Does CAS use disadvantage girls in VCE mathematics?

Helen Forgasz and Hazel Tan
Monash University
<helen.forgasz@education.monash.edu.au> <htan1@student.monash.edu.au>

In 2009, four mathematics subjects were offered at the year 12 (Unit 3/4) level in the Victorian Certificate of Education [VCE]. Using Barrington and Brown's (2005) categorisations they are:

- Advanced level: *Specialist Mathematics*
- Intermediate level: *Mathematical Methods; Mathematical Methods CAS*
- Elementary level: *Further Mathematics.*

The two subjects at the intermediate level—Mathematical Methods and Mathematical Methods CAS—run in parallel, that is, a student can be enrolled in only one or the other, the choice being made at the school level. The curricular content of the two subjects is virtually identical. The difference lies in the type of calculator that students use in class and in examinations. Students enrolled in Mathematical Methods use a graphics calculator; in Mathematical Methods CAS, the more sophisticated computer algebra systems [CAS] calculator is used.

Mathematical Methods CAS has been in place since 2002. For the first three years, it was introduced as an alternative, pilot program, with only a small number of schools (and students) involved. Since then, schools have been able to choose between the parallel offerings. From 2010, only Mathematical Methods CAS will be available. As a result, enrolment numbers in Mathematical Methods CAS have increased since 2002, particularly in the last couple of years.

For Mathematical Methods and Mathematical Methods CAS, there are three assessment tasks described in VCAA (2005):

1. A series of school-assessed tasks that "must be a part of the regular teaching and learning program and must not unduly add to the work-load associated with that program" (p. 160). This assessment task carries 20% of final assessment based on Unit 3 work and 14% based on Unit 4 work.
2. Examination 1—one hour—includes a collection of short-answer and some extended answer questions. It has been technology-free since 2006. This examination carries 22% of the final assessment and is common to both subjects.

3. Examination 2—two hours—includes a collection of multiple-choice questions and extended-answer questions. Calculator use is assumed: the graphics calculator for Mathematical Methods, and the CAS calculator for Mathematical Methods CAS. This examination carries 44% of the final assessment.

The years from 2002 to the present have provided a unique opportunity to observe and compare the patterns of enrolment and achievement in the two parallel subjects. Of particular interest has been the comparison of the patterns for male and female students since previous research findings suggest that females might be disadvantaged by the use of the sophisticated CAS calculator. The aims of the present study were to determine:

- if boys' and girls' achievements in the two parallel subjects, Mathematical Methods and Mathematical Methods CAS, differed, and
- if the difference in the type of calculator used in the two subjects might be implicated in any gender differences identified.

A brief overview of previous research on gender and technology for mathematics learning that underpins these research goals is presented next.

Selected previous research on gender and technology for mathematics learning

Gender differences in the outcomes of mathematics learning have been studied extensively in Australia (e.g., Vale & Bartholomew, 2008) and internationally (e.g., Bishop & Forgasz, 2007; Leder, 1992). More recently, studies have also focussed on gender issues with respect to the learning of mathematics with technology—computers and calculators. Various Australian research findings are reported here.

Pierce, Stacey, and Barkatsas (2007) developed the *Mathematics and Technology Attitudes Scale* (MTAS) and administered it to 350 students in six schools, representative of the range of schools in Victoria. They found that boys' attitudes towards the learning of mathematics using technology was positively correlated to their confidence with technology, whereas girls' attitudes towards learning mathematics using technology was negatively correlated to their mathematics confidence. Forgasz (2004) surveyed over 1500 students in years 7–10 and found a strong and significant correlation between attitudes to computers for learning mathematics and attitudes to computers, but the correlation between attitudes to computers for learning mathematics with attitudes to mathematics was not significant. In other studies, boys, compared to girls, have been found to believe more strongly that computers assisted their learning of mathematics, and were more confident about and more competent in using computers; teachers also had higher expectations of boys (Forgasz, 2003). Vale and Leder (2004) noted differences in boys' and girls' behaviours in mathematics lessons when computers were used: "[g]irls viewed the computer-based learning environment less favourably than boys and boys and girls thought differently about the value of computers in their mathematics lessons" (p. 308).

Forster and Mueller (2002) examined the Western Australian Calculus Tertiary Entrance Examinations [Calculus TEE] enrolments and results for 1995-2000, that is, three years before and three years after the graphics calculator was introduced and used in the subject in that state. During the period, it was noted that males' enrolment numbers had decreased by 3% while females' enrolments dropped by 22%. Three curriculum-related reasons were put forward to explain the declining enrolments, particularly for girls: increased technology use, Calculus no longer being a prerequisite for some university courses, and changes in university entrance requirements. For the years 1996-2000, girls' overall mean scores were found to be slightly higher than males' overall mean scores. For the years 1995-2000, females outperformed boys at the lower end of the achievement scale, but boys performed better at the top end of the scale. Forster and Mueller claimed that the outcomes could be partially explained "by the lower participation in TEE Calculus by girls, where one aspect is that fewer girls at the lower end of ability take the subject" (p. 806). No link to the use of the graphics calculator explained the girls' statistically superior performance over boys in the year 2000.

