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PREDICTING MATHEMATICS ACHIEVEMENT: THE INFLUENCE OF PRIOR ACHIEVEMENT AND ATTITUDES

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ABSTRACT. Achievement in mathematics is inextricably linked to future career opportunities, and therefore, understanding those factors that influence achievement is important. This study sought to examine the relationships among attitude towards mathematics, ability and mathematical achievement. This examination was also supported by a focus on gender effects. By drawing on a sample of Australian secondary school students, it was demonstrated through the results of a multivariate analysis of variance that females were more likely to hold positive attitudes towards mathematics. In addition, the predictive capacity of prior achievement and attitudes towards mathematics on a nationally recognised secondary school mathematics examination was shown to be large ($R^2 = 0.692$). However, when these predictors were controlled, the influence of gender was non-significant. Moreover, a structural equation model was developed from the same measures and subsequent testing indicated that the model offered a reasonable fit of the data. The positing and testing of this model signifies growth in the Australian research literature by showing the contribution that ability (as measured by standardised test results in numeracy and literacy) and attitude towards mathematics play in explaining mathematical achievement in secondary school. The implications of these results for teachers, parents and other researchers are then considered.

KEY WORDS: achievement, attitudes, gender issues, mathematics, structural equation modelling

Introduction

In contemporary society, achievement in mathematics can be a gateway to some well-rewarded and high-status positions. Accordingly, students, teachers, parents and researchers all have an interest in the factors that influence mathematics achievement. Although there seems to be common agreement among these stakeholders that an individual's disposition towards mathematics is a key factor, there is some uncertainty as to the nature of this relationship. Researchers also differ concerning the factors involved and methods of measuring and accounting for these factors. Such factors include gender, attitude, ability, prior achievement, enabling skills and environmental setting. The current study set out to examine the extent to which a number of these factors predicted achievement on a nationally recognised mathematics assessment in an Australian setting.

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Literature review

The literature review that follows considers the influence of attitude, gender and ability on mathematics achievement. Particular attention is paid to research studies that focus on senior primary and junior secondary school samples.

Attitude Towards Mathematics

The term *attitude* is variously defined in the literature. Some use the term similarly to beliefs, whereas others see it in a less cognitive sense—more akin to emotions (McLeod, 1992). In this study, mathematical attitudes were viewed as a positive or negative response towards mathematics that is relatively stable, similar to what some might call dispositions.

There have been many studies worldwide that have examined attitudes to mathematics at various levels (see, e.g. Grootenboer & Hemmings, 2007; Leder & Forgasz, 2006; Zan, Brown, Evans & Hannula, 2006). It is clear that many people (children and adults) have negative attitudes towards mathematics, and these attitudes are seen as hindering mathematical learning and engagement (Garden, 1997; McLeod, 1992). However, while some studies have shown that negative mathematical attitudes and poor achievement and/or engagement with mathematics are related, it is less clear about whether the attitudinal response causes or is a result of low attainment. Indeed, given the complexity of affectivity, cognition and performance in mathematics learning, it is likely that the relationship is symbiotic and complicated by other factors as well (Furinghetti & Morselli, 2009). Nevertheless, the exploration and unravelling of this relationship is important for the improvement of learning and teaching in mathematics (Gresalfi & Cobb, 2006; Grootenboer & Hemmings, 2007).

