PISA: Behind the headlines and past the rankings

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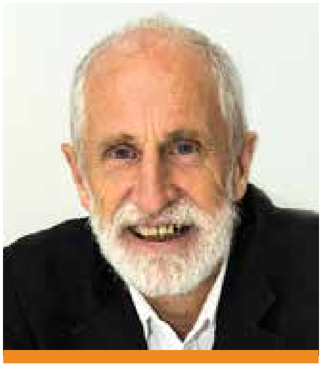
Dr Thomson has also fulfilled the roles of National Research Coordinator for Australia in the International Association for the Evaluation of Educational Achievement (IEA) Trends in International Mathematics and Science Study (TIMSS) since 2002, National Project Manager for Australia in the Organisation for Economic Co-operation and Development (OECD) Programme for International Student Assessment (PISA) since 2004, and National Research Coordinator for Australia in the IEA Progress in International Reading Literacy Study (PIRLS) since 2008.

Dr Thomson's research at ACER has involved extensive analysis of large-scale national and international data sets — the Longitudinal Surveys of Australian Youth (LSAY), as well as TIMSS and PISA. She is involved in several projects involving analysis of the longitudinal data collection associated with the PISA surveys. She was engaged as an expert writer on the National Numeracy Review, and has consulted with a variety of government departments at both Commonwealth and state levels, as well as with the Catholic Education Commission, on a variety of data-analysis projects related to TIMSS and PISA. Dr Thomson is an Associate Editor for the *Australian Journal of Education*



Chris Wardlaw PSM

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Chris Wardlaw PSM is currently Chair of the Victorian Curriculum and Assessment Authority. Chris held a Deputy Secretary position in education in Hong Kong (2002 to 2008) and Victoria (2009 to 2013) and is now retired. In the Hong Kong Government Chris had responsibility for curriculum, assessment and quality assurance for pre-primary, basic education, senior secondary education and the interface with tertiary education, and in Victoria for strategy and review across the portfolio.

Chris has considerable experience authorising, funding, and learning from national and international assessments in a range of domains across jurisdictions. Hong Kong has improved its already high standing in successive international assessments from 2000 to the present.

Chris has had an extensive career in Victorian education during which he took a leading role in major reforms supporting school-level decision-making and evaluation and review.

Chris was awarded the Public Service Medal (PSM) in the 2013 Queen's birthday Honours list and was made a fellow of Monash University in 2013.

In a parallel sporting career, Chris was Head Coach of the Australian Athletics Team at the 2000 Sydney Olympic Games; an Olympian in 1976 and 1980 in the 10 000m and marathon events; and coach of marathoners Steve Moneghetti and Kerryn McCann and distance runner Craig Mottram. Chris was awarded the Australian Sports Medal in 2000.

Abstract

Whenever the results of the Programme for International Student Assessment (PISA) are announced, media headlines are full of reports about rankings, about how many countries Australia is outperformed by and outperforms. In early rounds of PISA, Australia ranked among the top 10 countries across all three education domains assessed. However, over time Australia's position has declined, rather than improved, and Australia no longer sits in the top 10 of any of the assessed domains.

This presentation will go behind the headlines and past the rankings, to look at where Australia has declined, and look at how we can improve outcomes for students and achieve a world-class education system.

In particular this presentation will focus on mathematics.

Whenever the results are released from one of the international assessments, the Programme for International Student Assessment (PISA) in particular, the headlines are full of reports about rankings, about how many countries Australia is outperformed by and outperforms. PISA is part of the National Assessment Program, acting as a component of the evaluation of the Melbourne Declaration on Educational Goals for Young Australians, which in the preamble explained:

> Australia has developed a high-quality, world-class schooling system, which performs strongly against other countries of the Organisation for Economic Co-operation and Development (OECD). In international benchmarking of educational outcomes for 15-year-olds in the 2006 OECD Programme for International Student Assessment, Australia ranked among the top 10 countries across all three education domains assessed. Over the next decade Australia should aspire to improve outcomes for all young Australians to become second to none amongst the world's best school systems. (MCEETYA, 2008)

However, over the following seven years and two further cycles of PISA, Australia's position has declined, rather than improved, and Australia no longer sits in the top 10 of any of the assessed domains.

