maths students were expected to be *Very familiar* with many more items (Table 7.7). The difference is particularly notable for Ordinary and Foundation level students.

7.3.2 Space & Shape

Given the relatively poorer performance of students in Ireland on the Space & Shape subscale, both in 2003 and 2012 (Perkins et al., 2013), Space & Shape items were a focus of additional attention in the TCRP. In the curriculum analysis, the 17 PISA Space & Shape items reviewed were deemed to be covered under a number of pre-2010 content areas and Project Maths syllabus strands as shown in Table 7.8. Consistent with the overall pattern of familiarity ratings, students studying Project Maths are expected to be more familiar with the Space & Shape items than those studying the previous

Table 7.7
*Percentage of Items with which Students Are Expected to Show varying Degrees of Familiarity, for Concept, Context, and Process of Change & Relationships PISA mathematics items (*n *= 17)*

	Pre-2010			Project Maths		
	Not familiar	Somewhat familiar	Very familiar	Not familiar	Somewhat familiar	Very familiar
Concept – Higher	17.6	41.2	41.2	0.0	17.6	82.4
Concept – Ordinary	23.5	58.8	17.6	11.8	11.8	76.5
Concept – Foundation	70.6	17.6	11.8	23.5	17.6	58.8
Context – Higher	23.5	47.1	29.4	0.0	11.8	88.2
Context – Ordinary	47.1	35.3	17.6	5.9	11.8	82.4
Context – Foundation	64.7	17.6	17.6	11.8	23.5	64.7
Process – Higher	11.8	41.2	47.1	0.0	0.0	100.0
Process – Ordinary	11.8	70.6	17.6	5.9	17.6	76.5
Process – Foundation	64.7	23.5	11.8	17.6	5.9	76.5

Table 7.8
*Coverage of PISA Space & Shape Items (*n *= 17)*

Pre-2010 Content Area		Project Maths Syllabus Strand	
Applied arithmetic and measure	8	Number	7
Geometry	6	Geometry and trigonometry	6
Trigonometry	1		
		Algebra	2
Not assigned to any content area	2[1]	Not assigned to any content area	2[2]

[1] These items were covered by Algebra under Project Maths.
[2] One of these items was covered by Applied arithmetic and measure under Pre-2010 and one by Geometry.

curriculum (Table 7.9). Ratings for the pre-Project Maths curriculum suggest low levels of familiarity, and this is consistent with the results achieved in PISA in earlier cycles. For the Project Maths curriculum, students are expected to be familiar with more of the items but *Very familiar* with the concept and context of fewer than three-quarters of the items reviewed.

7.3.3 Quantity

The items from the Quantity subscale received the highest familiarity ratings for both the pre-Project Maths and the Project Maths curricula, though students studying Project Maths are again expected to be more familiar overall (Table 7.10). Reflecting the emphasis in Project Maths on using real-world contexts for questions, just as in the PISA framework, the difference in ratings is most dramatic for context, with 18 of the 19 items *Very familiar* to Higher level Project Maths students compared to 7 of 19 rated as *Very familiar* to the pre-Project Maths students at the same level.

Table 7.9
*Percentage of Items with which Students Are Expected to Show varying Degrees of Familiarity, for Concept, Context, and Process of Space & Shape PISA mathematics items (*n *= 17)*

	Pre-2010			Project Maths		
	Not familiar	Somewhat familiar	Very familiar	Not familiar	Somewhat familiar	Very familiar
Concept – Higher	29.4	23.5	47.1	0.0	29.4	70.6
Concept – Ordinary	29.4	47.1	23.5	11.8	35.3	52.9
Concept – Foundation	64.7	29.4	5.9	35.3	35.3	29.4
Context – Higher	29.4	41.2	29.4	0.0	29.4	70.6
Context – Ordinary	41.2	47.1	11.8	5.9	35.3	58.8
Context – Foundation	70.6	23.5	5.9	11.8	35.3	52.9
Process – Higher	11.8	47.1	41.2	0.0	5.9	94.1
Process – Ordinary	41.2	29.4	29.4	0.0	35.3	64.7
Process – Foundation	70.6	23.5	5.9	11.8	23.5	64.7

Table 7.10

*Percentage of Items with which Students Are Expected to Show varying Degrees of Familiarity, for Concept, Context, and Process of Quantity PISA mathematics items (*n *= 19)*

	Pre-2010			Project Maths		
	Not familiar	Somewhat familiar	Very familiar	Not familiar	Somewhat familiar	Very familiar
Concept – Higher	5.3	21.1	73.7	0.0	5.3	94.7
Concept – Ordinary	5.3	42.1	52.6	0.0	21.1	78.9
Concept – Foundation	31.6	47.4	21.1	15.8	36.8	47.4
Context – Higher	10.5	52.6	36.8	0.0	5.3	94.7
Context – Ordinary	31.6	47.4	21.1	0.0	15.8	84.2
Context – Foundation	52.6	26.3	21.1	5.3	21.1	73.7
Process – Higher	5.3	26.3	68.4	0.0	0.0	100.0
Process – Ordinary	15.8	31.6	52.6	0.0	21.1	78.9
Process – Foundation	47.4	31.6	21.1	10.5	10.5	78.9

7.3.4 Uncertainty & Data

Finally, the ratings for Uncertainty & Data items showed the largest differences between the curricula for Higher level students (Table 7.11). Those at Ordinary and especially Foundation levels were also expected to be less familiar with more of the Uncertainty & Data items than items on other subscales. Again, however, there has been an increase in familiarity levels at all syllabus levels for the Project Maths curriculum. Students in Ireland have generally fared well on questions concerning statistics and probability on PISA and it is the subscale on which students in Ireland scored highest in PISA 2012 (Perkins et al., 2013).

Table 7.11

*Percentage of Items with which Students Are Expected to Show varying Degrees of Familiarity, for Concept, Context, and Process of Uncertainty & Data PISA mathematics items (*n *= 18)*

	Pre-2010			Project Maths		
	Not familiar	Somewhat familiar	Very familiar	Not familiar	Somewhat familiar	Very familiar
Concept – Higher	0.0	44.4	55.6	0.0	22.2	77.8
Concept – Ordinary	22.2	38.9	38.9	5.6	33.3	61.1
Concept – Foundation	44.4	50.0	5.6	27.8	38.9	33.3
Context – Higher	11.1	50.0	38.9	0.0	16.7	83.3
Context – Ordinary	27.8	44.4	27.8	0.0	16.7	83.3
Context – Foundation	50.0	44.4	5.6	5.6	22.2	72.2
Process – Higher	0.0	38.9	61.1	0.0	11.1	88.9
Process – Ordinary	22.2	50.0	27.8	0.0	38.9	61.1
Process – Foundation	61.1	16.7	22.2	11.1	27.8	61.1

7.4 Analysis of Space & Shape Released Items

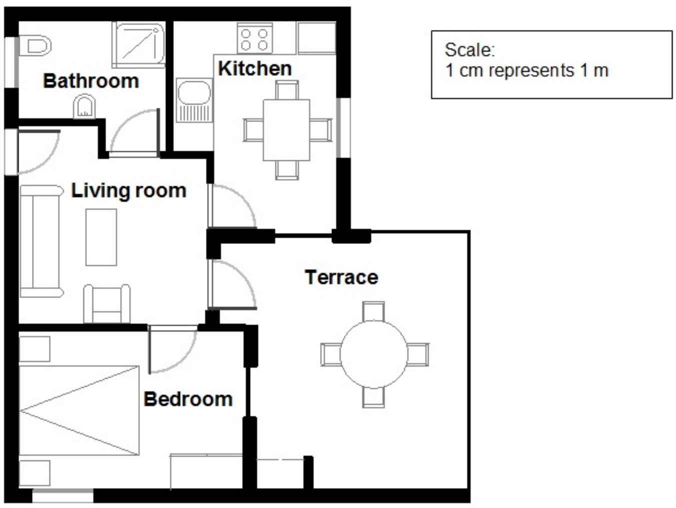
This section examines five released items drawn from the PISA Space & Shape cluster. These items were not rated by our expert raters, but they did examine them and discuss the underlying processes in an attempt to understand the reasons for lower achievement on this subscale among students in Ireland, and the extent to which those reasons might be addressed by the Project Maths curriculum. Details on how these items are scored and of the performance of students in Ireland, where available, and across OCED countries are provided in Appendix A7; two of the items were among a set of easier items not administered in Ireland

Apartment Purchase

This item is a good example of a PISA item that presents students with extraneous information, though it was not included in the tests administered in Ireland. Students in Ireland are likely to be familiar with compound shapes and to have been taught to find the area by addition of the two rectangles or subtraction of the negative space in the top-right of the diagram. According to the raters, in the pre-2010 curriculum, geometry was taught in the abstract with little reference to drawing or sketching so students may have been unfamiliar with the style of presentation used here.

Furthermore, this item illustrates the higher literacy demands of PISA items compared with those in the pre-2010 curriculum. While even First year students should have learned about measuring irregular shapes, the formulation of the question and the focus on identifying rather measuring lengths is unfamiliar. However, the Project Maths curriculum is likely to make students more comfortable with this type of question context. Project Maths students are also more likely to have

This is the plan of the apartment that George's parents want to purchase from a real estate agency.



Question 1: APARTMENT PURCHASE

To estimate the total floor area of the apartment (including the terrace and the walls), you can measure the size of each room, calculate the area of each one and add all the areas together.

However, there is a more efficient method to estimate the total floor area where you only need to measure 4 lengths. Mark on the plan above the **four** lengths that are needed to estimate the total floor area of the apartment.

taken part in group discussion of different approaches to measurement. In this way, they may reach more than one of the solutions to the question.

Sailing Ships

To solve this item, students are expected to use Pythagoras's Theorem and Higher and Ordinary level students of both versions of the curriculum should be able to use Pythagoras's Theorem. The diagram also suggests that this is like a standard trigonometry question. Alternatively, students could use the sine rule to answer this question, though the sine rule does not appear explicitly at any level on the Project Maths curriculum at junior cycle.

Question 2: SAILING SHIPS

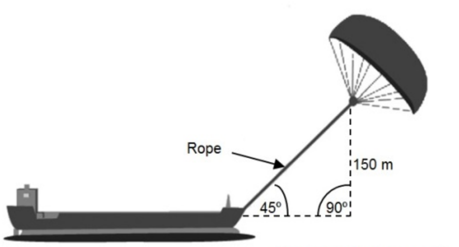
Approximately what is the length of the rope for the kite sail, in order to pull the ship at an angle of 45° and be at a vertical height of 150 m, as shown in the diagram opposite?

A → 173 m

B → 212 m

C → 285 m

D → 300 m

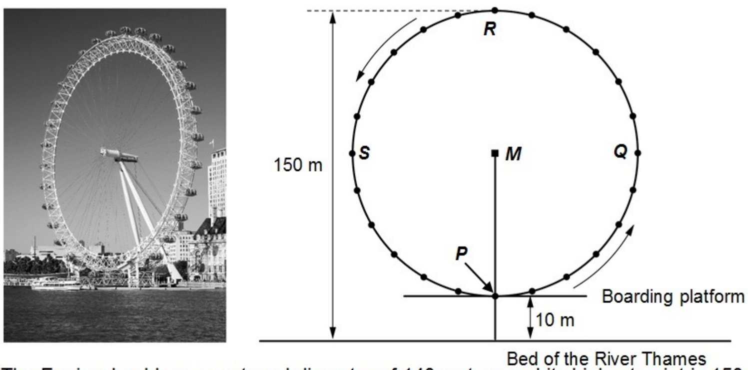


Note: Drawing not to scale.
© by skysails

London Eye

As with other items, the effort to create an applied setting for questions on the radius and the rotation of a circle makes for a complex diagram with extraneous and somewhat misleading information. However, once students are able to correctly interpret the precise question and the relevant information from the diagram, they should be equipped to answer correctly. According to the raters, however, the skills required are not necessarily those of geometry and the question can be answered using arithmetic only.

In London along the river Thames is a giant Ferris wheel called the London Eye. See the picture and diagram below.



The Ferris wheel has an external diameter of 140 metres and its highest point is 150 metres above the bed of the river Thames. It rotates in the direction shown by the arrows.

Question 1: LONDON EYE

The letter *M* in the diagram indicates the centre of the wheel.

How many metres (m) above the bed of the river Thames is point *M?*

Answer: .... m

Question 2: LONDON EYE

The Ferris wheel rotates at a constant speed. The wheel makes one full rotation in exactly 40 minutes.

John starts his ride on the Ferris wheel at the boarding point, *P*.

Where will John be after half an hour?

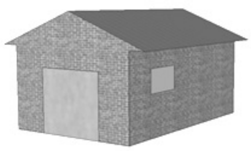
A At *R*
B Between *R* and *S*
C At *S*
D Between *S* and *P*

Garage

This item was identified as a particularly unfamiliar item for students in Ireland based on a limited tradition of visualisation or of drawing and modelling problems in the Irish curriculum. The first question requires mental rotation, an ability that can be developed through the use of models and other objects. Three-dimensional images are included in the Project Maths curriculum. The second Garage question demands a number of skills from students: the ability to read a plan accurately; and knowledge of Pythagoras's Theorem to make the appropriate calculations. Students in Ireland are well trained for the second part, which was among the most difficult PISA items, but not for the first.

A garage manufacturer's "basic" range includes models with just one window and one door.

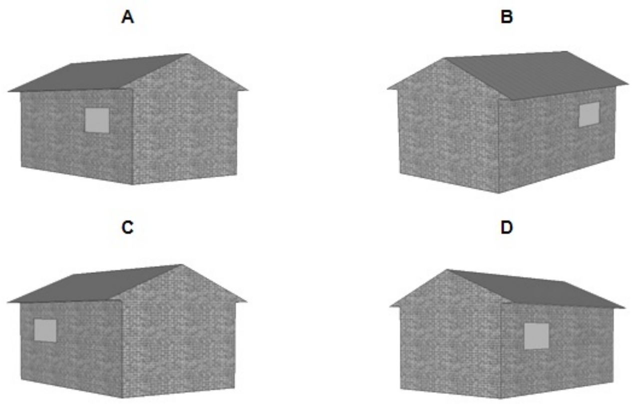
George chooses the following model from the "basic" range. The position of the window and the door are shown here.