Forgasz and Griffith (2006) reported that teachers were generally confident about the effects that the introduction of the CAS calculator into the Victorian VCE mathematics subjects would have "on their teaching, on student learning, and on the curriculum" (p. 28). They also reported on the trends in the three trial years of Mathematical Methods CAS (2002-2004) of the comparative performance of girls and boys in Mathematical Methods (graphics calculator used) and Mathematical Methods CAS. They found that in both subjects higher percentages of males than females achieved the highest grades, and that the gender gap appeared greater for Mathematical Methods CAS than for Mathematical Methods. This was found to be the case in each of the three separately reported assessment tasks for each subject. They noted that enrolments in Mathematical Methods CAS were very small in the trial years, but cautioned that the trends identified "send cautionary warnings about the potential for the widening of the gender gap favouring males at the very top end of achievement when CAS calculators are used in high stakes assessment" (Forgasz & Griffith, 2006, p. 22).

In the present study, the enrolment and achievements of students in Mathematical Methods and Mathematical Methods CAS were derived from data found on the Victorian Curriculum and Assessment Authority [VCAA] website [http://vcaa.vic.edu.au]. The data were examined for the patterns, over time, in enrolments and achievements by gender.

Results

Enrolment data

The enrolment data for all VCE mathematics subjects from 2002 to 2008 are shown in Figures 1–4. The combined enrolments for Mathematical Methods and Mathematical Methods CAS are shown in Figure 5. Please note that all graphs have been drawn with the same axes to enable comparisons to be seen clearly by eye. The data in Figures 1–5 are shown by gender within cohort. The percentages illustrated were calculated as follows: the number of males/females enrolled in the subject was expressed as a percentage of the number of males/females enrolled in the Victorian Certificate of Education. The calculations were done this way in order to compare like quantities, as there are more females than males enrolled in VCE. In 2008, for example, the VCE numbers were: 27 400 females and 23 223 males, that is, females comprised 54% of the VCE cohort. Using within subject percentages would have distorted this VCE enrolment imbalance by gender and could have led to incorrect interpretations.

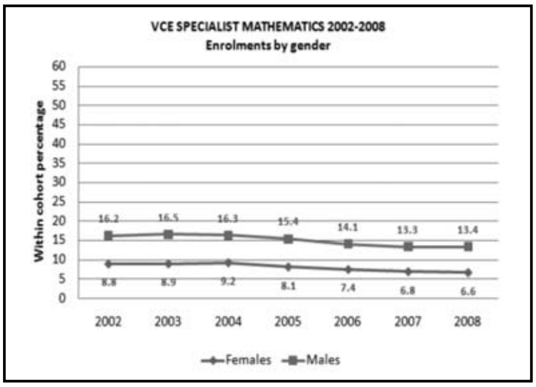

Figure 1. Specialist Mathematics enrolments 2002–2008.

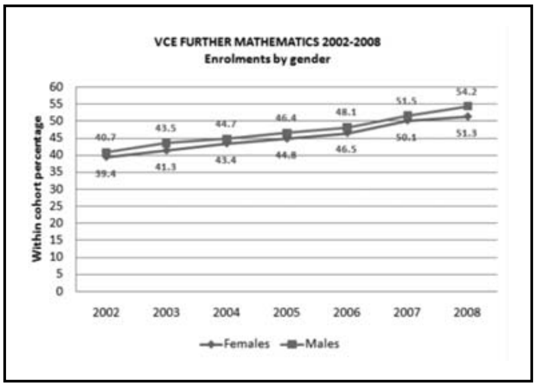

Figure 2. Further Mathematics enrolments 2002–2008.

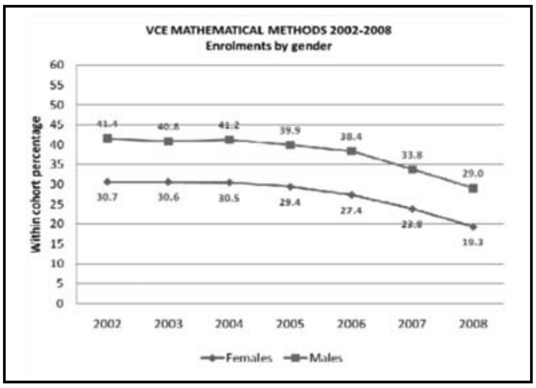

Figure 3. Mathematical Methods enrolments 2002–2008.