Helmke (1989) stated that "[t]he state of research concerning the impact of affective variables on academic achievement is characterised by confusion: positions vary from the assertion that affective variables are powerful determinants of achievement to the assertion that they are irrelevant" (p. 915). Since then, researchers have sought to understand and clarify this relationship, but there still appears to be great scope for development. Wilkins, Zembylas & Travers (2002) identified three groups of variables that related to student achievement in mathematics and science: *personal* variables, including affective qualities; *pedagogical* variables, such as the quality of the teaching; and *environmental* variables, including social factors related to home and school. These three groups of variables were used by Ercikan, McCreith & Lapointe (2005) in a mathematics study across three countries (viz., USA, Canada and Norway). They found that "the strongest predictor of participation in advanced mathematics courses was students' attitudes towards mathematics" (p. 5), and in Canada and Norway, mathematical confidence was the strongest predictor of mathematical achievement. Furthermore, they found that there were gender differences that favoured the boys across all three countries. They concluded that "there is a great deal of evidence to confirm that the relationship between attitudes towards mathematics learning and participation, even though our understanding of how this association develops and maintained is limited" (pp. 12–13). The findings from other studies point to a significant and positive relationship between attitude towards mathematics and mathematics attainment (see, e.g. Ai, 2002; Ma & Kishor, 1997; Singh, Granville & Dika, 2002).

Gender, Attitudes and Achievement in Mathematics

As mentioned previously, issues of gender have spawned much of the interest and research into affective factors in mathematics education. Over a decade ago, Fennema (1995) summarised the previous gender-based research and noted that gender differences are decreasing in mathematics, but they still exist particularly in complex mathematics, in affective responses to mathematics and in career choices involving mathematics. These differences varied when a range of other factors were considered including socioeconomic background and ethnicity. Gallagher & Kaufman (2005) suggest that these differences are still prevalent and require attention from educators and researchers.

The underachievement of girls, compared to that of boys, has been reported for many years and it has been postulated that the discrepancy is due, at least partially, to mathematical attitudinal differences (Leedy, LaLonde & Runk, 2003). The seminal work into the differential performance of girls in mathematics undertaken by Fennema & Sherman (1978) was largely grounded in their 'Mathematics Attitudinal Scales', and they found many significant attitudinal differences between the genders among their high school participants, including confidence in learning mathematics. In general, these findings were consistently reported by other researchers who undertook their studies in different contexts and settings, with different age groups and even with different instruments (see, e.g. Leder & Forgasz, 2006; Young-Loveridge, 1992). More recently, Leedy et al. (2003) found that traditional gender-based differences in beliefs, attitudes and confidence still prevailed among the mathematically talented students (and their parents and teachers). Furthermore, gender differences seem to be exacerbated as students progress through their schooling (Ercikan et al., 2005) and negative experiences at high school are critical in the development of poor mathematical attitudes (Bowd & Brady, 2003). The finding that females hold more negative mathematical attitudes than males, and that this increases with age, is an issue that needs to be addressed because it limits girls' participation in mathematics and their capacity to learn mathematics. And, clearly, their options and opportunities are restricted as a result (Hyde, Fennema, Ryan, Frost & Hopp, 1990). Even though there has been a major emphasis on girls and mathematics, researchers have also been concerned about the poor achievement of boys as some studies have shown an apparent under-performance by boys, vis-à-vis the performance of girls (see, e.g. Burton, 2001; Cortis & Newmarch, 2002; Holmes, 2007).

Ability and Achievement in Mathematics

Studies, carried out in a range of Western contexts, have demonstrated that ability (as frequently measured through previous school achievement) is a predictor of current achievement (see, e.g. Brookhart, 1997; Rothman & McMillan, 2003; Spinath, Spinath, Harlaar & Plomin, 2006). Not unexpectedly, research that has concentrated on primary and secondary school students indicates that mathematical ability (or previous achievement in mathematics) is a good predictor of mathematical success at school. For example, Aubrey, Dahl & Godfrey (2006), researching within a British context and using longitudinal mathematical data, showed that early mathematical abilities and skills were strongly related to later achievement in mathematics. Yates (2000), utilising a 2-year longitudinal design, found that previous results in mathematics were highly predictive of later mathematical success in a sample of Australian school students. Her study drew on data from students whose ages varied from 8 to 12 years.

