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The leaky mathematics pipeline for girls

A motivational analysis of high school enrolments in Australia and the USA

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Abstract

Purpose – Why do girls and women progressively opt out of maths-related study and careers? This study aims to examine motivations influencing female adolescents' choices for maths participation during high school, which has implications for their long-term careers.

Design/methodology/approach – Two longitudinal samples were included from different contexts – one from Sydney, Australia ($N=459$), and the other from Southeastern Michigan, USA ($N=266$). Both samples involved adolescents from upper middle-class backgrounds, from coeducational government schools, and data in both settings were collected in the mid 1990s. Australian data spanned a three-year period through grades 9 to 11; while the US sample spanned a five-year period, with data from grades 8, 10, 11, and 12. The Expectancy-Value model of Eccles (Parsons) *et al.*, framed structural equation modelling analyses for the influences of maths ability-related beliefs and values on boys' and girls' subsequent choices for senior high maths participation.

Findings – Boys selected higher levels of maths than girls in the Australian setting, although not in the US sample. There was no support for gendered maths achievement as a basis for gendered maths participation. Interest in and liking for maths were the strongest influence on the Australian adolescents' choices for maths participation, with ability beliefs also influencing choices over and above prior mathematical achievement. Ability-related beliefs and different kinds of values also predicted adolescents' choices in the US sample, more strongly for girls than boys.

Practical implications – Interpretations and implications focus on ways to increase girls' and women's retention in the leaky maths pipeline.

Originality/value – Longitudinal data allow one to determine the extent to which different kinds of motivations predict boys' and girls' mathematical course-taking through senior high school across Australian and US samples. This has implications for their long-term careers.

Keywords Students, Women, Mathematics, Motivation (psychology), Australia, United States of America

Paper type Research paper

Girls and women who opt out of mathematics in high school or soon after prematurely restrict their educational and career options (Heller and Parsons, 1981; Meece *et al.*, 1990; Secada, 1989). Maths has been identified as the "critical filter" which limits access to many high-income and high-status careers (Sells, 1980), through acting as a gateway to many careers and fields of study. The participation of girls and women in mathematics decreases markedly as they progress to higher educational and professional levels (Herzig, 2004). At each successive educational level, girls are more likely than boys to opt out of the so-called "STEM" fields – science, technology, engineering, and maths. Girls and women are both less likely to choose careers in

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traditionally male STEM domains (Jacobs *et al.*; Watt, 2006), and more likely than males to drop out if they do enter those fields (Mau, 2003; National Science Foundation, 1999). This pattern has been called the "leaky pipeline" (National Center for Education Statistics, 1997; Oakes, 1990a; Stage and Maple, 1996).

Since Sells' 1980 paper, a burgeoning interest into the reasons which contribute to gendered participation at all stages of the maths pipeline has been triggered. From a standpoint of gender equity, it is necessary to identify the multiple points at which females opt out of the maths pipeline, and to understand the reasons for their decisions to discontinue maths at each of those points. Not taking maths can restrict or exclude girls and women from certain kinds of university degrees, or other forms of education and training, which in turn lead to many high-status high-income careers. Just how early does the maths pipeline begin to "leak"? Secondary school is a particularly critical context on which to focus, since this is the time when young adults are often deciding what post-school directions to pursue, and permits the greatest access to ask about their decisions and perceptions, before they self-select out of further studies in general, or out of maths-related studies in particular. If girls start to opt out of maths during high school, this can preclude them from access to certain university degrees and careers, which depend on senior high maths preparation.

Gender-stereotypical patterns of high school maths enrolments have been identified in both Australian (e.g. Leder, 1992; Leder *et al.*, 1996; Watt, 2002; 2005; 2006) and US samples (e.g. Eccles (Parsons), 1984; Eccles, 1985; Updegraff *et al.*, 1996). In the USA, most school systems now require a greater number of maths courses than previously, which has reduced the opportunity for girls to drop out of maths early in high school (US Dept. of Education, National Center for Education Statistics, 2000), and may have helped close the gender gap in senior high maths participation. We examine gendered maths participation in senior high school within two longitudinal samples from Australia and the USA, and associated motivational influences. Identification of important predictors of boys' and girls' maths participation will provide valuable guidance regarding how to promote adolescents' choices to continue to participate in the maths "pipeline", particularly for girls.

Senior high course enrolment structures

In the USA, students select those courses that they wish to undertake from grades 9 through 12, and most schools require at least two years of maths over that period. Maths participation in the US context is typically operationalised as the number of courses that students undertake (e.g. Eccles (Parsons), 1984; Eccles, 1985). Courses are organised according to topic areas, with some topics generally regarded as less difficult (e.g. general maths, beginning algebra), and others are regarded as the most difficult (e.g. calculus and trigonometry), although there is no formal classification of the difficulty levels for the various topic areas. Because courses are structured around topic areas, rather than along an underlying continuum of complexity, a greater number of maths courses does not necessarily imply participation in increasingly higher-order and more complex mathematics.