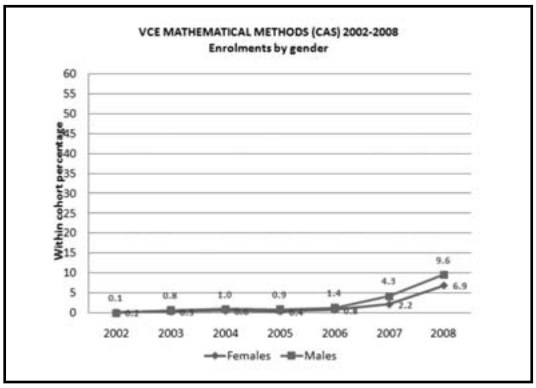

Figure 4. Mathematical Methods CAS enrolments 2002–2008.

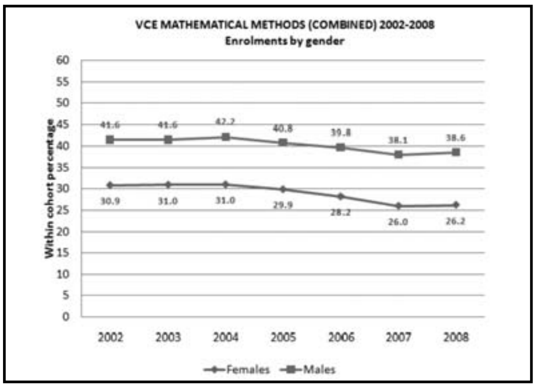

Figure 5. Combined enrolments for Mathematical Methods and Mathematical Methods CAS 2002–2008.

Figure 1 reveals a clear decline in Specialist Mathematics enrolments over the seven-year period for both males and females. A clear increase for males and for females in Further Mathematics enrolments over the seven-year period can be seen in Figure 2. Figures 3, 4, and 5 should be looked at simultaneously. While the enrolments in Mathematical Methods have decreased over the seven-year period (Figure 3) there has been a clear increase for Mathematical Methods CAS (Figure 4). In 2010 all students will be taking Mathematical Methods CAS, and Mathematical Methods will no longer be offered. However, the combined enrolments in the two subjects indicate an overall decrease in numbers in Mathematical Methods. For females there was a 4.7% drop from 30.9% of all females enrolled in VCE in 2002 to 26.2% in 2008. For males it was a smaller drop of 3%, from 41.6% of the VCE male cohort in 2002 to 38.6% in 2008.

The first finding from this exploration is that, over time, the trend appears to be for smaller proportions of both the male and the female VCE cohorts to study Mathematical Methods or Mathematical Methods CAS; the downward trend appears to be slightly stronger among females than among males. In general, there has also been a decline in enrolments in the most challenging mathematics subject (Specialist Mathematics). Over the same time period, there was a substantial enrolment increase in the least challenging subject (Further Mathematics). While the increase in enrolments in Further Mathematics can be interpreted as a positive, in that more students are taking mathematics at the VCE level, the decrease in enrolments in the more difficult subjects is an issue of concern. The reasons for the changes in enrolment patterns invite further investigation.

Performance data

VCE performance data are reported in different ways. However, for each VCE subject, the results for each of the three assessment tasks are reported in terms of the proportions of enrolled students, and by gender, achieving each of the awarded grades (A+, A, B+, B, C+, C, D+, D, E+, E, and UG – ungraded). In Figure 6, there are six graphs reflecting the proportions of males and females achieving each of the grades A+, A, and B+ for the school-assessed task for Mathematical Methods and Mathematical Methods CAS. Figures 7 and 8 include similar groups of six graphs revealing the proportions of students achieving each of the three grades A+, A, and B+ in the two subjects for Examination 1 and Examination 2 respectively.

Close inspection of Figures 6, 7, & 8 reveals that:

- For each assessment task, there was a more stable pattern, over time, for male and female achievements in Mathematical Methods than for Mathematical Methods CAS. The low numbers in the CAS subject in the early years may contribute to the instability which appears to be less extreme in the later years.
- For both subjects, a higher proportion of males than females received the grade A+ for the School Assessed Tasks, Examination 1, and Examination 2 and, for each assessment task, the gender gap (i.e., the

Mathematical Methods: 2002–2008 Grades A+, A, & B+ School-based assessment task	Mathematical Methods CAS: 2002–2008 Grades A+, A, & B+ School-based assessment task

