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Research Review:

Engaging girls in STEM

a summary of academic research

by Kate Broadley

A child's mind is a raw resource, but unlike coal and iron ore it has an infinite potential. The difficulty is in nurturing that infinite potential towards scientific pursuits. (Universities Australia, 2012)

Girls are born with an inquiring mind. Through the nurture of their parents and families, the influence of friends, and the impact of education, these girls emerge from Year 12 ready to tailor their studies into careers. Somewhere along this journey a large proportion of girls disengage from Science, Technology, Engineering and Mathematics (STEM) and cut themselves off from the career prospects that flow from these fields. In particular, girls are far less interested in studying the 'enabling subjects' of higher-level mathematics, chemistry and physics. Why?

There are numerous answers to this question, which this research review will explore. A second underpinning question is - should we care if girls are not studying and working in the STEM fields in the same proportions as boys? Governments are grappling with these issues across the globe. Australia, New Zealand, Britain, the USA, and many countries in Europe and Asia have launched national STEM initiatives, developed policies and commissioned research to encourage girls (and boys) into STEM. Universities Australia (2012, p. 4) sums up the quandary neatly: "despite the current generation being voracious consumers of all things technological it appears that they are not increasing their ambitions to be the creators and innovators of tomorrow".

Innovative women who have trained in STEM sustain economies, think scientifically and critically, solve social justice inequalities, and inspire more girls into these fields. We need girls to follow the path of Nobel Prize winner Elizabeth Blackburn - the first Australian woman to win the prize - so that there are far fewer 'firsts' for women in STEM. Engaging girls in STEM is vital and valuable work, particularly for educators in girls' schools. The world's "dependence on knowledge and innovation will grow and not diminish and to be ahead in the race, a community needs the skills to anticipate rather than follow" (Office of the Chief Scientist, 2012b, p. 6).

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The broad STEM picture

There is no doubt that there are a decreasing number of students completing Year 12 studies in physics, chemistry and advanced mathematics (Engineers Australia, 2009). Over the past decade "there has been a decline in students studying science and mathematics at school, and fewer people seeking to train or undertake higher education in these fields" both nationally and internationally (Government of South Australia, 2011, p. 4). Enrolment of Australian "senior school students in science subjects is at present on a long-term declining trend in both absolute numbers and as a proportion of the total cohort" (Office of the Chief Scientist, 2012, p. 10). Specific statistics demonstrate:

> *Between 1992 and 2010 the percentage of the Year 12 cohort enrolled in Biology fell from 35.3 per cent to 24 per cent. For Chemistry the decline was from 22.9 per cent to 17.2 per cent; and for Physics it was from 20.8 per cent to 14.2 per cent. Mathematics participation declined from 76.6 per cent to 72.0 per cent between 2002 and 2010, and there is a continuing shift from intermediate and advanced levels of mathematics to the elementary level (Office of the Chief Scientist, 2012, p. 10).*

The disturbing fact is that there is no evidence this decrease in STEM enrolments has stopped or is slowing (Goodrum, Druhan & Abbs, 2011, p. 52). An Engineers Australia report (2009, p. 1) stated that "in Tasmania and the Northern Territory less than 5 percent, and Australia wide less than 12 percent of Year 12 students are studying advanced mathematics".

The underrepresentation of girls and women in STEM

Despite girls generally achieving just as highly as boys in these subjects, there is a distinct gender imbalance in the proportion of males and females who study these enabling subjects. After "controlling for capacities and achievements, female students still choose maths and science subjects in secondary school, and STEM courses in higher education far less frequently than male students" (Universities Australia, 2012, p. 5).

Forgasz has documented the concerning decline in the proportion of female students participating in secondary schools mathematics and she observes that girls are continuing to limit their career options by not pursuing mathematics to Year 12 (Tytler et al., 2008, p. 26). In Victoria, the 2011 enrolment pattern for specialist mathematics was 5.1% of girls compared with 11.1% of boys.