In contrast, in the State of New South Wales (NSW) Australia, maths is required for everyone up until the end of grade 10, after which students select the difficulty level of maths that they wish to study for senior grades 11 and 12. Although it is no longer compulsory for students to take maths in senior high school years, the overwhelming majority of students choose to do so, given this is a prerequisite for entry to many university degrees and often expected by employers. This is an ideal location for studying gendered choices in terms of course enrolment, since the extent of participation in increasingly high level maths can be easily operationalised. Maths coursework selections are hierarchically organised according to course demand and difficulty in senior grades 11 and 12, when students elect which one of five ordered difficulty levels of mathematics they wish to study. At the lowest difficulty level is Maths in Practice (MIP), followed by the basic but more demanding Maths in Society (MIS), with the difficulty increasing in unit value through 2-unit (2U), 3-unit (3U) and the most advanced 4-unit (4U) math (MacCann, 1995). This naturally occurring ordered metric provides a measure of students' participation in increasingly complex maths in senior high school.

Theoretical framework

Gender differences in maths achievement do not explain the gender differences in maths participation, and this is why it is so important to study adolescents' motivations and perceptions related to maths. Two comprehensive meta-analyses (Friedman, 1989; Hyde *et al.*, 1990) established that males and females generally perform equivalently in secondary school maths. Eccles and colleagues have argued that it is still important to include achievement measures as a control in studying influences on maths participation, to be able to measure the unique influences of students' motivations over and above their measured mathematical achievement (see Updegraff *et al.*, 1996). In our study, measures of prior and later mathematical achievement were included in modelling motivational influences on senior high maths course selections, also permitting examination of whether both boys and girls choose to participate in maths at levels commensurate with their demonstrated abilities.

The Expectancy-Value model of Eccles and her colleagues (see Eccles *et al.*, 1983) was developed specifically to predict gendered enrolment choices and mathematical achievement (for an overview see Eccles (Parsons) *et al.*, 1983; Eccles, 2005; Wigfield and Eccles, 2000). In their model, they proposed that educational, vocational and other achievement-related choices are directly related to two sets of beliefs: the individual's expectations for success, and the importance value that he or she attaches to the task. Expectancies and values have been empirically demonstrated to relate to maths course enrolment choices and also to mathematical achievement (e.g. Eccles (Parsons) *et al.*, 1983; Eccles (Parsons), 1984; Eccles, 1985; Wigfield, 1994).

Success expectancies depend on an individual's beliefs about how much ability he or she possesses, and are defined by Eccles and colleagues (Eccles (Parsons) *et al.*, 1983) as beliefs about how well one will perform on an impending task – distinguished conceptually from ability beliefs which are defined as perceptions of one's current competence at a given activity (Eccles (Parsons) *et al.*, 1983). Expectations for success are shaped over time by the individual's experiences and his or her interpretations of those experiences (see Eccles and Wigfield, 1995). For example, if a person attributes a success to superior skill, that person is likely to have his or her ability beliefs bolstered by the success; whereas another person who thinks that his or her success has been a result of simply trying hard, is unlikely to have his or her self concept of ability boosted by that success. Eccles and colleagues have not, however, been able to distinguish empirically between their ability and expectancies constructs in factor analytic work (Eccles and Wigfield, 1995; Wigfield and Eccles, 2000), and frequently combine these measures together in analyses. Talent perceptions were proposed by Bornholt *et al.* (1994) as a way of measuring ability beliefs distinct from performance, based on early discussion about the distinction between aptitude and achievement by Green (1974).

These have been developed and found to be empirically distinguishable from both ability beliefs as they are commonly operationalised, and also success expectancies (see Watt, 2002; 2004; 2005); while a higher-order self-perceptions factor has also been validated, combining talent perceptions and success expectancies.

However, beliefs about ability describe only one aspect of how individuals relate to tasks. The value that a person holds for a task is also critical, and this is influenced by a number of factors: does the person enjoy the task? Is the task instrumental for any of the person's short- or long-term goals? Does the person think the task is suited to people like him or her? Intrinsic value has been identified as a major predictor of maths participation choices in both high school and college (see Benbow and Minor, 1986; Updegraff *et al.*, 1996; Watt, 2005). It has been likened to interest and enjoyment, while utility value taps more instrumental reasons for task engagement. Attainment value refers to the importance to the individual of doing well on the task, in order to confirm aspects of his or her identity. Utility value and attainment value have also been combined and termed "importance value" (e.g. Fredricks and Eccles, 2002; Jacobs *et al.*, 2002).

Study aims

The present study investigates the impact of students' motivations on their senior high maths enrolment choices and mathematical achievement. Comparative data from Michigan USA and NSW Australia will show how these influences play out in two culturally similar yet separate contexts, to impact each of the amount of maths undertaken in the USA setting, as well as the difficulty level undertaken in the Australian setting. In the USA, students have the choice of the number of maths topics they wish to undertake, although this number is largely dictated for those students who aim to go on to college, in a climate where maths has become a critical determinant of college and university entrance. This context appears to provide for very little choice in the number of courses students undertake (i.e. most students bound for college take maths all four years of high school). In NSW Australia, students have the choice of which difficulty level of maths to undertake. Although maths is required for entrance to most university degrees, no university degree requires the highest 4-unit level of maths as a prerequisite, and almost none requires the next highest 3-unit level of maths, providing for greater choice than the US context. The two different systems for course selections allow us to make interesting comparisons.