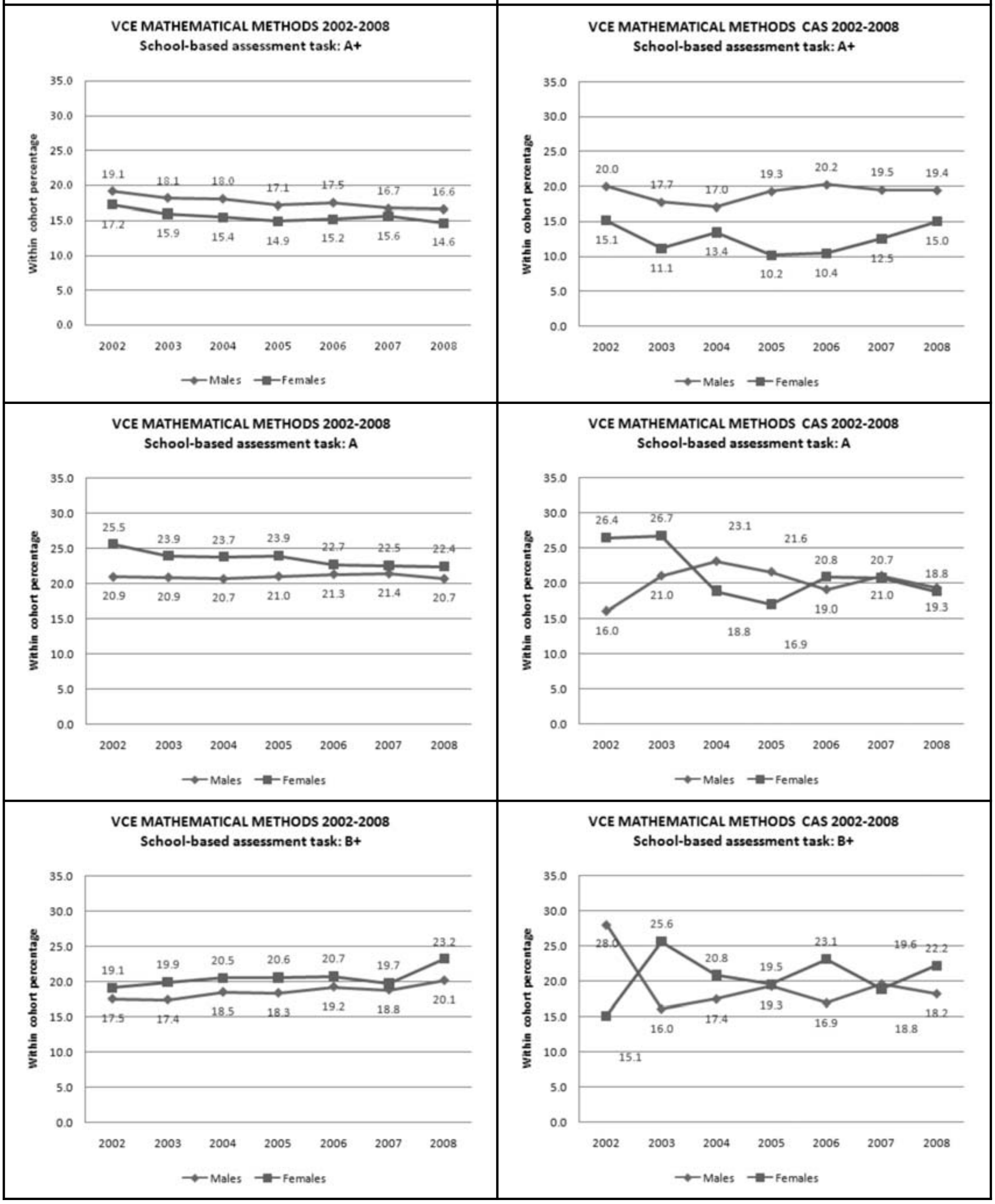

Figure 6. Male and female performance on the School Assessed Tasks: Mathematical Methods and Mathematical Methods CAS, 2002–2008.

difference in the percentage of male and female students achieving the grade) was greater for Mathematical Methods CAS than for Mathematical Methods.

- The gender gap favouring males was widest for the A+ grade in Mathematical Methods CAS for Examination 2, the assessment task for which the calculator is assumed.

Mathematical Methods: 2002-2008 Grades A+, A, & B+ Examination 1 (technology-free from 2006)	Mathematical Methods CAS: 2002-2008 Grades A+, A, & B+ Examination 1 (technology-free from 2006)