Question 1: GARAGE

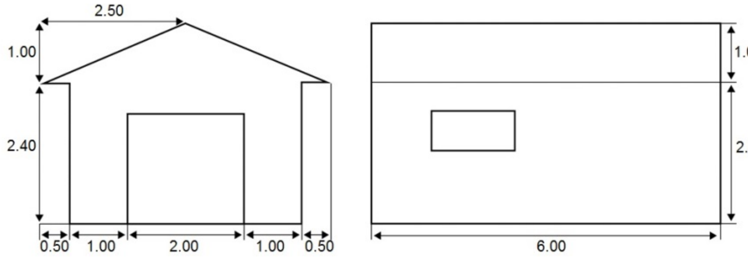
The illustrations below show different "basic" models as viewed from the back. Only one of these illustrations matches the model above chosen by George.

Which model did George choose? Circle A, B, C or D.



Question 2: GARAGE

The two plans below show the dimensions, in metres, of the garage George chose.



Front view Side view

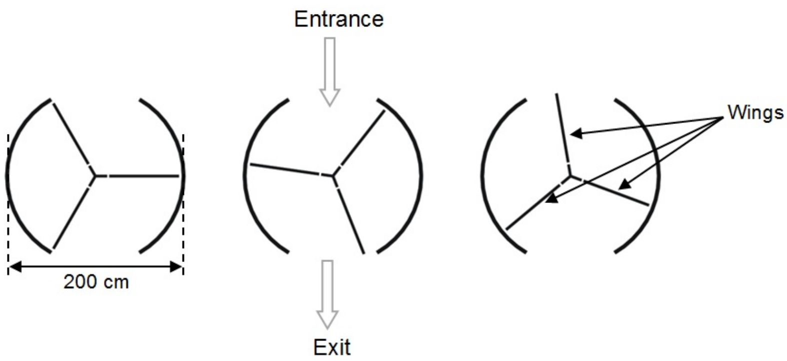
Note: Drawing not to scale.

The roof is made up of two identical rectangular sections.

Calculate the **total** area of the roof. Show your work.

Revolving Door

The presentation of the concept may be unfamiliar in the real-life context of a revolving door but should be familiar as a pie chart. The first question could be interpreted as asking about the angle formed by one-third of a circle, something with which students in Ireland are likely to be familiar. The second question requires a transformation, usually covered in lessons on geometrical rotation. However, there are two elements that were identified as potential impediments for students in Ireland. Firstly, the diagram shows the incorrect solution whereas demonstrations of the correct solution are more conventional in the Irish curricula. Secondly, the term 'arc length' may be new or unusual for students in Ireland.



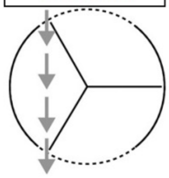
Revolving Door – Question 1

What is the size in degrees of the angle formed by two door wings?

Size of the angle: .... °

Revolving Door – Question 2

The two door **openings** (the dotted arcs in the diagram) are the same size. If these openings are too wide the revolving wings cannot provide a sealed space and air could then flow freely between the entrance and the exit, causing unwanted heat loss or gain. This is shown in the diagram opposite.



What is the maximum arc length in centimetres (cm) that each door opening can have, so that air never flows freely between the entrance and the exit?

Maximum arc length: .... cm

7.5 Discussion of Issues Raised During the TCRP

Raters repeatedly pointed to the literacy demands of PISA items, with the implication that a high level of basic literacy is required to successfully complete PISA mathematics items. They also noted differences in the mathematics vocabulary used in PISA and that found in students' textbooks which some students might find confusing. It was proposed that a glossary of terms and their synonyms 'estimate', 'solve', 'explain', 'maximum' and 'minimum', 'total', and 'net' be prepared and used as part on ongoing mathematics teaching and learning. If students are familiar with the range of related terms used in mathematics, they are less likely to be limited by the words used in a question, regardless of the context in which it appears.

Related to the issue of literacy is the amount of extraneous information included in PISA items. On the pre-2010 Junior Certificate syllabus, the custom and practice was to provide only information and data that were directly relevant to answering the question and no information could be shown on a diagram that was not in the written description. The presentation of information in the Project Maths syllabus is more like PISA than in the pre-2010 syllabus.

The extent to which students might be able to apply skills learned in other subjects to PISA also arose. Items involving maps and charts might be easier for students who had covered similar material in geography, for example, and students of technical graphics may have a significant 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.

Several curricular 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 PISA items were deemed not to be covered by the Project Maths curriculum. The two items in question concern 2-D and 3-D rotation of objects. Another item with which Project Maths students might still be unfamiliar involved relating information on a table to 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. The Project Maths syllabus was considered to have minimal coverage of data tables and the skill of interpreting data from tables.

The final issue, which was raised in relation to the Apartment Purchase item in particular, had to do with an implicit attitude to spatial mathematics in the pre-2010 curriculum. It may not have been valued as highly as purer, more abstract areas and may have been considered functional rather than conceptual. The emphasis in the pre-2010 curriculum was on formulating and solving equations as the highest form of mathematics skill, with other applications considered less important. The TCRP raters felt that the skills required for the practical application of spatial relations should be valued higher. The question arose as to whether there should be a Project Maths learning outcome specifically related to spatial visualisation, a process central to several of the PISA items reviewed. Patterns increasingly feature in Project Maths teaching materials and problems. Diagrams in PISA which were intentionally incomplete or implied additional elements might prove problematic to students in Ireland who are used to assuming that diagrams are complete. In order to work through such items, it was felt that it might be useful for students to draw or sketch additions to the diagram, though they have been unused to that under the pre-2010 curriculum.

Some general observations about Project Maths were shared by the raters. Teachers were thought to be having some difficulty in interpreting the learning outcomes of the curriculum, and were facing some conflicts between the pedagogy in which they were trained and the new approach in Project Maths. One issue that the raters felt was likely to be resolved over time is the compartmentalised teaching of the Project Maths strands. This, they believed, occurred largely due to the phased introduction of the syllabus. When fully implemented, Project Maths could be more like PISA in how content areas and processes overlap. 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 as well. An emphasis on practical pedagogy was apparent in the workshops with use of manipulables by teachers and encouragement to implement small-group discussion, 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.

7.6 Conclusion

Overall, the analysis presented here indicates that Project Maths at junior cycle level is closer in its conceptualisation to PISA mathematics than the pre-2010 junior cycle curriculum, suggesting that for PISA 2012 students in Initial schools might be better equipped for the types of items that PISA presents to students. 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 providing students with too many problems where the structure is clear and the solution is obvious.

Concerns have been raised in recent years over Ireland's relatively poor performance on PISA Space & Shape, which was significantly below the OECD average in both 2003 and 2012, with female students doing particularly poorly (Perkins et al., 2013). The same issue was identified across a number of English-speaking countries (OECD, 2014a), 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 solve problems.

8. Modelling Achievement on PISA 2012 Mathematics and Junior Certificate Mathematics

The focus throughout this report has been on bivariate comparison of the achievements, attitudes, and behaviour of students in Initial and Non-initial schools; gender comparisons have been included on the basis of a small difference in the gender balance between students in Initial and Non-initial schools. However, direct associations between two variables in isolation may overlook their relationship with other factors. Regression analysis involves predicting an outcome on one variable, in this case, mathematics achievement, based on one or more other variables. Because of the sampling method used for PISA 2012, whereby students were clustered in schools, it is important to separate the variation due to individual differences between students from school-level variation that affects every student in the school, using multi-level modelling. This chapter presents multi-level hierarchical linear regression models for print mathematics and for Junior Certificate results. The models include school- and student-level demographic and attitudinal variables.

8.1 Method

Regression analysis was conducted to assess whether attending an Initial school influences performance on the PISA mathematics scale or on the Junior Certificate mathematics examination when controlling for gender, grade level, ESCS, and a number of variables reflecting attitudes and behaviour at the student level as well as the school mean ESCS and school sector. The validity of a model rests on assumptions about normal distribution of data, independent errors, linearity, homoscedasticity, and the avoidance of multicollinearity and these assumptions are tested as the models are constructed. Analysis was conducted using HLM 6 (Raudenbush, Bryk, & Congdon, 2009).

8.1.1 Selection and Treatment of Variables

The main purpose of the models was to examine whether attendance at an Initial or Non-initial school was a significant predictor of mathematics achievement when controlling for other possible predictors. The PISA model uses scores on print mathematics and the Junior Certificate model uses results from Junior Certificate 2011, which included two Project Maths strands for students in Initial schools, and Junior Certificate 2012, which had four strands from the Project Maths curriculum; none of the students taking the Junior Certificate Examination in either of these years in Non-initial schools had any exposure to Project Maths prior to participating in PISA and sitting the Junior Certificate Examination. Project Maths status was the first variable selected. Based on the analysis presented in the main report on PISA 2012 and in this report, consistent predictors of mathematics achievement were identified. Gender was associated with a 15.3 point difference in scores between male and female students in PISA 2012. Students' ESCS and grade level were also associated with significant differences in achievement. As detailed in Chapter 4, a number of variables measuring students' attitudes to education and to mathematics were significantly correlated with achievement as well as differing significantly between Initial and Non-initial schools: intrinsic motivation, mathematics self-concept, mathematics anxiety, and self-responsibility for failure in mathematics. At the school level, school mean ESCS and sector were included, alongside Project Maths status. Arguments could have been made to include other variables that could have increased the predictive power of the final models but, in order to maintain the focus on Project Maths, the number of variables in the models was restricted. Reading literacy was considered, as detailed below, based on the observations in Chapter 7 on the literacy demands of PISA, but was ultimately excluded due to high co-linearity with mathematics. The variables used in the models are listed in Table 8.1.

8.1.2 Participants for the PISA 2012 Analysis

Participants were from the PISA 2012 sample with 62 cases (0.1%) removed on account of missing values on one or more of the variables in the model; there were no missing data on the school-level variables. The attitude variables were based on the PISA questionnaire which used a rotated design, as detailed in Chapter 2. Each of the questions contributing to the attitude scales was answered by two-thirds of students and scores were imputed for students who skipped items. In order to maintain the full dataset, a missing indicator was included alongside each scale variable. There were no differences in mathematics performance between students with missing data on a scale, and students for whom data on the scale was available. The four attitude scales and ESCS were standardised to a mean of 0.0 and standard deviation of 1.0. Categorical variables, such as grade level, required the use of dummy variables whereby one category was designated as the reference group to which all others are compared; in the case of grade level, Grade 9 corresponding to Third year was the reference group. Data were weighted according to the normalised population weights used in PISA 2012.

8.1.3 Participants in the Junior Certificate analysis

The State Examinations Commission provided Junior Certificate results from 2011 and 2012 for all students at the schools sampled for PISA 2012. Among the 5,016 students in PISA, matches could not be made for 150 students (2.99%) and among these 95 completed the examinations in 2013 or 2014. The remaining 55 students could not be matched for other reasons, including moving to a school in the PISA sample after completing the Junior Certificate elsewhere in 2011 or moving school after the PISA data collection in March 2012 and before the Junior Certificate examinations in June 2012. Accordingly, the sample for the model of Junior Certificate results was 4,866.

Junior Certificate results range from A to F at three levels: Higher, Ordinary, and Foundation. In order to devise a model of Junior Certificate results, it was necessary to use a single scale and a

Table 8.1
Variables used in Analysis of PISA 2012 Mathematics Achievement and Junior Certificate Mathematics Grade

Variable	
School Project Maths status	Initial and Non-initial
School mean ESCS	ESCS mean = 0, *SD* = 1
School sector	Secondary (reference group), Community and Comprehensive, and Vocational
ESCS	*M* = 0, *SD* = 1
Gender	Male and female
Grade level	Third year (references group), First and Second year[1], Fourth year, Fifth year
Mathematics anxiety	*M* = 0, *SD* = 1
Mathematics self-concept	*M* = 0, SD = 1
Self-responsibility for failure in mathematics	*M* = 0, SD = 1
Intrinsic motivation	*M* = 0, SD = 1

[1] First and Second year students were included in the PISA 2012 model but not in the Junior Certificate Examination model

Table 8.2
Junior Certificate Performance Scale Scores

JCPS score	Higher	Ordinary	Foundation
12	A		
11	B		
10	C		
9	D	A	
8	E	B	
7	F	C	
6		D	A
5		E	B
4		F	C
3			D
2			E
1			F

number of options were explored. The 12-point Junior Certificate Performance Scale (JCPS; Cosgrove et al., 2005) was considered first. As illustrated in Table 8.2, there is some overlap between the levels. The distribution of scores on the JCPS is slightly skewed, as depicted in Figure 8.1, and Cosgrove (2005) explored alternative 8- and 10-point scales that resulted in distributions closer to the normal distribution. However, the distribution of scores was not considered problematic so the 12-point scale was used to allow for clearer comparisons with Cosgrove et al.'s (2005) work.

8.1.4 Analysis strategy

The following sequence of analyses was conducted for each model:

1. Pearson product-moment correlations among the selected variables were conducted to test the assumption of multicollinearity. The correlation between reading literacy and mathematics was $r = .87$ so reading literacy was not included in the models. Table 8.3 shows the correlations for the variables used in the modelling analysis and, while there are some significant correlations and those between self-concept and both anxiety and intrinsic

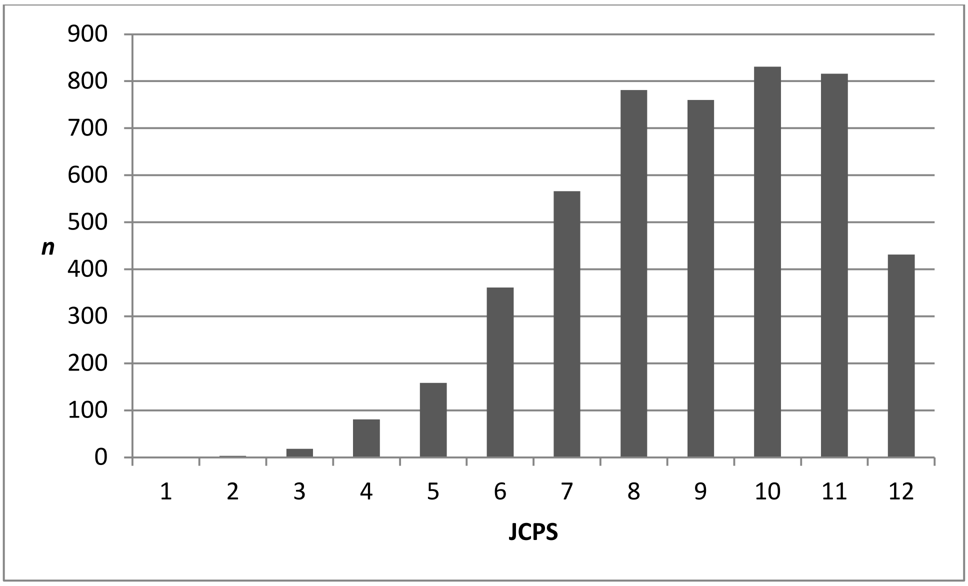


Figure 8.1. Distribution of Scores on the Junior Certificate Performance Scale

motivation are in the strong range, multicollinearity is not considered a risk. Junior Certificate results are also included in the correlation matrix in Table 8.3.

