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Gender and PISA Mathematics: Irish results in context

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ABSTRACT This article examines the Irish results in PISA (Programme for International Student Assessment) mathematics, with particular reference to gender differences. As in most PISA countries, male students in Ireland achieved a significantly higher mean score than females on the overall mathematics scale in all PISA cycles to date. In 2003, when mathematics was a major assessment domain, male students in Ireland outperformed females on all four mathematics subscales representing the overarching ideas, with the largest difference on Space and Shape. This is contrasted with the stronger performance of female students on the state Junior Certificate (JC) mathematics examination, taken by all students at the end of 9th Grade. The authors' analyses suggest that the stronger performance of male students on PISA is related to differential performance across content areas and cognitive levels, stronger performance at the top end of the overall mathematics proficiency scale, stronger performance on multiple-choice items, and stronger self-efficacy in and lower anxiety about mathematics. The findings are discussed in relation to existing theories of gender differences in mathematics and to features of schooling in Ireland. Throughout the article, reference is made to gender difference in PISA mathematics in other European countries.

Introduction

Historical Overview

Gender differences in mathematics teaching, learning and achievement have been the subject of research for many years, to a greater extent in the period 1970 to 1990, and to a lesser extent in more recent years, as the differences became less pronounced, particularly in school mathematics attainments. Leder (1992) found that over 10% of the articles published in the *Journal for Research in Mathematics Education* between 1978 and 1990 had gender issues in mathematics education as their main focus, with the majority of them addressing issues to do with gender differences in achievement. A variety of explanatory theories and models associated with gender differences were addressed in the gender and mathematic studies, including theories incorporating biological, socio-cultural, pedagogical, and student cognitive and attitudinal variables (Leder, 1992; Hanna, 1996; Gallagher & Kaufman, 2005).

Side by side with the trend of reducing gender differences in mathematics is the phenomenon whereby males considerably outnumber females at the top level and at the lower levels on distributions of mathematics performance. This can be viewed as a matter of greater variability in mathematical ability among males rather than differences in central tendency between males and females (Halpern et al, 2007). This finding has been maintained over many years (Gallagher & Kaufman, 2005). Another anomaly is the consistent finding that male students have significantly higher self-efficacy scores than females in mathematics (but not normally in other subjects). Self-efficacy is an affective measure which is usually mildly positively associated with mathematics achievement. The effect is mainly evident in secondary schooling where mathematics is often

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stereotyped as a male subject domain (Leder, 1992). Another related variable, showing a similar trend to self efficacy, is anxiety about mathematics, where females show higher levels of anxiety about mathematics than males (Hembree 1990). Also relevant is the finding that multiple-choice questions, in mathematics particularly, favour males (e.g. Bolger & Kellaghan, 1990; Wilder & Powell, 1989).

Gender in International Surveys of Mathematics

International surveys such as TIMSS (Trends in International Mathematics and Science Study) and PISA (Programme for International Student Assessment) have provided a much broader base in which to examine gender differences in mathematics. In TIMSS 1995, in most countries, males and females in the 4th and 8th Grades had about the same average mathematics achievement. When analysed by content area, however, there were a number of differences in average performance by gender. For example, in the area of measurement, males had higher achievement than females in a few countries at both grade levels (Beaton et al, 1996; Mullis et al, 1997). On the other hand, the pattern for algebra showed females having higher achievement than males in several countries (Beaton et al, 1996). However, in most countries, in the final year of secondary school, males had significantly higher average achievement than females on both basic and advanced mathematics tests. In the TIMSS 1999 assessment (carried out at 8th Grade only) and the 2003 assessment (carried out at 4th and 8th Grades), results on gender differences in mathematics showed little or no change on the 1995 results (Mullis et al, 2000a, 2004). Boys also had a more positive attitude to mathematics than girls, a result consistent with the 1995 findings.

Whereas TIMSS assessed mathematics common across curricula in the participating countries, the PISA mathematics studies (2000, 2003, 2006) assessed how well students approaching the end of the period of compulsory schooling (15 year-olds) could use mathematics to solve problems mainly of a realistic nature, and used the term *mathematical literacy* to describe this ability. In contrast to the TIMSS 8th Grade gender results, the PISA 2003 study, in which mathematics was the major focus of assessment, found significant gender differences, in favour of males, in overall mathematics performance in most countries (with the exception of Iceland, where females did better). Further, in most countries male students achieved higher mean scores than females on the four overarching content areas, with the largest difference in Space and Shape (which parallels, to a large degree, the Measurement and Geometry areas in TIMSS). The PISA 2003 international report put forward the explanation that females and males make different choices in terms of schools, tracks, and programmes, but that, within these, females tend to perform at a lower level than males. While, overall, the gender gap in countries tends to be small (particularly when compared with the large gap in favour of females on reading literacy), much larger differences are observed within individual schools (Organisation for Economic Cooperation and Development [OECD], 2004).

