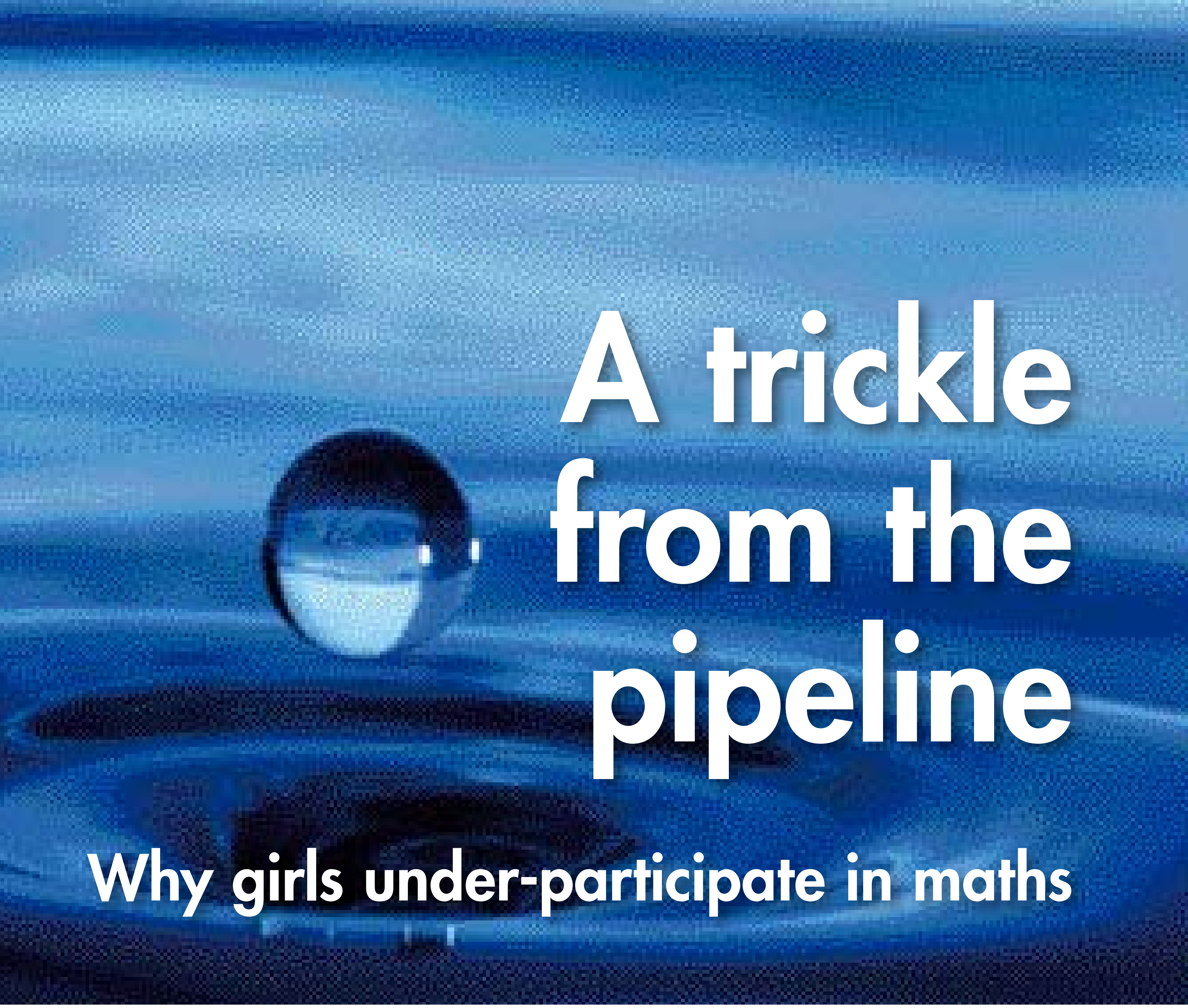

A trickle from the pipeline

Why girls under-participate in maths

Why do more girls than boys choose low-level maths in senior high school, and why do fewer girls than boys aspire to maths-related careers? **Helen Watt** explains what the research says, and what educators can do to increase the supply of females down the maths pipeline from a trickle into a flow.