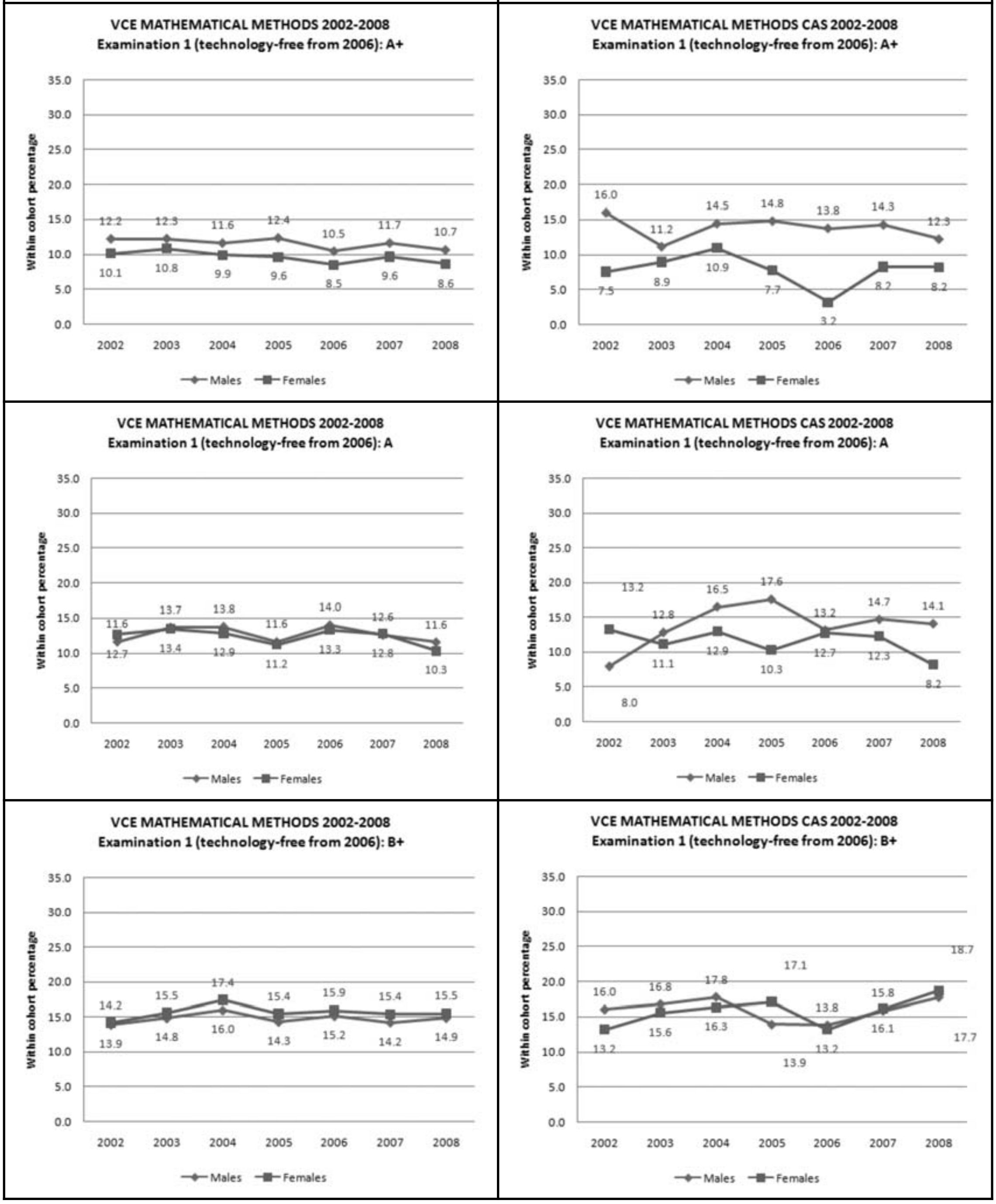

Figure 7. Male and female performance on Examination 1 (technology-free from 2006): Mathematical Methods and Mathematical Methods CAS, 2002–2008.

A few differences were also noted in the graphs for the various assessment tasks:

- Figure 6: for Mathematical Methods, a higher proportion of females than males received the grades A and B+ on the School Assessed Task, while the gender pattern for achieving these grades in Mathematical Methods CAS was inconsistent.

Mathematical Methods: 2002-2008 Grades A+, A, & B+ Examination 2 (with technology)	Mathematical Methods CAS: 2002-2008 Grades A+, A, & B+ Examination 2 (with technology)