Aspects of the Irish Educational System

Against this rather complex background of gender differences, it is useful to look at how the PISA gender effect plays out in the case of an individual country such as Ireland. An in-depth look at the Irish results in relation to features of the Irish education system and to selected Irish studies of mathematics and gender provides comparisons and contrasts with the broader international picture. First, a brief outline of the Irish educational system is presented.

Formal education in Ireland takes place in three stages. Primary education begins at age 4 and continues for 8 years until age 12. At the age of 12 all students are entitled to enter the second-level system, although students may be over age 12 on leaving primary school. Participation in formal education is compulsory up to the age of 16 years. Second-level education is typically of six years' duration, from about age 12-13 to age 17-18. At age 17, students who meet the necessary requirements may enter third-level education, including the universities and other institutes of higher education. Approximately 80% of those who enter the second level complete the full second-level cycle. In addition, about 50% of the age cohort goes on to higher education (Department of Education and Science [DES], 2007). In recent years, females have attained higher aggregate grades in the public examinations than males (DES, 2007). Females are also more likely than males to complete second-level schooling. Males slightly outnumber females in third-level education.

In Ireland, there is also a strong tradition of single-sex education. About 40% of students at second level are in single-sex schools and almost 40% of those at primary level are in either totally, or mostly, single-sex schools (apart from infant classes which are usually coeducational). Females are more likely than males to attend single-sex schools at second level. About half of all females in second level are in single-sex schools compared with about one-third of males (DES, 2007). This difference reflects a parental preference for single-sex education for adolescent females, as Irish parents are free to send their children to the school of their choice.

At second level, pupils follow a core curriculum (usually for three years) up to the completion of the Junior Certificate examination, at the age of approximately 15 years. Irish, English and Mathematics are compulsory Junior Certificate subjects in all types of second-level schools. Mathematics is therefore compulsory for all students up to age 16. It can be taken at three levels, Higher, Ordinary, and Foundation.

Aim of the Current Study

One aim of the current study is to examine gender differences in mathematics of the Irish PISA survey samples with respect to performance on (i) the overall PISA mathematics scale and corresponding proficiency scale; (ii) the four PISA overarching ideas and mathematics contexts/situations; (iii) the three PISA competency clusters; (iv) distribution of scores across proficiency level; (v) the different item formats; and (vi) attitudes towards mathematics. A second aim is to relate these findings to the performance of the Irish survey samples on the Junior Certificate (JC) mathematics examination. Where appropriate, reference is made to the PISA performance of other European countries.

Irish PISA Mathematics Performance and Gender

Overall Results

Ireland has been placed around the OECD country average in PISA mathematics in all three cycles to date. As in most countries, there was a statistically significant difference of about one-sixth of a national standard deviation in favour of male students in each PISA cycle (Table I).[1] Ireland's performance in mathematics contrasts with reading literacy, where Ireland's mean score was significantly above the OECD average in each cycle, and females in Ireland had a mean score that was about one-third of a standard deviation higher than males.

Year/Gender	2000		2003		2006	
	Mean scale score		Mean scale score		Mean scale score	
	Ireland	OECD	Ireland	OECD	Ireland	OECD
All	503	500	503	500	501	498
Male	510	506	510	506	507	503
Female	497	495	495	494	496	492
Male–Female (SED)	*13* (5.1)	*11* (1.2)	*15* (4.2)	*11* (0.8)	*11* (4.1)	*11* (0.7)

SED: Standard error of the difference. Significant differences in italic.

Table I. Mean scale scores of students on PISA mathematics, by gender and year – Ireland and OECD average.

This is also in contrast to the results of 15 year-olds on the JC mathematics examination which they sit at the end of their third year in secondary school. For each PISA cycle, the examination grades of PISA students and all students nationally were placed on an overall mathematics performance scale.[2] In 2000, female students in PISA had a significantly higher performance scale score than males (Table II). While females had higher JC performance scores than males in 2003 and 2006, the differences were not statistically significant. Nationally in 2003 and 2006, the performance difference was 4 scale points in favour of females. Further, in all three years, more females than males achieved the highest grades. For example, in 2003, 53% of female candidates and 48.3 % of males taking the Higher level examination achieved grade A or B (State Examinations Commission [SEC], 2003).

	2000		2003		2006	
	Mean performance score		Mean performance score		Mean performance score	
	PISA sample	All candidates	PISA sample	All candidates	PISA sample	All candidates
Male	7.6	8.1	8.5	7.9	8.6	8.2
Female	*8.0*	8.2	8.6	8.3	8.8	8.6
Total	7.8	8.1	8.6	8.1	8.7	8.4

Significant differences are in italic. Significance is not assessed in the case of 'All candidates' as these consist of the population of students taking JC mathematics.

Table II. Mean JC performance scale scores in mathematics by gender and year – Irish PISA sample and all candidates.

The advantage for females on the JC mathematics examination is part of a consistent trend dating back to the early 1990s. Prior to that, male performance on the examination had always been higher than that of females (DES, 2007).