Method

Australian sample and setting

Participants were 459 adolescents who were in grade 9 when the longitudinal study commenced in 1996, and grade 11 at the final time-point in 1998. Sixty-five per cent of participants were present for all three occasions, 88 per cent were present for at least two, and multiple imputation was used to impute missing data (Schafer, 1997). The sample contained 43 per cent females, and mainly English Speaking Background (ESB) students (73 per cent), with the largest ethnic subgroup being Asians (22 per cent). Participants were from three matched upper-middle class (ABS, 1991) coeducational secondary schools in metropolitan Sydney. In the State of NSW Australia, students attend secondary school grades 7 through 12. Maths syllabi exist for each of grades 7 and 8, grades 9 and 10, and grades 11 and 12. Junior grades 7 and 8 are focused largely on consolidation of material learned through primary grades 3 through 6. In grades 9 and 10, students are streamed into levels of "advanced", "intermediate" and "standard" maths, based on their demonstrated ability up to that point. In senior grades 11 and 12, which lead up to a major external examination supplemented by within-school assessment results called the higher school certificate (HSC), students elect which subjects they wish to study. In addition to students selecting which academic subjects they wish to study for the HSC, they also select which difficulty level within their chosen subjects they wish to undertake.

US sample and setting
US data were from the Childhood and Beyond Study (CAB; Eccles *et al.*, 1993). CAB is a multicohort, longitudinal study of children from elementary through high school. The study began in Michigan in 1986, and the sample consisted of children largely from middle- to upper middle-class households, with 95 per cent of the children being European American. Here we included participants from the two eldest of the three cohorts ($N = 266$ of the original 606, representing 45 per cent of the eldest and 42 per cent of the middle cohorts) who were retained in the study by grade 11. Data were collected from those cohorts beginning from the 3rd and the 1st grade, respectively, for the eldest and middle cohorts. Attrition is due to the length and scope of the CAB longitudinal study, where most attrition occurred through the transition from elementary to secondary school. Participants were in grade 10 in each of 1993 and 1995, respectively, for the eldest and second-eldest cohorts. The final sample contained 52 per cent girls – the same proportion as when the CAB Study commenced. In the USA, maths is required through elementary school and middle school/junior high school. From grades 9 through 12, students begin to have more choice in whether they take maths courses each year. Most schools require at least two years of maths, and strongly recommend that students intending to go to college take more years than that. Courses are structured according to topic areas and each year students can decide the maths courses that they take.

Materials
Motivations
Questionnaires assessed students' motivations in grade 10. In the US sample, items were those developed by Eccles and colleagues for self-concept/expectancies, intrinsic value, and importance value (see Wigfield and Eccles, 2000). Australian items were based on these as modified by Watt, for self-perceptions (a composite of talent perceptions and success expectancies) and intrinsic value (full details of modifications and good construct validity and reliability based on the present sample are reported by Watt, 2002; 2004). The items used for each sample are listed in Table I (Australian sample) and Table II (US sample), along with Cronbach alpha measures of internal consistency. Factors were therefore similar, but not identical, in the two samples. In particular, no measure of maths importance value was included in the Australian analyses.

Participation
For the Australian sample, senior high maths participation was students' actual HSC course levels selected at grade 11, when students indicated on the survey, which course level they were studying. In the USA, senior high maths participation was measured through the total number of maths courses students undertook through grades 11 and 12.

Achievement

Mathematical achievement was assessed in the Australian sample at each of grades 9 and 11, using standardised multiple-choice Progressive Achievement Tests (ACER, 1984). US maths achievement was measured at grades 8 and 11 via students' school grades.

Results

Australian findings

Gender differences in achievement, motivations, and participation. There were no statistically significant gender differences in mathematical achievement at either grade 9 ($F(1,401) = 0.75$, $p = 0.39$) or grade 11 ($F(1,346) = 0.04$, $p = 0.84$) – meaning that boys and girls had similar performance at both grades. Despite this, boys rated their self-perceptions ($F(1,379) = 30.70$, $p < 0.001$, boys $M = 5.03$, SD = 0.88, girls $M = 4.52$, SD = 0.87) and intrinsic value ($F(1,353) = 9.35$, $p = 0.002$, boys $M = 3.95$, SD = 1.71, girls $M = 3.43$, SD = 1.39) significantly higher than girls on the 7-point scales. Students' senior high mathematics enrolments are shown in Figure 1. Most students undertook 2-unit maths – the level most frequently required for entry to a range of university degrees. Greater proportions of boys than girls undertook the highest 4-unit and 3-unit maths courses, while more girls undertook the low level Maths in Society (with negligible proportions of students taking the lowest Maths in Practice option).

Table I. Subscale items and measures of internal consistency for the Australian sample

	Item stem [response options all of the form 1(not at all)-7(very)]
Self-perceptions 80[a]	*Comparative talent perceptions:*
	Compared with other students in your class, how talented do you consider yourself to be at maths?
	Compared with other students in your Year at school, how talented do you consider yourself to be at maths?
	Compared with your friends, how talented do you consider yourself to be at maths?
	Domain-specific talent perceptions:
	How talented do you think you are at problem solving in maths?
	How talented do you think you are at geometry in maths?
	How talented do you think you are at measurement and number in maths?
	How talented do you think you are at statistics in maths?
	Success expectancies:
	How well do you expect to do in your next maths test?
	How well do you expect to do in school maths tasks this term?
	How well do you think you will do in your school maths exam this year?
Intrinsic value 94	How much do you like maths, compared with your other subjects at school?
	How interesting do you find maths?
	How enjoyable do you find maths, compared with your other school subjects?