TOO few women are represented at the top of the corporate ladder in maths-related careers largely because too few aspire to be involved in advanced maths. A pipeline metaphor has frequently been used to explain why this is the case, since the inadequate supply starts in secondary school, flows through university and eventually spills – or trickles – into the workforce. A consideration of gender differences and gendered influences at each of the critical pump stations in the pipeline is the key to interventions designed to promote women's participation.

In Australia and elsewhere, we've seen a concentration of research efforts and policy interventions designed to promote girls' and women's participation in mathematics over the past 25 years. Why then does a gender imbalance remain – and does it matter?

Despite equivalent levels of mathematical achievement, more girls than boys choose lower levels of maths in senior high school, and fewer girls aspire to maths-related careers than boys. This persistent pattern has been repeatedly identified and is currently of concern in Australia and many other countries. Two perspectives inform this concern: from a gender equity position girls do not share equally in the advantages of the mathematically well-prepared; while from an economic standpoint women are an under-utilised pool that could supplement the critical shortage of people electing the so-called STEM careers, in science, technology, engineering and mathematics.

Participation in advanced sciences and mathematics education has exponentially declined in the United States over the last two decades, to the point where there is grave concern about the viability of those disciplines to sustain economic growth and development according to reports by the US National Science Board in 2003 and the National Science Foundation in 2002. As is the case in many other Western nations, similar concern exists in Australia, as Kwong Lee Dow noted in his 2003 report for the Commonwealth government, as did the National Committee for the Mathematical Sciences of the Australian Academy of Science in 2006. Asian countries, however, do not show the same systematic pattern, as Janis Jacobs noted in the 2005 special edition of *New Directions for Child and Adolescent Development* – called 'Leaks in the pipeline to math, science and technology careers.' In the US, for example, the National Science Foundation's 2004 examination showed only 32 per cent of Bachelor degrees were in science or engineering; while according to the National Science Foundation's 2000 study, declines in undergraduate mathematics, engineering and physical sciences enrolments through the 1990s were 19 per cent, 21 per cent and 13 per cent respectively.

At the same time, the association of high-status, high-salary careers with advanced participation in the STEM disciplines has continued to fuel the concern of researchers with an interest in gender equity. Ever since Lucy Sells voiced social concerns in 1980 about lower female participation in maths courses in her identification of maths as the 'critical filter' limiting access to many high-status high-income careers, others have also argued that many females prematurely restrict their educational and career options by discontinuing their mathematical training in high school or soon after.

This has important ramifications for women's wellbeing, both from an economic or sociological and from a psychological point of view, as Judith Meece pointed out last year in 'Trends in women's employment in the early 21st Century.' First, gender differences in earning potential are important because women are more likely than men to be single, widowed or single heads of households, and therefore likely to need to support themselves and other dependants financially without assistance from a partner or significant other. Secondly, women as well as men need to develop and deploy their talents and abilities in their work outside the home, since this substantially impacts their general life satisfaction and psychological wellbeing.

The result of the under-representation of women in STEM careers is that these careers tend to reflect the values of the majority of male professionals. This in turn reinforces the gender imbalance through girls' and women's perceptions regarding the culture of those careers. This is most noticeable in relation to the ways in which such careers accommodate – or fail to accommodate – the familial obligations women often carry. The culture associated with male-dominated professions may affect girls' and women's aspirations towards those careers in the first place, stunt their development and progression should they enter those careers, and deter them from persisting.