It is noteworthy that no significant gender differences in performance in mathematics were found in two national surveys in 1999 and 2004 at 4th Grade in primary school (Shiel & Kelly, 2001; Shiel et al, 2006). Also, in TIMSS 1995, there were no significant gender differences in overall mathematics found among Irish students at the 4th or 8th Grade (Beaton et al, 1996; Mullis et al, 1997).

So far, we can see from the data that, on curriculum-based assessments of mathematics achievement (such as the JC mathematics examination), gender differences favoured males prior to the 1990s, but gradually began to favour females over the following years. In contrast, in non-curriculum-based assessments such as PISA, which also focuses on more realistic problem contexts, gender differences have continued to favour males. In TIMSS 1995 mathematics, which has curriculum validity (although to a lesser extent than the JC mathematics examination), there were no differences between male and female students in Ireland.

In order to investigate further the gender differences among Irish students in PISA, we now look at how gender differences play out in the Irish PISA data when they are analysed along a number of the PISA framework and instrument variables.

Overarching Ideas

It is of interest in considering gender effects in mathematics to see if they are accentuated to any degree in one content area of mathematics rather than another.

In PISA, mathematical content is described in terms of four categories that encompass the kinds of problems arising through interaction with everyday phenomena. These are called 'Overarching Ideas' and include: Quantity, Space and Shape, Change and Relationships, and Uncertainty. When the performance of Irish students on each of the four PISA mathematical content subscales in 2003 was analysed by gender, it emerged that males significantly outperformed females on all four subscales (Table III).

Overarching idea	No. of Items	Male scale score	Female scale score	Male–female diff.	SED
Space and Shape	20	489	463	*25*	4.3
Change and Relationships	22	512	500	*13*	4.4
Quantity	23	506	497	*9*	4.3
Uncertainty	19	525	509	*15*	4.6

Significant differences in italic. SED: Standard error of the difference.

Table III. Scale scores of Irish students in PISA 2003 by gender and overarching idea.

This was also the case with most of the other participating countries, with the exception of the Quantity subscale, where less than half the countries showed significant differences in favour of males. The difference for Irish students on the Space and Shape subscale (25 scale points) was much larger than it was for the other three content areas – Change and Relationships (13), Quantity (9), and Uncertainty (15). This gender difference for Space and Shape was among the largest of the 40 participating countries – only Korea (27), Luxembourg (28), the Czech Republic (30), the Slovak Republic (35), and Liechtenstein (39) had larger differences.

Notwithstanding the statistically significant differences on Change and Relationships, Quantity, and Uncertainty in Ireland, the difference in Space and Shape is the dominant one. We cannot see if this effect is mirrored in the JC mathematics examination as results broken down by gender within content area are not available. Close & Oldham (2005) categorised the questions in the 2003 JC examination papers using the PISA 2003 framework.[3]. For the overarching ideas categories, they found that, on average across the three examination levels, a little over a quarter of the JC examination items mapped on to the PISA Space and Shape category (Table IV).[4]

JC examination level/PISA category	PISA 2003 Maths Test (85 items) %	2003 JCE Higher Level Maths (77 items) %	2003 JCE Ordinary Level Maths (81 items) %	2003 JCE Foundation Level Maths (32 items) %
Quantity	27.1	16.9	30.9	53.1
Space and Shape	23.5	33.8	27.2	12.5
Change and Relationships	25.9	37.7	32.1	21.9
Uncertainty	23.5	11.7	9.9	12.5

Table IV. Percentages of items in the 2003 JC examination (JCE) mathematics papers corresponding to the overarching ideas categories of the PISA mathematics framework.

Thus, there appears to be little difference between the two assessments in terms of emphasis on Space and Shape as defined in the PISA framework. However, Oldham (2002) points out that PISA Space and Shape does not cover synthetic geometry, which is the main focus of geometry in the JC mathematics syllabus (along with transformational geometry). Synthetic geometry emphasises a formal deductive approach involving theorems and proofs.

When the PISA mathematics items and JC mathematics examination questions were mapped onto the JC mathematics examination content areas, a more informative picture emerged. As part of a PISA test-curriculum rating exercise in Ireland, three educators with extensive knowledge of the mathematics curriculum and/or teaching experience at post-primary level classified the PISA items according to which JC mathematics examination topic area they best fitted (Cosgrove et al, 2005b). The results of this classification are presented in Table V, along with the approximate proportions of JC mathematics examination questions that fall into each content area, based on the Chief Examiner's report.

