GENDER AND MATHEMATICS: THEORETICAL FRAMEWORKS AND FINDINGS

The meaning of gender equity, the degree and nature of gender equity in mathematical outcomes and pedagogical practices, and the theoretical position of researchers of gender and mathematics are the concerns of the review of literature presented in this chapter. Findings generally reveal few significant gender differences in mean scores for achievement in Australia and New Zealand for the period under review, but gender differences favouring males in a range of affective factors, and in senior secondary participation, persist. Feminist and post-modern theories influenced some research into pedagogical practices, however most of the Australasian research conducted in the current period drew upon difference or deficit theory.

Key words: achievement, affect, deficit theory, equity, feminism, post-modern theory

INTRODUCTION

In this chapter we continue the series of reviews of Australasian research into gender and mathematics education (Barnes, 1988; Barnes & Horne, 1996; Forgasz, Leder, & Vale, 2000; Leder; 1984; Leder & Forgasz, 1992; Vale, Forgasz, & Horne, 2004). These reviews have provided a continuous chart of progress towards, and achievements and concerns with respect to, gender equity in mathematics teaching and learning. Changes since the early 1980s in gender differences in various mathematical learning outcomes including participation, achievement, and affect, and in pedagogies with respect to gender equity were mapped in these reviews. Theoretical frameworks informing and emerging from the research were also documented.

Following the period leading up to the turn of the century in which there was a trend toward narrowing and disappearing gender differences in achievement and affect (Forgasz et al., 2000), the authors of the most recent review argued that evidence of continuing and re-emerging gender differences warranted on-going attention and research into gender and mathematics education (Vale et al., 2004). They noted the anti-feminist political and social agenda at the turn of the century and called on researchers in the field to be clearer with respect to the theoretical frameworks and meanings of equity that they used.

In conducting the current review of the literature we were interested in exploring the impact of the social and political context on the purpose and objectives of research studies and the theories informing the research. We have used the
meanings of equity discussed in the literature published during the period of the review to structure this chapter. In the first section we discuss the meaning of equity in relation to gender and the various feminist theories that have influenced the studies reviewed. In the second section papers concerned with equalities and inequalities in mathematical outcomes are reviewed. In this section research concerning affective and motivational factors and achievement, as well as research on the outcomes for indigenous students are reviewed. What the studies in this section have in common is that they primarily relate to processes taking place within individual students. In the final section we shift focus to studies that are more concerned with contextual factors that serve to advantage or disadvantage particular groups and hence investigate factors concerning equitable access to learning. This section includes classroom studies, studies of single-sex learning environments, and particular learning environments and processes. Although individual learners are still present in many of the studies reviewed in this section, it is the ways in which they interact with their environment that is given most weight. Some of the issues of interest or concern identified in the previous review by Vale et al. (2004) were evident in the recently published literature.

THEORETICAL FRAMEWORKS

Equality or equity

In a review of the literature Bishop and Forgasz (2007) discussed the meanings of equity in education and in so doing mapped the theoretical development of these ideas through research concerned with particular social groups, including gender. They reported that, in one sense, equity is defined as an outcome of education with access to learning a condition for achieving equity. This meaning of equity was associated with equality and the three aspects that Fennema (1995) originally identified with respect to gender: equal outcomes, equal opportunities and equal treatment. Bishop and Forgasz (2007) also presented a second meaning, where equity is considered a criterion for evaluating many aspects of education including outcomes, along with access, disposition, and the quality of teaching. In this sense equity is a quality involving fairness and justice and Bishop and Forgasz (2007) cited a number of studies to show that in this sense equity is not the same as equality. Anthony and Walshaw (2007) argued that equity was “relational” and situated:

Equity is about interactions between contexts and people; it is not about equal outcomes and approaches. Neither is it about equal access to people and curriculum materials. Setting up equitable arrangements for learners requires different pedagogical strategies and paying attention to the different needs that result from different home environments, different mathematical identifications, and different perspectives. (p. 10)

Given the contested meaning of equity we need to acknowledge and discuss the theoretical perspectives that inform these definitions from a gender perspective and for the studies reviewed in this chapter.
Deficit theory, difference theory, identity theory and agency

The theories and paradigms of researchers of gender equity as described by Kaiser and Rogers (1995) and more recently by Jungwirth (2003) were used to critique studies in previous chapters in which Australasian research on gender and mathematics was reviewed (e.g., Forgasz et al., 2000; Vale et al., 2004). According to deficit theory, differences in educational outcomes occur because of inherent deficiencies or weaknesses in girls' experiences, knowledge, and skills. Liberal feminist researchers argued, however, that these deficiencies were due to socialisation and that by attending to these deficiencies through particular educational programs equality of outcomes could be achieved. Radical feminist researchers, on the other hand, embraced differences between the genders and argued that patriarchal structure denied women the opportunity to use these differences as strengths for learning and achieving in mathematics. Radical feminists argued for changes to curriculum and teaching approaches. Post-modern researchers were critical of difference theory because it essentialised learners. They argued that groups of learners were not homogenous, rather individuals have multiple and shifting identities and these are shaped by the context in which they are situated. Analyzing the relationships and the power within these relationships in mathematics classroom explained differences in learning behaviours and outcomes and the identities formed by learners in these classrooms. According to this theory, paying attention to the relationships within the classroom, the different identities, and hence the different needs of students in the mathematics classroom, are central to equity. In their review of research of mathematics education, Anthony and Walshaw (2007) drew attention to pedagogies that meet these requirements and are effective for student learning. More recently critical theorists have questioned the notion of shifting identity and its implications for choice. The gendered social norms that underpin the choices that girls make, they have argued, deny girls agency, that is, the power to make a difference in their lives (Hirschmann, 2003).