2. Regression analysis was conducted separately for each variable and each was a significant predictor of mathematics achievement except Project Maths status. However, the Project Maths variable was retained in the model.
3. The assumption of linearity was tested by including the quadratic term of each of the scale variables in the model. Non-linear relationships were observed with four variables so their quadratic term was added to the model and the nature of the relationship was considered separately, as discussed below.
4. Interactions between Project Maths status and each of the other variables were also tested and no significant interactions were observed. This suggests that any impact of Project Maths is unlikely to differ based on any of these school or student characteristics.
5. Each model was estimated using full maximum likelihood and the goodness-of-fit of both fixed effects, that is, the variables in the model, and random effects were tested.
6. Regression analysis of the final models yielded *t* statistics and their statistical significance for each of the continuous variables was tested. For the categorical variables, the deviance difference was calculated. Deviance is a measure of quality of model fit and deviance difference compares the full model to a model without the variable in question, which is then compared to the chi-squared distribution to establish statistical significance. A

Table 8.3
*Correlations Among the Variables Used in the Models of PISA 2012 Print Mathematics Achievement (*n *= 4,954) and Junior Certificate Examination Grade (*n *= 4,866)*

	1	2	3	4	5	6	7	8	9	10	11	12
1. PISA print mathematics	-	.01	.38***	-.01	.38***	.02***	.02***	.24***	.40***	-.38***	-.19***	.75***
2. Project Maths	.01	-	-.01	.001	-.01	-.02***	-.01	-.04***	-.03**	.03**	.03***	.02***
3. School mean ESCS	.38	-.01	-	-.10**	.48***	-.01	-.07***	-.004	.05**	-.07***	.03	.41***
4. School sector	-.01	.001	-.10**	-	-.04*	.03*	-.01	-.01	.03	-.02	-.04	-.03***
5. Student ESCS	.38***	-.01	.48***	-.04	-	.01	-.04*	.08	.15	-.12	-.05	.43***
6. Gender	.023**	-.02***	-.01	.03*	.01	-	-.06***	.03	.14***	-.18***	-.10***	-.06***
7. Grade	.02***	-.01	-.07***	-.005	-.04*	-.06***	-	-.05**	-.01	-.01	.07***	-.06***
8. Intrinsic motivation	.24***	-.04***	-.004	-.01	.08***	.03	-.05**	-	.69***	-.49***	-.37***	.30***
9. Self-concept	.40***	-.03***	.05**	.03	.15***	.14***	-.01	.69***	-	-.75***	-.44***	.41***
10. Anxiety	-.38***	.03***	-.07***	-.02	-.12***	-.18***	-.01	-.49***	-.75***	-	-.20***	-.33***
11. Resp'bility for failure	-.19***	.03***	.03	-.04	-.05***	-.10***	.07***	-.37***	-.44***	-.20***	-	-.20***
12. JCPS score	.75***	.02***	.41***	-.03***	.43***	-.06***	-.06***	.30***	.41***	-.33***	-.20***	-

* $p < .05$
** $p < .01$
*** $p < .001$

parameter estimate is also reported for each variable which indicates the change in mathematics achievement score expected with a one unit change in the predictor. For the standardised scale variables, a one unit change represents one standard deviation while for the categorical variables the parameter is a comparison to the reference group.

7. The percentage variance explained by the full model was calculated. Principles of hierarchical regression were then applied to calculate the contributions of the demographic and school-level variables, the attitude scales, and Project Maths status to the explanatory power of the model.

8.2 Model of Mathematics Achievement on PISA 2012 Initial and Non-initial Schools

In the final model of mathematics achievement on PISA 2012, Project Maths status is a significant predictor of mathematics performance. According to the model, attending an Initial school is associated with a 10-point advantage on print mathematics over students in Non-initial schools when the influence of all the other variables is controlled for. Overall, the model explains 34.1% of the total variance in performance, 81.9% of the between-school variance and 22.8% of the within-school variance. Table 8.4 sets out the final model of PISA 2012 print mathematics.

Table 8.4
Model of PISA 2012 Print Mathematics Performance

Variable	Comparison	PE[1]	*SE*	Test statistic	*df*	*p*
	Intercept	502.25	3.27	$t = 153.69$	177	< .001
School-level						
Project Maths status	Initial-Non-initial	10.31	3.77	$t = 2.74$	177	.007
School mean ESCS	ESCS	22.72	1.82	$t = 12.48$	177	< .001
	$ESCS^2$	-5.14	1.11	$t = -4.62$	177	< .001
Sector	Comm., Comp.-Secondary	-9.70	5.18	$\Delta X^2 = 5.42$	2	.067
	Vocational-Secondary	-2.4	4.03			
Student-level						
Student ESCS	ESCS	17.58	1.29	$t = 13.64$	321	< .001
Gender	Female-Male	-13.41	2.50	$t = -5.38$	609	< .001
Grade	Grade 7 and 8-Grade9	-33.74	8.68	$\Delta X^2 = 179.67$	3	< .001
	Grade 10-Grade9	24.70	2.77			
	Grade 11-Grade9	24.01	3.87			
Attitudes towards mathematics	Mathematics anxiety	-9.97	2.13	$\Delta X^2 = 34.28$	2	< .001
	Mathematics $anxiety^2$	1.88	1.02			
	Missing mathematics anxiety	6.26	3.02			
	Mathematics self-concept	17.54	2.10	$\Delta X^2 = 87.57$	2	< .001
	Mathematics $self\text{-}concept^2$	1.89	1.14			
	Missing mathematics self-concept	6.26	3.02			
	Self-responsibility for failure	-5.38	1.65	$\Delta X^2 = 52.89$	2	< .001
	Self-responsibility for $failure^2$	-3.02	0.63			
	Missing self-responsibility for failure	1.73	2.44			
	Mathematics intrinsic motivation	9.08	1.71	$\Delta X^2 = 45.95$	1	< .001
	Missing mathematics intrinsic motivation	1.73	2.44			

[1] PE = Parameter Estimate

Four variables in the model had non-linear relationships with mathematics performance: school mean ESCS, mathematics anxiety, mathematics self-concept, and self-responsibility for failure in mathematics. Figures 8.2 to 8.5 graph the relationship between the expected change in achievement score for students scoring above or below average for each of the four scales. The impact of school mean ESCS is greater for low-ESCS schools, with the model predicting scores more than 60 points lower than average, while for high-ESCS schools the advantage is less pronounced (Figure 8.2). The relationships between mathematics achievement and both individual-level anxiety and self-concept show a similar pattern (Figures 8.3 and 8.4). Students with low levels of anxiety and those with high scores on the self-concept scale saw the largest predicted advantages, more than 40 points for those scoring two standard deviations above average. At the lower end of the self-concept scale, as with those reporting high levels of anxiety, the effect was smaller and negative. Finally, attributing responsibility for failure to others, as indicated by a low score on the scale, showed little impact on achievement. For students who attribute responsibility for failure to themselves (i.e. those with high scores on the scale), there was a clear negative impact on predicted performance.

The model can be conceptualised as a hierarchical model with the school-level demographic variables entered first, followed by the student-level demographics, then the student attitudes, and finally Project Maths status. Table 8.5 shows the additional variance accounted for by entering each set of variables sequentially. School-level variables account for just under half of the total variance explained by the model, with student demographic variables and student attitudes each contributing between one-quarter and one-third (ΔR^2). The contribution of Project Maths is small when all of the other variables have been accounted for, but it still makes a significant contribution to the explanatory value of the model.

The intercept corresponds to a male student in Third year at a Non-initial secondary school with average ESCS, from a family of average ESCS, with average attitudes towards mathematics and he would score 502.3 on PISA 2012. It is also interesting to consider the impact of the regression on the distribution of scores across schools. The score for mathematics performance for every student can be adjusted according to their demographic characteristics and attitudes, with adjusted school mean scores calculated from the adjusted student scores. Figures 8.6 and 8.7 show the distributions of print mathematics performance for Non-initial and Initial schools, and both reasonably approximate the normal curve. For both school groups, there is no dramatic difference between the adjusted and unadjusted distribution. However, the lack of differences risks masking large increases in some school mean scores compensating for large decreases in others. Figures 8.8 and 8.9 show the magnitude of the adjustment for each Non-initial and Initial school; a linear trend line is added to illustrate the aggregate effect of the adjustment on school mean scores. The graph for Non-initial

Table 8.5

Variances Explained in Hierarchical Regression of School-level Variables, Student-level Variables, and Project Maths status on Mathematics Performance on PISA 2012

	Between		*Within*		*Total*	
Variable	R^2	ΔR^2	R^2	ΔR^2	R^2	ΔR^2
School mean ESCS and Sector	82.95		-0.08[1]		15.76	
+ Student demographics	80.22	-2.73[1]	10.42	10.51	23.74	7.98
+ Student attitudes	81.66	1.44	22.80	12.38	34.03	10.29
+ Project Maths status	81.98	0.32	22.80	0.00	34.09	0.06

[1] A decrease in the percentage variance explained is attributable to measurement error rather than to a negative effect.

schools shows that school mean scores for lower-performing schools generally increased when adjusted for the variables in the model while those of higher-performing schools decreased. The effect holds even if a small number of outlier schools were to be excluded. A similar pattern is observed for the Initial schools, though it is less pronounced.

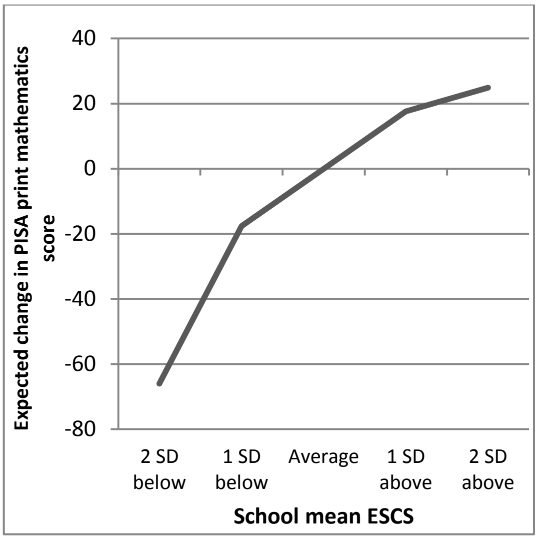


Figure 8.2. Relationship between School Mean ESCS and Mathematics Performance

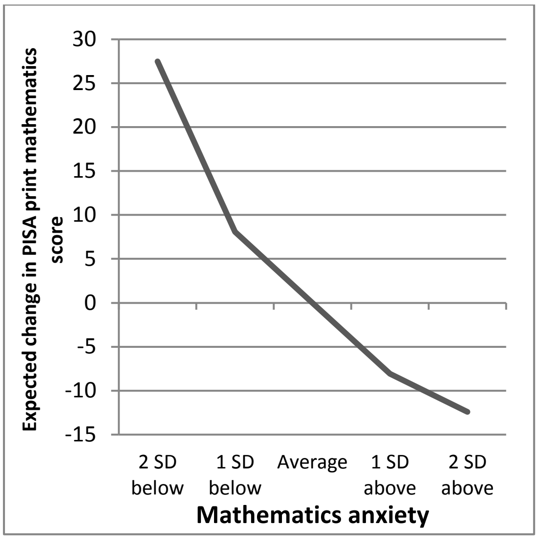


Figure 8.3. Relationship between Mathematics Anxiety and Mathematics Performance

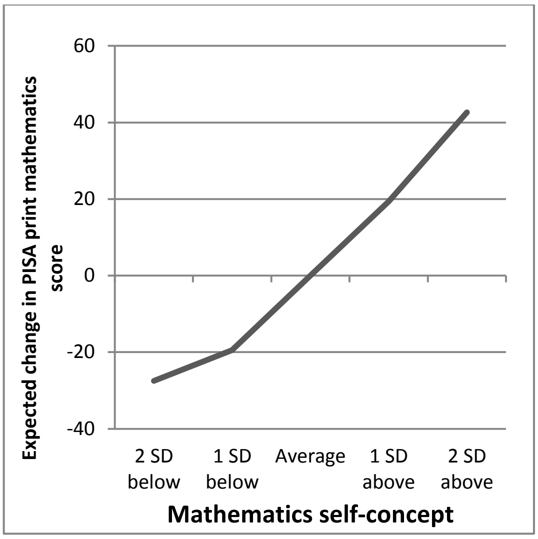


Figure 8.4. Relationship between Mathematics Self-concept and Mathematics Performance

Figure 8.5. Relationship between Self-responsibility for Failure in Mathematics and Mathematics Performance