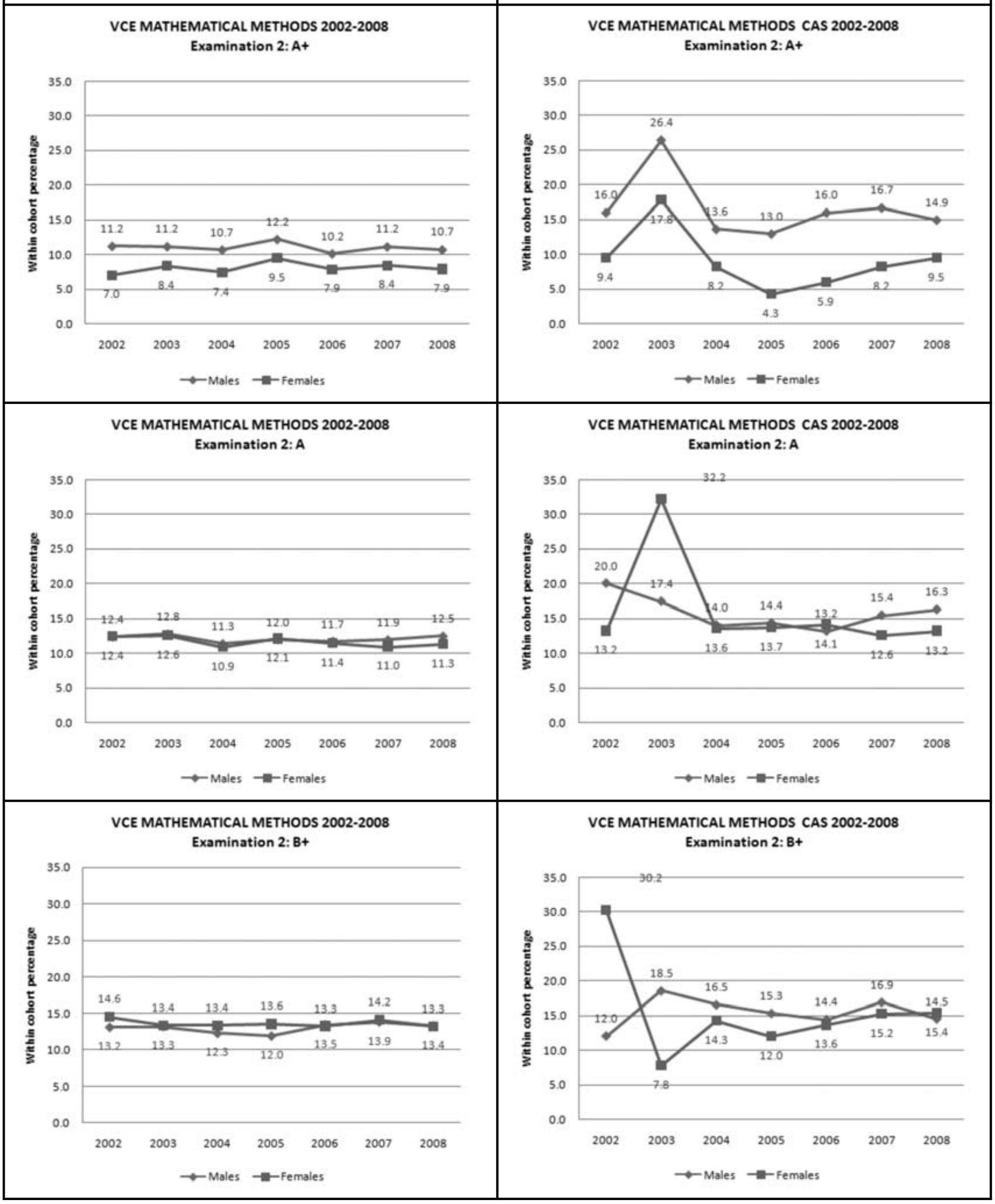

Figure 8. Male and female performance on Examination 2 (calculator assumed): Mathematical Methods and Mathematical Methods CAS, 2002–2008.

- Figures 7 & 8: similar proportions of males and females achieved grades A and B+ for Mathematical Methods. Although some fluctuation is evident, a similar gender pattern can be seen for Mathematical Methods CAS.

In summary, males are outperforming females at the highest levels of achievement, A+, on each of the three assessment tasks for both subjects. It was also very clear that for each assessment task at the A+ grade level, the gender gap in favour of males was larger for Mathematical Methods CAS than for Mathematical Methods. For Mathematical Methods, the gender differences are relatively small or non-existent for the grades A and B+ for the three tasks. If there are gender differences, a higher proportion of females than males appear to be achieving these grades. While the pattern is not quite as consistent, the trends are similar for Mathematical Methods CAS.

To examine, and clarify, the overall gender differences in achievement over the three top grades – A+, A, and B+ – the total percentages of students achieving these three grades were determined for each subject and for each of the three assessment tasks. The results are shown as stacked column graphs: Figure 9 - school-based assessment; Figure 10 - Examination 1; Figure 11 – Examination 2 (calculators mandated).

Figure 9 reveals that females are slightly outperforming males in the school-based assessment task for Mathematical Methods when the three grades A+, A and B+ are combined. However, males are clearly outperforming females in Mathematical Methods CAS.

For the two examinations, Figures 10 and 11 reveal similar patterns of gender difference over time. For Mathematical Methods the gender difference in favour of males over time is quite consistent in size. For the period 2002-2008 for Mathematical Methods CAS, however, there was more variability in the gender differences in favour of males (with one exception in favour of females in 2002 for Examination 2) and, in general, they appear larger than for Mathematical Methods. Interestingly, as enrolment numbers in Mathematical Methods CAS have increased over time, there is no apparent trend for a decrease in the size of the gender difference, as might have been expected if sample size were a contributing factor to the observed gender differences. This series of trends in the patterns and sizes of the gender differences in the various assessment tasks and in the two parallel running subjects comprise the second group of findings in this study.

Is gender a factor associated with success with CAS?

Based on the analyses of the VCE performance data reported above, it would appear that boys' and girls' performances in the two parallel courses—Mathematical Methods and Mathematical Methods CAS—are different at the very highest level of achievement (A+), with boys outperforming girls in both subjects and with the gender gap in favour of males appearing to be greater in Mathematical Methods CAS. The same pattern was generally evident when the percentages of males and females achieving the three top grades A+, A, and B+ were combined, with one exception. While females were slightly outperforming males for the school-based task in Mathematical Methods over the time period, the opposite pattern of gender difference was noted for Mathematical Methods CAS. Previous research has shown that females have outperformed males in school-based VCE mathematics tasks (e.g., Cox, Leder, & Forgasz, 2004).