Perhaps the most striking feature of the studies reviewed in this chapter is that the meaning of equity and the framework informing the study are rarely made explicit. We have tried to identify the assumptions made by researchers and the purpose of their research study. As Leder (2004) observed, liberal feminism, with an emphasis on helping females to assimilate, is perhaps still the dominant perspective in research on gender and mathematics education. However, as will be seen, particularly in the later sections of this review, a growing body of research is emerging which draws, often implicitly, on other paradigms. So, for example, while a number of researchers remained concerned with persuading girls of the value of studying mathematics to a high level (e.g., Watt, 2004), others were beginning to question the basic assumptions underlying such work, and instead investigated the valid decisions that girls made in relation to mathematics (e.g., Shannon, 2004). Such a move away from a deficit view of gender differences in mathematics is also evident in the increasing prevalence of studies in which the interplay of a range of factors in shaping the experiences of girls and boys in mathematics classrooms were explored. The influence of post-modern perspectives was evident in the reluctance of some researchers to treat gender as a
straightforward and stable category for the purposes of analysis (e.g., Barnes, 2005).

*Feminist theory applied more generally*

A theoretical development worth noting in the context of this review is that feminist theory, in various guises, appears as a theoretical tool in work in which issues other than gender differences were explored. For example, drawing on feminist post-structuralist theory, Klein (2006) explored pre-service primary teachers’ constructions of what constitutes an engaging pedagogy in mathematics. Atweh (2004) also drew on the ideas of feminist theorists when writing about international collaborations in mathematics education.

This “mainstreaming” of feminist theory is to be welcomed. Like the shift away from an emphasis on the deficiencies of girls and women in relation to mathematics, it provides evidence that the ghettoisation of the female experience is fading. “Gender issues” and “feminist theories” are increasingly regarded as being of relevance to many concerned with mathematics education.

**STUDIES OF MATHEMATICAL OUTCOMES FOR LEARNERS**

In this section studies in which gender equity in mathematics education was evaluated in terms of mathematical outcomes are reviewed. Studies reviewed in the previous four-year period, at the turn of the century, did not reveal consistent findings with respect to gender differences in achievement or attitudes; the findings varied according to mathematical knowledge and skills, the method of assessment and the affective variables that were being measured (Vale et al., 2004). Vale, Forgasz, and Hörne (2004) also reported that gender differences in achievement and affect also varied according to the socio-economic status of students. In the period of the current review, gender comparisons in achievement, participation and affect were included in a broad range of studies at all levels of schooling.

*Achievement*

The Third International Mathematics and Science Study (TIMSS) of 2002-3 and the Program of International Student Assessment (PISA) of 2003 revealed gender equality in mean scores in mathematics and mathematics literacy of Australian and New Zealand primary and secondary males and females. That is, there were no significant gender differences in the mean scores of nine year-old or 13 year-old students in mathematics (Ministry of Education, NZ, 2004a, 2004b; Thomson & Fleming, 2004), or among 15 year-old students in mathematical literacy (Thomson, Cresswell, & De Bortolli, 2004). However, three years later, the PISA 2006 results revealed significant gender differences favouring 15 year-old boys in mathematical literacy in Australia and New Zealand (OECD, 2007). In Australia the gender difference was greater than the OECD average, and gender differences favouring males were also apparent in the results for each state/territory. However, the overall gender difference (14 points) was much smaller than the significant
difference in scores between students from low and high socio-economic status groups (78 points) (Thomson & De Bortoli, 2008). The instability in findings with respect to gender differences in large-scale international studies of mathematics is, perhaps, not surprising since there are contradictory findings among researchers studying achievement for other age groups. Horne (2004) found that significant gender differences favouring males in average performance of students emerged during the first three years of primary schooling for number, although there were no differences in the other content domains of space and measurement. For senior secondary mathematics in Victoria, Cox, Leder and Forgasz (2004) reported that females received higher mean scores than males on the vast majority of comparisons made, although no inferential statistics accompanied these findings.

While the comparison of mean scores in these studies provides a snapshot of gender differences relevant for assessing the performance of education systems, they are not sufficient for confirming gender equity or inequity in mathematics education. It is also important to compare the distribution of results for males and females and the distribution of results for students of particular social groups since demonstrating particular mathematical proficiencies or performing at particular levels of achievement is what provides students with access to the power that achievement in mathematics affords.