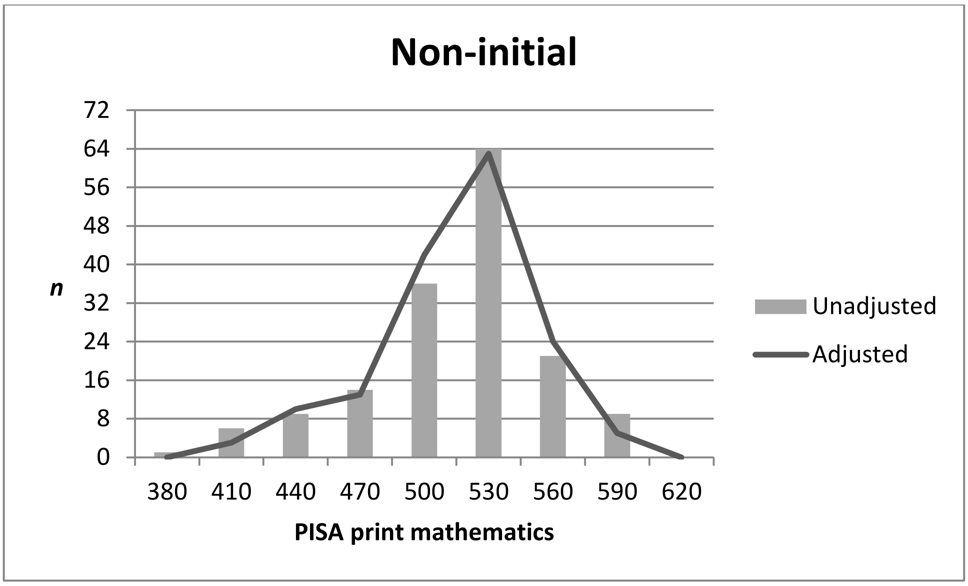


Figure 8.6. Distribution of Unadjusted and Adjusted School-mean Mathematics Performance for Non-initial Schools

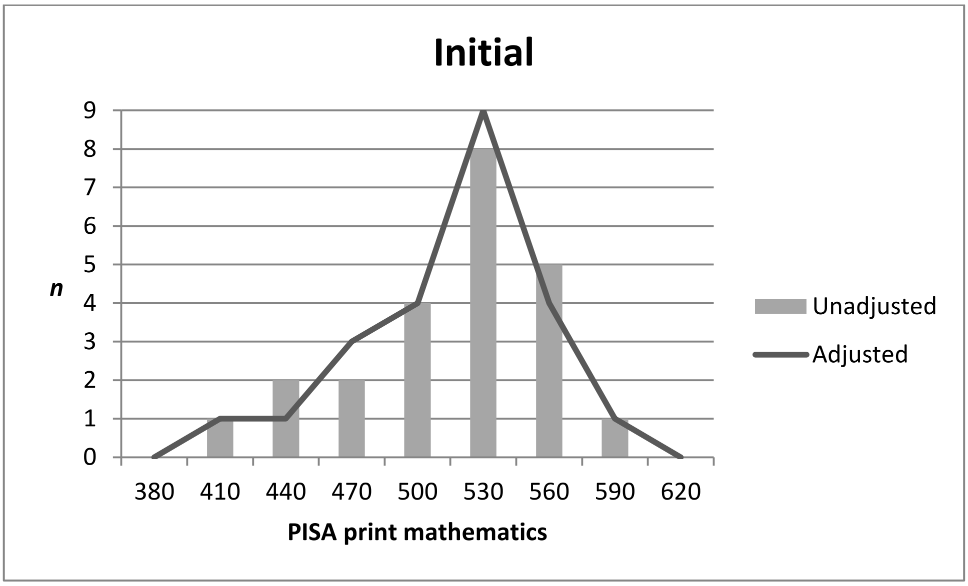


Figure 8.7. Distribution of Unadjusted and Adjusted School-mean Mathematics Performance for Initial Schools

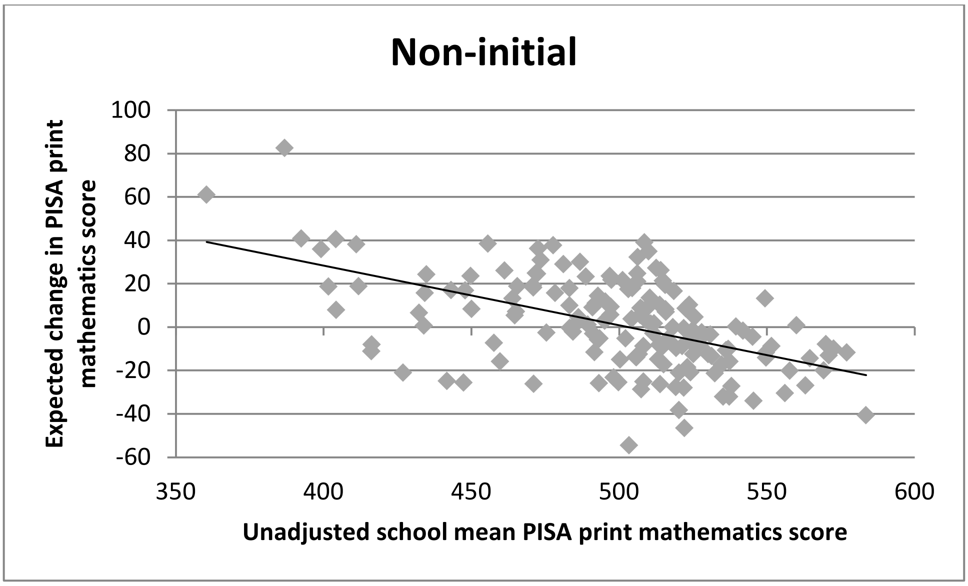


Figure 8.8. Expected Change in School-mean Mathematics Performance for Non-initial Schools

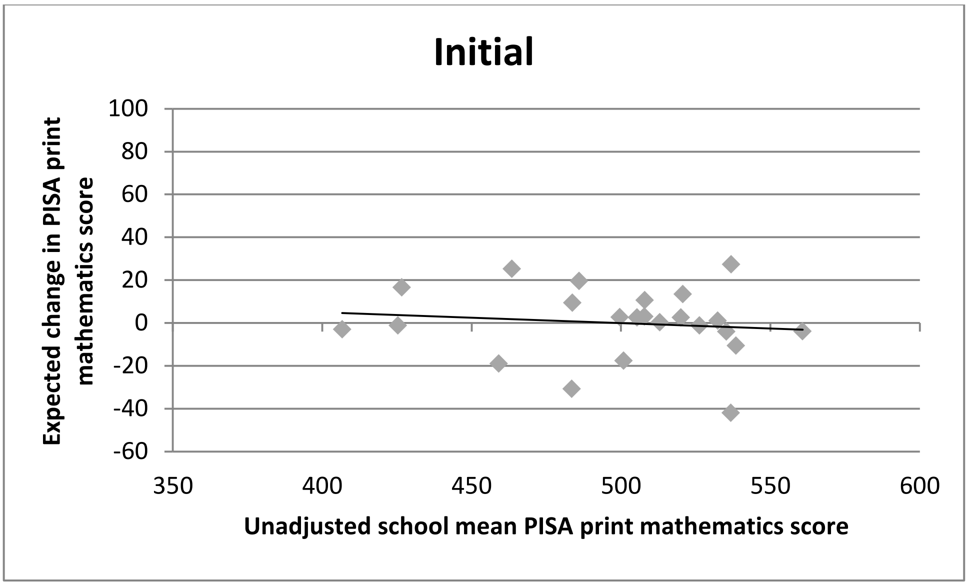


Figure 8.9. Expected Change in School-mean Mathematics Performance for Initial Schools

8.3 Model of Junior Certificate results in Initial and Non-initial Schools

The purpose of the model of Junior Certificate results was to determine if a model in which Junior Certificate mathematics grades was the outcome variable showed similar associations with the predictor variables. As a preliminary step in the analysis, Figure 8.10 presents the distribution of scores on the Junior Certificate Performance Scale for Initial and Non-initial schools. The results for 2011 and 2012 are combined, and this is somewhat problematic given that different examination papers were administered to students in Initial and Non-initial schools, and that students in Initial schools were examined in two of the Project Maths curriculum strands in 2011 and four in 2012, though 60.5% of the PISA sample sat the Junior Certificate in 2012 compared to 37.6% in 2011. The

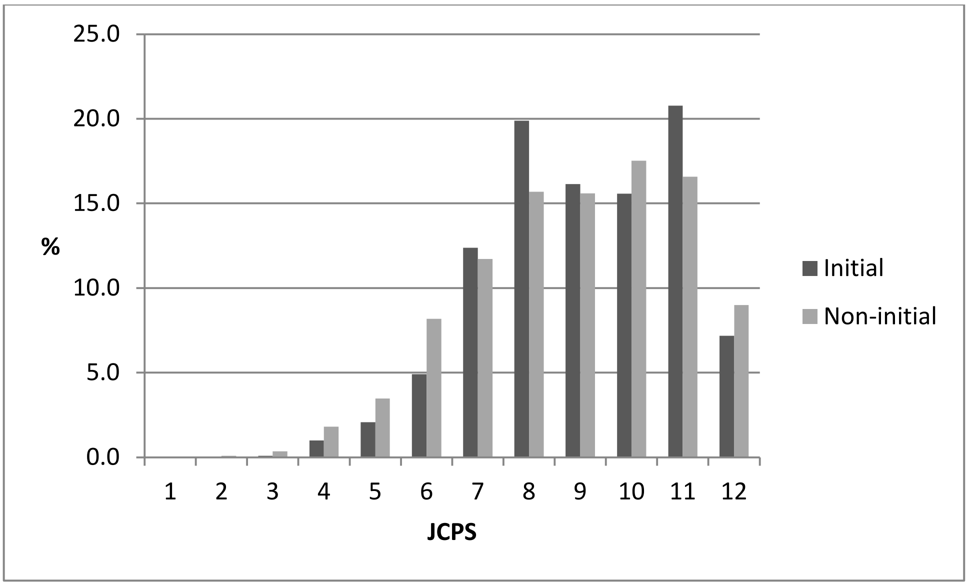


Figure 8.10. Distribution of Junior Certificate Mathematics Grades on the Overall Performance Scale for Initial and Non-initial Schools

combined results, however, show significant differences between the two school groups (χ^2 (10) = 108.8, p < .001); the variance within each group was heterogeneous so a non-parametric test was used. More students in Initial schools scored at point 8 (corresponding to Grade E at Higher level and Grade B at Ordinary level) and point 11 (Grade B at Higher level), while more students in Non-initial schools scored at point 6 (Grade D at Ordinary level and A at Foundation), and at points 10 and 12 (Grade C and Grade A at Higher level respectively). The distributions of grades at Higher, Ordinary, and Foundation levels are shown in Appendix A8 though no tests of difference are reported. The correlation between Junior Certificate results and PISA print mathematics performance is r = .76 for Initial schools and r = .75 for Non-initial.

The structure of the model for Junior Certificate mathematics is very similar to the one for PISA print mathematics (Table 8.6). Project Maths status is a small but significant predictor of Junior Certificate mathematics performance, accounting for one-third of a grade difference in scores. The only difference from the PISA model is that mathematics anxiety is not a predictor of Junior Certificate scores and possible reasons for this are considered below. There was one non-linear relationship in the model, between Junior Certificate performance and self-responsibility for failure in mathematics. Figure 8.11 shows the graph of the relationship and indicates that those with very low or low scores on responsibility for failure in mathematics, which correspond to attributing responsibility to others, score close to the average Junior Certificate performance while those with high levels of self-attribution for failure perform less well on Junior Certificate mathematics. Grade level is a significant predictor of performance on both the PISA mathematics scale and the Junior Certificate Performance Scale but the pattern of predicted scores differs. For the Junior Certificate, those who go on to Transition year have a predicted score that is higher than expected while those who begin Fifth year after the Junior Certificate have a lower predicted score. This contrasts with the PISA 2012 model where Transition year and Fifth year students have the same predicted score (Perkins et al., 2013). Table 8.7 sets out the proportions of variance explained by the school-level variables, student demographics, student attitudes, and Project Maths status and the pattern is similar to the PISA model.

Table 8.6
Model of Junior Certificate Mathematics Performance

Variable	Comparison	PE	*SE*	*Test statistic*	*df*	*p*
	Intercept	8.87	0.08	t = 116.89	177	< .001
School-level						
Project Maths status	Initial-Non-initial	0.34	0.09	t = 3.71	177	< .001
School mean ESCS	ESCS	0.53	0.05	t = 10.81	177	< .001
	$ESCS^2$	-0.16	0.03	t = -5.09	177	< .001
Sector	Comm., Comp.-Secondary	-0.28	0.15	ΔX^2 = -8.44	2	.015
	Vocational-Secondary	-0.22	0.10			
Student-level						
Student ESCS	ESCS	0.54	0.03	t = 18.68	4789	< .001
Gender	Female-Male	0.35	0.06	t = 5.83	4789	< .001
Grade	Grade 10-Grade9	0.19	0.07	ΔX^2 = -1.64	1	< .001
	Grade 11-Grade9	-0.20	0.10			
Attitudes towards mathematics	Mathematics anxiety	-0.06	0.05	ΔX^2 = -5.35	2	.069
	Missing mathematics anxiety	0.11	0.07			
	Mathematics self-concept	0.58	0.05	ΔX^2 = -172.42	2	< .001
	Missing mathematics self-concept	0.11	0.07			
	Self-responsibility for failure	-0.11	0.04	ΔX^2 = -37.50	3	< .001
	Self-responsibility for failure^2	-0.05	0.01			
	Missing self-responsibility for failure	0.03	0.06			
	Mathematics intrinsic motivation	0.31	0.04	ΔX^2 = -96.14	2	< .001
	Missing mathematics intrinsic motivation	0.03	0.06			

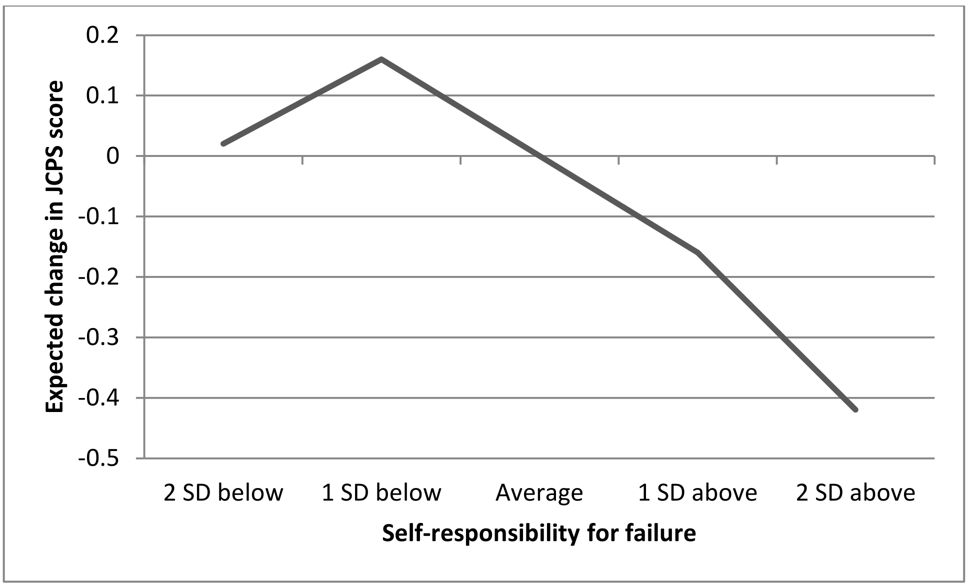


Figure 8.11. Relationship Between Self-responsibility for Failure in Mathematics and Junior Certificate Overall Performance Score

Table 8.7
Variances Explained in Hierarchical Regression of School-level Variables, Student-level Variables, and Project Maths status on Junior Certificate Performance

	Between		Within		Total	
Variable	R^2	ΔR^2	R^2	ΔR^2	R^2	ΔR^2
School mean ESCS and Sector	75.96		0.00		18.69	
+ Student demographics	75.68	-0.28	10.11	10.11	26.33	7.64
+ Student attitudes	80.01	4.34	23.81	13.70	37.72	11.38
+ Project Maths status	80.46	0.45	23.81	0.00	37.83	0.11

[1] A decrease in the percentage variance explained is attributable to measurement error rather than to a negative effect.

