Are Raelene, Marjorie and Betty still in the race?

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> Women and girls have made remarkable gains in education during the past 100 years, disrupting the belief—now largely unspoken—that boys and men are better "suited" to intellectual work. Today, few journalists or policy-makers would publicly admit to such a prejudice. (Corbett, Hill, & St Rose, 2008, p. xi)

Over the past four decades, gender differences in mathematics learning have continued to attract attention from both the research and broader communities, in Australia and internationally. Key and persistent findings can be summarised briefly as follows. Much overlap is consistently found in the performance of females and males. Gender differences in mathematics performance are rarely reported before or during the early years of elementary school. However, from the beginning of secondary schooling and beyond, males often, but not unfailingly, outperform females on tests in mathematics. Corbett et al. (2008, p. 15) concluded from a sustained testing program of American students: "A gender gap favouring boys in math is small and inconsistent among younger students but more evident among older students". These findings are representative of those reported more widely. Whether performance differences are found seems to depend on many factors. These include the format and content of the tests (Cox, Leder, & Forgasz, 2004; Leder, Rowley, & Brew, 1999), whether high or low cognitive level items predominate (Cooper & Dunne, 1999; Hyde et al., 2008; Leder, 2007), and whether standardised tests or classroom-based data are compared (Kenney-Benson, Pomerantz, & Ryan, 2006; Kimball, 1995). Standardised tests, it seems, often favour boys while classroom based work often favours girls. The composition of the group has also been found to be an important variable - with gender differences, typically in favour of boys, more likely to be found when the sample consists of high achievers (Leder, Forgasz, & Taylor, 2006; McGraw, Lubienski, & Strutchens, 2006; Mullis & Stemler, 2002). Nevertheless, when consistent gender differences are found they are invariably dwarfed by much larger within-gender group differences.

The relatively lower participation rates of females in mathematics, and particularly in more advanced mathematics subjects, have also attracted considerable attention—since students who opt out of post-compulsory mathematics courses typically restrict their longer term educational and career opportunities. Many courses and employment fields continue to include specific levels of mathematics attainment among their entry requirements, whether or not these levels are actually needed for such work.

Over the years, means to achieve gender equity have been introduced in many countries. These have included putting in place legislation to address discriminatory practices in fields such as education and employment, and media campaigns to encourage females to continue with mathematics and enter traditional male fields which rely on a strong mathematical background. Within Australia, the initiatives introduced have undoubtedly been effective. Females' participation in areas long considered to be male domains has improved over time. Such reported progress invariably attracts media attention. The following extract from The Age, a daily metropolitan newspaper, serves as a representative example:

> Australia ranks among the top 10 countries for closing the gender gap between men and women, a new international study shows. It comes 10th in the table of 58 nations compiled by the World Economic Forum (WEF) measuring patterns of inequality. New Zealand ranks sixth.(Australia among top 10 for closing gender gap, The Age, May 16, 2005)

Some now believe that intervention programs aimed at improving schooling for females have been so successful that boys should now be regarded as the educationally disadvantaged group (Department of Education, Science and Training 2003; House of Representatives Standing Committee on Education and Training, 2002; Weaver-Hightower, 2003). However, more recent performance data in mathematics seems not to justify this stance.

Recent findings

Data from two large assessment programs, the National Assessment Program for Literacy and Numeracy [NAPLAN] tests and the Trends in International Mathematics and Science Study [TIMSS], reveal that small but identifiable gender differences in mathematics achievement persist. In both the 2008 and 2009 tests, males slightly outperformed females in numeracy in grades 3, 5, 7, and 9 – though of course there was much overlap in the performance of the two groups (NAPLAN, 2009). Similarly, there was much overlap in the performance of females and males on the TIMSS 2003 and TIMSS 2007 tests, but again small gender differences in favour of males were found on both tests (Thomson, Wernert, Underwood, & Nicholas, 2008). Thomson et al. (2008) further pointed out that "the significant gender difference in favour of males found in Year 8 mathematics (not previously seen in 2003 or 1995) appears to be due to a significant decline in the average score for females over the 1995 – 2007 time span" (p. vi).