The analysis of the distribution of scores reported in the studies cited above reveal evidence of generally persistent gender differences in achievement favouring males and that these discrepancies are of concern for particular social or cultural groups. Males were consistently more highly represented among the highest achievers in mathematics for studies involving primary, junior secondary and senior secondary students (Cox et al., 2004; Thomson et al., 2004; Thomson & Fleming, 2004). Almost twice as many 15 year-old Australian male as female students performed at the highest level in mathematical literacy (PISA) in 2003 and 2006 (Thomson et al., 2004; Thomson & De Bortoli, 2008). These findings were also apparent in some Australian states with large gender differences among the highest achievers favouring males in New South Wales (NSW), Victoria, and Tasmania. The only exception was in the Australian Capital Territory (ACT) where females were more highly represented among the top achievers. Males were also more highly represented among the top achievers in studies of gifted and talented mathematics students (Leder, 2006).

Mathematics content and cognitive domains
Comparisons of performance in particular mathematical domains and cognitive domains have also been reported. Items used in TIMSS 2002-3 were of three cognitive types: knowing facts, procedures and concepts; applying knowledge and understanding; and reasoning. There were no gender differences on these types of items for grade 5 students in New Zealand, though grade 9 girls recorded significantly higher scores on reasoning items than boys (Ministry of Education, 2006). Meaney (2005) included a gender comparison in the ways in which final year secondary students in New Zealand presented justifications for algebra items but results were not conclusive for this small pilot study.
Horne (2004) found that in the first four years of schooling in Victoria boys developed more efficient strategies for counting, addition and subtraction, and multiplication and division and had a stronger grasp of place value than girls, suggesting greater fluency with operations and number sense among boys than girls. The findings of Young-Loveridge and Taylor (2005) with respect to strategies in multi-digit computation among 9-11 year old primary students in New Zealand contradicted these findings to some extent. In their study girls were more likely to give an alternate strategy, suggesting more flexible thinking or fluency in number operations. Thomson and Fleming (2004) reported that, on average, 13-year old Australian boys performed better than girls on number and measurement items in the TIMSS 2002-3.

Nine year-old primary girls in Australia and New Zealand recorded higher mean scores than 9 year-old boys for the geometry items on TIMSS 2002-3 (Ministry of Education, 2004a; Thomson & Fleming, 2004) but 15 year-old Australian boys performed better than girls on space and shape items in the PISA 2003 study (Thomson et al., 2004). Lowrie and Diezmann (2005) found that boys in grade 4 performed better than girls on six types of graphical “languages”, suggesting that boys had higher-order visual-spatial reasoning capacity than girls. On the surface these different findings appear contradictory since the same content domain was the concern in each of these studies. Teaching and learning practices at different year levels may explain these findings; so too may the differences in the cognitive demands of the mathematical tasks used in the studies.

Forgasz, Griffith, and Tan (2006) compared the achievement of males and females in the Victorian Certificate of Education (senior secondary mathematics). They were particularly interested in the effect of digital technology and analysed the results of students taking equivalent advanced mathematics subjects, one in which graphics calculators were required and the other in which students used CAS (computer algebra system) calculators. They found that higher proportions of male than female students were awarded the highest grades (A+, A and B+) in the CAS environment than in the graphics calculator environment.

Of interest in this review is the theoretical position and recommendations made by the researchers arising from findings such as those reported above. In the past, deficit theory was used to explain these findings; and this explanation of gender difference was still evident in some studies in which mathematical achievement for particular content and skills was compared. For example, Lowrie and Diezmann (2005) focussed on the deficit of girls’ knowledge, suggesting that teachers need to develop girls’ skills in using and interpreting graphic images involving shape, size and orientation (even though average gender differences were only significant for number line tasks in their study). Horne (2004) on the other hand asked how the teacher and teaching practices, in other words, the socialisation practices within the classroom may be contributing to the likelihood of girls being “rule compliant” and boys being “risk takers”. Young-Loveridge and Taylor (2005) who also investigated children’s views of mathematics found that “more boys than girls reported that effort put into a problem was more important than getting a correct solution” (p. 83). It is not clear whether this finding is consistent with gendered ‘rule compliance’ in mathematics classrooms but the apparent contradictory
findings from these studies, occurring in different countries and education systems, show that teaching practices are relevant. Forgasz, Griffith, and Tan (2006) argued that teachers were not aware of possible gendered effects of using technology in senior secondary mathematics but it is not at all clear whether they were arguing against the use of technology, for teachers to intervene to improve girls’ performance in CAS environments, or for teachers to change their teaching practices in some way.