Notes: [a]Item parcels from each of comparative and domain-specific talent perceptions and success expectancies were used as indicators for the latent self-perceptions factor. Cronbach's alpha is based upon the three averaged item subscales

Table II.
Subscale items and measures of internal consistency for the US sample

		Item stem
Ability/expectancy beliefs	88	If you were to list all the students in your grade from worst to best in math, where would you put yourself? 1 (one of the worst)-7 (the best) How good at math are you? 1 (not at all)-7 (very good) How well do you expect to do in math next year? 1 (not at all well)-7 (very well) How good would you be at learning something new in math? 1 (not at all good)-7 (very good)
Intrinsic value	90	How much do you like doing math? 1 (a little)-7 (a lot) In general, I find working on math assignments: 1 (very boring)-7 (very interesting) Compared to other activities, how much do you like math? 1 (not as much as…)-7 (a lot more than…)
Importance value	81	In general, how useful is what you learn in math? 1 (not at all)-7 (very useful) Compared to other activities, how useful is what you learn in math? 1 (not as useful) – 7 (a lot more useful) For me, being good at math is… 1 (not at all important)-7 (very important) Compared to other activities, how important is it to you to be good at math? 1 (not as important)-7 (a lot more important)

Gendered relationships among achievement, motivations, and participation. To investigate the relative importance of ability self concepts and intrinsic value on each of boys' and girls' choice of HSC senior high course level and senior high achievement, structural equation models were estimated using LISREL. Grade 9 maths achievement was included as a control, followed by grade 10 self-perceptions and intrinsic value, with grade 11 HSC course level and grade 11 achievement as the outcomes. Estimated structural paths were from grade 9 achievement to grade 10 perceptions and grade 11 outcomes, from grade 10 perceptions to grade 11 outcomes, as well as from grade 11 course level to grade 11 achievement. For maths achievement at each of grades 9 and 11, the 28 items were parcelled into four groups to estimate the latent maths achievement factors (Cronbach's alpha = 0.91 at grade 9, and 0.87 at grade 11, for the averaged item parcels). Construct correlations and measurement paths were freely estimated, although the error variance for grade 11 course level was necessarily fixed to zero since this factor had only one indicator variable. The error covariance between grade 10 ability self concept and grade 10 intrinsic value was freely estimated, since these constructs were measured at the same time point.

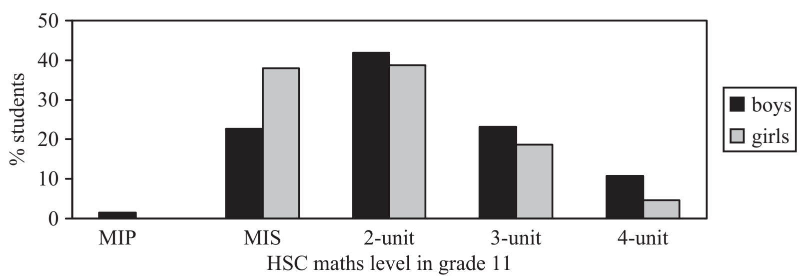


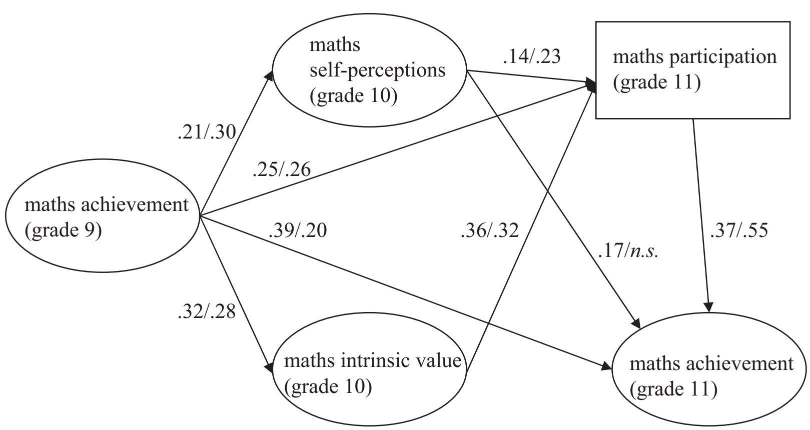
Figure 1.
Students' senior high maths participation in NSW Australia

Models exhibited good fit across a range of frequently emphasised fit indices (boys: normal theory weighted least squared chi-square = 227.365 d.f. = 81, RMSEA = 0.083, NFI = 0.942, NNFI = 0.947, GFI = 0.896, AGFI = 0.846; girls: normal theory weighted least squared chi-square = 223.346 d.f. = 81, RMSEA = 0.095, NFI = 0.933, NNFI = 0.943, GFI = 0.868, AGFI = 0.804) and there were no large modification indices. In the interests of parsimony, only statistically significant ($p < 0.05$) completely standardised structural paths are summarised in Figure 1, although further information including measurement paths is available on request[1].