Whether any gender differences found varied by content domain and topic area was also explored. At both grades 4 and 8, males and females were found to have different strengths and weaknesses across the content and cognitive domains. For example, at the grade 4 level, males scored significantly higher than females in "number"; females in "data display". At the grade 8 level males in Australia, but not in other countries, performed significantly better than females in data and chance, number, and the cognitive domain of knowing. These findings, we argue, warrant a further investigation of the performance in mathematics by Australian students. Data from a large national data base, the long running Australian Mathematics Competition [AMC], is a fruitful source for doing this.

The Australian Mathematics Competition

The AMC is conducted under the auspices of the Australian Mathematics Trust [AMT] and is open to students of all standards. About one-quarter of Australia's secondary school students typically participate in the competition. Since 2004 the Competition has also been open to primary school students.

The AMC papers are prepared by a specially convened committee, drawn from teachers and university academics. Five separate Competition papers are now set. Three are for high school students: for those in grades 7 and 8, in grades 9 and 10, and in grades 11 and 12 and two for primary school students: those in grades 3 and 4, and for those in grades 5 and 6.

The questions are graded. The early questions are intended to be accessible to students of all standards from their classroom experience. Problems placed later in the papers are challenging to the most elite students and are designed to test mathematical thinking rather than focus on the calculations per se. These differences are reflected in the scoring scheme: with more marks assigned to questions later in the paper. Students write their responses on a mark-sense sheet.

Data from the AMC have been used intermittently to explore gender differences in mathematics performance. Earlier investigations revealed that boys, as a group, consistently perform somewhat better than girls (Atkins, Taylor, Leder, & Pollard, 1994; Edwards, 1984; Taylor, Leder, Pollard, & Atkins, 1996) and that there are consistently more boys than girls among the highest scoring students (Leder, Forgasz, & Taylor, 2006). It has also been reported that the performance gap in the AMC appears to have narrowed over time and that gender differences in performance can vary by question category (Atkins et al., 1994; Leder, Pederson, & Pollard, 2003; Leder et al., 2006). An early example of a question on which gender differences in favour of males were particularly marked was discussed by Edwards (1984)[1].

Our recent detailed explorations of the data base for the years 2004[2] to 2008, with students from grades 3 to 12 participating in the competition, have revealed that the previously reported gender differences in favour of males persist. For the five years of AMC papers we looked at, gender differences in performance in favour of males were invariably statistically significant at levels of p = .001 or stronger. Effect sizes[3] ranged from 0.15 to 0.25 for students in grade 3 to effect sizes of 0.31 to 0.42 for students in grade 12. These figures reflect the generally larger gender difference at the higher grade levels. No consistent year-by-year trend was found for the five years of AMC results.

To supplement the data on mean scores, we also looked at the distribution of scores, that is, the standard deviations. Consistently, not only for the years 2004 to 2008 but throughout the AMC data base, males had a higher standard deviation in scores. Thus, although the boys' mean

1. In a race of 2000 m, Raelene finishes 200 m ahead of Marjorie, and 290 m ahead of Betty. If Marjorie and Betty continue to run at their average speeds, by how many metres will Marjorie finish ahead of Betty?
(A) 90
(B) 100
(C) 120
(D) 180
(E) 200
2. This five year period was selected since 2004 was the first year AMC papers were set for primary school students.
3. Effect size is a way of quantifying the difference between two groups. An effect size around 0.20 is usually described as small; one around 0.40 as moderate (Cohen, 1988).

scores were slightly higher overall, their scores were more widely dispersed, and boys also dominated among those with the very lowest scores (particularly those with zero scores).

Over the years, consistent coding has been used within the AMC to describe the items on the AMC papers. Key descriptors are shown in Table 1.

Table 1. Descriptors of AMC items.

Mutually exclusive categories				
Basic (simple/ one operation)	Arithmetic	Algebra	Geometry	Problem solving (familiar context)
Routine (more advanced)	Arithmetic	Algebra	Geometry	Problem solving (unexpected setting)
Additional optional descriptors				
Geometry	2D diagram/No diagram		3D diagram/No diagram	
Other	Enumeration	Mechanics	Ratio	

Items from recent AMC papers on which the largest gender differences in performance were found—either in favour of boys or in favour of girls—are shown below.