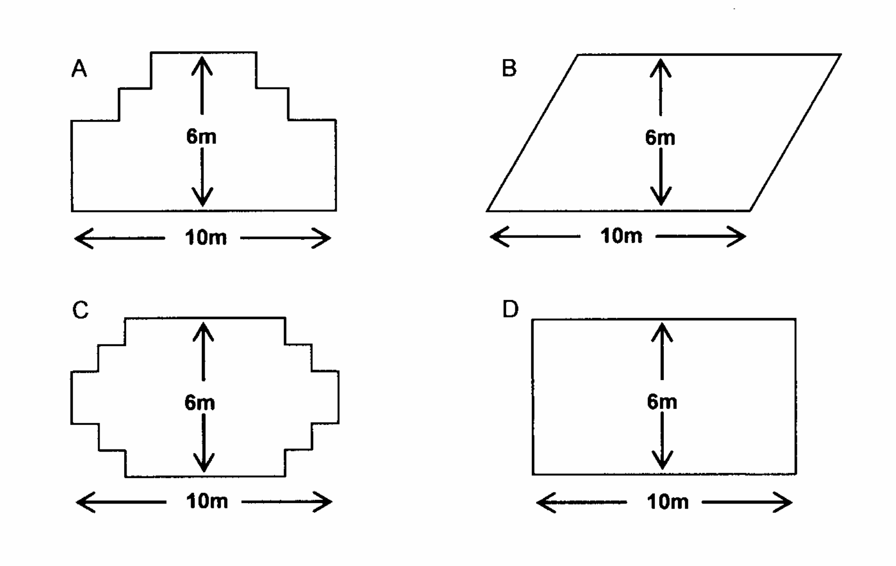
Junior cycle content area	Approx. per cent of PISA items in content area	Approx. per cent of 2003 JCE questions in content area
Sets	0	6
Number Systems	10	1
Applied Arithm/Measure	33	33
Functions and Graphs	4	10
Algebra	5	16.6
Geometry	0	16.6
Trigonometry	0	6.6
Statistics	20	10
Not on either syllabus	30	-

Based on data from Cosgrove et al (2005a); and the Chief Examiner's report on the JCE in mathematics for 2003 (www.examinations.ie).

Table V. Percentages of PISA items and 2003 JCE questions mapping onto the JC syllabus content areas.

It can be seen that the expert raters considered that none of the PISA Space and Shape items fitted into the JC syllabus category of Geometry, but rather many of them were seen as better fitting the Applied Arithmetic and Measure content area, although there was a strong spatial element to the items in addition to the measurement aspect (e.g. the Carpenter item). In this item, students were given illustrations of four designs for a border around a vegetable plot. Students had to indicate which designs could be made with 32 metres of timber (the quantity of wood available to the carpenter). On average across OECD countries, 20% of students correctly evaluated all four designs; in Ireland, just 13% did so (see Figure 1).

A carpenter has 32 metres of timber and wants to make a border around a garden bed.
He is considering the following designs for the garden bed.



Circle either *Yes* or *No* for each design to indicate if it can or cannot be made with 32 metres of timber.

Yes/No Design A
Yes/No Design B
Yes/No Design C
Yes/No Design D

Figure 1. Carpenter item from PISA 2003. Source: Cosgrove et al (2005a, p. 247).

It can also be seen in Table V that just one-half of PISA Statistics items can be located in the JC mathematics syllabus and examination. This is because the syllabus/examination does not contain Probability, which is, however, part of Uncertainty in the PISA study. Only 5 of the 85 PISA items were classified as Algebra (including Functions and Graphs), a topic which constitutes about a quarter of the JC mathematics examination. It might also be noted that there is a major difference between PISA and the JC mathematics examination to the extent that just one-third of the JC mathematics examination questions are based on realistic situations or contexts, compared to 80% for PISA (Close, 2006).

The better performance of males in Ireland and elsewhere on Space and Shape can be seen as fitting in with the TIMSS 1995 and 1999 finding that, in the area of Measurement (where many of the items involve diagrams of shapes or visualisation of shapes), males had higher achievement than females in many countries. It is also relevant to observe that, in TIMSS, females had higher achievement in Algebra than males in many countries (Mullis et al, 2000b). This effect would have come into play to a much lesser extent in PISA, where Algebra was under-represented, in comparison to TIMSS.

Competency Clusters

The PISA competency dimension is divided into three clusters of processes at different levels of complexity to reflect the more varied cognitive demands of realistic mathematical tasks. The clusters are: Reproduction – processes involved in performing calculations, solving equations, reproducing memorised facts or 'solving' well-known routine problems; Connections – processes involved in integrating information, making connections within and across mathematical domains, or solving problems using familiar procedures in context; and Reflection – processes involved in recognising and extracting the mathematics in problem situations, using that mathematics to solve non-routine problems, analysing and developing models and strategies, or making mathematical arguments and generalisations.

Data on item facilities were used to estimate mean percentage mathematics scores of Irish students in the PISA 2003 sample by gender and competency cluster, as Item Response Theory (IRT) scores were not available.[5] Mean percentage scores within the male and female subgroups on the Reproduction items were greater than the scores for Connections or Reflection. For example, male students in Ireland achieved 66% of Reproduction items correct, compared with 49% of Connection items. Although differences in mean percentage scores between male and female students on each of the Reproduction, Connections, and Reflection clusters did not reach significance, they were generally of similar magnitude, and in favour of males on each cluster (Table VI). This consistency in magnitude of the gender differences in scores of Irish students on the competency clusters is not necessarily reflected in the results for other countries, e.g. the Nordic countries where there were smaller though more varied gender differences across clusters (Kupari & Tornroos, 2006). The expectation from earlier research that females perform substantially better than males on reproduction tasks and less well than males on more complex tasks, such as those involving the Connections and Reflection processes, is not fully borne out in the Irish and Nordic data, though there is a slight effect in this direction.