8.4 Conclusion

In models which include school characteristics, student demographics, and student attitudes towards mathematics, Project Maths status is a significant predictor of PISA mathematics performance and Junior Certificate mathematics grade, accounting for increases of 10 points and one-third of a grade, respectively. Another significant predictors is ESCS, measured at both the school average level and the individual level, as is consistently observed in other models of achievement based on PISA (Cosgrove et al., 2005; Perkins et al., 2012). Also unsurprisingly, 15-year olds who were in Transition or Fifth year would perform better on PISA, after accounting for other variables in the PISA model, than those in Third year, perhaps on the basis of their exposure to differing levels of mathematical content, while those in First or Second year would have a significant negative increment. The pattern of grade-level difference in Junior Certificate performance highlights a difference in favour of students who take Transition year compared with those who continue to Fifth year after junior cycle. Aside from anxiety, the relationships between the other scales of attitudes towards mathematics are similar for PISA and the Junior Certificate. The gender gap in the PISA model predicts higher scores among male students while the Junior Certificate model predicts the opposite, with female students expected to have scores that are higher by about one-third of a grade. Overall, the models of mathematics performance have less explanatory power than previous models of PISA results (Cosgrove et al., 2005; Perkins et al., 2012) and Junior Certificate performance (Sofroniou, Cosgrove, & Shiel, 2002), perhaps because of their focus on variables that were associated with the Project Maths status of the schools. The explanatory power for between-school variance is at similar levels (approximately 80%) but it is lower in the present study for within-school variance (23% compared to 50% in Cosgrove et al., 2005)

The relationship between mathematics anxiety and performance is a complex one. As reported in Chapter 4, students in Initial schools reported higher levels of mathematics anxiety and this was associated with a 10-point decrease in expected performance on PISA print mathematics. In the model of Junior Certificate mathematics, however, it was not a significant predictor of performance. Project Maths may have led to an increase in the anxiety associated with tackling problems and worry about grades, issues both related to the implementation of Project Maths.

There are indications from these models of factors in mathematics performance on which policy could have an impact. Intrinsic motivation, which has to do with students' expectations that studying mathematics will be worthwhile for their future life and career, is a significant predictor of performance and providing students with additional information on the value of mathematics might be an attainable goal. The relationship between mathematics self-concept, that is, believing one is good at mathematics, and performance on tests is likely to be a circular one. However, if being good at mathematics was conceptualised less as an immutable personality trait and more as something that could be achieved by all students through effort, it may be possible to improve the mathematics self-concept of students, and their performance.

Overall, there is evidence that attending an Initial school predicts higher scores on PISA mathematics and in the Junior Certificate when controlling for a range of other factors. However, the strongest influences on performance reside beyond the classroom, in the background of each student and their peers. The final chapter sets out recommendations on how the impact of what happens inside the school and inside the classroom can be maximised to the benefit of students.

9. Conclusions

The research presented here on Project Maths and PISA 2012 includes comparisons of student achievement and attitudes in Initial and Non-initial schools, analysis of the resources and policies of those schools, reports of teachers' practices, a test-curriculum rating project, and models of performance on PISA 2012 print mathematics and Junior Certificate mathematics. Overall, students in Initial schools had slightly higher scores on the PISA 2012 print mathematics scale and subscales; significantly higher scores were observed on the Interpreting process subscale for male students in Initial schools and on the Space & Shape subscale for female students in Initial schools. Attitudes and behaviours were generally more negative among students in Initial schools, though the relationship between attitudes and performance is a complex one whereby anxiety had a significant negative association with PISA mathematics, but no significant association in the model of Junior Certificate mathematics. Aside from Project Maths status, there were few differences between the Initial and Non-initial schools, suggesting that there was nothing unusual about the resources or practices of the Initial schools and that implementation should operate similarly in all schools. Contrasting with the attitudes of their students, principals in Initial schools were more positive and more enthusiastic about Project Maths. Teachers in Initial and Non-initial schools reported different recent experiences consistent with their school's Project Maths status: Those in Initial schools had higher levels of participation in CPD and used more resources other than textbooks and examination papers, including ICT. The curriculum analysis demonstrated that students studying Project Maths should be more familiar with PISA items than those studying the previous curriculum, though it is possible that the raters in the TCRP may have focused on the pre-2010 curriculum as it came to be implemented, rather than as originally intended, while Project Maths was assessed with closer reference to the curriculum documentation. Finally, the models of PISA mathematics and Junior Certificate mathematics indicated that there was an advantage for students in Initial schools when controlling for a range of relevant school and student variables.

9.1 Implementation of Project Maths

Curriculum change is a long-term process, and the overall impact of Project Maths is only beginning to be established but there are examples of how PISA has shown evidence of the impact of earlier reforms. Changes to the junior cycle mathematics curriculum in 2000 did not have a discernible immediate impact on PISA mathematics in either 2003 or 2006 (Eivers, Shiel, & Cunningham, 2008) but in the report on PISA 2012, Perkins et al. (2013) suggest that the introduction of social, environmental, and scientific education in the revised primary curriculum in 1999 and changes in the junior cycle science syllabus in 2003 may have contributed to the significant increase in science achievement observed in Ireland in 2012, and manifested to a lesser extent in 2009. Following considerable reform of the science curriculum and investment in teacher development in science at primary and lower secondary levels, akin to the Project Maths reform and implementation, there was an improvement in performance consistent with Fullan's (2001) ten-year timeframe for curricular reform.

Implementation of Project Maths placed additional pressures and demands on students and on teachers, evident in some of negative attitudes observed in the current study. For example, there were high levels of reported anxiety among girls in Initial schools, and it remains to be seen whether these attitudes can be attributed to the transition itself or are down to issues in the teaching, learning, and assessment of Project Maths. The transition period was characterised by increased scrutiny that may have contributed to anxiety among teachers and parents, which in turn could have contributed to higher levels of anxiety among students. The same attitudes may not persist following full implementation. In Initial schools, there was uncertainty about less predictable examination questions, while students in Non-initial schools could be more immersed in examinations that may have become somewhat more predictable and could begin to focus on the examinations earlier. Differing levels of commitment between principals and teachers may also explain some negative attitudes. In all of this; however, it is important to bear in mind that there was scope for considerable variation in how Project Maths was presented at school and classroom levels, and how it was interpreted by students, so experience of the curriculum may not have been uniform.

Based on the survey of teachers reported here, there is considerable demand for CPD as Project Maths proceeds. The teachers in Initial schools benefited from the availability of an RDO but the ratio of direct support to teachers was reduced as Project Maths reached national scale. Continuing professional development was seen as the primary means of making the necessary changes involved in scaling-up curricular reform and national implementation would be strengthened with the provision of continuing support for teachers.

At a pedagogical level, Project Maths allows for multiple correct answers, a principle that requires a shift in thinking among teachers in order to be able to introduce the concept to students. Likewise, recognising the inter-connection of topics will be a challenge, even for more able students. The OECD (2014b) report on PISA 2012 problem-solving suggests that opportunities to develop curiosity, perseverance, and creativity should be prioritised in teaching, and this is consistent with the aims of Project Maths. There is a growing trend of greater ICT usage in all aspects of students' lives and Project Maths was intended to make more and better use of ICT in teaching and learning. There is evidence that this occurred more in Initial schools, but even then certain aspects such as use of spreadsheets could have been emphasised to a greater extent. Finally, students in Ireland scored well below the OECD average for participation in extra-curricular activities involving mathematics, and the levels of activities offered directly by schools were low for both Initial and Non-initial schools. This is an area to which all schools could pay greater attention in the future.

9.2 Space & Shape

Given Ireland's history of relatively weak performance on Space & Shape, it was the focus of particular attention in this report. There was a significant advantage for female students in Initial schools, bringing them in line with the OECD average for females, with the effect that the mean score for all students in Initial schools was not significantly different from the OECD average. Continuing to improve performance on Space & Shape in PISA could require changes in the primary mathematics curriculum, such as inclusion of more transformational geometry topics and higher order geometric thinking, and more practical work in geometry and measure and there is evidence of some movement in this direction in a recent publication by the Professional Development Service for Teachers (2013). Similarly, the junior cycle Project Maths curriculum could include informal deduction and connection with applied measures. The Project Maths curriculum covers modelling of patterns and of geometric and compound shapes in real-world situations in a way that is similar to the outgoing syllabus: It consists of what could be viewed as a rather isolated and formal set of synthetic geometry axioms and theorems which many students may learn by rote with little or no understanding of the nature of proof or the applications of theorems. The geometry and trigonometry strand of the Project Maths curriculum should be reviewed and brought into line with the overall thrust of Project Maths, including a stronger focus on learning-for-understanding and a specific learning outcome on spatial visualisation. The theoretical emphasis in the Project Maths Geometry and trigonometry strand may also need to be examined in terms of its impact on students' spatial reasoning and visualisation.

Some PISA items had diagrams that were incomplete or that implied additional elements and the TCRP participants proposed that drawing or sketching the diagram might be useful for students. A stronger focus on Space & Shape and problem-solving more generally could be achieved through the provision of short courses on spatial reasoning and the application of such reasoning to other aspects of mathematics including algebra (see Perkins et al., 2013). The potential of appropriate software to increase the skill in spatial reasoning should also be explored (e.g. Uttal et al., 2013).

9.3 Literacy

Concerns were repeatedly raised in the present study about the literacy demands of Project Maths, with teachers in Initial schools particularly conscious of the challenge. In order to achieve the aim of situating questions in a real-world context, it is necessary to include a narrative description of the context. A relatively high level of verbal literacy appears to be necessary to successfully complete real-life mathematics items. For students with limited literacy skills, the additional information could act as a barrier to understanding rather than a facilitator. To address this and provide a stronger sense of balance, some context-free, abstract items could be used in teaching alongside some with narrative.

The curriculum analysis identified that PISA items often make use of extraneous information. Under the previous curriculum, students were less familiar with the process of identifying which information to attend to in answering a question, whereas students of the Project Maths curriculum were expected to be more familiar with that form of presentation. The range of terminology used in PISA was identified as being wider than in the Irish curriculum. As part of teacher CPD, and consistent with the focus of the National Strategy to Improve Literacy and Numeracy (DES, 2011b), lists of mathematical terms could be prepared that give synonyms and informal expressions, and strategies for engaging students in mathematical discourse beginning in primary school could be emphasised more strongly. Students could be supported in developing fluency in communicating mathematically during mathematics lessons through presentations, and group and pair work. A key element of this involves students explaining their mathematical reasoning, which can be extended through skilful teacher questioning. Other relevant teacher activities include following the student's lead, cueing and prompting, inviting further comment, use of repetition, recall, and expansion, modelling the use of vocabulary in sentences, and use of topic elaboration (Dooley, 2011).

9.4 Socio-demographic Factors

Notwithstanding the impact of Project Maths status or of gender, the strongest predictors of PISA 2012 scores and of Junior Certificate results were measures of socio-economic status, both at the individual level and at the school level. Most of the variation between schools was accounted for by socio-economic status, as was the case for the other PISA domains (Perkins et al., 2013; Perkins & Shiel, 2014). Within schools, there was a wide range of abilities even if Ireland has relatively small between-school differences by OECD standards, implying a more equitable school system. Despite this, Perkins et al. (2013) showed large differences between students in DEIS schools and those in non-DEIS schools. While it was not possible to look at disadvantage in the current study due to the small number of Initial DEIS schools, it will be important to monitor the effects of the revised mathematics curriculum on schools with different SES intakes. On both print and computer-based mathematics, there were wider gender gaps in Initial schools compared with Non-initial schools. As the achievement scores of female students were generally lower, this suggests that male students may have benefitted more from Project Maths at this stage.

9.5 Recommendations for Future Research

It is possible that the negative attitudes of students, and some teachers, in initial schools could be attributable to the transition to Project Maths, a period of heightened attention, commentary, and perceived pressure on the schools, teachers, and students involved. If this is so, then attitudes should return to the average levels following full implementation. The persistence or otherwise of those differences remains to be established and there are two possible methods of tracking future changes: re-testing students in Initial schools to examine whether attitudes have changed; and re-interviewing students in Initial schools about their attitudes. The performance gains made by Initial schools, and the possible negative impact on attitudes, were measured at only one point in time in this study.