Relationships among maths participation, achievement and perceptions for boys and girls appeared similar, and are graphically depicted in Figure 2. Grade 9 maths achievement directly influenced grade 10 self-perceptions ($\gamma = 0.21$ for boys, $\gamma = 0.30$ for girls), grade 10 intrinsic value ($\gamma = 0.32$ for boys, $\gamma = 0.28$ for girls), HSC maths course level ($\gamma = 0.25$ for boys, $\gamma = 0.26$ for girls), and grade 11 maths achievement ($\gamma = 0.39$ for boys, $\gamma = 0.20$ for girls). Grade 10 self-perceptions had direct effects on HSC maths course level ($\beta = 0.14$ for boys, $\beta = 0.23$ for girls), as well as on grade 11 achievement for boys ($\beta = 0.17$)[2]. Grade 10 intrinsic value directly influenced grade 11 HSC maths course level ($\beta = 0.36$ for boys, $\beta = 0.32$ for girls), and HSC maths course level affected grade 11 maths achievement on the standardised test ($\beta = 0.37$ for boys, $\beta = 0.55$ for girls). Consistent with the Expectancy-Value theory, self-perceptions positively influenced subsequent achievement even when prior achievement was controlled, and intrinsic value positively impacted on subsequent choices for participation in maths.

US findings

Gender differences in achievement, motivations, and participation. Similar to the Australian sample, there were no statistically significant gender differences at either time-point in measured mathematical achievement (grade 8: $F(1,209) = 3.569$, $p = 0.06$, grade 11: $F(1,209) = 2.290$, $p = 0.13$). Boys again rated their mathematical abilities/success expectancies statistically significantly higher than girls ($F(1,414) = 6.531$, $p = 0.01$, boys $M = 5.016$, SD = 1.255, girls $M = 4.698$, SD = 1.275), although there were no significant gender differences in these students' intrinsic or importance values



Note: Completely standardised structural paths singnificant at $p < 0.05$ only are represented for boys/girls

Figure 2. NSW Australian structural equation models for relationships among maths participation, achievement, ability self concepts and values

related to maths. Most students in the US sample undertook a total of four maths courses through senior grades 11 and 12, and small proportions of students studied none or one maths course during this time (see Figure 3). There were no apparent gender differences in the number of maths courses taken.

Gendered relationships among achievement, motivations, and participation. Structural equation models again estimated relationships among constructs. Grade 8 maths achievement was included as a control, followed by grade 10 ability/expectancy beliefs, intrinsic value and importance value, with number of senior high maths courses and grade 11 maths achievement as the outcomes. For the US analyses, it was necessary to run separate models involving each of the grade 10 ability/expectancy beliefs, intrinsic value and importance value, due to their high inter-correlations. Estimated structural paths in each case were from grade 8 achievement to grade 10 perceptions and grade 11 outcomes, from grade 10 perceptions to grade 11 outcomes, as well as from grade 11 course level to grade 11 achievement. Construct correlations and measurement paths were freely estimated, although error variances for the number of maths courses taken in senior high, as well as grades 8 and 11 maths achievement, were fixed to zero, since each of these constructs was measured by a single indicator.

Models exhibited marginal but acceptable fits for boys (ability/expectancy beliefs: normal theory weighted least squared chi-square = 25.072, d.f. = 10, RMSEA = 0.109, NFI = 0.962, NNFI = 0.948, GFI = 0.946, AGFI = 0.849; intrinsic value: normal theory weighted least squared chi-square = 10.616, d.f. = 6, RMSEA = 0.078, NFI = 0.974, NNFI = 0.971, GFI = 0.973, AGFI = 0.904; importance value: normal theory weighted least squared chi-square = 29.610, d.f. = 10, RMSEA = 0.125, NFI = 0.913, NNFI = 0.868, GFI = 0.937, AGFI = 0.824) and girls (ability/expectancy beliefs: normal theory weighted least squared chi-square = 27.137, d.f. = 10, RMSEA = 0.111, NFI = 0.955, NNFI = 0.936, GFI = 0.947, AGFI = 0.851; intrinsic value: normal theory weighted least squared chi-square = 7.853, d.f. = 6, RMSEA = 0.047, NFI = 0.977, NNFI = 0.984, GFI = 0.981, AGFI = 0.935; importance value: normal theory weighted least squared chi-square = 22.695, d.f. = 10, RMSEA = 0.096, NFI = 0.946, NNFI = 0.934, GFI = 0.955, AGFI = 0.874).

Relationships among maths participation, achievement and perceptions for boys and girls are graphically depicted in Figures 4a through 4c. Summarising across the three models, grade 8 maths achievement directly influenced grade 10 ability/expectancy beliefs ($\gamma = 0.54$ for boys, $\gamma = 0.30$ for girls), grade 10 intrinsic value ($\gamma = 0.36$ for boys, $\gamma = 0.17$ for girls), and grade 10 importance value for boys ($\gamma = 0.24$). Grade 8 maths achievement also impacted on senior high course-taking and grade 11 mathematical achievement. Grade 10 ability/expectancy beliefs had direct effects on