In the most recent assessment, PISA 2012, compared only to those countries that took part in PISA 2003 (years in which mathematical literacy was the major focus of the assessment):

- four countries significantly outperformed Australia in both cycles
- six countries whose scores were not significantly different to Australia in 2003 outperformed Australia in 2012
- three countries whose performance was significantly lower than Australia in 2003 scored at the same level as Australia in 2012
- two countries whose performance was significantly lower than Australia in 2003 significantly outperformed Australia in 2012.

Typical of headlines in Australia after the most recent PISA study was this one that asked: Australia's PISA slump is big news but what's the real story? (Riddle, Lingard & Sellar, 2013)

What *is* the real story? This presentation will go behind the headlines and past the rankings, to look at where Australia has declined, and look at how we can achieve what the ministers hoped in 2008.

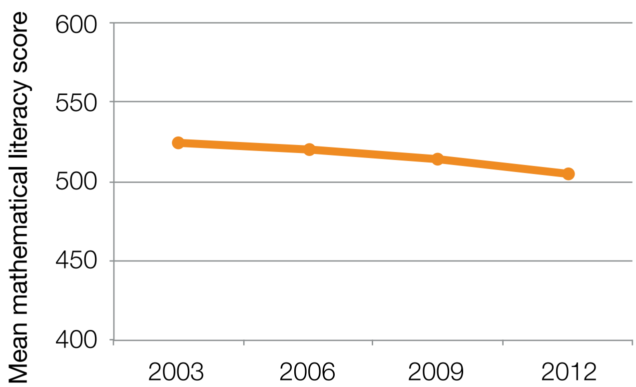
In particular this presentation will focus on mathematics. The Australian Council of Learned Academies recommends that Australia needs to grow its pool in the area of science, technology, engineering and mathematics (STEM), and expanding this talent pool requires increasing the participation of young women, a resource that is at the moment underutilised (Marginson, Tytler, Freeman & Roberts, 2013). The Year 10 students in particular that are assessed as part of PISA are at a crucial stage in their education — ready to make decisions about the subjects they choose to study in senior secondary school and what careers they may go in to. A strong influence on their decision-making will be what they are confident and interested in.

Mathematical literacy

In each cycle of PISA, three main areas are assessed: reading literacy, mathematical literacy and scientific literacy. In each cycle the assessment areas are rotated so that one domain is the major focus (the major domain), with a large amount of the assessment time being devoted to this domain compared to the other two domains (the minor domains). Mathematical literacy was the major domain in the second PISA assessment in 2003, and as this was the first year that this was the case, comparisons are generally made back to this date. Mathematical literacy was also the major domain of the most recent PISA assessment, in 2012.

As the headlines indicated, Australia's average score has declined, from 524 score points to 504 score points, as shown in Figure 1. In both cycles this score is significantly higher than the OECD average, however in PISA 2012 this was because the OECD average had also significantly declined (from 500 to 494 score points — perhaps due to the inclusion of some low-performing countries in the OECD in the 2012 cycle). While it appears that there was a decline from one cycle to the next in Australia, it was only the decline from 2003 to 2012 that reached statistical significance.

Figure 1 PISA mathematical literacy 2003–2012, Australia



To examine whether this decline was for students of all abilities, or whether it was concentrated amongst students at particular levels of ability, the distribution of achievement for each PISA cycle was examined. The distribution of each cycle was described by five percentiles (the 10th, 25th, 50th or the median, 75th and 90th) and their associated standard errors. A percentile is the value of a variable, the PISA mathematics scale score in this instance, below which a certain per cent of the population fall. For example, in 2012, the 90th percentile in mathematical literacy was 630, which means that 90 per cent of the population scored below 630 on the PISA mathematical literacy scale.

Figure 2 shows that rather than a single decline in scores at any one point of the distribution, the decline has occurred more gradually over time across the whole distribution. The smallest decline was at the 90th percentile, however it was still a statistically significant decline of 14 score points since 2003. The largest differences were seen in the middle of the distribution: at the 50th percentile the decline was 24 score points, a little more than two-thirds of a year of schooling.[1]

In addition to mean scores, PISA attaches meaning to the performance scale by providing a profile of what skills and knowledge students have achieved. The performance scale is divided into levels of difficulty, referred to as proficiency levels. In mathematical literacy there are six proficiency levels described, ranging from low (Level 1):

> Students can answer questions involving familiar contexts where all relevant information is present and the questions are clearly defined. They are able to identify information and carry out routine procedures according to direct instructions in explicit situations. They can perform actions that are almost always obvious and follow immediately from the given stimuli. (Thomson, De Bortoli & Buckley, 2013)

to high (Level 6):