A recent report by Mack and Walsh (2013) analysed the proportion of NSW HSC students in mathematics and science. The authors compared data from the 1980s and found that, despite an increasing number of students participating in HSC, the proportion of total girls' participation in at least one maths and one science subject was 13.8% in 2011 (compared to 18.6% boys) (Mack & Walsh, 2013, p. 8). This data also reflected Foragsz' research, which showed that the only 1.5% of females studied advanced mathematics, physics and chemistry for their HSC. Of particular concern is the 21.5% of eligible females completing their 2011 NSW HSC who did not study *any* mathematics in their HSC subjects.

"Despite girls' underrepresentation in STEM in many countries, single-sex schools are bucking these trends and encouraging girls into STEM in greater proportions than their coeducational counterparts."

Girls are opting out of these subjects, despite their strong academic achievement:

> *Gender impacts significantly upon student career aspirations and subject selection. Research…finds that there are more female students choosing lower-level math courses than males, and that this difference is not based upon mathematics achievement. Controlling for prior performance, female students are over-represented in lower-level math courses and under-represented in higher-level math courses. Males are more likely to continue in STEM study than their female peers irrespective of past performance (Tytler et al., 2008, p. 93).*

The underrepresentation of girls in all mathematics, but particularly higher-level maths, is particularly worrying because mathematics is:

> *arguably the most fundamental enabling science, underpinning scientific research and innovation in all other areas of natural and physical science as well as being central to social sciences such as economics and demography. Mathematical sciences play a crucial role in a broad and diverse range of settings, among them data analysis, forecasting, modelling, risk assessment and design (Office of the Chief Scientist, 2012, p. 167).*

The majority of students who study science in secondary school "still do the traditional disciplines of biology, chemistry and physics in that order of popularity. There has been a slight increase in the other sciences, especially the subject of psychology (Goodrum et al., 2011, p. 49) which is taught in some Australian states. Biology remains the most common science subject among Year 12 students (Office of the Chief Scientist, 2012, p. 163).

There are obvious implications from the underrepresentation of girls in STEM in secondary school and the lack of women in the STEM tertiary sector. For students "there appear to be two important study decision points; the choosing of maths and science subjects in high school, and the choosing of STEM subjects in higher education… the choice of STEM subjects in higher education does not automatically follow from their choices and successes in science and maths subjects in high school" (Universities Australia, 2012, p. 5).

Women "represent the majority of Australian university enrolments (54%) but less than a third of tertiary STEM enrolments" (Tytler et al., 2008, p. 23). Women are "persistently overrepresented in the biological sciences" (Lyons et al., 2012, p. 4). At the university level, data from Australian universities for 2010 revealed:

> *The gender balance is roughly even in the broad field of Natural and Physical Sciences, but each narrow discipline has a different mix of male and female students. In the case of students enrolled in a BSc or similar degree and taking subjects at the continuing level, 2010 female student participation rates in the enabling sciences of chemistry, mathematics and physics were 46, 35 and 24 per cent respectively. Female enrolments in the Information Technology and Engineering fields… are both 14 per cent (Office of the Chief Scientist, 2012, p. 9).*

The National Centre for Social and Economic Modelling confirmed these figures: "…there are stark gender differences, with information technology, engineering, architecture and building courses all heavily skewed toward male student enrolments. Between 78% and 91% of all students in these courses are men" (Cassells et al., 2012, p. 14).

There is some evidence that significant changes in educational curriculums over the past two decades have contributed to the declining numbers in STEM. Students have more choice about the subjects they study, which means other "traditional subjects such as economics, accounting, geography, and political and social studies" have also seen decreasing enrolments while subjects such as business studies, hospitality, music, performing arts, creative and visual arts "have seen a substantial increase in enrolments" (Office of the Chief Scientist, 2012, p. 12).