Studies conducted in the USA have also pointed to a strong association between ability (or previous achievement) and current achievement in mathematics. To illustrate, Reynolds (1991) highlighted the effect of previous mathematics achievement on year 8 mathematical knowledge. In fact, his measure of previous achievement, when combined with a set of other potential predictors, was the most salient predictor in a model he tested. Interestingly, Aiken (1972) revealed that linguistic abilities also influence the mathematics achievement of school students at the senior primary school level. He reported correlations between reading ability and mathematics results in the range of 0.40 to 0.86 for the sample of primary school students. More recently, Thomas (2002) calculated a correlation of 0.46 between reading proficiency and mathematics attainment. This study drew on year 8 data compiled in the National Education Longitudinal Study. This result, and the findings of Aiken (1972), is relatively consistent with a correlation reported by Marks & Ainley (1997). They pooled Australian literacy and numeracy (years 7–9) data across a 20-year time-frame and found a correlation coefficient between reading comprehension and numeracy of 0.60. Given that standardised literacy and numeracy testing is widely practised across Australia, it is surprising that no other study reporting the relationship between literacy and numeracy test results has been acknowledged in the literature. Furthermore, there is a dearth of published information that describes how performance in these tests could be related to future achievement in mathematics and whether or not the results in these tests have a bearing on the attitudes students form about mathematics. In fact, no recent Australian study has attempted to model and test the relationships between and among these various factors.

Aim of the Study

In the current study, a theoretical framework has been adopted which assumes that subsequent achievement in mathematics is predicted by ability, as indicated by standardised test results. It is anticipated that this relationship exists over an extended period of schooling. Moreover, it is predicted that attitude towards mathematics will improve this prediction.

The review of literature has identified that attitude towards mathematics, gender and ability (or prior achievement) all have an effect on mathematical success. It is also evident from this review that Australian studies examining the relationships among these factors are rare and that little has been reported recently about how the relationships could be modelled and tested. Accordingly, the main aim of this study was to explore the relationships among attitude towards mathematics, ability (as measured by year 7 standardised tests) and mathematical achievement. This exploration was also to be supported by a focus on gender effects. In order to realise this aim, three research questions were framed to guide the study:

1. Do gender differences exist for the year 7 numeracy and reading test results, attitude toward mathematics and year 10 mathematics examination results?
2. After controlling for the effects of the year 7 test results and attitude towards mathematics on year 10 mathematics examination results, are there gender effects?

3. What are the relationships among the two year 7 test results, attitude towards mathematics and year 10 mathematics examination results? And, is it possible to develop an appropriate model to test the fit of these data?

Method

Participants

The participants were students who had enrolled at year 7 (in 2004 or 2005) in an independent co-educational secondary school situated in regional New South Wales (NSW). This school draws from middle- to high-income families and is one of several non-government schools located in a regional city. Within each year, there were four graded mathematical classes and this pattern would have continued for each cohort across a 4-year period (that is, 2004−2007 or 2005−2008).

The age of the students at the beginning of year 7 varied from 12.4 to 13.6 years. These students had sat Literacy and Numeracy National Assessment (LANNA) tests[1] during year 7 and then continued their schooling to year 10 at the same school. During year 10, these students were administered a short survey and, in addition, completed state-wide School Certificate (SC) examinations. The particular examination relevant to the current study was mathematics and this examination was compulsory for all students in NSW.

Procedure

Several of the measures required for this study were provided by the participating school but sourced from other authorities. To illustrate, the LANNA *Numeracy* and *Reading* test results were initially compiled by the Australian Council for Educational Research (ACER) and the *SC Maths* scores were derived by the NSW Board of Studies. These data were then supplied to the school's administrators and accessed by the authors. The year 10 survey data were gathered by one of the school's administrators and then with the help of a research assistant entered into an Excel spreadsheet for subsequent use in SPSS (version 16.0). Apart from some demographic information such as gender, these data were based on the students' responses to questions about their attitude towards mathematics and the effort they expend in doing their schoolwork. The items asked participants to indicate their level of agreement or disagreement with a statement using a five-point scale. A measure, referred to as *Maths Attitude*, which had been previously derived from a factor analysis of the Kids' Ideas about Maths instrument (see Grootenboer, 2007; Grootenboer & Hemmings, 2007) was developed. Maths Attitude was formed from six items which were verified using a scale analysis with the current samples. It needs to be noted that one item from the original seven-item scale was deleted as part of this process. The Cronbach's alpha values were 0.84 (2007, $N=66$) and 0.89 (2008, $N=78$) and calculated by using the Reliability programme in SPSS, version 16.0. The items related to schoolwork effort were not considered in this paper.