Competency cluster	No. of items	Per cent correct		Per cent correct		Per cent correct	
		Males		Females		Males–Females (Difference)	
		Mean	SE	Mean	SE	Mean	SED
Reproduction	25	65.8	1.84	62.0	1.92	3.8	2.66
Connections	40	48.8	1.87	45.0	1.99	3.7	2.73
Reflection	19	37.7	1.80	33.7	1.91	4.0	2.62

SE = Standard error of the mean; SED = Standard error of the difference.

Table VI. Mean percentage mathematics scores of Irish students in PISA 2003, by gender and competency cluster.

In considering the data in Table VI, it is worth noting that Close (2006) reported a major difference between PISA and the JC mathematics examination in terms of the relative emphasis on different competency clusters. In the PISA test, there was a reasonable spread of items across the three competency clusters. In the JC mathematics examination papers (2003), most of the items fell into the Reproduction cluster, with very few in the Connections cluster and none in the Reflection cluster (Figure 2). Given the stronger performance of females on the JC mathematics examination, one might have expected females to have done better at least on PISA reproduction tasks. Yet, the data point to stronger performance for males on all clusters, though not to a significant degree.

Distribution of Scores across Proficiency Levels by Gender

The combined PISA mathematics scale was divided into six levels of proficiency, each characterised by different levels of skills and knowledge. Level 6 is the most advanced and typically involves higher-level skills such as generalising, modelling non-routine problems, and mathematical argumentation. Level 1 is the least advanced and involves lower-level skills such as solving routine problems, implementing practised procedures, and making simple interpretations. There is also a 'below level 1' category for students who did not demonstrate competencies required by the easiest

PISA tasks. Each level is defined by the ability to complete more difficult tasks than those exemplifying the level(s) below it, while also including the skills required at the lower levels. Proficiency scales were constructed for the combined mathematics scale and for each content subscale.

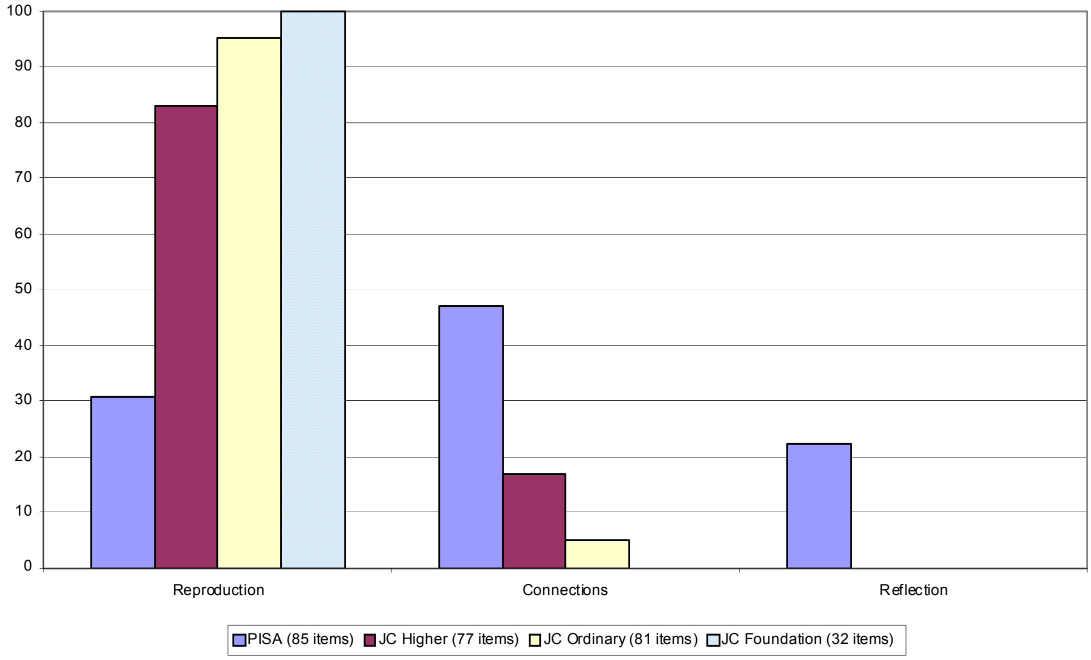


Figure 2. Percentage of items testing the three competency clusters distributed across PISA 2003 test and the 2003 JC higher, ordinary, and foundation examination papers.