These combined reports paint a bleak picture. Physical sciences, technology, engineering and mathematics participation rates at secondary school and in the tertiary sector have been in decline for decades. While the number of boys in these subjects has decreased, the gender disparity is worse for girls. Many girls are largely ruling themselves out of further study and a career in STEM by the subject choices they make at school.

Girls' schools champion STEM

Despite girls' underrepresentation in STEM in many countries, single-sex schools are bucking these trends and encouraging girls into STEM in greater proportions than their coeducational counterparts. The Institute of Physics in Britain (2012, p. 7) found that "girls were almost two and a half times more likely to go on to do A-level physics if they came from a girls' school rather than a co-ed school." The authors of this report speculated that physics "appears to be perceived differently in co-ed schools compared with single-sex schools. There is something about doing physics as a girl in a mixed setting that is particularly off-putting". Tytler et al. (2008, p. 95) describes this similarly: "in mixed gender classes teachers have been shown to subscribe to subtle, or not so subtle, expectations that boys have a natural inclination towards and talent for physical sciences and mathematics, and this is relayed through differential attention and through language, and reinforced by similar presumptions by boys".

Tully and Jacobs (2010) used enrolment data from engineering courses at the University of Technology in Sydney. Their study showed that 40% of all women engineering students at UTS attended a single-sex high school (p. 458). Approximately 22% of all female secondary students in NSW attend a single-sex school. "This is a striking comparison; the single-gender female participation in engineering [at UTS] is almost twice the average of female attendance at single-gender secondary schools" (p. 463). Echoing conclusions from the British IOP study, Tully and Jacobs (2010, p. 465) stated that "female single-gender classrooms can often display the most gender equitable learning environment when compared to coeducational classrooms and may pave a way for increased options for young women into future engineering paths". The "culture of a single gender school may provide a unique socialisation process, which allows a young woman the freedom to reach beyond stereotypical career expectations" (p. 463).

Using a similar study design, Griffiths and Richardson (2010) asked British women working in ICT about their career trajectories. More than 90% of women in the study attended single-sex schools and these women believed that their schooling countered attitudes "against sex stereotypes" (p. 107). Single-sex classes "provide a learning environment where the female voice is not marginalised. The personal attributes of the teachers, most notably their encouragement, care and availability… motivate these female students from single gender schools to excel" (Tully & Jacobs, 2010, p. 464).

A review of the place and progress of women in science in Australia by Bell, O'Halloran, Saw and Zhao (2009, p. 36) concluded that: "girls perform better in science in single-sex schools, especially when science and mathematics are compulsory subjects in high school." Schneeweis and Zweimuller (2012, p. 497) also determined:

> *Studies in educational science show that girls are doing better in male dominated subjects like math and science, are more likely to choose these subjects and are more likely found in male dominated occupations, if they are educated in single-sex classes. Coeducational settings appear to reinforce gender-stereotypes, while single-sex schooling gives more freedom in exploring interests and abilities, especially for female students.*

Kim and Law's (2012, p. 99) findings from Korea also concluded that "single-sex education shields girls from exposure to the prevailing gendered society and provides a favourable atmosphere for their success in maths and science." The school effect can be sizeable, as demonstrated by Legewie and Di Prete (2011, p. 1) who found that "the size of the gender gap in STEM orientation is quite sensitive to local high school influences; going to school at a high school that is supportive of a positive orientation by females towards math and science can reduce the gender gap in STEM bachelor degrees by 25% or more".

All of this research highlights the difference that girls' schools make; girls in single-sex schools study the enabling sciences and mathematics in greater proportions than girls in coeducational schools. However, there is more to be done. How can we continue to engage girls in STEM? Which programs work to encourage girls? In order to answer these questions, we must first look specifically at why girls are disengaging with STEM.

Why are girls disengaging with STEM?

For every girl there is a different answer to this question and we must not lose sight of individual girls when data and studies are analysed. However, some common themes have emerged that might explain the gender imbalances in STEM. This complex question will be broken down into four sections with possible solutions explored in the remainder of the research review. Many girls are disengaging with STEM before the age of 14; they are still affected by gender stereotypes and gender bias; they are influenced greatly by others and by the effects of STEM pedagogy and the curriculum.