Davis, Clarke, and van den Heuvel-Panhuizen (2005) tested difference theory as an explanation for gender differences in mathematics achievement among primary students. Based on the TIMSS 2002-3 results of children in the Netherlands that showed significant gender differences favouring males, test items were defined as “boys items” or “girls items”. For the sample of grade 6 Australian children these items followed the predicted pattern of gender difference in correct responses but the difference was only significant for one “boys item”. This finding shows that it is important not to essentialise girls and boys with respect to mathematics skills. The authors argued that the nature of the curriculum and teaching practices may explain the different results for Australian children. However in reflecting on this finding the authors argued that the performance of girls could be improved if they had the opportunity to rehearse “boys items”, but they offered no suggestions regarding improving boys’ performance on “girls items”, perhaps because they thought that boys were performing well on the important mathematics items, that is, those requiring flexibility in number sense and operations.

Indigenous students
In Australia, indigenous secondary students scored significantly lower than non-indigenous students in the TIMSS 2002-3 mathematics and PISA 2003 mathematical literacy, with distributions skewed toward lower levels of achievement (Thomson et al., 2004; Thomson & De Bortoli, 2008; Thomson, McKelvie, & Murnane, 2006). Anthony and Walshaw (2007) noted similar differences between Maori and non-Maori students in New Zealand. In Australia 15 year-old female indigenous students performed particularly poorly on mathematical literacy in the 2003 PISA study (Thomson et al., 2006). Achievement above the highest international benchmark was rare for indigenous female students and higher proportions of indigenous female students (45%) than indigenous male students (29%) failed to reach the lowest international benchmark. The difference between indigenous and non-indigenous students is most striking for females since only 10% of non-indigenous females did not reach the lowest benchmark. There was no significant difference in the results for PISA 2003 and 2006 with respect to average differences in mean scores for indigenous and non-indigenous students. The differences remained vast (80 score points) and significant (Thomson & Bortoli, 2008). In 2006, the proportion of indigenous males and females performing at the lowest level (38% and 40% respectively) was closer than in the earlier survey. Perhaps the nature of the sampling was responsible for this apparent improvement for indigenous females and deterioration for indigenous males. Clearly though, participation and access to mathematical learning, or rather limited or restricted access is the only reasonable explanation for these overall findings.
Anthony and Walshaw (2007) argued for the consideration of socio-political realities that shape students’ identities, and mathematical teaching practices that acknowledge diversity, respect cultural identity and provide an ethic of care, explicit instruction and respectful exchange of mathematical ideas.

**Summary**
These results indicate that deficit and difference theories are not helpful in explaining gender differences observed in mathematics achievement. The contradictory findings with respect to mathematical domains and skills suggest that teachers need to be more aware of the way in which their teaching approach and the demands of the documented curriculum might influence the achievement of the girls and boys in their classrooms. The deterioration in gender equity apparent in the re-emergence of gender differences in mean scores in mathematical literacy (PISA 2006) in both New Zealand and Australia, warrant closer attention and consideration by governments and mathematics curriculum writers.

**Participation in mathematics**
Forgasz (2006) reported on a study of enrolment in year 12 mathematics subjects of Australian students from 2000-2004. She focussed her analysis on the mathematics subjects in the different state jurisdictions in Australia that are the minimum pre-requisites for continued mathematics study in tertiary education. National and international concerns regarding declining enrolments in tertiary mathematics were the impetus for this study. Of equal interest was the gendered pattern of enrolments favouring males reported in earlier studies, and the desire to discern whether these patterns were still evident and whether or not they had improved or deteriorated. The findings for Australia overall showed that for the five-year period enrolments in these particular mathematics subjects had declined. There were more males than females enrolled in these subjects in each state, except the ACT. Declining enrolments by girls during this period contributed to the overall fall in enrolments in each of the states that recorded a decline in enrolments in this subject. These findings contradict the trend of closing the gender gap in participation observed during the 1990s (Forgasz et al., 2000). Forgasz (2006) claimed that the data “indicate that females are continuing to limit their career options” (p. 220) suggesting the need to amend the girls’ choices; a more critical approach would be to investigate the curriculum and gendered social norms that are influencing girls.

**Affect**
The authors of the previous MERGA review noted that while research associated with participation and self-concept continued to report differences favouring males, findings from studies considering the gender-stereotyping of mathematics were more equivocal, with new instruments throwing up some surprising results. A further finding to emerge from the literature was that the increasing use of computers in mathematics classrooms was resulting in “a retrograde shift in
attitudes towards mathematics being viewed, once again, as a male domain” (Vale et al., 2004, p. 86). In the current review period research findings followed similar patterns.

Building on earlier work, Forgasz, Leder, and Kloosterman (2004) continued to investigate ‘mathematics as a male domain’. They suggested that some items from the original Fennema-Sherman Mathematics Attitude Scales, developed 30 years earlier, might be anachronistic and no longer reliably interpretable. Two new scales were developed and administered in Australia and the US, Mathematics as a Gendered Domain and Who and Mathematics. It was found that in both countries, most students regarded mathematics as a neutral domain. The items relating to enjoyment in mathematics showed the surprising result that among the Australian students, females were thought more likely than males to enjoy mathematics. This reverses trends that have been found previously, with boys thought more likely to enjoy mathematics.