Visual analysis indicated very little difference between the mean scores of the two cohorts, namely, 2004–2007 and 2005–2008, on all measures. This lack of cohort difference was confirmed by a subsequent multivariate analysis of variance (MANOVA) that failed to produce any univariate differences across the four measures. In order to establish a single dataset for the planned analyses, standardised scores were computed within each cohort and these values were used in a combined dataset ($N=100$). However, because of enrolment losses between years 7 and 10 as well as student absences during test and survey administration, this sample size could have been considerably larger. In fact, sample attrition was calculated at approximately 30%. All the same, a MANOVA showed that the individuals with missing values did not differ from the intact group on SC Maths and Maths Attitude.

It is worth noting that the four measures had kurtosis and skewness values within or relatively close to the range −1 to +1. This meant that they were deemed to be appropriately normally distributed and suitable for analysis using bivariate and multivariate techniques (see, e.g. Hair, Anderson, Tatham & Black, 1998).

Results

A breakdown by gender revealed that 53 females and 47 males were involved in the analysis. Table 1 shows the means and standard deviations for the four measures by gender.

A correlation matrix is presented in Table 2. An examination of these correlations revealed that all the measures were positively and significantly related ($p<0.01$). Numeracy and Reading were highly correlated and had the strongest relationships with SC Maths. The association between Maths Attitude and SC Maths was moderately strong.

TABLE 1

Descriptive statistics for the four measures by gender

Measure	*Gender*	*Mean*	*Standard deviation*
Numeracy (*Z* score)	Female	0.029	0.965
	Male	0.116	0.779
Reading (*Z* score)	Female	0.144	1.027
	Male	−0.111	0.838
Maths Attitude (*Z* score)	Female	0.345	0.899
	Male	−0.345	0.951
SC Maths (*Z* score)	Female	0.273	0.988
	Male	0.013	0.889

A MANOVA was used to contrast the females and males on the four measures as a way of identifying specific sources of difference. A significant difference for gender was found across the measures (Pillai's Trace = 0.195, $F[4, 101] = 5.823$, $p < 0.001$) and the $\acute{\eta}^2$ value was 0.195. A review of the univariate test results using a conservative criterion ($p < 0.001$) identified that Maths Attitude was the sole significant measure and pointed out that females, as opposed to males, were more inclined to view mathematics favourably. The explained variance as indicated by the $\acute{\eta}^2$ was 12.4% and the observed power was 96%.

In order to ascertain whether there were any gender effects after controlling for Numeracy, Reading and Maths Attitude on SC Maths, a multiple regression analysis was conducted using the Regression programme in SPSS, version 16.0 (refer to Table 3). Entering gender as a final step showed no effect. Both Numeracy and Reading predicted 65.9% of the variance in SC Maths, and when Maths Attitude was combined with these two predictors, the explained variance of the criterion increased to over 69%.

TABLE 2

Correlation matrix

Measures	*1*	*2*	*3*	*4*
1. Numeracy	1			
2. Reading	0.684*	1		
3. Maths Attitude	0.306*	0.277*	1	
4. SC Maths	0.758*	0.730*	0.433*	1

*$p < 0.01$ (two-tailed)

TABLE 3

Summary of multiple regression analysis

Step	R^2	R^2 *change*	*Significance of F change*
1. Numeracy	0.575	0.575	0.000
2. Numeracy, Reading	0.659	0.083	0.000
3. Numeracy, Reading, Maths Attitude	0.692	0.034	0.002
4. Numeracy, Reading, Maths Attitude, Gender	0.694	0.002	0.419

As a means of addressing the third and final research question, a model was proposed and considered for testing. However, initial testing of a path model, which included the Numeracy and Reading measures, was unsuccessful and indicated the need to create a latent construct. This construct was termed year 7 Ability and preceded the other measures in the model by approximately 4 years. It was postulated that year 7 Ability and Maths Attitude would predict SC Maths and that, to obtain an appropriate fit, it was necessary for a correlation to exist between the latent ability measure and Maths Attitude (see Figure 1).