It cannot be said with certainty that it is the CAS calculator which explains

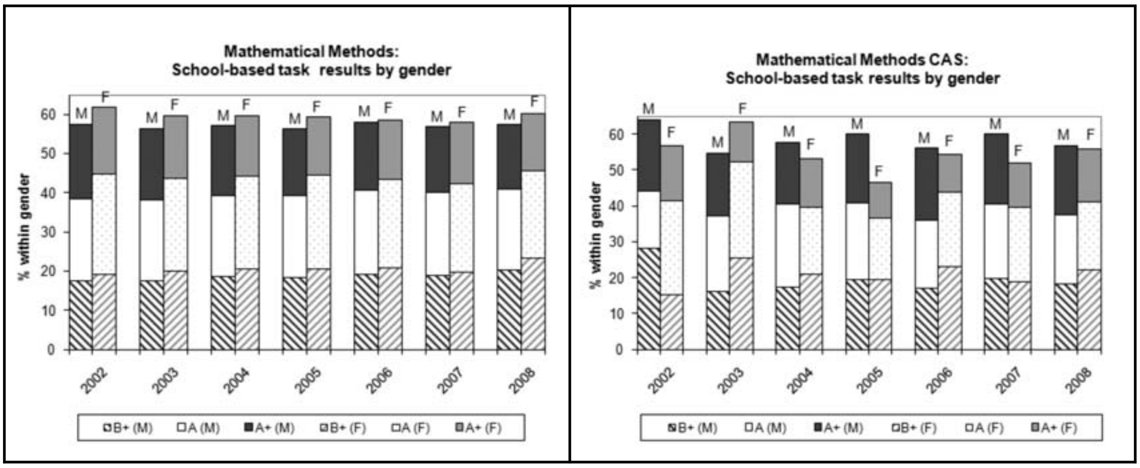

Figure 9. Percentages of males and females obtaining grades A+, A, and B+ for the school based task in Mathematical Methods and Mathematical Methods CAS, 2002–2008.

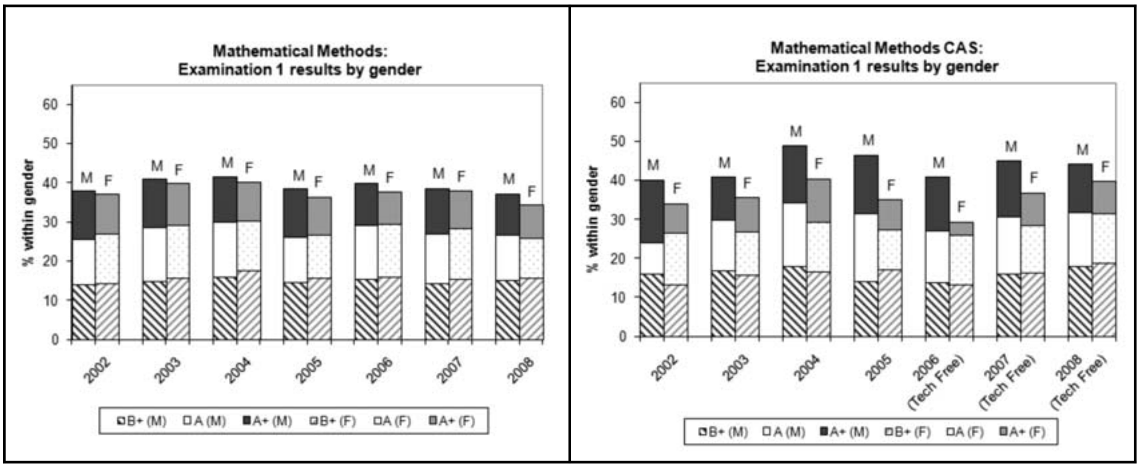

Figure 10. Percentages of males and females obtaining grades A+, A, and B+ for Examination 1 in Mathematical Methods and Mathematical Methods CAS, 2002–2008.