However, as will be seen below, the affective responses of individuals tell a less up-beat story, and this eradication, or even reversal, of previous stereotypes relating to mathematics does not extend to the ways in which males and females respond to their own mathematics learning. It is also the case that students’ achievements in mathematics have a bearing on their affective responses; unsurprisingly Banfield (2005) found that mathematically gifted adolescent boys recorded higher levels of self-concept, self-esteem, and mathematical self-efficacy than boys of average mathematical ability. The two large international studies during the current review period, TIMSS 2002-3 and PISA 2003, included items exploring affective issues that were analysed by gender. In the TIMSS study of 2002-3 Australian males scored significantly higher levels of self-confidence in mathematics learning than girls for both 9-year old and 13-year old students (Thomson & Fleming, 2004). Thomson and Fleming (2004) also found that self-confidence was more strongly correlated with achievement than was value of mathematics. Findings from the PISA study were similar. Fifteen-year old Australian males reported higher levels of enjoyment, interest, self-efficacy and self-concept, and held stronger beliefs on the value of mathematics than did females (Thomson et al., 2004). Females were more anxious than males but reported more favourable relations with teachers and a stronger sense of belonging. Using Hierarchical Linear Modelling, Thomson, Cresswell, and De Bortolli (2004) found that self-efficacy and self-concept had the strongest relationship with mathematical literacy among the affective variables measured in the PISA study.

Based on the findings of the PISA 2003 study, Thomson, Cresswell, and De Bortolli (2004) argued that the participation of females in tertiary mathematics and related disciplines could be increased if teachers attended to girls’ attitudes:

PISA suggests a reason for [lower participation of females], finding that there are much larger gender differences at age 15 in approaches to learning mathematics than performance itself. Females appear to be less engaged, more anxious, and less confident in mathematics than males. This finding suggests that approaches to reducing these gender differences need to start at
an early age in order to increase females' engagement in mathematics and build their confidence in their mathematical abilities. (p. xvi)

**Attitudes to digital technology in mathematics**

Using different survey instruments and methods three different studies of junior secondary students in Victoria reported gender-related attitudes to the use of digital technology in mathematics favouring males. In a mixed methods study of students in two secondary mathematics classes (grades 8 and 9) in which computers were regularly used in mathematics lessons, Vale and Leder (2004) collected data through questionnaires, interviews and observations. They observed that, in general, girls and boys were positive about the use of computers but girls viewed the use of computers in mathematics less favourably than boys. While boys thought that computers provided pleasure and relevance in mathematics, girls were more concerned about whether computers aided their learning or enabled success in mathematics. Analysis of responses to the Attitudes to Computer-Based Mathematics Scale (ACBM), composed of eleven items, confirmed these findings. Boys’ attitudes were more strongly correlated with the desire to perform well at computing than were girls’ attitudes.

Pierce, Stacey, and Barkatsas (2007) and Barkatsas (2005) developed the Mathematics and Technology Attitudes Scale (MTAS). In contrast to the ACBM scale that referred only to computers, the items measuring attitudes to use of technology for learning mathematics (MT) in the MTAS scale can be adapted to refer to computers, graphics calculators or other digital technologies. The MTAS instrument was used to gather responses from 350 Victorian students in grades 8-10. The decision to use the graphics calculator version of the MT sub-scale was not explained by the researchers, although they did comment that the low scores on this subscale at one school might be explained by the lack of experience with using technology, and that the very high scores at another school might have been due to students’ recent experience with graphics calculators. Significant differences favouring males were recorded for mathematics confidence, affective engagement, confidence in using technology, and attitude to the use of technology for learning mathematics, but not for behavioural engagement. They also found that attitude to learning with technology was positively correlated to confidence with technology for boys, and negatively correlated with mathematics confidence for girls.

Forgasz (2004) also reported significant gender differences in attitude to the use of computers in mathematics favouring males. Her study involved 1613 Victorian students from grades 7-10 and used a five-item scale (Attitudes to computers for learning mathematics: ACM). She also compared attitudes and ownership of computers according to other equity factors: socio-economic status, language, Aboriginality and location. Personal ownership was more likely for boys, high socio-economic status, non-English speaking background and metropolitan students. In common with the other two studies, Forgasz (2004) also found a strong and significant correlation between attitudes to computers for learning mathematics and attitudes to computers, but not with attitudes to mathematics. Multivariate analysis was not used in this study but may have illuminated the relative strength
of the various factors included in the study. Within gender differences were commented on in each of these studies.