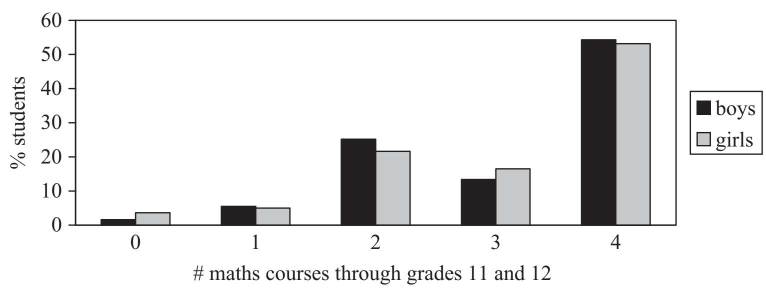
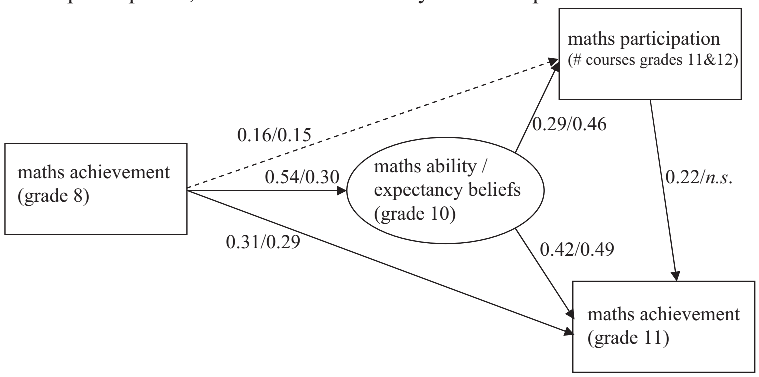
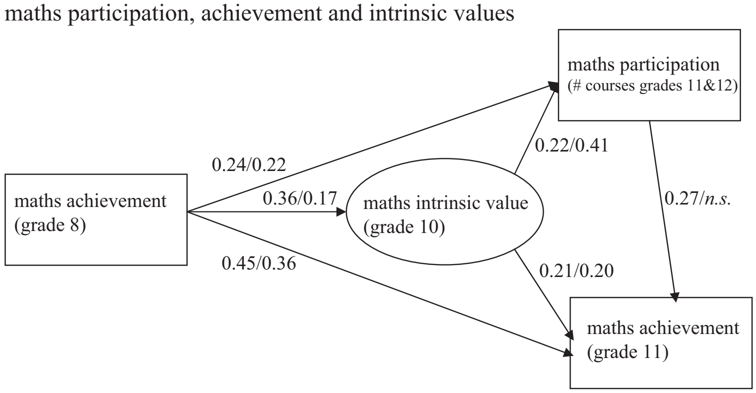


Figure 3.
Students' senior high maths participation in Michigan USA

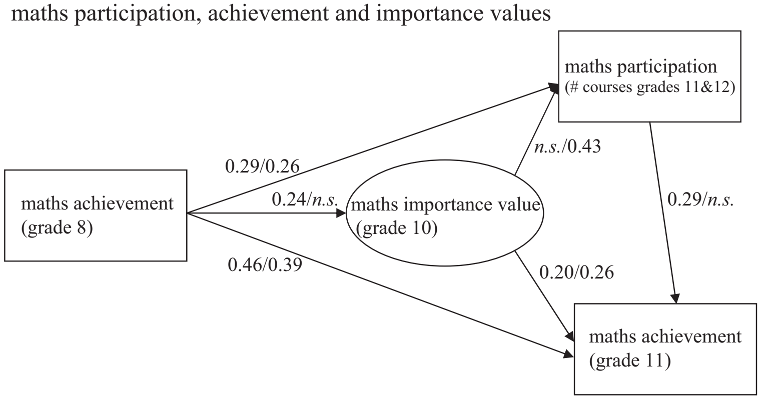
(a) Michigan USA gendered structural equation models for relationships among maths participation, achievement and ability self concepts



(b) Michigan USA gendered structural equation models for relationships among maths participation, achievement and intrinsic values



(c) Michigan USA gendered structural equation models for relationships among maths participation, achievement and importance values



Notes: Completely standardised structural paths significant at $p < 0.05$ only are represented for boys/girls. The dashed line indicates $p < 0.10$ (in this case $t = 1.57$ for boys, 1.95 for girls). The latent correlations between these two constructs were 0.32 for boys and 0.29 for girls

Figure 4.

the number of senior high maths courses studied ($\beta = 0.29$ for boys, $\beta = 0.46$ for girls), as well as on grade 11 achievement ($\beta = 0.42$ for boys, $\beta = 0.49$ for girls). Grade 10 intrinsic value also directly influenced senior high number of courses ($\beta = 0.22$ for boys, $\beta = 0.41$ for girls) and grade 11 achievement ($\beta = 0.21$ for boys, $\beta = 0.20$ for girls). Grade 10 importance value affected senior high course-taking for girls ($\beta = 0.43$), and grade 11 maths achievement for boys and girls ($\beta = 0.20$ for boys, $\beta = 0.26$ for girls). Number of senior high courses undertaken related to grade 11 maths achievement for boys, but not for girls. Similar to the Australian findings, ability/expectancy beliefs influenced both maths participation and achievement when prior mathematical achievement was controlled. Unlike the Australian findings, values also influenced later mathematical achievement. Also similar to the Australian findings, intrinsic value impacted on maths participation. Importance value impacted on maths participation, although only for girls.