Although there were no significant gender differences among Irish students at any of the six proficiency levels on the combined mathematics scale (Table VII), there were significant differences at Level 6 (2.5% male vs. 1.1% female) and below Level 1 (8.6% male vs. 13% female) on the Space and Shape subscale, and at Level 6 (5.2% male vs. 2.7% female) on the Uncertainty scale (Cosgrove et al, 2005a, Tables B3-B6).

Level	Males		Females		Males–Females Difference	
	% students	SE	% students	SE	% Diff	SED
< Level 1	4.2	0.79	5.2	0.74	-1.0	1.08
Level 1	10.8	1.13	13.5	1.28	-2.7	1.71
Level 2	22.5	1.44	24.7	1.37	-2.2	1.99
Level 3	27.8	1.46	28.2	1.36	-0.4	2.00
Level 4	21.0	1.63	19.4	1.21	1.6	2.03
Level 5	10.8	1.09	7.4	0.83	3.4	1.37
Level 6	2.9	0.50	1.6	0.36	1.3	0.62

SE = Standard error; SED = Standard error of difference.

Table VII. Percentages of Irish students at each combined mathematics proficiency level in PISA 2003 and percentage differences, by gender.

This reaffirms the finding that poor female performance on Space and Shape was one of the factors contributing to the mediocre performance of Irish students in PISA 2003 mathematics, though it is also clear that males could have done better on Space and Shape. The greater number of males at Level 6 is in keeping with findings in large-scale surveys in general that males are more dominant at the high end of distributions of mathematics achievements, an effect which increases with age (Gallagher & Kaufman, 2005; Halpern et al, 2007). It is also noteworthy that the standard deviations on the distributions of mean percentage correct scores for Irish males and female on Overarching Ideas, Competency Clusters and Item Formats (see below) show slightly greater variability for females than males (about a twentieth of a standard deviation more on average).

Item Format and Gender

Five item response formats were utilised in the PISA mathematics test – two multiple-choice response formats (simple and complex) and three constructed response formats (short, closed extended, and open extended), along with partial credit marking in the case of some items. This varied range of formats, arguably, enables PISA to assess mathematical knowledge in a broader and deeper way than previous surveys which have relied almost exclusively on the multiple-choice and short constructed response formats, and also fits in better with country examination systems, such as the Irish JC examination, where short constructed and extended constructed responses with partial credit are the norm.

Item facilities were again used to estimate mean percentage mathematics scores of Irish students in the PISA 2003 sample by gender. Two categories of items were examined: multiple-choice (both simple and complex) versus constructed response formats (i.e. short, open extended and closed extended). A difference in favour of males was significant for the multiple-choice format but not for the constructed response format (Table VIII). (Scores are based on item facility levels as IRT scales had not been constructed for item format.) The outcome suggests that females found some multiple-choice questions more difficult to deal with than did males. This is in keeping with Bolger & Kellaghan (1990) and Wilder & Powell (1989), who also reported that multiple-choice questions in mathematics favour males. This could be related to females' lesser self-confidence and greater anxiety in mathematics, leading to less of the risk-taking behaviour which may be involved in multiple-choice items. With regard to gender differences on PISA and the JC mathematics examination, it should be mentioned that there are no multiple-choice items on the JC mathematics examination.

Format	No. of Items	Males %		Females %		Males–Females Difference %	
		Mean	SED	Mean	SED	Mean	SED
Multiple Choice	28	*53.5*	1.90	47.8	2.08	*5.7*	2.80
Construct Response	56	50.2	1.81	47.4	1.89	2.8	2.62

Significant differences in italic (adjusted alpha level: 0.5/2).

Table VIII. Mean percentage mathematics scores of Irish students on PISA 2003, by gender and item format.

Attitudes to Mathematics

In PISA, data on a range of variables relating to attitudes to mathematics, which are traditionally positively associated with achievement, were collected, including interest and enjoyment, motivation to learn, self-efficacy, and anxiety. Among these variables the one most strongly associated with mathematics performance was self-efficacy, which explained a remarkable OECD average of 23% of total variance in student performance (OECD, 2004). Self-efficacy in mathematics was measured by asking students to rate their confidence, on a four-point scale, in solving each of a number of mathematical tasks, e.g. solving an equation for x (e.g. $3x + 5 = 17$), or calculating the petrol consumption rate of a car. In Ireland, where the mean self-efficacy score was about the OECD average, students who reported high self-efficacy in mathematics achieved a significantly higher mean score in mathematics than students with low self-efficacy, as was the case *within* practically all countries. Self-efficacy did not show a similar relationship *across* countries as students in some of the highest achieving countries had significantly lower self-efficacy scores than those in many lower scoring countries. Obviously socio-cultural and curriculum factors have a strong influence here and would vary in their nature and effect across groups of countries. In general, however, males had higher self-efficacy scores than females within countries, including Ireland.