Because of the significance of univariate and multivariate normality in structural equation modelling (SEM), a Mahalanobis D^2 measure was used to detect extreme outliers (Byrne, 2001). This procedure showed that one case needed to be deleted from the sample and, as a result, the final sample size was 100. Checking and trimming of the data and the subsequent modelling was carried out using the AMOS programme in SPSS, version 16.0. A summary of the goodness-of-fit indices (GFIs) and other statistics appears in Table 4 and these indicate that the model is one that offers a reasonable fit of the data. Barrett (2007), for example, contends that the "chi-square is the only substantive test of fit for SEM"

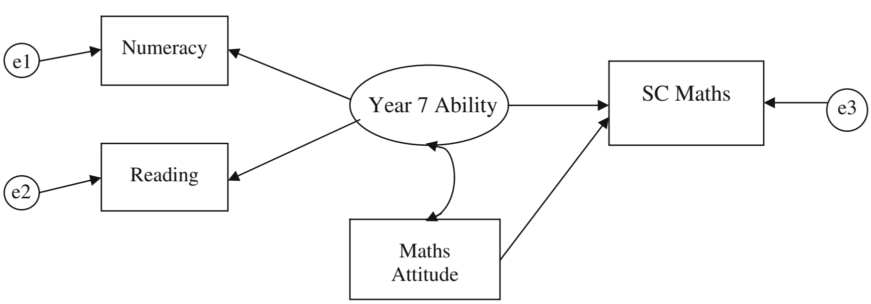

Figure 1. Hypothesised theoretical model

TABLE 4

GFIs and other statistics for the tested model

GFIs/other statistics	*Result*
Chi-square	5.892
df	2
p	0.053
GFI	0.972
NFI	0.970
TLI	0.939
IFI	0.980
CFI	0.980

(p. 815) and the chi-square test result recorded here points out that the ‘probability of occurrence’ was > 0.05, evidence that the model is fitting. Additional evidence that the model is fitting the data is the fact that the selected GFIs generally exceed the 0.95 cut-off (see, e.g. Mulaik, 2007).

The tested model is depicted in Figure 2 and all estimated paths were significant. Even though year 7 Ability is strongly predictive of SC Maths, Maths Attitude also contributed to the criterion measure. Because the explained variance in SC Maths is extremely high, that is 81%, it can be argued that the model has very good explanatory and predictive power for the students sampled in the current study.

Discussion

Three research questions were framed to guide this study and these questions will be addressed in turn. Firstly, it was shown through the

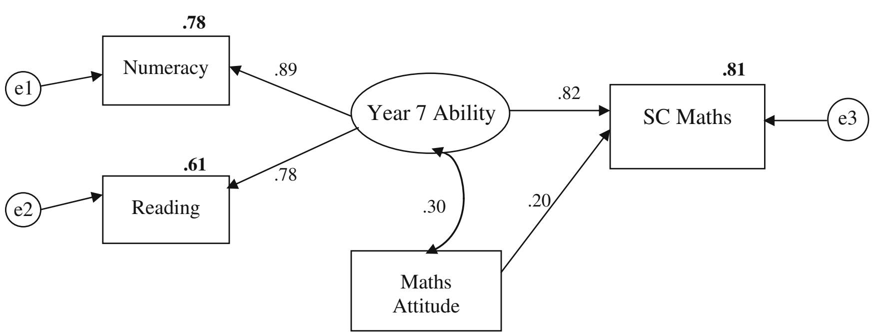

Figure 2. Estimation of theoretical model for SC Maths

results of a MANOVA that gender differences did exist with respect to Maths Attitude. To elaborate, the female students sampled, compared with their male counterparts, were more likely to hold positive attitudes towards mathematics ($p < 0.001$). This finding is at odds with the research reported by Hyde et al. (1990) and Young-Loveridge (1992). However, a lengthy time differential does exist between these studies and the current study. Numeracy and SC Maths scores were not significantly different across gender.