Gender differences in performance

The five questions in the AMC data base for the years 2004 to 2008 with the greatest performance difference in favour of boys are shown first, followed by the five items which discriminated most in favour of girls. The question numbers are taken directly from the AMC papers. "Senior" refers to papers for students in grades 11 and 12; "Intermediate" to papers set for students in grades 9 and 10; and "UP" to a paper set for students in grades 5 and 6.

Items favouring boys

1. 2007 Senior Q4

   Of the following, which is the largest fraction?

   (A) $\frac{7}{15}$ (B) $\frac{3}{7}$ (C) $\frac{6}{11}$ (D) $\frac{4}{9}$ (E) $\frac{1}{2}$

2. 2008 UP Q3

   If 100 tickets are sold in a class raffle, how many tickets will Matthew have to buy to have a $\frac{1}{10}$ chance of winning?

   (A) 100 (B) 1 (C) 20 (D) 10 (E) 5

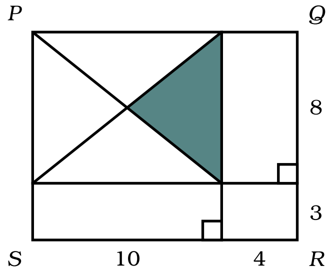
3. 2008 UP Q6

   The cost of petrol is 149.9 cents per litre on a Tuesday and 153.5 cents per litre the next morning. What was the increase in cents per litre overnight?

   (A) 6.4 (B) 4.3 (C) 16.4 (D) 3.5 (E) 3.6

4. 2006 Senior Q9

What fraction of the rectangle *PQRS* in the diagram is shaded?



(A) $\frac{1}{16}$ (B) $\frac{3}{5}$ (C) $\frac{1}{8}$ (D) $\frac{1}{10}$ (E) $\frac{10}{77}$

5. 2008 Senior Q6

\$3 is shared between two people. One gets 50 cents more than the other. The ratio of the larger share to the smaller share is

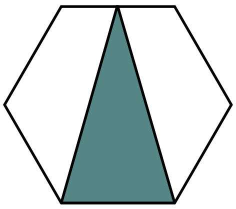
(A) 6 : 1 (B) 7 : 5 (C) 4 : 3 (D) 5 : 3 (E) 7 : 4

The difference in favour of boys on these questions ranged between 15 and 19 points. Each of these items, it can be seen, appeared early in the paper—in the first set of 10 questions worth the lowest number of marks. Four of the items can best be described as a Basic Arithmetic question; the other as a Basic Geometry question. This pattern of comparatively easy, Basic Arithmetic questions among the items strongly favouring males was also repeated for the next five such discriminating items.

Items favouring girls

1. 2007 Intermediate Q16

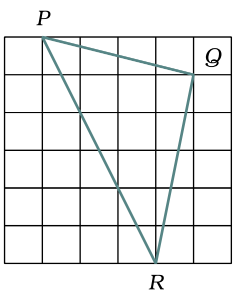
What fraction of the regular hexagon in the diagram is shaded?



(A) $\frac{1}{4}$ (B) $\frac{1}{3}$ (C) $\frac{3}{8}$ (D) $\frac{5}{12}$ (E) $\frac{1}{2}$

2. 2005 Intermediate Q12

The grid is a 1 cm grid.

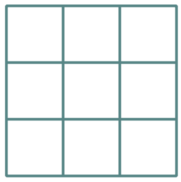


The area of PQR is

(A) 15 cm^2 (B) 10.5 cm^2 (C) 12 cm^2 (D) 13 cm^2 (E) 13.5 cm^2

3. 2004 Intermediate Q18

In how many ways can an x be placed in the cells of the grid shown so that each row and each column contains exactly two cells with an x?