A somewhat similar pattern emerged for anxiety about mathematics, although it was not as strong a variable as self-efficacy, as it accounted for about 13% of variance in student performance (versus 23% for self-efficacy). Students were asked to respond to a number of statements designed to rate their general concerns about their achievement in mathematics on a four-point scale. As with self-efficacy, levels of anxiety about mathematics varied considerably across countries but, on average, students with high anxiety performed significantly less well in mathematics than students with low anxiety, in all countries. In all countries bar two (Poland and Serbia), male students reported significantly less anxiety about mathematics than females. The difference in Ireland (about one-sixth of a standard deviation) was smaller than the OECD average (one-quarter of a standard deviation), but was statistically significant nonetheless.

Gender differences in favour of males in attitudinal variables such as self-efficacy and anxiety, in the context of mathematics, are relatively larger than those for achievement and also show a very consistent trend over many years, particularly in secondary school. As pointed out in the PISA 2003 international report (OECD, 2004), the male advantage may be the result of the broader socio-cultural context or educational policies and practices. In Ireland, about half of all females and one-third of all male students attend higher performing single-sex schools. Traditionally, attitudes to mathematics and the physical sciences have been quite different with these subjects being less favoured in all-female schools compared with all-male schools (Lyons et al, 2003). Although this effect has been reducing over time, it may still have some influence on females' attitudes to mathematics, if not their achievement.

There is other evidence that the gender difference in favour of male students in Ireland is a substantive one. In a multilevel model based on performance in mathematics that included a range of student and school variables (among them, student- and school-level socio-economic status and student home educational resources), the contribution to the fitted score for male students was 24 score points (over one-quarter of a standard deviation) (Cosgrove et al, 2005a). Further, there were no statistically significant interactions between gender and other variables in the model. Interestingly, when self-efficacy in mathematics and anxiety about mathematics were added to the model, the explained variation improved by 4.9% at the school level, and by 14.7% at the student level, so that the model explained 83.8% of variance at school level, and 44.3% at individual level. However, as indicated earlier, the precise relationship between attitudinal variables such as self-efficacy and anxiety and mathematics achievement is unclear, and aspects of these variables may themselves be proxies for mathematical performance.

Discussion

The analysis of the gender aspect of Irish mathematics results on the PISA surveys highlights the complex manner in which the gender variable manifests itself in the Irish educational system, involving socio-cultural and educational factors, as well as features of the assessment. As a result, it is difficult to arrive at clear-cut implications for practice or further research.

As occurred in most PISA countries, male students in Ireland achieved a significantly higher mean score than females on the overall mathematics scale and on all four subscales representing the overarching ideas, with the largest difference on the Space and Shape subscale. This is contrasted with the stronger performance of female students on the state JC mathematics examination, taken by all students in Ireland at the end of 9th Grade. Our analyses suggest that the stronger performance of male students on PISA is related to a number of factors, including:

- differential performance across content areas, with differences in Space and Shape in favour of males in Ireland contributing more to the overall gender difference than differences in the other overarching ideas;
- a greater proportion of questions on PISA requiring higher-level competency clusters (Connections and Reflection), which may favour males, compared with the JC mathematics examination, where almost all questions can be described as involving the Reproduction competency cluster, and may favour females;

- stronger representation of male students in Ireland at the highest proficiency levels – 13.7% of males but only 9% of females achieved at the highest levels (Levels 5 and 6), while 15% of males and 17.8% of females achieved at the lowest levels (Level 1 or below); this is a long-standing phenomenon internationally, which shows itself prior to any elective course taking in maths, typically from 15 or 16 years of age onwards, but is not apparent in the JC examination in Ireland;
- the presence of a substantial number of multiple-choice items on PISA, compared to the JC mathematics examination, where there are no multiple choice items. In line with earlier research, males in Ireland did better on PISA multiple-choice items than females. (In this context, it is worth noting that TIMSS 1995 included a substantial proportion of multiple-choice items, yet there was no overall advantage for male students.);
- a moderately strong association between self-efficacy in mathematics and achievement, with male students reporting higher self-efficacy than females;
- a somewhat weaker association between low anxiety about mathematics and achievement, with male students in Ireland reporting lower levels of anxiety. (Of course, the higher mathematics self-efficacy among males and their lower anxiety levels are not unique to PISA [Petersen et al, 1982].)

The stronger performance among male students in Ireland was confirmed in a multilevel model of mathematics achievement, where the gender difference in favour of males was in the order of a quarter of a standard deviation once the contributions of variables such as school and student socio-economic status had been controlled for (Cosgrove et al, 2005a).

The fact that males performed better than females on the rather novel and atypical PISA mathematics test, and that females performed better than males on the more predictable and traditional JC mathematics examination could be attributed to many of the factors discussed above, including content, process skill type and complexity, item formats, task contexts, and self-efficacy and anxiety about mathematics levels.

There are also conflicting aspects to this performance difference in favour of Irish males. PISA mathematics items generally demand a considerably higher reading level than the questions on the JC mathematics examination papers (Close & Oldham, 2005), many of which have little or no text, so one might have expected Irish females to outscore males as they do on PISA reading and the JC English examination. But perhaps this effect was overridden by weightier affective and/or mathematical process skill factors. There are also socio-cultural factors such as career and occupational choices and aspirations to be considered, as pointed out in the PISA 2003 main report (OECD, 2004).