1. Girls are switched onto STEM or turn away from STEM before they are 14 years old

Interest in science, technology, engineering and mathematics starts when girls are very young and is fostered at school. Researchers have found that, for the majority of students, "life aspirations are formed before the age of 14, with the implication that engaging students in STEM pathways becomes increasingly difficult after the early secondary school years" (Tytler et al., 2008, p. viii). Archer et al. (2012, p. 881) concurred "evidence suggests children's science aspirations are largely formed within the critical 10 to 14 age period." Kiwana, Kumar and Randerson (2011, p. 1) also stated that "girls are effectively ruling themselves out of a degree in engineering by the age of 14".

Therefore primary school and early secondary school are "critical phases in developing attitudes" (Tytler et al., 2008, p. 125). Tytler and colleagues also found that "across the primary-secondary transition numbers are not lost but students develop aspirations outside of STEM that influence their later choices. Thus in these years we can talk of a loss of aspiration related to STEM" (p. 5).

Goodrum et al. (2011, p. iv) believe that "the lower secondary years 7 to 10 are also important in terms of generating interest in science. The decrease in the number of students studying senior science is a reflection of our failure to engage students in science in lower secondary". The decision to enrol in Year 11 and 12 science and mathematics courses are made during the lower secondary years. Motivation for "post-school STEM study and STEM careers are well developed before students make subject choices for Year 12" (Anlezark, Lim, Semo & Nguyen, 2008, p. 6).

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Rowan-Kenyon, Swan and Creager (2012, p. 2) found that "students' early perceptions of support and sense of engagement in math classes and math activities strongly influence the broadening or narrowing of their math interest". Interest in science "at age 10 has been shown to be high and with little gender difference… although stark gender differences emerge as children get older. In the United Kingdom, research has shown that the point of decline begins in the final year of elementary school when students are aged 10/11" (Archer et al., 2012, p. 882).

Legewie and DiPrete (2011, p. 1) showed that the gender gap in STEM orientation "is largely a process that occurs during the high school years". Girls are "much more likely [than boys] to abandon a science career even when they expressed interest in eighth grade" (p. 13). Essentially, girls have a "lower rate of recruitment into a STEM orientation" between eighth grade and the final year of secondary school (p. 22). The effect of schools "on the science and engineering orientation of women is not temporary, but instead endures after high school" (p. 23).

On the flipside, Goodrum et al. (2011, p. 49) found that those who study science at Year 11 and 12 enjoy it. The "general picture that emerges is that fewer students are studying science but these fewer students enjoy the science they experience and it is in keeping with their expectations for the future. Science students have a very positive view about science and its importance in broader society" (p. 50).

Engage primary school girls in STEM

Girls need to be switched onto science and maths from the moment they enter formalised schooling. Interests "stabilise at an early age… efforts to increase girls' interests in the STEM fields to bridge the gender gap may also need to be initiated at formative years when children are developing gender roles and perceptions of appropriate careers" (Su, Rounds & Armstrong, 2009, p. 879).

If girls are either switched onto or turned off STEM by the time they are 14, then the primary school years are crucial for engaging girls. These subjects must be "taught systematically in all primary schools" (Engineers Australia, 2009, p. 2). Engagement is increased by "hands-on, learning-by-doing methodology" (Universities Australia, 2012, p. 2).

The teaching of spatial skills in the primary school warrants particular attention. Scores of "high-quality studies conducted over the past 50 years indicate that spatial thinking is central to STEM success" (Newcombe, 2010, p. 30). The relationship "between spatial thinking and STEM is a robust one, emerging for ordinary students and for gifted students, for men and women" (p. 30). Spatial thinking, defined as thinking concerning the "locations of objects, their shapes, their relations to each other, and the paths they take as they move" (p. 35) can be taught at school. Hill et al. (2010, p. 91) state that we need to "teach girls that intellectual skills, including spatial skills, are acquired…Spatial skills developed in elementary and middle school can promote student interest in mathematics, physics, and other areas".