EXPLANATIONS

Part of the explanation for the gender difference in maths participation lies in the fact that girls have less confidence in their mathematical abilities than boys – despite no gender differences in measured mathematical achievement. Does this

At a glance

- *Participation in advanced sciences and mathematics education is declining in general terms in Western countries, particularly for girls.*
- *Boys typically overestimate their mathematical abilities and over-participate in advanced maths, while girls typically underestimate their mathematical abilities under-participate in advanced maths.*
- *Competitive and 'performance-oriented' classroom environments, are likely to have deleterious effects and produce declines in maths interest and enjoyment, more so for girls than boys.*
- *Making explicit connections between maths and its social uses and purposes may help to enhance girls' interest.*

mean that girls are underestimating their mathematical abilities? In fact, there is a stronger relationship between mathematical ability beliefs and achievement for girls than for boys, suggesting that girls may actually be more realistic about their abilities, and that boys may be overestimating their abilities. This is not a bad thing for boys, because higher confidence translates into a spiral of benefits including advanced mathematical preparation. In contrast, the greater 'realism' on the part of girls may translate into levels of maths participation which are more commensurate with their abilities, resulting in a situation of boys over-participating rather than girls under-participating in advanced maths. Given the current critical shortage of people entering maths-related careers, it would be somewhat silly to suggest that educators should be focusing on discouraging boys' participation in high-level maths. Rather, we should be aiming to promote greater participation for both boys and girls, and especially for girls.

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Another part of the puzzle is that girls are less interested and have less liking for maths than boys, which has strong flow-on effects to their level of maths participation in high school and maths-related career choices. This provides a particularly effective lever for change. Since we know that girls are more likely to be engaged by activities that they see as socially meaningful and important, it's essential that educators make explicit connections between mathematics and its social uses and purposes. Adolescents also often have quite inaccurate ideas about the careers that involve developed mathematical skills, which suggests a strong need to provide detailed information about the maths required for a range of careers.

We also need further research into exactly when young boys' and girls' ability beliefs and interests begin to diverge so that intervention efforts can be concentrated from that point. A US study found gender differences in mathematical ability beliefs as early as Year 2! The fact that these differences emerge early doesn't mean that we should give up trying to address them through secondary school where there is much educators can do to try and increase girls' interest in mathematics. We need be *very* concerned about girls' and women's lower interest and self-concepts in maths, since they have substantial impacts on their maths participation, and a significant impact on our workforce.

Over the past 15 years, there have been significant reforms in primary and secondary mathematics and science curricula, as well as teaching practices to incorporate more collaborative, problem-focused and authentic instruction as Judith Meece and Kate Scantlebury describe in their 2006 article, 'Gender and schooling: progress and persistent barriers.' This is in response to research by Jane Kahle and Judith Meece, reported in 1994 in 'Research on gender issues in the classroom,' and by Jacquelynne Eccles (Parsons), Caroline Kaczala and Judith Meece, reported in 1982 in 'Socialisation of achievement attitudes and beliefs: classroom influences,' which has found that girls take a more active role and respond favourably in individualised and cooperative learning environments. Similarly, at the other end of the pipeline, there have been interventions designed and implemented to meet professional women's needs within STEM careers.

It's still not clear how such reforms will change young women's motivation, performance, development or persistence. Despite a plethora of intervention efforts particularly targeting the secondary school years, most of these programs have not been formally evaluated. There's also been a lack of longitudinal rather than one-shot examinations, a lack of large-scale and representative samples rather than small and opportune groups, a lack of representation across diverse samples and sociocultural settings, and a lack of representation and integration of diverse theoretical perspectives. Previous research to identify why women are less likely to end up in traditionally male-dominated spheres collectively points to the importance of factors such as gender differences in the motivations, self-concepts, interests, values and life-goals of individuals. It also points to the important influences of family planning, parents and biology. Finally, it points to the importance of sociocultural affordances and constraints on women's career development.

IMPLICATIONS FOR EDUCATORS

Socialisation experiences in the home strongly influence children's beliefs and values as Hugh Lytton and David Romney showed in 1991, and according to yet-to-be-published research by Jacquelynne Eccles, parents report spending almost no time on maths activities with their children. This finding is in stark contrast to the emphases on early reading in the literacy domain, and perhaps what is called for is a systematic campaign about the importance of early numeracy experiences. Given the centrality of maths interest to choices about maths participation, and girls' lower interest in maths than boys', it might be worth encouraging parents to focus on engaging in maths-related activities such as mathematical puzzles and problem-solving particularly with their young daughters as a possible way to enhance their interest and liking for maths.