The poor performance of Irish students generally, and females in particular, on the Space and Shape items suggests the need for more emphasis on this area in the Junior Certificate syllabus (7th to 9th Grade). A similar recommendation has been made in the report on the 2004 National Assessment of Mathematics Achievement at 4th Grade where performance on the Shape and Space and Measure strands was of some concern (Shiel et al, 2006). Another finding of the current analysis, which showed that more males than females achieve at the highest levels of proficiency on the PISA mathematics combined scale, is common in many countries and the concern here is that it may be associated with lower female participation in higher-level mathematics courses and in science, engineering and technology courses at senior secondary school and college.

The significantly higher performance of males on multiple-choice items warrants some attention. Multiple-choice items are used widely on standardised tests. In a recent paper Halpern et al (2007) highlight the 'grade–test disparity' in North America with 'females achieving better grades in school and males achieving higher scores on tests designed for admissions to colleges, universities and graduate programs' (p. 4). College entrance tests tend to contain substantial numbers of multiple-choice items, which may confer an advantage on male students. This effect may be diminishing over time but should be considered for further research.

The finding that Irish males are higher than females in self-efficacy in mathematics is in keeping with international trends on this attribute, which have held firm over many years. It is worth adding that this advantage on the part of males may also have been associated with greater risk-taking on their part in the face of the unusual nature of the PISA items and consequently partly contributed to the gender differences in performance. Motivation may also play a part as female students in single-sex schools are strongly focused on 'high-stakes' examinations such as the JC mathematics examination – more so that male students, and hence may approach PISA in a different way.

The impetus for the present study is the contrast between the consistent trend of males outperforming females in PISA mathematics surveys and the corresponding trend in the Irish JC mathematics examination of females outperforming males. The above analyses show how a number of key variables may be involved, including: type of mathematical content, item complexity, greater variability in male mathematics performance, item format and attitudinal variables. Marks (2008) pointed out that, in many countries, the gender gap in favour of males in PISA mathematics is small compared with the gender gap in favour of females in PISA reading and attributes this to 'the successful implementation of policies to promote the educational outcomes of girls and young women' (p. 105), which he says may inadvertently contribute to a widening gap in reading literacy. Also, Penner (2003), in an analysis of gender by item difficulty interactions in TIMSS mathematics, and Hyde et al (2008), in an analysis of National Assessment of Educational Progress (NAEP) data from 10 US states, both found that gender differences were minimal on easier tasks and greater, in favour of males, on more complex tasks. Following on from the above, it could be argued that, in Ireland, changes in curriculum and examination policies have inadvertently favoured females by leading to a gradual reduction, over the past 20 years, in the complexity and novelty of tasks (including removal of multiple-choice tasks, increasing predictability of examination tasks, and greater emphasis on procedures) in the JC mathematics examination. On the other hand, the PISA mathematics tasks tend to be more complex and non-routine and thus favour males, despite the greater reading demands. This is reflected in particular in the heavy load of tasks involving routine algebraic procedures in the JC mathematics examination which are absent from the PISA mathematics test and the heavier load of more complex Space & Shape/Measurement tasks in PISA mathematics compared with the less complex tasks in these areas on the JC mathematics examination, as described earlier in the article.

In this regard it is interesting to note that the somewhat disappointing performance of Irish students on PISA mathematics has contributed to the decision by the Irish Department of Education and Science to set up a national project (Project Maths) to reform post-primary school mathematics curricula and examinations (National Council for Curriculum and Assessment [NCCA], 2008a, b). The project, which commenced in September 2008, will place much greater emphasis on student understanding of mathematics, using contexts and applications that will enable students to relate mathematics to everyday experience and also focus on developing students' problem-solving skills. It will be interesting to see how Project Maths impacts on the performance of male and female students in the JC mathematics examination, and ultimately, how it impacts on the performance of Irish students in future cycles of PISA mathematics.

Notes

[1] Only two of the four overarching ideas (Shape and Space and Change and Relationships) were assessed in 2000 and just 20 items were use to link the 2000 and 2003 scales. Therefore comparisons of gender groups need to be interpreted with due caution.

[2] The JC Performance Scale (JCPS) is used to place the performance of all students who sat the JC mathematics examination on the same underlying scale. This was achieved by assigning scores to students' grades on a scale from 1 (Foundation level, Grade F) to 12 (Higher level, Grade A).

[3] In 2003, 58,716 students in 9th Grade took the JC mathematics examination. Some 40.5% of students sat the Higher level papers; 46.9% sat the Ordinary level papers; and 12.5% sat the Foundation level papers. Approximately equal numbers of male and female students sat the JC mathematics examination at each level.

[4] The low performance of female students in Ireland on Space and Shape in PISA cannot be attributed to a larger proportion of females than males taking Foundation level. In 2003, 3026 female students and 4298 males took Foundation level. Together, they represented 12.5% of candidates.

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