(A) 6 (B) 9 (C) 12 (D) 18 (E) 27

4. 2006 Junior Q18

A $1 \times 1 \times 1$ cube is cut out of a $10 \times 10 \times 10$ cube. Then a $2 \times 2 \times 2$ cube is cut from the remainder followed by a $3 \times 3 \times 3$ cube and so on. What is the largest cube which can be cut out?

(A) $3 \times 3 \times 3$ (B) $4 \times 4 \times 4$ (C) $6 \times 6 \times 6$ (D) $7 \times 7 \times 7$ (E) $5 \times 5 \times 5$

5. 2006 Intermediate Q25

The vertices of a cube are each labelled with one of the integers 1, 2, 3, … 8. A face-sum is the sum of the labels of the four vertices on the face of the cube. What is the maximum number of equal face-sums in any of these labellings?

(A) 2 (B) 3 (C) 4 (D) 5 (E) 6

Although girls performed better than boys on these items, in each case the difference in performance was small—less than 3 points—that is, much smaller than the difference on the questions favouring boys. The items, as well as the next five most discriminating in favour of girls, are all geometry questions in terms of the AMC coding—some with diagrams; some without. All appeared in the middle of, or later in, the paper and had thus been judged as fairly challenging and certainly more difficult than the items on which the boys performed better than the girls.

Concluding remarks

There is much overlap between the scores of boys and girls on the AMC papers. Nevertheless, when differences are found they are generally in favour of boys. Through the years of school up to Year 9, the gender differences in performance are most appropriately described as small; for the highest years of high school, as moderate. In contrast to the findings reported for the TIMSS test, gender differences on the AMC papers have not increased over the last five years. At the same time, standard deviations for males continue to be consistently higher than those for females. Boys, then, dominate at both ends of the result scales of the AMC papers.

We note that the persistent performance difference in favour of males is seemingly in contrast to what is reported in various state grade 12 public examination results where females, on average, are often reported to perform better than males. For example, in 2008 a higher proportion of females than males satisfactorily completed the Victoria Certificate of Education [VCE] mathematics units but males outperform females in these mathematics subjects when actual grades obtained are considered, with more males than females scoring higher grades.Does the nature of the test contribute to such differences? Who performs better on an unseen test comprising multiple choice questions, such as the AMC papers, compared with performance on a comprehensively designed system for which students can prepare such as the VCE in Victoria, the South Australian Certificate of Education [SACE], and their equivalents in other Australian states? Might boys' better performance on the former indicate that they are smarter risk takers and are more prepared to guess the answer, particularly on easier questions?Might girls' better performance on the latter indicate that they are better organisers of their mathematics study than boys?

Our finding that it is particularly geometry and spatial perception questions on which females as a group did better than males as a group is particularly striking, given that it is those areas of mathematics on which males are typically considered to perform better. As an aside it is worth noting that geometry is not well represented in contemporary mathematics curricula. Our investigation of the AMC data base further reinforced the finding of females' more favourable performance in geometry on the AMC papers. While males still dominated when it came to topics such as mechanics and ratio, albeit at no greater levels than in earlier years, we observed that the differences were much lower in geometry. In fact at the younger ages, such as in primary schools, girls had higher overall scores than boys in some geometry categories.

Collectively our explorations indicate that "Raelene, Marjorie and Betty" are most certainly still in the (mathematics performance) race, but not way out in front.

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From Helen Prochazka's

Scrapbook

Equation photographs

To Justin Mullins, a British photographer, there are formulae that contain a mysticism and profound beauty. He searches for examples of equations that inspire him and then photographs them. He has even given his framed equation works as wedding gifts.

His favourite is the one he has titled “Romance” which he gave to his partner, Sandra, and describes a phenomenon discovered by Albert Einstein. It shows how two sub-atomic particles can be “linked in a very deep and fundamental way even though they may be separated by the width of the universe,” Mullins said. “She's now my wife so obviously it worked.”

Mullins says that if mathematicians are explorers, then his role is that of a photographer who retraces their steps and photographs what he finds. “I create snapshots of mathematical beauty. I call them mathematical photographs... For that reason, the equations in my photographs are much more than objects of ‘austere beauty’, as Bertrand Russell put it. I photograph them to explore their complex emotional and aesthetic values.”