Further analysis should be undertaken of the impact of SES, including whether there are differential effects of curriculum change for better-off and less well-off students, or students in schools with high and low average SES. In parallel, on-going research on teaching and learning in mathematics would identify changes in teaching practice including in areas such as Space & Shape. Beyond this, there needs to be a plan for the ongoing evaluation of mathematics in post-primary schools that encompasses not only international studies such as PISA and TIMSS but also national research that focuses on specific questions (teacher competence and confidence, student proficiency in specific aspects of mathematics, use of technology in mathematics classes, effects of state examinations on teaching and learning etc.). Such research should not rely only on grades achieved by students in examinations or the proportions taking Higher level examinations at Junior and Leaving Certification as the main outcome but should also include broader achievement and attitude measures linked to curriculum outcomes. Particular attention should be paid to the performance of higher-achieving students, at both Junior and Leaving Certificate levels.

9.6 Project Maths and PISA 2012

The purpose of this analysis was to compare Initial schools to Non-initial schools using data from PISA assessments, PISA questionnaires, national questionnaires, and PISA items. Even though the implementation of Project Maths is at an early stage as a curricular and assessment reform initiative, it has been fruitful to explore its impact on students, teachers, and schools, and on second-level mathematics. For students, attending an Initial school has made for a small performance advantage, but perhaps at the expense of more negative attitudes towards mathematics; it remains to be seen whether and when attitudes might change. For teachers, participation in the initial implementation of Project Maths challenged their existing teaching practices and attitudes but they reported positive changes in students' learning. For mathematics at second-level, Project Maths aims to make teaching and learning more engaging and help students develop their mathematical knowledge and skills. What difference it makes to a lifetime of mathematical reasoning and problem-solving remains to be seen.

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Appendices

Appendix A2

Table A2.1
Economic, Social, and Cultural Status of Students in Initial and Non-initial Schools

	Initial			Non-initial		
	M	*SE*	*SD*	*M*	*SE*	*SD*
ESCS	0.10	0.03	0.85	0.13	0.02	0.87
Parental occupation	51.89	0.82	20.82	52.49	0.45	21.04
Parental education (years)	13.46	0.10	2.45	13.58	0.05	2.31
Home educational resources	-0.13	0.04	0.93	-0.12	0.02	0.97
Cultural possessions	-0.17	0.04	0.92	-0.16	0.02	0.93
Material possessions	0.22	0.03	0.89	0.21	0.02	0.88
Number of books in home[10]	159.0	7.73	197.4	155.4	4.46	197.3
Parental interaction	0.02	0.04	0.99	0.00	0.02	1.00

Table A2.2
Gender of Students in Initial and Non-initial Schools

	Initial		Non-initial	
	%	*SE*	%	*SE*
Female	55.0	0.96	48.9	1.14
Male	45.0	0.96	51.1	1.14

Table A2.3
Family Structure of Students in Initial and Non-initial Schools

	Initial		Non-initial	
	%	*SE*	%	*SE*
One-parent families	10.2	1.23	11.0	0.65
Other family types	89.8	1.23	89.0	0.65

Table A2.4
Immigrant and Language Status of Students in Initial and Non-initial Schools

	Initial		Non-initial	
	%	*SE*	%	*SE*
Native	92.3	1.07	90.3	0.73
Immigrant with Eng/ Irish	3.4	0.83	5.2	0.41
Immigrant with other language	4.2	0.69	4.5	0.53

[10] Students were asked to estimate the number of books in their home, whether 0-10, 11-25, 26-100, 101-200, 201-500, or more than 500. These data were recoded to generate the national averages as follows: 0-10 books was coded as 5 books, 11-25 books to 18 books, 26-100 books to 63 books, 101-200 books to 150.5 books, 201-500 books to 350 books and more than 500 books to 750.5 books.

Table A2.5
Traveller Status of Students in Initial and Non-initial Schools

	Initial		Non-initial	
	%	*SE*	%	*SE*
Traveller	1.1	0.43	1.7	0.27
Settled	98.9	0.43	98.3	0.27

Table A2.6
Time Spent in Paid Work During Term Time by Students in Initial and Non-initial Schools

	Initial		Non-initial	
	%	*SE*	%	*SE*
None	84.6	1.60	83.8	0.75
Up to 4 hours a week	8.4	1.22	9.0	0.49
4 to 8 hours a week	3.8	0.84	3.9	0.34
More than 8 hours a week	3.2	0.74	3.3	0.28

Table A2.7
Duration of Pre-school Attendance by Students in Initial and Non-initial Schools

	Initial		Non-initial	
	%	*SE*	%	*SE*
No preschool	13.7	1.21	13.6	0.73
One year or less	40.6	1.93	43.7	0.95
More than one year	45.7	2.07	42.7	0.93

Table A2.8
Current Grade Level of Students in Initial and Non-initial Schools

	Initial		Non-initial	
	%	*SE*	%	*SE*
First or Second Year	2.0	0.43	1.9	0.18
Third Year	61.2	0.56	60.5	0.83
Transition Year	24.3	0.84	24.3	1.20
Fifth Year	12.4	0.79	13.3	1.06

Table A2.9
Early School-leaving Risk of Students in Initial and Non-initial Schools

	Initial		Non-initial	
	%	*SE*	%	*SE*
Not at risk	94.2	0.91	93.5	0.40
At risk	5.8	0.91	6.5	0.40

Table A2.10
Frequency of Skipping School in the Previous Two Weeks by Students in Initial and Non-initial Schools

	Initial		Non-initial	
	%	*SE*	%	*SE*
None	96.4	0.82	95.9	0.36
One or two days	3.6	0.82	3.3	0.31
Three or more days	0.0	0.00	0.7	0.16

Table A2.11
Frequency of Arriving Late for school in the Previous Two Weeks by Students in Initial and Non-initial Schools

	Initial		Non-initial	
	%	*SE*	%	*SE*
None	76.9	1.71	72.5	1.06
One or two days	16.7	1.48	20.3	0.77
Three or more days	3.0	6.3	7.3	0.62

Table A2.12
School Mean ESCS of Students in Initial and Non-initial Schools

	Initial			Non-initial		
	M	*SE*	*SD*	*M*	*SE*	*SD*
ESCS	0.11	0.01	0.42	0.13	0.02	0.41

Table A2.13
School Support Programme status of Students in Initial and Non-initial Schools

	Initial		Non-initial	
	%	*SE*	%	*SE*
SSP	7.3	0.32	21.3	2.96
Non-SSP	92.7	0.32	78.7	2.96

Table A2.14
Fee-paying Status of Students in Initial and Non-initial Schools

	Initial		Non-initial	
	%	*SE*	%	*SE*
Fee-paying	15.1	0.29	7.8	1.77
Non-fee-paying	84.9	0.29	92.2	1.77

Table A2.15

School Sector and Gender Composition of Initial and Non-initial Schools

	Initial		Non-initial	
	%	*SE*	%	*SE*
Girls' Secondary	24.0	0.46	21.5	1.26
Boys' Secondary	13.0	0.48	16.4	2.10
Mixed Secondary	18.0	0.56	20.4	2.34
Community & Comprehensive	18.2	0.43	16.7	0.30
Vocational	26.8	0.43	25.0	0.42

Table A2.16

Location of Initial and Non-initial Schools

	Initial		Non-initial	
	%	*SE*	%	*SE*
Town	69.3	0.63	49.9	3.81
City	20.2	0.40	27.0	3.24
Rural	10.4	0.53	23.1	3.11

Table A2.17

Proximity of other Schools to Initial and Non-initial Schools

	Initial		Non-initial	
	%	*SE*	%	*SE*
Two or more	58.8	0.74	75.6	3.5
One other	15.5	0.62	11.4	2.81
No others	25.7	0.84	13.0	2.58

Appendix A4

Table A4.1
Scales of Attitudes and Behaviour: Mean Scores for Male and Female Students in Initial and Non-initial Schools

	Initial *M* (*SE*)		Non-initial *M* (*SE*)	
	Male	Female	Male	Female
Intrinsic motivation	-.07 (0.07)	-0.13 (0.06)	0.09 (0.02)	0.04 (0.03)
Mathematics self-concept	-0.01 (0.09)	-0.30 (0.06)	0.09 (0.03)	-0.17 (0.02)
Mathematics anxiety	-0.002 (0.09)	0.43 (0.06)	-0.05 (0.03)	0.27 (0.02)
Self-responsibility for failure	-0.10 (0.06)	0.17 (0.07)	-0.20 (0.03)	-0.01 (0.02)
Mathematics-related behaviours	-0.49 (0.07)	-0.59 (0.06)	-0.41 (0.03)	-0.44 (0.02)
Mathematics-related intentions	-0.21 (0.08)	-0.37 (0.06)	0.05 (0.03)	-0.27 (0.03)
Mathematics-related subjective norms	0.03 (0.06)	0.04 (0.05)	0.12 (0.03)	0.14 (0.03)

Table A4.2

Percentages of Students who Agree or Disagree with various Statements about their Attitudes towards School in Initial and Non-initial Schools

	Initial		Non-initial	
	% Strongly agree/Agree (*SE*)	% Strongly disagree/Disagree (*SE*)	% Strongly agree/Agree (*SE*)	% Strongly disagree/Disagree (*SE*)
Attitudes towards school (learning activities in school)				
Trying hard at school will help me get a good job	95.4 (1.06)	4.6 (1.06)	95.2 (0.43)	4.8 (0.43)
Trying hard at school will help me get into college	**99.4*** (0.40)	0.6 (0.40)	98.1 (0.26)	1.9 (0.26)
I enjoy receiving good grades	98.0 (0.70)	2.0 (0.70)	98.1 (0.26)	1.9 (0.26)
Trying hard at school is important	97.0 (0.79)	97.0 (0.79)	96.1 (0.36)	3.9 (0.36)
Attitudes towards school (learning outcomes from school)				
School has done little to prepare me for adult life when I leave school	28.5 (2.34)	71.5 (2.34)	26.1 (0.93)	73.9 (0.93)
School has been a waste of time	10.4 (1.60)	89.6 (1.60)	9.3 (0.62)	90.7 (0.62)
School has helped give me confidence to make decisions	85.2 (1.95)	14.8 (1.95)	83.5 (0.71)	16.5 (0.71)
School has taught me things which could be useful in a job	86.8 (1.97)	13.2 (1.97)	88.5 (0.57)	11.5 (0.57)
Sense of belonging at school				
I feel like an outsider at school	8.6 (1.50)	91.4 (1.50)	9.1 (0.52)	90.9 (0.52)
I make friends easily at school	89.9 (1.39)	10.1 (1.39)	89.4 (0.56)	10.6 (0.56)
I feel like I belong at school	80.7 (1.70)	19.3 (1.70)	79.6 (0.88)	20.4 (0.88)
I feel awkward and out of place in my school	10.0 (1.62)	90.0 (1.62)	10.2 (0.63)	89.8 (0.63)
Other students seem to like me	94.0 (1.22)	6.0 (1.22)	94.1 (0.42)	5.9 (0.42)
I feel lonely at school	5.3 (1.07)	94.7 (1.07)	6.8 (0.46)	93.2 (0.46)
I feel happy at school	80.6 (2.08)	19.4 (2.08)	81.9 (0.78)	18.1 (0.78)
Things are ideal in my school	68.2 (2.40)	31.8 (2.40)	65.9 (1.09)	34.1 (1.09)
I am satisfied with my school	80.8 (1.96)	19.2 (1.96)	79.4 (0.99)	20.6 (0.99)

Table A4.3

Percentages of Students who Agree or Disagree with various Statements about their Instrumental Motivation to Learn Mathematics in Initial and Non-initial Schools

	Initial		Non-initial	
	Strongly agree/ Agree % (*SE*)	% Strongly disagree/Disagree (*SE*)	% Strongly agree/Agree (*SE*)	% Strongly disagree/Disagree (*SE*)
Making an effort in mathematics is worth it because it will help me in the work that I want to do later on	78.8 (2.19)	21.2 (2.19)	79.9 (0.77)	20.1 (0.77)
Learning mathematics is worthwhile for me because it will improve my career prospects and chances	89.5 (1.57)	10.5 (1.57)	88.3 (0.74)	11.8 (0.74)
Mathematics is an important subject for me because I need it for what I want to study later on	62.7 (2.52)	37.3 (2.52)	66.3 (0.97)	33.7 (0.97)
I will learn many things in mathematics that will help me get a job	77.4 (2.30)	55.6 (2.30)	75.5 (0.87)	24.5 (0.87)

Table A4.4

Percentages of Students who Agree or Disagree with various Statements about their Perseverance in Initial and Non-initial Schools

	Very much like me % (*SE*)	Mostly like me % (*SE*)	Somewhat like me % (*SE*)	Not much like me % (*SE*)	Not at all like me % (*SE*)
Initial					
When confronted with a problem, I give up easily	6.6 (1.41)	8.7 (1.44)	28.5 (2.42)	38.8 (2.48)	17.3 (1.73)
I put off difficult problems	10.7 (1.76)	15.4 (1.84)	30.7 (2.55)	30.0 (2.09)	13.2 (1.72)
I stay interested in the tasks that I start	13.8 (1.92)	39.8 (2.23)	27.8 (2.27)	15.2 (1.90)	3.4 (0.92)
I continue working on tasks until everything is perfect	23.5 (1.82)	23.8 (1.94)	30.6 (2.21)	16.8 (1.925)	5.3 (1.20)
When confronted with a problem, I do more than what is expected of me	9.98 (1.40)	19.0 (2.08)	35.9 (3.01)	27.8 (2.22)	7.3 (1.41)
Non-initial					
When confronted with a problem, I give up easily	25.3 (0.81)	25.3 (0.81)	25.3 (0.81)	25.3 (0.81)	25.3 (0.81)
I put off difficult problems	33.4 (1.05)	33.4 (1.05)	33.4 (1.05)	33.4 (1.05)	33.4 (1.05)
I stay interested in the tasks that I start	29.2 (0.87)	29.2 (0.87)	29.2 (0.87)	29.2 (0.87)	29.2 (0.87)
I continue working on tasks until everything is perfect	31.4 (0.85)	31.4 (0.85)	31.4 (0.85)	31.4 (0.85)	31.4 (0.85)
When confronted with a problem, I do more than what is expected of me	35.6 (0.85)	35.6 (0.85)	35.6 (0.85)	35.6 (0.85)	35.6 (0.85)

Table A4.5

Percentages of Students who Agree or Disagree with various Statements about their Self-efficacy in Initial and Non-initial Schools