Discussion

Among these two different samples of upper middle-class youth, gender differences early in the maths pipeline clearly emerged during senior high for the Australian sample, while no gender differences were apparent in the US sample. Motivations emphasised as important precursors to maths participation choices in the Expectancy-Value framework were found to predict course-taking decisions for boys and girls in both settings. How do these findings advance our understanding of when and why girls and women “leak” from the maths pipeline in these two contexts, in which gender differences in maths-related post-high school study and careers are clearly evident?

When does the mathematics pipeline start to “leak” for girls?

In the NSW Australian setting, fewer girls undertook the more difficult HSC maths courses. Because grade 11 is the first point where students are able to choose the difficulty level of mathematics that they wish to undertake, this implies that girls begin to opt out of the maths “pipeline” at their very first opportunity. Robust gender differences were apparent even among this sample of upper-middle class Australian adolescents. In contrast, in the US sample, boys and girls undertook similar numbers of maths courses, with the majority of students undertaking the maximum of four through grades 11 and 12. Given the increased importance of maths coursework to US college admission, and this upper-middle class sample demographic, it is not too surprising that most of these students undertook this high number of courses. In this setting, students may feel that they have little choice in how much maths they take. However, it is also important to keep in mind that the number of courses studied does not necessarily reflect the level of complexity in mathematical preparation that students experience. In the NSW Australian setting, although many university degrees specify maths as a prerequisite, none requires the highest 4-unit level for entry, and very few require the next highest 3-unit level. This greater choice in maths enrolments in the Australian setting, in combination with the operationalisation of maths participation according to difficulty level rather than amount, may be the main reasons for the gender differences in enrolments within the Australian sample.

Does this mean that the maths pipeline begins to “leak” later in the US than the Australian setting? It would appear that this is the case among the upper-middle class demographic, many of whom are likely to be university-bound, and therefore constrained in their freedom regarding how many maths courses to take. Fewer women still elect to study maths in post-secondary education (Bridgeman and Wendler, 1991;

Lips, 1992), and equally prepared women defect from maths in the undergraduate university context at a higher rate than men, especially in their early years of study (Oakes, 1990b). It seems that when girls and women are given the choice to opt out of maths, that they still do so more than is the case for boys and men. We should be concerned that girls continue to prematurely restrict their educational and career options through lower levels of participation in maths – the "critical filter" which channels access to many careers high in status and salary.

Why do girls choose to participate (or not participate) in maths?

Lower participation of girls in more difficult senior high maths in the Australian setting was not due to higher male achievement, either prior to or concurrent with the time at which students chose their grade 11 maths courses. Clearly, explanations other than gender differences in mathematical achievement must explain gendered maths participation[3]. The strongest influence on maths participation for both boys and girls was the extent to which they were interested in and liked maths – their intrinsic value for maths. This influence was stronger than that of their prior demonstrated mathematical achievement. A secondary factor was adolescents' self-perceptions about their own maths talent and their expectations for mathematical success. For girls, this effect appeared almost as strong as the influence of their prior mathematical achievement, while for boys it had a somewhat weaker impact. Self-perceptions also had a modest influence on senior high maths achievement, even when controlling for prior achievement in maths.

In the US sample, ability/expectancy beliefs, intrinsic value and importance value also had similarly strong impacts for girls. For boys, importance value did not predict maths course-taking, and ability beliefs and intrinsic value exerted similar yet somewhat weaker influences than for girls, of similar magnitude to the influences of prior mathematical achievement. It could be that boys' choices regarding whether to attend college are more constrained than those of girls, among this sample of upper-middle class adolescents, so that their personal motivations played a smaller role. Among this demographic, parents of boys have been reported to stress the importance of productive careers for their sons, while parents of girls emphasise being happy and well-adjusted as a primary goal for their daughters (Willis, 1989, p. 17). This may explain why importance value strongly influenced girls' course-taking but had no impact for boys. If expectations for boys to attend college among this sample were stronger, then it would make sense that the girls who attached greater importance to doing maths might be those with stronger aspirations to attend college.

Gender differences in motivations related to maths

Because intrinsic value and self-perceptions (in the Australian sample) or ability/expectancy beliefs (in the US sample) predicted senior high school maths participation over and above the influence of prior mathematical achievement, we need to ask about the sources of adolescents" mathematical perceptions. Are boys and girls equally interested in maths? In the Australian sample, boys indicated that they liked maths more than girls did, similar to previous research (Benbow and Stanley, 1984; Fredricks and Eccles, 2002; Updegraff *et al.*, 1996), although there was no gender difference in this US sample, perhaps a function of this particular demographic. Do boys and girls have similar self-perceptions related to maths, in line with their similar levels of maths achievement? Despite equivalent levels of mathematical achievement, in both samples boys rated their mathematical abilities significantly higher than girls. These findings are consistent with previous research (Eccles *et al.*, 1989; Eccles *et al.*, 1993; Singer and Stake, 1986), and imply that boys may be participating in maths to a higher degree than their actual ability levels warrant. This could create a spiral of benefits for boys, whose participation choices lead to preparation in more advanced maths, which then scaffolds their access to certain types of careers and educational opportunities. Even moderate levels of achievement in high level maths may promote this access for boys.