> Students can conceptualise, generalise and use information based on their investigations and modelling of complex problem situations, and can use their knowledge in relatively non-standard contexts. They can link different information sources and representations and move flexibly among them. Students at this level are capable of advanced mathematical thinking and reasoning. These students can apply this insight and understanding, along with a mastery of symbolic and formal mathematical operations and relationships, to develop new approaches and strategies for addressing novel situations. Students at this level can reflect on their actions, and can formulate and precisely communicate their actions and reflections regarding their findings, interpretations and arguments, and can explain why they were applied to the original situation. (Thomson, De Bortoli & Buckley, 2013)

Figure 3 shows the proportion of high-achieving and low-achieving students in each cycle of PISA. High achievers are those students who achieved at Proficiency Level 5 or Proficiency Level 6; low achievers are the proportion of students who failed to meet Proficiency Level 3. The proportion of high achievers in mathematical literacy dropped from 20 per cent in 2003 to 16 per cent in 2006 and then remained relatively stable in 2009 and 2012. Overall, though, the proportion of high achievers in 2012 was significantly lower than in 2003.

At the lower levels of achievement in PISA 2003, 33 per cent of Australian students failed to meet the minimum proficient standard. In the PISA 2012 assessment, this had risen to 42 per cent of students, a significant increase.

In summary, Australia's position overall declined significantly in mathematical literacy from PISA 2003 to PISA 2012. This decline has been right across the distribution of achievement levels, from high to low. While this decline has been fairly consistent across the distribution, there was a substantially larger proportion of students in 2012 at the lower achievement levels, resulting in four in ten students not achieving our own minimal proficient standard.

Trends in mathematical literacy performance by gender

According to news coverage following the release of PISA results, 'Australian girls' performance in maths has fallen to the OECD average — dragging down Australia's result.' (News Limited)

So this is where the blame lies! Is this indeed the case, and is it the whole story?

Internationally and in Australia, a vast body of research has been conducted into gender differences in mathematics over several decades. Campaigns in Australia that encouraged female students to undertake mathematics, in particular, seemed to have been largely successful. In the Trends in International Mathematics and Science Study (TIMSS) in 1994/95, Australia was one of the six countries that had no gender differences in mathematics for Year 8 students, and also was one of the countries that had equivalent results by gender in advanced mathematics at Year 12 (Lokan, Ford & Greenwood, 1997). In PISA 2003 only a few score points separated males and females, a difference that did not reach statistical significance. Both scored significantly better than the OECD average.

[1] It is possible to estimate the score point difference that is associated with one year of schooling. This difference can be estimated for Australia as there are a sizeable number of 15-year-olds who were enrolled in at least two different year levels in the PISA 2012 sample. Analyses of these data indicate that the difference between two year levels is, on average, 35 score points on the PISA mathematical literacy scale. This implies that one school year corresponds to an average of 35 score points in Australia.

Figure 2 Distribution of mathematics achievement, all students, Australia, PISA 2003–2012

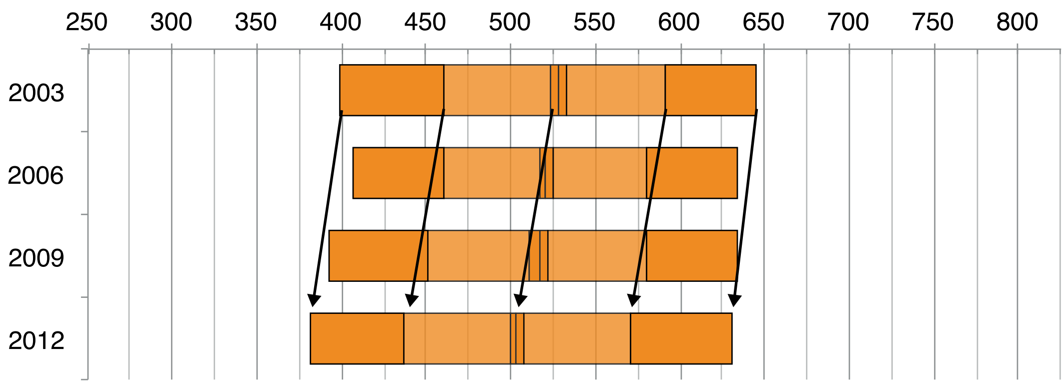


Figure 3 Percentage of high and low achievers, all students, Australia, PISA 2003–2012