	Initial		Non-initial	
	Very confident/ Confident % (*SE*)	Not very confident/Not at all confident % (*SE*)	Very confident/ Confident % (*SE*)	Not very confident/Not at all confident % (*SE*)
Using a train timetable to work out how long it would take to get from one place to another	86.6 (1.51)	13.4 (1.51)	85.8 (0.67)	14.2 (0.67)
Calculating how much cheaper a TV would be after a 30% discount	81.7 (1.81)	18.3 (1.81)	83.3 (0.83)	16.7 (0.83)
Calculating how many square metres of tiles you need to cover a floor	68.6 (2.19)	31.4 (2.19)	69.3 (0.95)	30.7 (0.95)
Understanding graphs presented in newspapers	**91.0*** (1.21)	9.0 (1.21)	87.8 (0.74)	12.2 (0.74)
Solving an equation like 3x+5=17	75.3 (2.38)	24.7 (2.38)	80.4 (0.93)	19.6 (0.93)
Finding the actual distance between two places on a map with a 1:10 000 scale	45.1 (2.36)	54.9 (2.36)	48.9 (1.16)	51.1 (1.16)
Solving an equation like 2(x+3)=(x+3)(x-3)	62.9 (2.18)	37.1 (2.18)	**73.0*** (0.95)	27.0 (0.95)
Calculating the petrol consumption rate of a car	46.7 (2.33)	53.3 (2.33)	**53.2*** (0.94)	46.8 (0.94)

Table A4.6

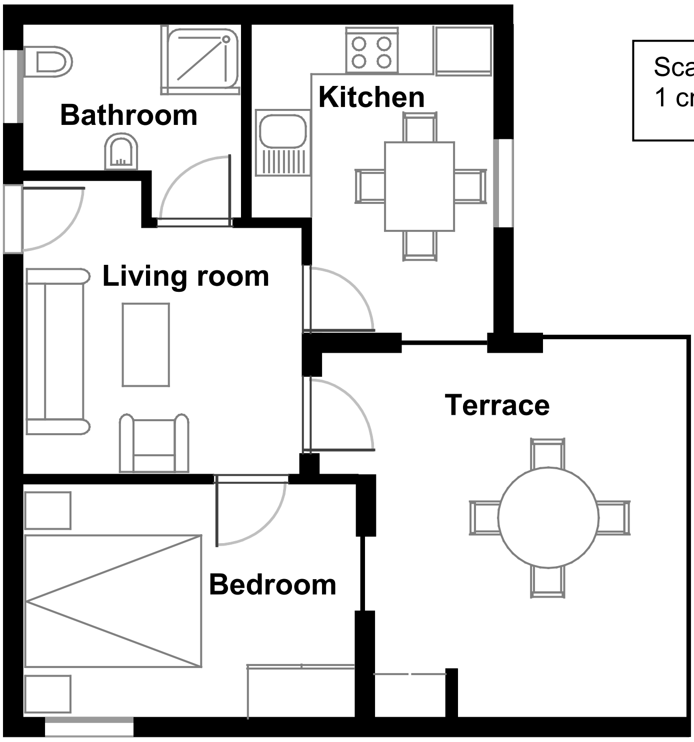
Percentages of Students who Agree or Disagree with various Statements about Openness to Problem-solving in Initial and Non-initial Schools

	Very much like me % (*SE*)	Mostly like me % (*SE*)	Somewhat like me % (*SE*)	Not much like me % (*SE*)	Not at all like me % (*SE*)
Initial					
I can handle a lot of information	18.7 (1.80)	31.3 (2.52)	35.0 (2.44)	12.7 (1.86)	2.3 (0.73)
I am quick to understand things	20.4 (2.05)	34.5 (2.65)	29.4 (2.08)	13.9 (1.85)	1.8 (0.73)
I look for explanations for things	26.1 (2.39)	40.5 (2.45)	22.6 (2.15)	9.3 (1.43)	1.4 (0.66)
I can easily link facts together	25.9 (2.20)	31.7 (2.32)	29.8 (2.17)	10.3 (1.72)	2.3 (0.74)
I like to solve complex problems	13.1 (1.83)	16.9 (1.95)	25.9 (2.33)	26.6 (2.23)	17.5 (2.33)
Non-initial					
I can handle a lot of information	17.4 (0.77)	35.1 (1.01)	30.2 (0.93)	13.7 (0.74)	3.5 (0.31)
I am quick to understand things	19.5 (0.77)	35.7 (1.03)	29.6 (0.92)	12.6 (0.62)	2.6 (0.28)
I look for explanations for things	28.3 (0.85)	37.8 (0.85)	23.0 (0.84)	9.1 (0.56)	1.8 (0.23)
I can easily link facts together	21.3 (0.80)	35.5 (0.95)	27.8 (0.90)	13.2 (0.65)	2.3 (0.27)
I like to solve complex problems	12.4 (0.59)	17.3 (0.73)	28.6 (0.78)	26.7 (0.80)	15.0 (0.62)

Appendix A7

PRINT MATHEMATICS UNIT 1: Apartment Purchase

This is the plan of the apartment that George's parents want to purchase from a real estate agency.



Scale:
1 cm represents 1 m

Question 1: APARTMENT PURCHASE

PM00FQ01 – 0 1 9

To estimate the total floor area of the apartment (including the terrace and the walls), you can measure the size of each room, calculate the area of each one and add all the areas together.

However, there is a more efficient method to estimate the total floor area where you only need to measure 4 lengths. Mark on the plan above the **four** lengths that are needed to estimate the total floor area of the apartment.

APARTMENT PURCHASE SCORING 1

QUESTION INTENT:

Description: Use spatial reasoning to show on a plan (or by some other method) the minimum number of side lengths needed to determine floor area

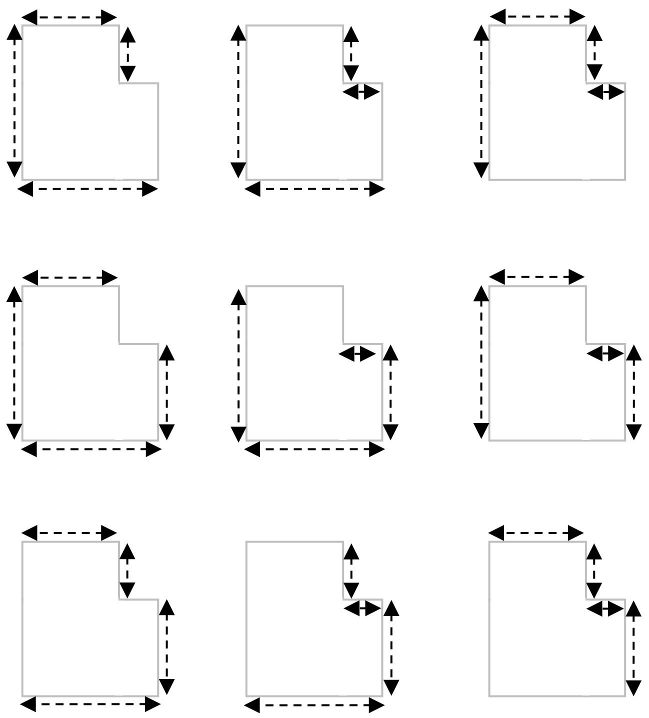
Mathematical content area: Space & shape

Context: Personal

Process: Formulate

Full Credit

Code 1: Has indicated the four dimensions needed to estimate the floor area of the apartment on the plan. There are 9 possible solutions as shown in the diagrams below.



A = (9.7m x 8.8m) – (2m x 4.4m), A = 76.56m^2 *[Clearly used only 4 lengths to measure and calculate required area.]*

No Credit

Code 0: Other responses.

Code 9: Missing.

Response	Ireland	OECD	Item Difficulty
Correct	45.8	44.6	Scale Score: 576.2 Proficiency Level 4
Incorrect	36.0	29.1	
Missing/Not reached	18.2	26.3	

PRINT MATHEMATICS UNIT 2: Sailing ships

Sailing Ships – Question 2

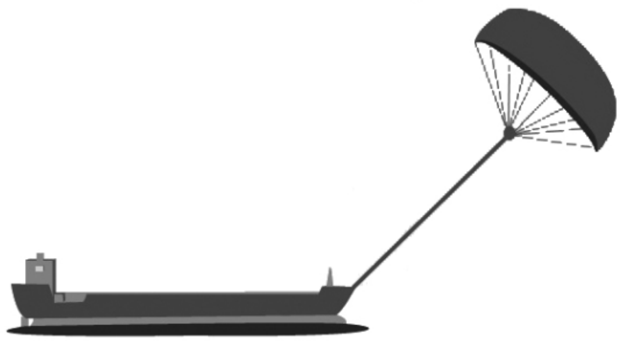
Approximately what is the length of the rope for the kite sail, in order to pull the ship at an angle of 45° and be at a vertical height of 150 m, as shown in the diagram opposite?

A 173 m

B 212 m

C 285 m

D 300 m



Note. Drawing not to scale.
© by skysails

SAILING SHIPS SCORING 3

QUESTION INTENT:

Description: Use Pythagorean Theorem within a real geometric context
Mathematical content area: Space & Shape
Context: Scientific
Process: Employ

Full Credit

Code 1: B. 212 m

No Credit

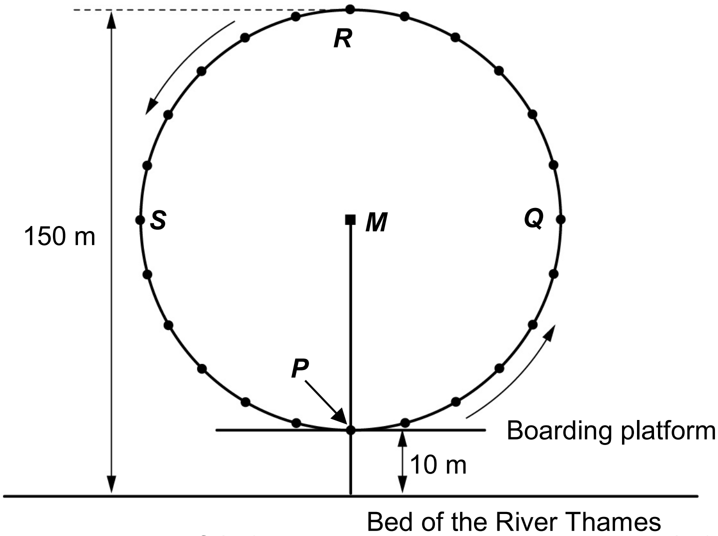
Code 0: Other responses.

Code 9: Missing.

Response	Ireland	OECD	Item Difficulty
Correct (option B)	47.8	49.8	Scale Score: 538.5 Proficiency Level 3
Incorrect	49.6	46.2	
Missing/Not reached	2.6	4.0	

PRINT MATHEMATICS UNIT 3: London Eye

In London along the river Thames is a giant Ferris wheel called the London Eye.
See the picture and diagram below.



The Ferris wheel has an external diameter of 140 metres and its highest point is 150 metres above the bed of the river Thames. It rotates in the direction shown by the arrows.

Question 1: LONDON EYE

PM934Q01 – 0 1 9

The letter *M* in the diagram indicates the centre of the wheel.

How many metres (m) above the bed of the river Thames is point *M?*

Answer: .... m

LONDON EYE SCORING 1

QUESTION INTENT:

Description: Calculate length based on information in a 2-D drawing
Mathematical content area: Space & Shape
Context: Societal
Process: Employ

Full Credit

Code 1: 80

Response	Ireland	OECD	Item Difficulty
Correct		16.0	Scale Score: 592.3 Proficiency Level 4
Incorrect		76.5	
Missing/Not reached		7.6	

Question 2: LONDON EYE

PM934Q02

The Ferris wheel rotates at a constant speed. The wheel makes one full rotation in exactly 40 minutes.

John starts his ride on the Ferris wheel at the boarding point, *P*.

Where will John be after half an hour?

E At *R*
F Between *R* and *S*
G At *S*
H Between *S* and *P*

LONDON EYE SCORING 2

QUESTION INTENT:

Description: Estimate location based on the rotation of an object and specified time taken

Mathematical content area: Space & Shape

Context: Societal

Process: Formulate

Full Credit

Code 1: C. At *S*

No Credit

Code 0: Other responses.

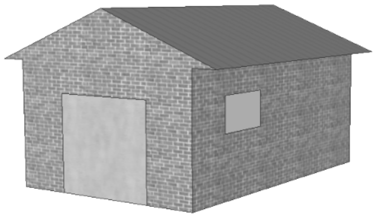
Code 9: Missing.

Response	Ireland	OECD	Item Difficulty
Correct		43.6	Scale Score: 481.0 Proficiency Level 2
Incorrect		54.0	
Missing/Not reached		2.4	

PRINT MATHEMATICS UNIT 4: Garage

A garage manufacturer's "basic" range includes models with just one window and one door.

George chooses the following model from the "basic" range. The position of the window and the door are shown here.



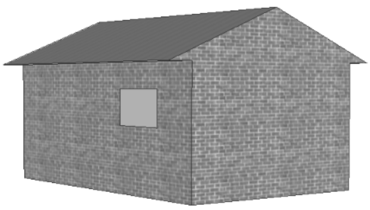
Question 1: GARAGE

PM991Q01

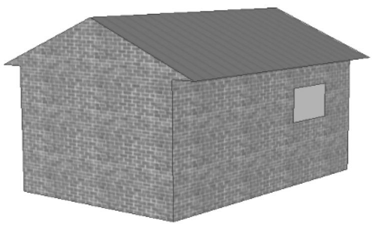
The illustrations below show different “basic” models as viewed from the back. Only one of these illustrations matches the model above chosen by George.

Which model did George choose? Circle A, B, C or D.

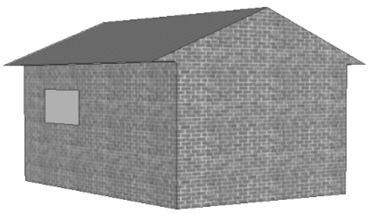
A



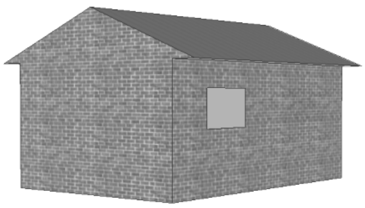
B



C



D



GARAGE SCORING 1

QUESTION INTENT:

Description: Use space ability to identify a 3D view corresponding to another given 3D view

Mathematical content area: Space & Shape

Context: Occupational

Process: Interpret

Full Credit

Code 1: C [Graphic C]

No Credit

Code 0: Other responses.