Because intrinsic value and self-perceptions were important influences on the extent of boys' and girls' later maths participation, girls' lower intrinsic value and self-perceptions are of particular concern. Such differences are evident even in very young boys and girls. A qualitative study based on seven women who had "opted out" of maths following completion of an undergraduate maths major (Stage and Maple, 1996) identified that interest in maths and beliefs about mathematical aptitude since early childhood had been the main determinants of their decision to complete a maths major. A study by Jacobs and her colleagues based on the present US sample (Jacobs *et al.*, 2002) identified higher maths values and ability perceptions for boys from as early as the second grade. Another study based on the present Australian sample also established that boys maintained higher levels of intrinsic value and self-perceptions throughout secondary school (Watt, 2004). Collectively, these findings show that gender differences in maths-related intrinsic value and self-perceptions are in place from early on, and imply that they need to be addressed from childhood. We need research studies to focus on exactly when it is that young boys' and girls' maths intrinsic values and self-perceptions begin to diverge, so that intervention efforts can be concentrated from that point.

Implications and outlook

Why is it that males continue to outnumber females in the field of mathematics, after more than two decades of research has investigated gendered maths participation? Although gender differences in senior high enrolments were not apparent within the US sample, it seems likely that women begin to opt out of maths in that context when they are given a real choice to do so. This may now be happening later in the US, at least among college-bound youth, given the increased importance of maths preparation for college entry. In the NSW Australian sample, where students have more degrees of freedom in their selected levels of senior high maths, we see that girls opt out of the more difficult maths courses during senior high school. Does this mean that we should more tightly constrain students' maths course-taking as in the US to enhance girls' retention in maths through high school completion? Should we develop policies to keep girls in the maths pipeline for as long as we can? But how long can we constrain girls to keep taking maths?

The maths "pipeline" metaphor has been critiqued by researchers such as Herzig (2004) and Adelman (1998). They have argued that such a metaphor implies students are passive actors in their education, reacting to "encountering a crack in the pipe" (Herzig, 2004, p. 199). The pipeline view has meant that researchers have tended to view limited career options as a result of limited participation in mathematics courses. In contrast, more than two decades ago Armstrong and Price (1982) suggested that causality may be operating in the reverse direction. They suggested that girls elect to opt out of studying maths due to recognition of limited career options. A long-term longitudinal study in the US has shown that many young women opt out of the choice of maths- and other STEM-related careers largely because of their desire for a family-flexible career (Frome *et al.*, 2006). These careers appear to have remained insufficiently flexible with regard to women's family responsibilities in practice, even if not in policy. Those researchers also found, similar to our present study, that women's lower ability-related beliefs and intrinsic value for maths were part of the explanation for their decision to abandon earlier-held STEM-related career aspirations. The "pipeline" is likely more complex than a sequential funnelling effect, with girls' prospective perceptions about the broader social milieu prematurely restricting their participation in maths.

Efforts to heighten adolescents' interest in and liking for maths should promote girls' participation in the maths "pipeline". Key factors which have previously been found to influence task interest include personal relevance, familiarity, novelty, activity level, and comprehensibility (Hidi and Baird, 1986). What we need to be asking as educators, is whether these factors are equally fulfilled for both boys and girls in maths classrooms. Over the past 15 years there have been significant reforms in elementary and secondary mathematics curricula and teaching practices to incorporate more collaborative, problem-focused and authentic instruction (Meece and Scantlebury, 2006). This has been because of the suggestions from prior research that girls take an active role and respond favourably in individualised and cooperative learning environments (Kahle and Meece, 1994; Parsons *et al.*, 1982). Eccles and her colleagues have demonstrated that girls are engaged by activities that they perceive to be socially meaningful and important (e.g. Vida and Eccles, 2003), while maths is often taught in skills-based, abstract and decontextualised ways. Making explicit connections between maths and its social uses and purposes may help to heighten girls' interest. Adolescents also often have quite inaccurate ideas of what careers involve developed mathematical skills, and detailed information about the maths required for a range of careers would be likely to promote girls' interest, when their preferred careers involve mathematics. Further, we need to better understand why it is that girls perceive themselves as having less talent or ability, and lower expectations of success at maths than boys, even though they perform similarly. Continued investigations into the origins and sources of gender differences in maths intrinsic values and self-perceptions promise to shed further light on the reasons for persistent "leaks" from the maths pipeline for girls. At the same time, we need to be focused on workplace reforms which provide family-friendly policies and practices, if we wish to attract girls and women towards careers related to maths in the long term.

Notes

1. Prior multigroup confirmatory factor analyses for boys and girls showed invariance of measurement properties across gender groups, a necessary first step before comparing structural paths for boys and girls.
2. Note that despite no significant structural path from grade 10 self-perceptions to grade 11 math achievement for girls ($\beta = 0.03$, n.s.), the correlation between these two constructs was similar for girls (0.39) to that for boys (0.38), indicating a possible suppression effect, likely due to the stronger correlation between self-perceptions and intrinsic value for girls (0.54) than boys (0.34).
3. It is important to point out that measured mathematical achievement is not synonymous with quantitative reasoning ability, because it depends partly on other factors including effort and study skills.

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