Theories linking affect and participation

In a series of papers exploring the interplay between a range of affective factors and students’ participation in mathematics courses among students in NSW, Watt (2004, 2005a, 2005b, 2006; Watt, Eccles, & Durik, 2006) found persistent gender differences. Watt (2006) looked at the intended and actual participation of girls and boys in New South Wales in senior high school mathematics programmes, and the mathematics-relatedness of the students’ intended careers. The results showed a “remarkably robust” and statistically significant tendency for boys to plan and take higher-level mathematics subjects than girls, and for boys to be more likely to plan mathematical careers than girls. These gender differences in the actions of girls and boys were mirrored by gender differences in their self-perceptions of mathematics talent and their expectations of success that also favoured boys. However, gender differences in mathematics subjects taken, and planned careers were not accounted for by differences in achievement (Watt, 2005b). Furthermore despite similar success in mathematics, boys rated their talent more highly than did girls. Although prior success in mathematics was found to influence subject choice, students who rated the intrinsic value of mathematics, and their self-perception higher, took higher-level mathematics subjects, even when prior success was controlled for. Furthermore, while boys who saw mathematics as moderately useful were likely to aspire to mathematics related careers, only girls who saw mathematics as highly useful were likely to do so. Watt (2006) argued that:

Boys maintained higher intrinsic value for maths and higher maths related self-perceptions than girls throughout adolescence. Since the present study has identified the importance of these factors in maths participation choices, both for senior high and planned careers, girls’ lower levels are particularly problematic. We need to understand how it is that boys come to be more interested and like maths more than girls; and also why girls perceive themselves as having less talent, even when they perform similarly. (p. 319)

She concluded that educators might focus on explicating the high utility value of mathematics to girls.

In a survey of year 11 students in Victoria conducted in 2001 and 2003, Forgasz (2005) investigated whether the role of digital technology, and computers in particular, was influencing students’ decision to enrol in senior mathematics subjects that provided a pathway to tertiary mathematics in ways that may explain the gendered pattern of enrolments in senior secondary mathematics. Her findings were not conclusive. For one year only, a significantly higher proportion of males stated that the use of computers in mathematics had contributed to their decision to continue studying mathematics. Forgasz (2005) urged further investigation of the relationship between digital technology and mathematics participation.
Summary
These studies indicate that the beliefs, participation and feelings of individuals continue to show differences along gendered lines. Males are more likely to exhibit self-confidence, to regard mathematics as relevant and of intrinsic value and to be motivated by the use of technology in mathematics. These factors appear to be responsible for continuing lower participation rates in advanced mathematics among females, which cannot be explained by differences in achievement.

Significantly, however, these differences are not mirrored in students' more general perceptions of who can do mathematics; when they are not responding about themselves, they see few differences between the sexes, and even respond that girls may be more likely than boys to enjoy mathematics. This apparent inconsistency suggests that although females no longer believe that pursuing mathematics would be inappropriate for them by virtue of their gender, there remain factors that tend to leave them, as a group, less enthusiastic than males about mathematics and about using technology in mathematics. While the studies reviewed have focused on explanations located within individual girls, a radical or critical feminist interpretation of these findings would advocate change in approaches to teaching and curriculum.

STUDIES OF CONTEXT FOR MATHEMATICAL LEARNING

As noted above, equity can only be achieved when learners have access to mathematical learning. Researchers in the past have found that access to learning is concerned with more than enrolment and participation in mathematics learning, but that the curriculum, teaching practices and social norms of the classroom may exclude some students from learning and result in differential experiences and effects on boys and girls (Forgasz et al., 2000). In the previous four-year review Vale, Forgasz, and Horne (2004) reported that technology based classroom settings and general mathematics classrooms advantaged boys' learning, especially those identifying with hegemonic masculinities. Which boys and which girls benefited in mathematics classrooms depended on the mathematical discourse, the teaching methods, the use of technology, and the attitudes of teachers. During the period of the current review, Australasian researchers continued to explore the effects of different classroom structures and teaching approaches on girls' and boys' engagement in mathematical learning.

Single-sex classrooms

Single-sex classrooms were an intervention strategy originally implemented by liberal feminists to target the needs of girls in mathematics. However, at the turn of the century teachers and parents were advocating that these settings enabled teachers to tailor their teaching approaches to suit the needs of boys in single-sex and co-educational settings (Forgasz et al., 2000), and 'boy friendly' methods of teaching gained attention in the education community (Vale et al., 2004). Not surprisingly then, in the current period of review Australasian researchers
investigated the case of single-sex classrooms as settings that may improve the performance of boys.

Interviews with the principal, teachers, and students from a primary school in which single-sex classes were introduced for grade 7 students to address the educational and social needs of boys, revealed that the gendered pedagogies that the teachers implemented reinforced rather than challenged hegemonic masculinities (Martino, Mills, & Lingard, 2005). Improvements in boys’ emotional literacy were noted by the researchers but they also reported that the “hands on”, competitive, activity based learning used by teachers in the boys’ classrooms reinforced teachers’ essentialised views about how boys learn, and denied boys in this program access to higher order learning. Mulolland, Hansen, and Kaminski (2004) reported the effects on mathematics and English achievement in their study of single-sex classes at grade 9 that were implemented in a co-educational secondary school to improve the under-achievement of males. In the short time frame for which data were collected, the English performance of boys and girls in the single-sex classes improved compared to the co-educational classrooms, but there was no improvement for girls or boys in advanced mathematics in the single-sex classes. Interviews with the teachers revealed that they had implemented gender-stereotyped teaching and learning strategies, that is, “girl-friendly” or “boy-friendy” approaches, as appropriate, in English and mathematics in the single-sex settings. These approaches appeared to have had some impact in English, but not in mathematics. The authors argued however that the program at this school allowed the students to elect to join the single-sex classes and that this may be an important source of empowerment for them. No data on affective factors were collected to support this view however.