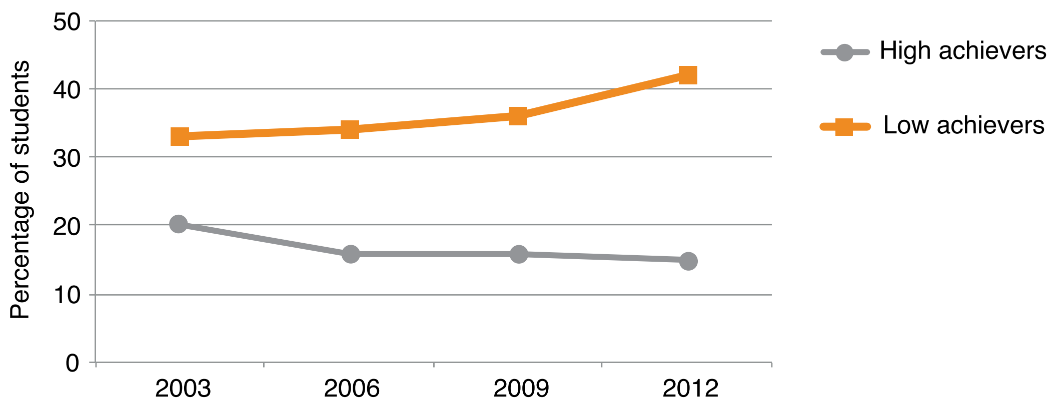


Figure 4 Mean PISA mathematical literacy scores, Australia, by gender

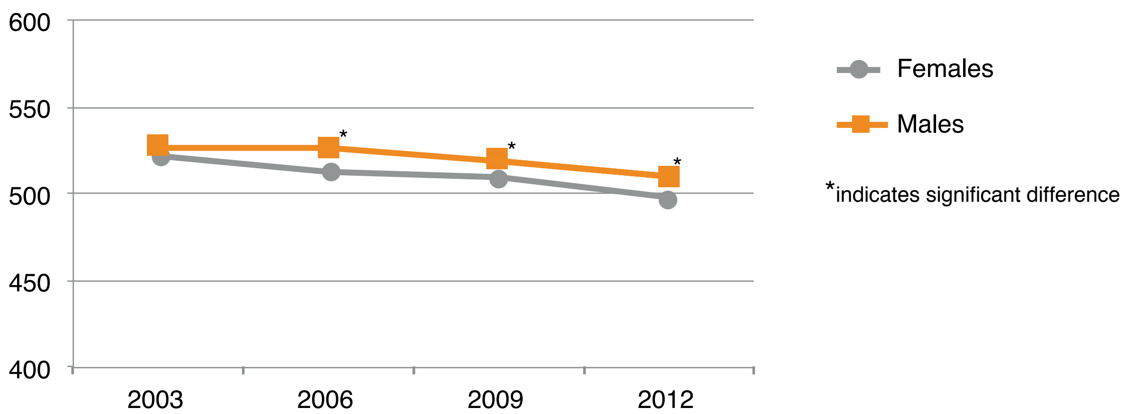


Figure 5 Differences in mathematical literacy score for males and females between PISA 2003 and PISA 2012, Australia, by percentile