The importance of parental beliefs as an influence on students' achievement-related attitudes, performance and career decisions has been established by a large body of literature reported in 'The career plans of science-talented rural adolescent girls,' by Janis Jacobs, Laura Finken, Nancy Griffin and Janet Wright. As Janis Jacobs and Jacquelynne Eccles have noted in various articles, parents' perceptions about their children's maths abilities are powerful influences on children's own perceptions, and parents' gendered perceptions of their children's mathematical ability are likely influences on students' gendered perceptions of their own abilities. Similarly, according to research by Kathleen Jodl, Alice Michael, Oksana Malanchuk, Jacquelynne Eccles and Arnold Sameroff, parents' maths values shape their children's maths values and occupational envisioning of themselves in the future.

Margaret Signorella and colleagues have pointed out, in 'Developmental differences in children's gender schemata about others,' that the male and female role

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models that children encounter, as well as the role models portrayed in the media, are broader important socialisation agents in the development of children's beliefs and values. To actively counter the stereotypes that promote men in maths-related domains, educators might explicitly provide maths-related female role models for children. It would be relatively simple, for example, to provide illustrations and biographies of important female mathematicians in children's stories and in the maths curriculum, rather than privileging 'patriarchs' of the discipline. Of course we could further contextualise this argument within a broader discourse addressing the exclusion of major contributions from other cultural groups aside from the contributions of contemporary women – for example, the historically important contributions from Arabic mathematicians.

Equally, 'performance-oriented' classroom environments, involving instructional practices such as pointing out ability differences, showing the work of best students as exemplars, and emphasising competition, have been found to produce declines in maths interest and enjoyment. Classes where students have high levels of desire to learn, according to Judith Meece, in 'The classroom context and students' motivational goals' in 1991, are ones that are characterised by opportunities for students to develop an increased sense of competence and to engage in self-directed learning, with an emphasis on authentic ability-related information and evaluation, peer cooperation and collaboration, and the intrinsic value of learning. Current emphases on external standards and the competition that characteristically follows don't typically engage learners.

For girls more than boys, competitive environments are likely to have deleterious effects. According to research by Jacquelynne Eccles, boys have been found to do better in competitive maths environments and worse in cooperative ones, while the reverse is true for girls. At best, it seems that girls find competitive environments less motivating, and at worst, aversive – learning less and perhaps avoiding future similar competitive environments, Eccles says. In contrast, according to Lynley and Eric Anderman, greater maths interest has been found for both boys and girls in cooperative classrooms.

Key factors which Suzanne Hidi and William Baird found in 1986 to influence task interest include personal relevance, familiarity, novelty, activity level and comprehensibility. What we need to be asking ourselves as educators, is whether these factors are equally fulfilled for both boys and girls in maths classrooms. Eccles and her colleagues have demonstrated that girls are less interested in maths than boys due to their desire to engage in activities that they perceive as socially meaningful and important. Maths is often taught in skills-based, abstract and decontextualised ways, and is unlikely to capture girls' interest for these reasons. Making explicit connections between maths and its social uses and purposes may help to enhance girls' interest. For example, students often have quite inaccurate ideas of what careers involve developed mathematical skills. Detailed information about the mathematical skills required across a range of careers would be likely to promote girls' interest in maths, when their preferred careers involve mathematics.

To enhance girls' participation in maths, I view the major tasks for future research as being to understand why girls express less liking for and interest in maths than boys from an early age, and to examine the bases for boys' and girls' perceptions about their own mathematical abilities. As well as modelling factors which promote maths participation, future studies could simultaneously investigate barriers to participation. Continued attention to contextual variables will shed further light on the persistent issue of the trickle of females from the maths pipeline.

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For references go to www.acer.edu.au/professionaleducator/references.html