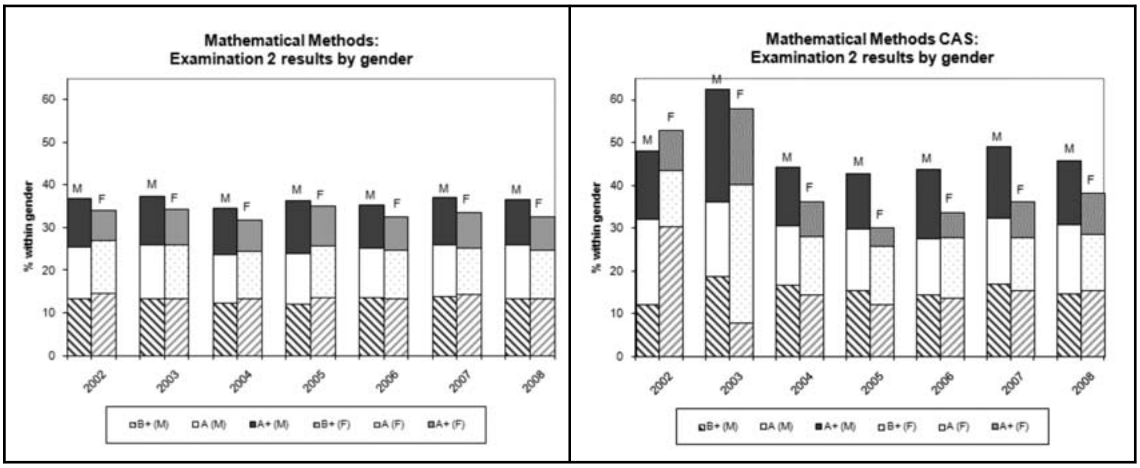

Figure 11. Percentages of males and females obtaining grades A+, A, and B+ for Examination 2 (with technology) in Mathematical Methods and Mathematical Methods CAS, 2002–2008.

the consistent patterns of gender difference in performance over the time period 2002–2008. Yet, it is not unreasonable to suggest that the CAS calculator may well be implicated. It could be argued that the greater decline in enrolments for females over males when the numbers taking the two Mathematical Methods subjects were combined provides additional support for this hypothesis. In other words, girls' flight from Mathematical Methods may be partially explained by their growing awareness that girls do not perform as well with the CAS calculator as with the graphics calculator.

Clearly more research is needed to find convincing evidence to support the hypothesis put forward here. It will, of course, be interesting to see if the trends noted from 2002–2008 persist into 2009, the final year in which the two parallel courses run. If it turns out that the CAS does contribute to females' lower levels of performance and to their flight from the subject, one is left to ponder what can be done to address the issue.

Acknowledgments

Our thanks are extended to Frank Barrington who provided us with some of the enrolment data in the various VCE subjects and to Gilah Leder who commented on an earlier draft of the article.

References

Barrington, F., & Brown, P. (2005). *Comparison of year 12 pre-tertiary mathematics subjects in Australia 2004–2005*. Melbourne: International Centre for Excellence for Education in Mathematics and Australian Mathematical Sciences Institute. Retrieved 9 May 2009 from: http://www.ice-em.org.au/images/stories/FileDownloads/2.pdf

Bishop, A. J., & Forgasz, H. J. (2007). Issues in access and equity in mathematics education. In F. Lester (Ed.), *Second handbook of research on mathematics teaching and learning* (Vol. 2, pp. 1145–1167). Reston, VA: NCTM.

Cox, P. J., Leder, G. C., & Forgasz, H. J. (2004). Victorian Certificate of Education: Mathematics, science and gender. *Australian Journal of Education, 48*(1), 27–46.

Forgasz, H. J. (2003). Girls, boys, and computers for mathematics learning. In B. Clarke, A. Bishop, R. Cameron, H. Forgasz, & W. T. Seah (Eds.). *Making mathematicians* (pp. 346–361). Melbourne, Vic.: Mathematical Association of Victoria.

Forgasz, H. J. (2004). Equity and computers for mathematics learning: Access and attitudes. In M. Johnsen Høines & A. B. Fuglestad (Eds.), *Proceedings of the 28th annual conference of the International Group for the Psychology of Mathematics Education* [PME] (Vol 2, pp. 399–406). Bergen, Norway: PME.

Forgasz, H., & Griffith, S. (2006). CAS calculators: Gender issues and teachers' expectations. *Australian Senior Mathematics Journal, 20*(2), 18–29.

Forster, P., & Mueller, U. (2002). What effect does the introduction of graphics calculators have on the performance of boys and girls in assessment in tertiary entrance calculus? *International Journal of Mathematical Education in Science and Technology, 33*(6), 801–818.

Leder, G. C. (1992). Mathematics and gender: Changing perspectives. In D. A. Grouws (Ed.), *Handbook of research on mathematics teaching and learning* (pp. 597–622). New York: Macmillan.

Pierce, R., Stacey, K., & Barkatsas, A. (2007). A scale for monitoring students' attitudes to learning mathematics with technology. *Computers and Education, 48*(2), 285–300.

Vale, C., & Bartholomew, H. (2008). Gender and mathematics: Theoretical frameworks and findings. In H. Forgasz et al. (Eds.), *Research in mathematics education in Australasia 2004–2007* (pp. 271–290). Netherlands: Sense.

Vale, C. M., & Leder, G. C. (2004). Student views of computer-based mathematics in the middle years: Does gender make a difference? *Educational Studies in Mathematics, 56*(3), 287–312.

Victorian Curriculum and Assessment Authority [VCAA]. (2005). *Mathematics. Victorian Certificate of Education study design.* Melbourne: Author. Retrieved 9 May 2009 from: http://www.vcaa.vic.edu.au/vce/studies/mathematics/mathsstd.pdf