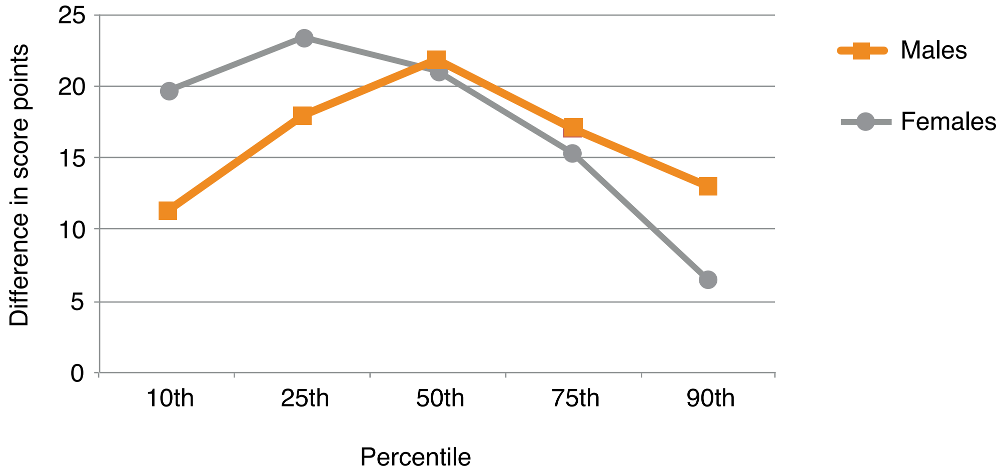


Figure 6 Score point difference between males and females, 2003 and 2012

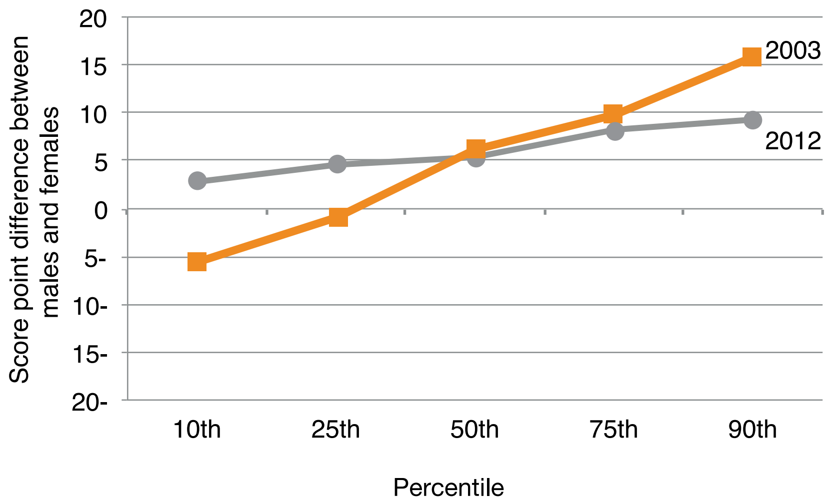
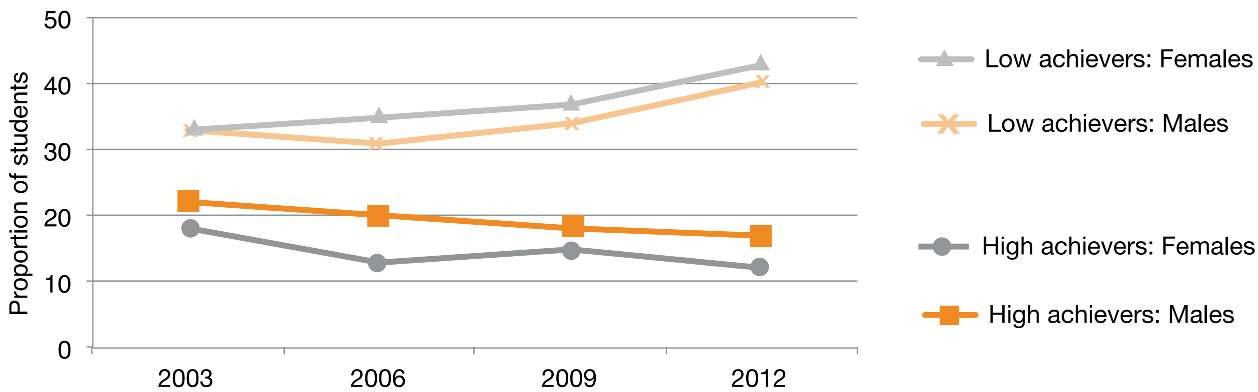


Figure 7 Percentage of high and low achievers, by gender, Australia, PISA 2003–2012



Over the period 2003 to 2012, the average score for both males and females declined significantly — by 17 score points for males and 24 score points for females (Figure 4). In PISA 2012 in Australia, males achieved a mean score of 510 score points, which was significantly higher than the mean score of 498 score points for females. This difference of 12 score points equates to around one-third of a year of schooling, and the average score for female students has declined to such an extent that it is no longer significantly different to the OECD average.

Figure 5 shows the difference in mathematical literacy scores between PISA 2003 and PISA 2012, for males and females separately. What we can learn from this is that for females the largest decline was amongst lower-achieving students — more than 20 score points at the 10th, 25th and 50th percentiles, while for higher-achieving students (those at the 90th percentile) the decline was only six percentage points. For males the decline was more general — 11 percentage points at the 10th percentile peaking in the middle, with the 'average' student's score declining by 22 score points, and then at the 90th percentile a decline of 13 score points over the nine years.