Classroom processes

While many studies include an element of classroom-based research, a relatively smaller number can be said to be classroom studies in the sense that their focus is on classroom processes. Notable among those studies that do focus specifically on the classroom is Mary Barnes’ exploration of collaboration in high school mathematics (Barnes, 2004). Using positioning theory, this work explored the range of positions taken up by students during mathematics lessons in which students were working in groups. By looking at commonalities in the ways students took up various positions, a number of common patterns of participation were identified. The study did not set out to explore gender differences in particular, and Barnes (2004) argued that this approach avoided the tendency to dichotomise that is evident in much work on gender and mathematics, and which can “create differences as artifacts of the research process” (p. 8). By introducing gender as a variable only in the final stage of the analysis, it was possible to explore the complexities of classroom interactions. Considerable variation was found in the positions taken up by both boys and girls in the class. Some patterns of participation, for example, “Attention-Avoiders” and “Responsive Intellectuals”, were found among both male and female students. Furthermore, she found that even those girls who took up stereotypically feminine positions were not powerless.
(as they are often constructed as being). Rather, all students acted to promote their own ends in lessons.

In a study of two intermediate school classrooms, Darragh (2005) also looked at student interactions and peer learning, this time in the context of the New Zealand numeracy project. Her focus, however, was not those occasions when collaborative work was planned and organized, but the informal interactions between students who have been told 'you can work with a partner if you like'. Like Barnes (2004), she did not set out to explore gender differences, but gender did emerge as an interesting variable during the course of the analysis, particularly in connection with the attitudes to their work of students in the most advanced mathematics groups. She found that while many of these students were critical of the work that they were given, boys were much more likely to actively reject the activities they had been set. In accounting for this difference, Darragh (2005) drew on Walkerdine's (1989) work into the ways different behaviours are validated and reinforced in girls and in boys. Darragh's (2005) work also offers insights into the ways in which fellow students join in 'policing' the ways in which their peers engage with mathematics.

A significant feature of recent studies of the learning environment was a trend towards considering the benefits for all students of “girl friendly pedagogies”. Thus Barnes (2004) argued that collaborative learning, traditionally seem as benefiting girls, can be of benefit to students of both sexes. Similarly, in a PhD thesis focusing on ‘second chance’ mathematics courses, Miller-Reilly (2006) used the literature on connected knowing and teaching (Gilligan, 1982; Belenky et al., 1986; Rossi Becker, 1995) to theorise the success of one-to-one teaching sessions with a mature male student who had a debilitating fear of mathematics. In both studies, approaches growing out of female responses to mathematics have been found to have a broader relevance.

A different finding with respect to the general usefulness of “girl friendly” pedagogies emerged from the discussion of the ‘classroom culture’ in mathematics lessons in two schools (Bartholomew, 2004). Bartholomew (2004) critiqued the ostensibly ‘girl friendly’ environment of mathematics lessons at a single sex girls school. She found that while teachers at the school experienced considerable success at creating a ‘safe’ environment ensuring fairness and minimizing differences between students, it came at the expense of giving students opportunities to take responsibility for their own learning.

Such perspectives illustrate the shift away from a focus on interventions that may enable girls to ‘catch up’ with boys, towards a greater recognition that the experiences of girls may illustrate more general issues and point the way towards improving the mathematical experiences of students more generally. This, too, marks a departure from the dichotomising of girls and boys, and can be regarded as part of a move away from a liberal feminist perspective towards radical or post-modern understandings of gender issues in mathematics.
Pedagogies that support the learning of socially disadvantaged groups were the focus of a case study on the use of digital technologies in mathematics reported by Vale (2006). As was the situation in other studies reviewed, gender was not the main focus of this study, rather the nature of the setting, an all girls school, provided insights into the ways that mathematics can be connected to the personal and social interests of students and their mathematical learning needs. In this case, the students used digital tools in their mathematical investigation of phenomena for integrated curriculum and the teacher scaffolded students' understanding, drawing attention to key mathematical ideas by using the dynamic feedback afforded by digital technologies in a whole class investigation setting.

Norton (2005, 2006) found that the scaffolding of mathematical learning through guided discussion and modelling was also important for girls' engagement with, and attitudes to, mathematics. Norton (2006) used a design based methodology to investigate the use of technology integrated learning with two different classes, one a single-sex girls class. Norton took an essentialised and possibly deficit view of girls, believing that by integrating technology with mathematics girls may become more interested in mathematics-related careers. The focus was proportional reasoning and, in the first stage of the study, students constructed machines using lego-technics to solve particular design problems involving gear ratios. While the test results showed that girls improved their mathematical understanding of proportion, their attitude to mathematics was worse at the end of the first stage of the study. Interviews with the girls in the class revealed their dissatisfaction with the lack of modelling and the disconnection of the phenomenon in mathematics and technology lessons. In the second stage of the study, conducted in an all girls setting, the integration of mathematics and technology used multiple contexts and technologies. The teacher drew attention to the proportional phenomenon being modelled in each of the problems. Both affect and achievement improved in the second stage. In both of these studies, the teacher's skills in drawing attention to the features of the mathematics that matter for learning were critical to student engagement with mathematics.