Secondly, the predictive capacity of Numeracy, Reading and Maths Attitude on a state-wide year 10 Mathematics examination was shown to be large ($R^2 = 0.692$). However, when these predictors were controlled, the influence of gender was non-significant. This is in contrast to studies of the numeracy results in Australasian contexts as these have typically pointed to an advantage in favour of males (see, e.g. Rothman & McMillan, 2003; Grootenboer & Hemmings, 2007).

Thirdly, it was possible to develop a model of SC Maths performance drawing on three measures, namely, Numeracy, Reading and Maths Attitude. In terms of importance, year 7 Ability, a composite of Numeracy and Reading, was found to be clearly the best predictor of SC Maths (the regression weight being 0.82). This particular result is consistent with the literature. Reynolds (1991), for example, demonstrated the dominance that prior achievement (or a proxy for ability) exerts on later mathematical performance. And, more recently, Spinath et al. (2006) have shown how cognitive ability has proven to be the strongest predictor of school achievement, including mathematical achievement. The latter study, however, did focus on the skills and abilities of primary school children.

Caution does need to be exercised when discussing and interpreting model fit as alternative models may fit the data equally well (see, e.g. MacCallum & Austin, 2000) and that models based on a sample size of < 200 have possible shortcomings (see, e.g. Barrett, 2007). However, it needs to be kept in mind that a reasonable fit was associated with very strong effects with the tested model ($R^2 = 0.81$). Additionally, it was apparent that an ability construct was a critical feature of the tested model because Numeracy and Reading would not fit in an initial model as stand-alone variables when SC Maths was the criterion measure. It is worth emphasising that the proposal and testing of a model signifies growth in the Australian research literature by filling an identified void.

It is important to recognise a number of limitations of the current study. To begin with, the data were drawn from one school only and a suitably sized dataset had to be built from two separate cohorts attending the school. As a consequence, questions in relation to the generalisability of the results could be raised. In addition, the Maths Attitude measure was based on self-reports and no verification from teachers about student behaviour and practices was available to substantiate the reporting.

The fact that Maths Attitude was shown to be a significant predictor of year 10 Mathematics has implications for both teacher practice and parenting. Interventions need to be derived at the school level to try to impact positively on students' attitudes towards mathematics. Such interventions need to highlight the connections between mathematics and other contexts as well as generate greater student engagement, interest and challenge. Perhaps an appraisal of earlier mathematical learning and experiences and how these influence attitudes positively and negatively needs to be undertaken since attitudes are formed relatively early. Moreover, it would be interesting to gauge how stable attitudes towards mathematics are across a time-frame such as years 7 to 10.

Clearly, strategies that are specific to males also need to be considered as this group, in comparison to females, held attitudes which were markedly more negative. Parents also need to be more positive about mathematics in their interactions with their child(ren) and model the various uses of mathematics in their daily life. Not only do attitudes shape subsequent behaviour, but current behaviour has a strong link to attitudinal change.

From a theoretical viewpoint, the results of the SEM indicate that ability and attitude work in tandem to both explain and predict mathematical success. Although a relatively simple conceptualisation, this modelling needs to be replicated and tested with other samples and age groups, including groups which would allow an SEM analysis with separate gender groups. It would be particularly intriguing to use a measure of attitude towards mathematics taken at year 7, alongside standardised numeracy and reading test scores, and test their predictive capacity on SC Maths 4 years later. Future study would also profit from examining the relationships between a range of reading and numeracy measures and other measures of mathematical attainment, e.g. year 12 Mathematics results.