Figure 6 presents the differences between male and female mean scores at each percentile. Female students at the very lowest levels of achievement outperformed their male counterparts by five percentage points. At the 25th percentile, there was negligible score difference between the two groups. At the 90th percentile, the difference was some 15 score points in favour of male students.

In 2012, several differences can be noted. From Figure 5 we know that the performance of females declined more than that of males, and so perhaps it is not surprising that in 2012 males outscored females at both the 10th and 25th percentiles, and while there was little change around the middle of the distribution, females at the 90th percentile had decreased the lead of male students from 16 score points to nine score points.

These findings are also reflected in changes in the proportions of male and female students reaching various proficiency levels (Figure 7). From 2003 to 2012, the proportion of female students not achieving the Australian proficient standard (Proficiency Level 3) grew from 33 per cent to 43 per cent. At the same time the proportion of males not achieving this level increased from 33 per cent in 2003 to 40 per cent in 2012. While it is of concern that the proportion of females at the lower levels of achievement has increased so far in nine years, it is of more concern that the performance of both males and females has declined to such an extent.

At the same time, at the higher levels of achievement, the proportion of both male and female students at Proficiency Level 5 or Level 6 has declined by about the same amount — from 22 per cent to 17 per cent for males and from 18 per cent to 12 per cent for females.

In summary, the overall decline in Australia's score in mathematical literacy is a reflection of a decline by both males and females over the last ten years; however this has been more marked in female students. While the average score for males remains significantly higher than the OECD average, the score for females slipped to a level where it is not significantly different to that mean. However, the data also reveal that much of the decline for females has been at the lower end of the achievement distribution, with the gender gap at the highest percentile actually decreasing between 2003 and 2012. For both males and females, there are a larger proportion of students failing to achieve the minimum benchmark of Proficiency Level 2, and fewer achieving the higher proficiency levels.

Students' motivation and engagement can have a profound impact on their classroom performance in the short term and can affect the quality of their learning in the long term. A number of attitudes have been examined in both PISA 2003 and PISA 2012, allowing an investigation of whether these have changed across time.

Attitudes and beliefs: The value of context

Past the rankings, PISA provides contextual information about students' beliefs and attitudes about mathematics. Are there attitudinal differences between males and females that might help explain the differences in their achievement levels? In PISA students are asked to rate their level of agreement to a range of contextual questions, usually on a Likert scale ranging from strongly agree to strongly disagree, where each scale is constructed to have a mean over the OECD of 0 and a standard deviation of 1. Positive or negative values do not necessarily mean that students responded positively or negatively to the underlying questions, rather that they responded more or less positively than students on average across the OECD.

A summary of the mean index score for each of these in 2003 and 2012 for males and females is shown in Table 1. Scores for females on each one of the attitudinal variables is significantly lower than the equivalent score for males, in both 2003 and 2012. In both years, female students showed lower levels of intrinsic motivation, self-efficacy and self-concept in mathematics than those of their male counterparts and lower than the average for all students across the OECD. While none of these has changed over time it is likely that they all contribute to the big picture, and should be addressed.

Intrinsic motivation

Students' level of intrinsic motivation was measured in PISA as the amount of interest or enjoyment students felt in relation to mathematics. Females responded less positively than males on every item in this scale. For example, on the item 'I am interested in the things I learn in maths', 46 per cent of females agreed or strongly agreed, compared to 61 per cent of males and an average of 53 per cent across the OECD. On average, Australian females scored more negatively than the OECD average while males were more positive, as a whole.

Instrumental motivation

In addition to being motivated by how much they enjoy the subject, students will also be influenced to participate in mathematics if they perceive it to be useful for their future. This was measured in PISA by four statements comprising the instrumental motivation to learn mathematics scale. An example of this: 'Mathematics is an important subject for me because I need it for what I want to study later on' gained agreement from 80 per cent of males and 67 per cent of females. In this instance, the scores for males and females were both significantly higher than the OECD average, but the score for boys was substantially higher than that for females, indicating males felt much more that maths would be useful for them.