Learner identity

In a number of studies, students' responses to mathematics in relation to their identities have been theorised. Identity is useful in that it provides a theoretical tool that can interrogate the interplay between the individual and the social. In a case study of a mathematically talented grade 13 female student in a New Zealand school, Shannon (2004) used a post-structuralist framework to theorise her rejection of mathematics. In an interview, the student, Jane, drew on common discourses of mathematics as irrelevant and "taught differently" from other subjects, and having no space for creativity. The ways in which these constructions of mathematics intersected with Jane's feminine identity were examined. Shannon concluded that for students like Jane, with many pathways open to them, it was unsurprising that Jane opted out of mathematics.
Rodd and Bartholomew (2006) interviewed a group of female students who had opted to pursue mathematics to a high level, in a study of female, final year mathematics undergraduates in a British University. They found that, although many of the women were highly successful students, they were also strangely ‘invisible’. Many had a great deal of difficulty ‘owning’ their success, clearly becoming uncomfortable when discussing the matter, and preferring to tell a story of hard work and a good memory than of ability. The ways in which their narratives drew on common discourses of women and mathematics suggested that balancing success in mathematics with their feminine identities was problematic for these students. This finding was reinforced by observations of some of their lectures: for example, on one occasion when one of the female students correctly answered a lecturer’s question, she endured a negative reaction from the group. The conclusion to Shannon’s (2004) article was also pertinent in relation to this study:

I see encouraging girls into advanced mathematics as a noble goal. However, ‘fixing’ mathematics so that girls are not alienated by its current pedagogical structure is, in my opinion, a much more important and critical goal to be addressed. Until girls enjoy mathematics, I believe that we will find it difficult to justify to them that it is socially relevant and a way of improving their quality of life. (Shannon, 2004, p. 515)

Summary

The salient lesson from these studies is that it is important not to dichotomise girls and boys or to think that all girls will be interested or disinterested in mathematics and particular contexts and processes within mathematics lessons.

CONCLUSION

A very wide range of studies is reviewed here, and it is hard to make generalisations about them, but there are a number of trends worth noting. Internationally, over the past decade, Australia and New Zealand have had a very good record with respect to gender equity in mathematics. However the most recent finding of gender differences favouring males in the 2006 PISA survey on mathematical literacy, and the persistent finding in a number of studies of gender inequalities in the distribution of achievement results, with boys more often among the highest achievers, put this reputation in jeopardy. Boys also continue to be more likely to enrol in higher-level mathematics subjects in senior secondary mathematics. An interesting finding to emerge from the affective studies was that while the old gender stereotypes around mathematics appear to have broken down, there remains a difference in the ways that male and female students respond to their own mathematical experiences. In a number of studies boys reported higher levels of enjoyment, interest and self-efficacy in mathematics than did girls, and boys more highly valued the use of technology in mathematics. A number of studies reviewed in this chapter confirm or support the argument that there is a
positive relationship between these affective factors and enrolment in more advanced mathematics subjects in senior secondary mathematics.

Attention to gender equity in the achievement and affect of particular groups of girls and boys by researchers was not as prevalent in the period of the current review as was evident in previous reviews. However the studies show that indigenous students remain particularly disadvantaged in mathematics, and that respectful and engaging teaching approaches are needed for indigenous and Maori students, especially indigenous girls.

Studies of classroom settings, pedagogical practices, and students' mathematical identities revealed that teachers should not assume that particular gender-preferred or stereotyped interventions, teaching approaches, contexts and tools will necessarily improve the performance of, or be preferred by, all girls or boys in their classrooms. Collaborative approaches and teaching from a “care” perspective have broader appeal than their “girl-friendly” pedagogical origins. Yet further research is needed on suitable pedagogies for high achieving girls and on the curriculum and pedagogical practices in senior secondary mathematics to advance gender equity in mathematics.

In the majority of studies reviewed, there was no explicit theoretical framework. In terms of numbers of papers, the majority was located within an implicit liberal feminist framework. When differences were looked for, these differences were understood to be located within individuals (relatively independently of context), and recommendations centred on finding ways of eradicating the differences. There remained an assumption that when girls were opting out of mathematics, the solution lay in persuading them of the importance of continuing with the subject. Having said this, the influence of radical feminist or post-modern perspectives was increasingly in evidence, not just in those few studies in which these frameworks were explicitly adopted. A number of researchers were looking at the context and suggesting ways of widening the appeal of mathematics, even if they remained located within a perspective that essentialised the sexes and adopted a somewhat deficit view of women.

REFERENCES


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