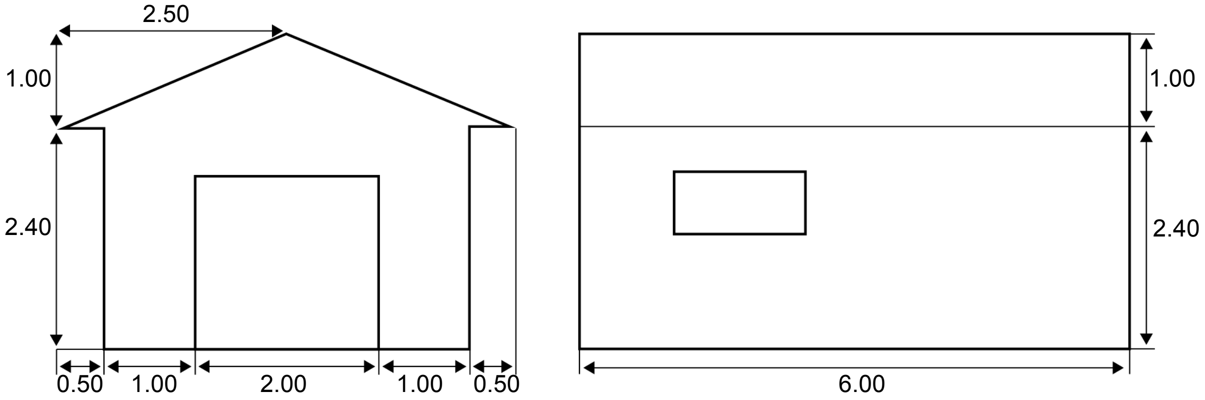
Code 9: Missing.

Response	Ireland	OECD	Item Difficulty
Correct		65.1	Scale Score: 419.6 Proficiency Level 1
Incorrect		31.6	
Missing/Not reached		3.3	

Question 2: GARAGE

PM991Q02 – 00 11 12 21 99

The two plans below show the dimensions, in metres, of the garage George chose.



Front view

Side view

- Note. Drawing not to scale.

The roof is made up of two identical rectangular sections.

Calculate the **total** area of the roof. Show your work.

. ...

....

....

....

GARAGE SCORING 2

QUESTION INTENT:

Description: Interpret a plan and calculate the area of a rectangle using the Pythagorean theorem or measurement

Mathematical content area: Space & Shape

Context: Occupational

Process: Employ

Full Credit

Code 21: Any value from 31 to 33, either showing no working at all or supported by working that shows the use of the Pythagorean theorem (or including elements indicating that this method was used). *[Units (m^2) not required].*

$12\sqrt{7.25}$ m^2

$12 \times 2.69 = 32.28$ m^2

32.4 m^2

Partial Credit

Code 11: Working shows correct use of the Pythagorean theorem but makes a calculation

error or uses incorrect length or does not double roof area.
$2.5^2 + 1^2 = 6$, $12 \times \sqrt{6} = 29.39$ *[correct use of Pythagoras theorem with calculation error]*
$2^2 + 1^2 = 5$, $2 \times 6 \times \sqrt{5} = 26.8$ m^2 *[incorrect length used]*
6 × 2.6 = 15.6 *[Did not double roof area.]*

Code 12: Working does not show use of Pythagorean theorem but uses reasonable value for width of roof (for example, any value from 2.6 to 3) and completes rest of calculation correctly.
2.75 × 12 = 33
3 × 6 × 2 = 36
12 × 2.6 = 31.2

No Credit

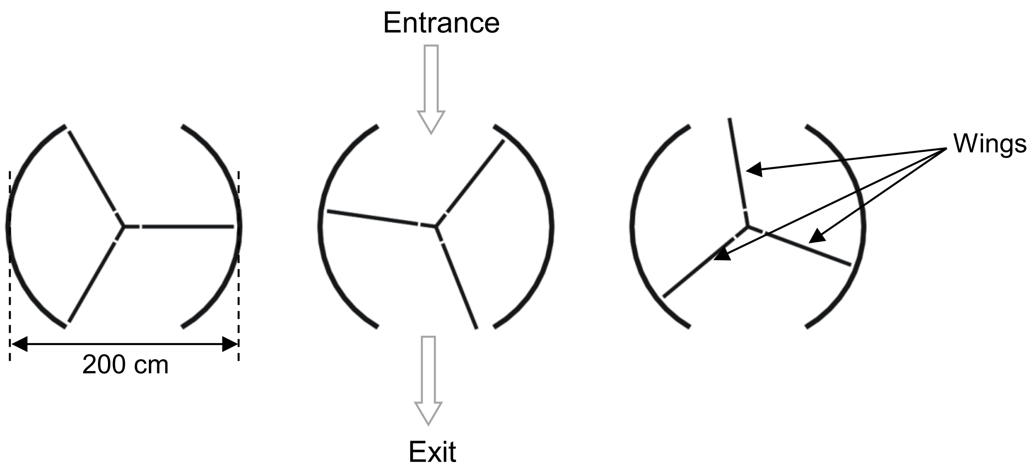
Code 00: Other responses.
2.5 × 12 = 30 *[Estimate of width of roof lies outside the acceptable range which is from 2.6 to 3.]*
3.5 × 6 × 2 = 42 *[Estimate of width of roof lies outside the acceptable range which is from 2.6 to 3.]*

Code 99: Missing.

Response	Ireland	OECD	Item Difficulty
Correct		2.7	Scale Score: 687.3 Proficiency Level 6
Incorrect		3.4	
Missing/Not reached		31.3	

PRINT MATHEMATICS UNIT 5: Revolving door

A revolving door includes three wings which rotate within a circular-shaped space. The inside diameter of this space is 2 metres (200 centimetres). The three door wings divide the space into three equal sectors. The plan below shows the door wings in three different positions viewed from the top.



Revolving Door – Question 1

What is the size in degrees of the angle formed by two door wings?

Size of the angle: .... °

REVOLVING DOOR SCORING 1

QUESTION INTENT:

Description: Compute the central angle of a sector of a circle
Mathematical content area: Space & Shape
Context: Scientific
Process: Employ

Full Credit

Code 1: 120 *[accept the equivalent reflex angle: 240]*.

No Credit

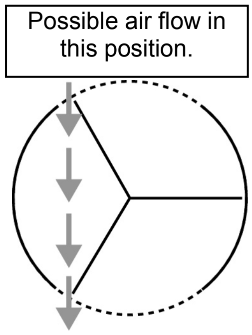
Code 0: Other responses.

Code 9: Missing.

Response	Ireland	OECD	Item Difficulty
Correct	63.4	57.7	Scale Score: 512.3 Proficiency Level 3
Incorrect	30.1	32.8	
Missing/Not reached	6.5	9.5	

Revolving Door – Question 2

The two door **openings** (the dotted arcs in the diagram) are the same size. If these openings are too wide the revolving wings cannot provide a sealed space and air could then flow freely between the entrance and the exit, causing unwanted heat loss or gain. This is shown in the diagram opposite.



What is the maximum arc length in centimetres (cm) that each door opening can have, so that air never flows freely between the entrance and the exit?

Maximum arc length: .... cm

REVOLVING DOOR SCORING 2

QUESTION INTENT:

Description: Interpret a geometrical model of a real life situation to calculate the length of an arc

Mathematical content area: Space & Shape

Context: Scientific

Process: Formulate

Full Credit

Code 1: Answers in the range from 103 to 105. *[Accept answers calculated as 1/6th of the circumference ($\frac{100\pi}{3}$). Also accept an answer of 100 only if it is clear that this response resulted from using π = 3. Note. Answer of 100 without supporting working could be obtained by a simple guess that it is the same as the radius (length of a single wing).]*

No Credit

Code 0: Other responses.
209 *[states the total size of the openings rather than the size of "each" opening].*

Code 9: Missing.

Response	Ireland	OECD	Item Difficulty
Correct	2.4	3.5	Scale Score: 561.3 Proficiency Level 4
Incorrect	76.0	69.6	
Missing/Not reached	21.6	26.9	

Appendix A8

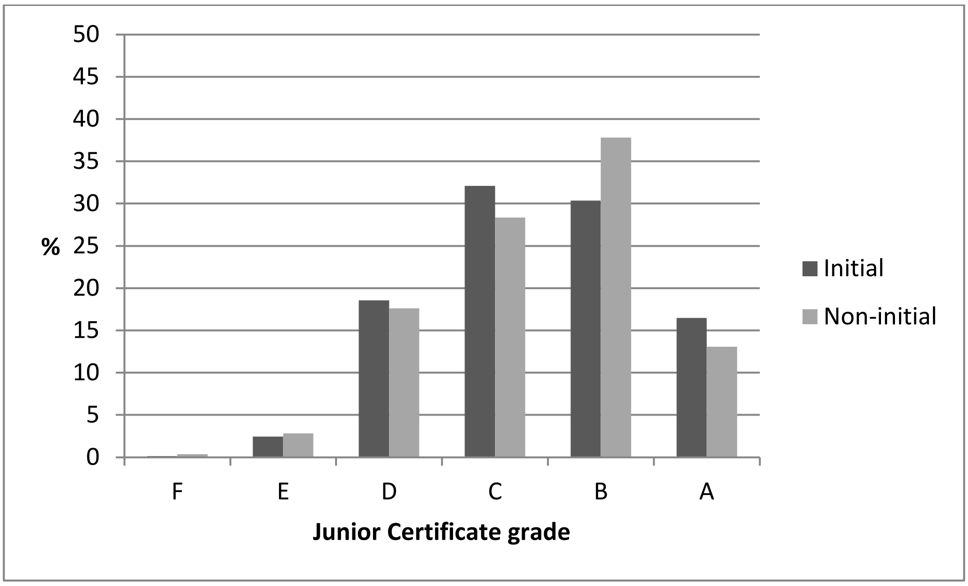


Figure A8.1. Distribution of Junior Certificate Grades at Higher Level for Initial and Non-initial Schools, 2011 and 2012 Combined

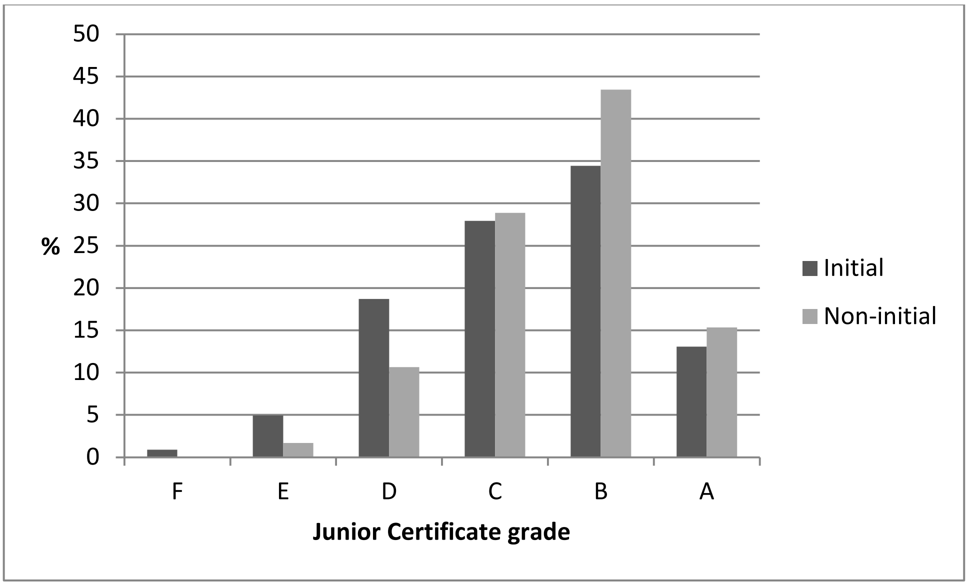


Figure A8.2. Distribution of Junior Certificate Grades at Ordinary Level for Initial and Non-initial Schools, 2011 and 2012 Combined

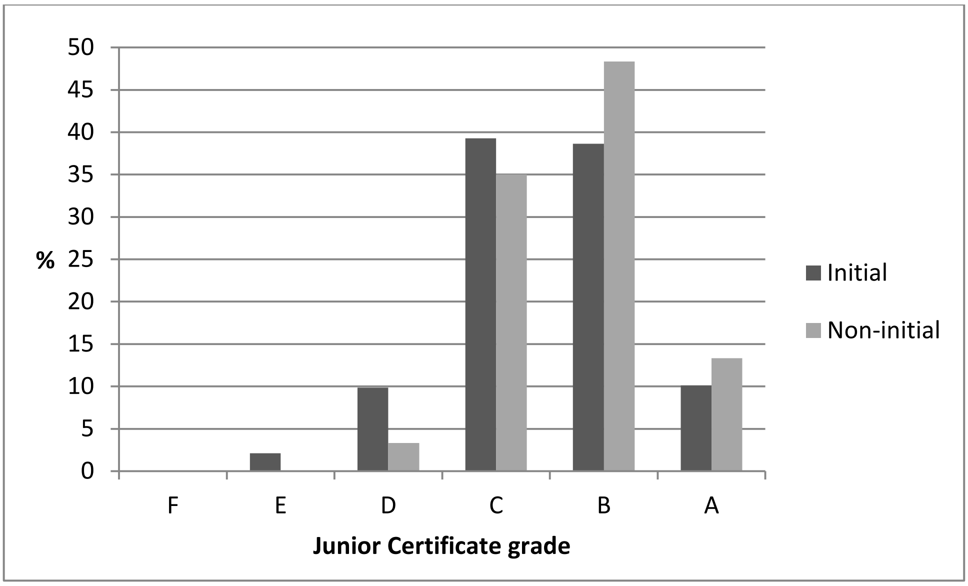


Figure A8.3. Distribution of Junior Certificate Grades at Foundation Level for Initial and Non-initial Schools, 2011 and 2012 Combined

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