Self-concept

Self-concept and self-efficacy can be thought of as constructs that relate to students' competency-related beliefs at different levels of generality; mathematics self-concept relates to how confident a student feels in mathematics in general, while mathematics self-efficacy has to do with how confident a student feels in relation to particular mathematics tasks. Self-concept was assessed in PISA with statements such as 'I learn maths quickly', with which 62 per cent of males and 46 per cent of females agree, compared to the OECD average of 52 per cent.

The index scores for self-concept show that the average self-concept in mathematics of Australian females was significantly more negative than both the male students and the OECD on average.

Self-efficacy

Self-concept and self-efficacy are both forms of competency beliefs; however, self-efficacy is more specific and asks how competent students anticipate they will be on a defined task. For example, students in PISA 2012 were asked how confident they would be doing a variety of tasks, including 'calculating the petrol consumption rate of a car'. This item showed the most difference in confidence levels of males and females in Australia, with 41 per cent of females saying they were confident or very confident of being able to calculate this, compared to 66 per cent of males and 54 per cent of students on average across the OECD.

Maths anxiety

Maths anxiety (or the worry or tension felt when confronted with mathematical tasks) can have a negative impact on students' ability to demonstrate their potential in a subject. In PISA 2003 and PISA 2012 anxiety was measured by asking students their level of agreement with five statements:

- I often worry that it will be difficult for me in mathematics classes.
- I get very tense when I have to do mathematics homework.
- I get very nervous doing mathematics problems.
- I feel helpless when doing mathematics problems.
- I worry that I will get poor grades in mathematics.

This was the only one of the attitudinal variables listed in Table 1 on which scores changed from PISA 2003 to PISA 2012, and showed a significant increase in maths anxiety for females, making the already significant difference in scores for males and females even larger (Figure 8).

Figure 9 shows the level of maths anxiety for students in each proficiency level for PISA 2012. The overall pattern of this relationship is as would be expected, with higher levels of anxiety at lower levels of achievement and lower levels of anxiety at higher levels of achievement. Notable is that the anxiety levels of female students are higher than those of male students at each proficiency level, including Proficiency Level 6, where there is a substantial difference (0.7 of a standard deviation) despite there being no significant difference in the scores of male and female students.

So yes, the headline at the beginning of this section was correct — girls' performance has declined, although to say it is dragging down Australia's results is exaggerated. However, girls are performing well overall, given their level of belief and confidence in themselves. If, however, Australians believe in improving the achievement levels of all students, including females, there needs to be work done in the area of changing perceptions and dealing with the underlying causes of maths anxiety.

Table 1 Mean scores on attitudinal variables, PISA 2003 and PISA 2012

	2003					2012				
	Females		Males		Sig	Females		Males		Sig
	Mean	Se	Mean	Se		Mean	Se	Mean	Se	
Intrinsic motivation	-.10	.02	.18	.02	*	-.05	.03	.18	.04	*
Instrumental motivation	.11	.02	.34	.02	*	.13	.03	.31	.03	*
Self-concept in maths	-.08	.02	.29	.02	*	-.11	.03	.23	.03	*
Self-efficacy	-.09	.02	.28	.03	*	-.11	.04	.23	.04	*
Maths anxiety	.09	.02	-.19	.02	*	.19	.03	-.20	.03	*