NOTE

[1] The literacy component was measured by tests in reading, writing and spelling, whereas numeracy was assessed by a single test examining number, space, measurement, chance and data. It is worth noting that the LANNA tests have been administered from

1999 to 2007 and that approximately 80,000 primary and secondary school students enrolled in the non-government school sector have sat these tests during this period.

References

Ai, X. (2002). Gender differences in growth in mathematics achievement: Three-level longitudinal and multilevel analyses of individual, home, and school influences. *Mathematical Thinking and Learning, 4*(1), 1–22.

Aiken, L. R. (1972). Language factors in learning mathematics. *Review of Educational Research, 42*(3), 359–385.

Aubrey, C., Dahl, S., & Godfrey, R. (2006). Early mathematics development and later achievement: Further evidence. *Mathematics Education Research Journal, 18*(1), 27–46.

Barrett, P. (2007). Structural equation modelling. *Personality and Individual Differences, 42*(5), 815–824.

Bowd, A. D., & Brady, P. H. (2003). Gender differences in mathematics anxiety among preservice teachers and perceptions of their elementary and secondary school experience with mathematics. *The Alberta Journal of Educational Research, 49*(1), 24–36.

Brookhart, S. M. (1997). Effects of the classroom assessment environment on mathematics and science achievement. *The Journal of Educational Research, 90*(6), 323–330.

Burton, L. (2001). Fables: The tortoise? The hare? The mathematically underachieving male. In B. Atweh, H. Forgasz, & B. Nebres (Eds.), *Sociocultural research on mathematics education: An international perspective* (pp. 379–392). New York: Routledge.

Byrne, B. N. (2001). *Structural equation modeling with AMOS*. Mahwah: Lawrence Erlbaum Associates.

Cortis, N., & Newmarch, E. (2002). Boys in schools: What's happening. In S. Pierce & V. Muller (Eds.), *Manning the next millennium: Studies in masculinities* (pp. 151–168). Fremantle: Black Swan Press.

Ercikan, K., McCreith, T., & Lapointe, V. (2005). Factors associated with mathematics achievement and participation in advanced mathematics courses: An examination of gender differences from an international perspective. *School Science and Mathematics, 105*(1), 5–14.

Fennema, E. (1995). Mathematics, gender and research. In G. Hanna (Ed.), *Gender and mathematics education, an ICMI Study* (pp. 21–38). Lund: Lund University Press.

Fennema, E., & Sherman, J. (1978). Sex-related differences in mathematics achievement and related factors: A further study. *Journal for Research in Mathematics Education, 9* (3), 189–203.

Furinghetti, F., & Morselli, F. (2009). Every unsuccessful problem solver is unsuccessful in his or her own way: Affective and cognitive factors in proving. *Educational Studies in Mathematics, 70*, 71–90.

Gallagher, A. M., & Kaufman, J. C. (Eds.). (2005). *Gender differences in mathematics: An integrative psychological approach*. Cambridge: Cambridge University Press.

Garden, R. A. (1997). *Mathematics and science performance in middle primary school: Results from New Zealand's participation in the Third International Mathematics and Science Study*. Wellington: Research and International Section, Ministry of Education.

Gresalfi, M. S., & Cobb, P. (2006). Cultivating students' discipline-specific dispositions as a critical goal for pedagogy and equity. *Pedagogies: An International Journal, 1*(1), 49–57.

Grootenboer, P. J. (2007). Measuring students' affective responses to mathematics and mathematics education. In C. S. Lim, S. Fatimah, G. Munirah, S. Hajar, M. Y. Hasimah, W. L. Gan, & T. J. Hwa (Eds.), *Meeting challenges of developing quality mathematics education culture. Proceedings of the 4th East Asia Regional Conference on Mathematics Education* (pp. 273–280). Penang: Universiti Sains Malaysia.

Grootenboer, P., & Hemmings, B. (2007). Mathematics performance and the role played by affective and background factors. *Mathematics Education Research Journal, 19*(3), 3–20.

Hair, J. F., Anderson, R. E., Tatham, R. L., & Black, W. L. (1998). *Multivariate data analysis* (5th ed.). Upper Saddle River: Prentice-Hall.

Helmke, A. (1989). Affective student characteristics and cognitive development: Problems, pitfalls, perspectives. *International Journal of Educational Research, 13*, 915–932.

Holmes, M. (2007). *What is gender? Sociological approaches*. London: Sage.

Hyde, J. S., Fennema, E., Ryan, M., Frost, L. A., & Hopp, C. (1990). Gender comparisons of mathematics attitudes and affect. *Psychology of Women Quarterly, 14*(3), 299–324.

Leder, G. C., & Forgasz, H. J. (2006). Affect and mathematics education: PME perspectives. In A. Gutiérrez & P. Boero (Eds.), *Handbook of research on the psychology of mathematics education: Past, present and future* (pp. 403–427). Rotterdam: Sense.

Leedy, M. G., LaLonde, D., & Runk, K. (2003). Gender equity in mathematics: Beliefs of students, parents, and teachers. *School Science and Mathematics, 103*(6), 285–292.

Ma, X., & Kishor, N. (1997). Assessing the relationship between attitude towards mathematics and achievement in mathematics: A meta-analysis. *Journal for Research in Mathematics Education, 28*(1), 26–47.

MacCallum, R. C., & Austin, J. T. (2000). Applications of structural equation modeling in psychological research. *Annual Review of Psychology, 51*, 201–226.

Marks, G. & Ainley, J. (1997). *Reading comprehension and numeracy among junior secondary school students in Australia*. LSAY Research Report 3. Melbourne: Australian Council for Educational Research.

McLeod, D. B. (1992). Research on affect in mathematics education: A reconceptualization. In D. Grouws (Ed.), *Handbook of research on mathematics teaching and learning* (pp. 575–596). New York: Macmillan.

Mulaik, S. (2007). There is a place for approximate fit in structural equation modeling. *Personality and Individual Differences, 42*(5), 883–891.

Reynolds, A. J. (1991). The middle schooling process: Influences on science and mathematics achievement from the longitudinal study of American youth. *Adolescence, 16*(101), 132–157.

Rothman, S. & McMillan, J. (2003). *Influences on achievement in literacy and numeracy*. LSAY Research Report Number 36. Melbourne: Australian Council for Educational Research.

Singh, K., Granville, & Dika, S. (2002). Mathematics and science achievement: Effects of motivation, interest, and academic engagement. *The Journal of Educational Research, 95*(6), 323–332.

Spinath, B., Spinath, F. M., Harlaar, N., & Plomin, R. (2006). Predicting school achievement from general cognitive ability, self-perceived ability, and intrinsic value. *Intelligence, 34*(4), 363–374.

Thomas, J. P. (2002). *An examination of the relationship between learning variables and academic achievement outcomes* (Document No. TM 034 700). Grayslake: College of Lake County (ERIC Document Reproduction Service No. ED 471 988).

Wilkins, J. L. M., Zembylas, M., & Travers, K. J. (2002). Investigating correlates in mathematics and science literacy in the final year of secondary school. In D. F. Robitaille & A. E. Beaton (Eds.), *Secondary analysis of the TIMMS data* (pp. 291–316). Boston: Kluwer.

Yates, S. (2000). Task involvement and ego orientation in mathematics achievement: A three-year follow-up. *Issues in Educational Research, 10*(1), 77–91.

Young-Loveridge, J. (1992). Attitudes towards mathematics: Insights into the thoughts and feelings of nine-year-olds. In B. Bell, A. Begg, F. Biddulph, M. Carr, J. McChesney, & J. Young-Loveridge (Eds.), *SAMEpapers 1992* (pp. 90–116). Hamilton: Centre for Science and Mathematics Education Research.

Zan, R., Brown, L., Evans, J., & Hannula, M. (2006). Affect in mathematics education: An introduction. *Educational Studies in Mathematics, 63*(2), 113–121.

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