Figure 8 Maths anxiety, PISA 2003 and PISA 2012, by gender

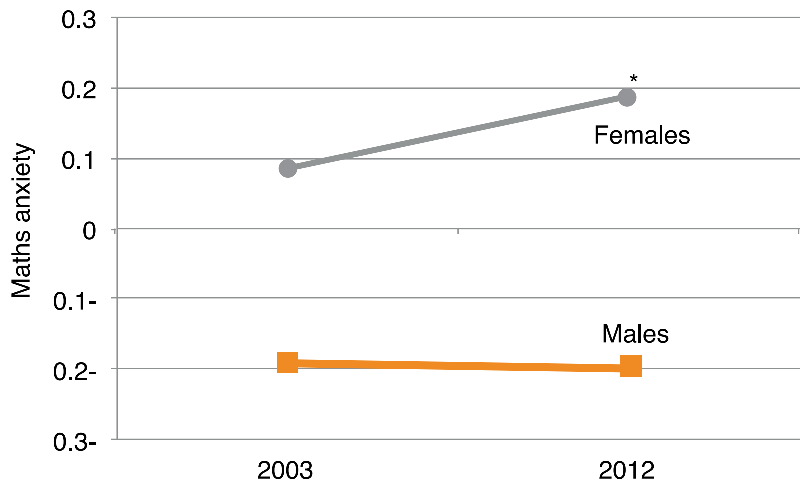


Figure 9 Maths anxiety by proficiency level, PISA 2012, by gender

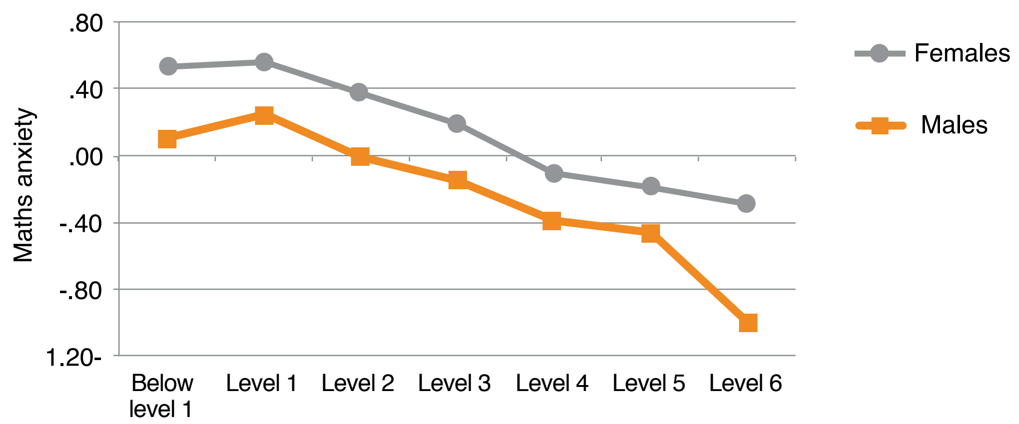
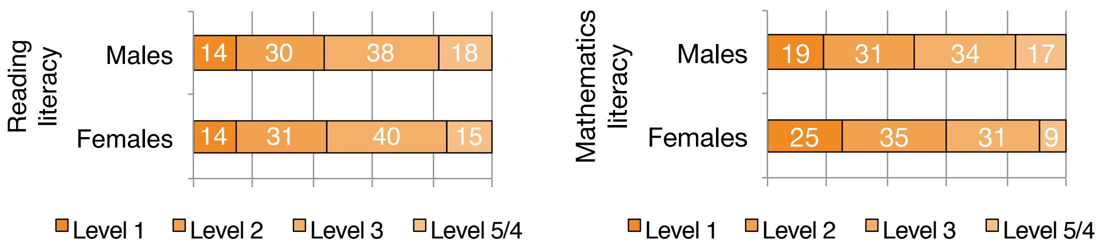


Figure 10 Proficiency levels in reading and mathematics, PIAAC 2012



Conclusions

Gender differences in mathematics are important. There is evidence from PISA that scores for females are declining at a faster rate than scores for males, and that on all attitudinal variables, female students have more negative perceptions than male students about their ability and capacity to do mathematics, and lower levels of enjoyment coupled with higher levels of anxiety, even when there is no possible reason to exhibit these characteristics. In purely economic terms, Hanushek and Woessman (2015) have calculated that if all students in Australia were to achieve the minimum OECD proficiency, Proficiency Level 1, there would be a possible 16 per cent increase in gross domestic product (GDP). One can only imagine the impact on the economy if all students were to achieve Proficiency Level 2.

PISA also highlights gender differences in reading scores (whereby females are outperforming males), and it is true that these differences are of a much larger scale than the gender differences in mathematics. However the most recent findings of the Programme for the International Assessment of Adult Competencies (PIAAC) provide the outcomes for adults in Australia in both reading and mathematics. The proficiency levels for each are shown in Figure 10, and show clearly that while males have well and truly caught up with females by adulthood in reading, this is not the case for mathematics. Female students in PISA are showing an enormous lack of engagement, and this is translating into them dropping mathematics as soon as they are able to, resulting in a continued decline in scores into adulthood.

The data derived from PISA are invaluable in terms of being able to see the big picture of how a system is faring against other systems internationally, systems whose students will enter the workforce and work in industries competing against those for which Australian students will eventually work.

The data are also invaluable within a country to see how different equity groups or subgroups within the population are faring over time. The data available are rich, and provide more than just the means and rankings, enabling educators and policy-makers to look more deeply into differences that are apparent.

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