2. Gender bias and gender stereotypes

Gender bias is subtle but very powerful and it still exists. As well as the more obvious forms of gender bias and gender stereotyping in the media and in popular culture, biases can form in girls, parents and educators. Moss-Racusin et al. (2012, p. 16476) found that female and male tertiary science professors displayed "strong pre-existing subtle bias against women". This gender bias against women translates into "large real-world disadvantages in the judgment and treatment of female science students" and it "impedes women's full participation in science" (p. 16477). Support and mentoring was seen as key to overcoming gender bias.

A 2012 campaign designed by the European Commission to promote girls in science saw the launch of a video called *Science: It's a girl thing!* In this ill-conceived video three women strut around in heels while a male scientist in a lab coat stares at them, and these shots are interspersed by exploding cosmetics. This example serves to show that gender stereotyping is still prevalent and an ongoing, uphill battle for the girls in our classrooms.

Role models counteract gender bias and gender stereotypes

Many girls still do not have realistic ideas about what STEM jobs look like. Only 5% of girls in OECD countries, on average, expect a career in engineering and computing, while 18% of boys expect a career in these fields (OECD, 2012, p. 2). Legewie and DiPrete (2011, p. 10) also found that "boys are more than twice as likely as girls to expect to work in science or engineering" in eighth grade.

One answer to girls' low STEM expectations and the gender bias they encounter is the vital presence of female role models. Girls need to be exposed to successful female role models in the STEM fields. Role models "can help counter negative stereotypes because girls see that people like them can be successful and stereotype threat can be managed and overcome" (Hill, Corbett & Rose, 2010, p. 42).

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Stout, Dasgupta, Hunsinger and McManus (2011, p. 255) conducted research into the use of experts to "inoculate women's self-concept in STEM". They found that "women's implicit self-perceptions and attitudes were profoundly affected by the presence versus absence of female experts" (p. 269). Seeing other "successful women in STEM promises to free young women in the present generation from a societally constrained view of their abilities" (p. 269). These researchers encouraged schools to actively promote women in STEM. Increasing the "visibility of a critical mass of female scientists, engineers, and mathematicians, and providing women opportunities to have personal contact with them, has a profound positive effect on young women's self-perceptions in science, math, and engineering" (p. 269).

Girls' schools are the ideal environment to foster mentors. Girls studying the enabling subjects in Years 11 and 12 can mentor primary and lower secondary girls. Links can be made with universities so that tertiary women can mentor school girls. Women who have successful STEM careers usually love to share their experiences with girls. The Alliance's website page *Women of Achievement* has dozens of examples of women who have made impactful careers in STEM. There are dozens of programs and websites which aim to link STEM mentors with school students in each country. The most successful STEM approaches and programs all use female mentors and role models.

3. The influence of others

Many researchers have examined how other people can encourage or dissuade girls from pursuing STEM. People of influence for girls may include parents, friends, teachers, mentors and careers advisors. In primary school it is largely parents who guide children but as they get older, girls are increasingly influenced by their peers and educators. Social support and cues from important people in children's lives contribute directly to their "ability to envision themselves in a future science career, which, in turn, predicts their interest in and motivation for a science career" (Buday, Stake & Peterson, 2012, p. 197).

The influence of teachers and inspirational teaching

The Office of the Australian Chief Scientist commissioned surveys of senior secondary school students and commencing university students. Both groups "nominated teachers as the most influential factor in determining a student's interest in and attitudes toward science. The most interesting and stimulating styles of teaching and learning were said to be student-led research, practical activities, and the study of real-world examples within the student's sphere of experience" (Office of the Chief Scientist, 2012, p. 10). Science students in high school and university "saw science teachers as an important source of inspiration for science learning. Teachers therefore hold a unique and central position in influencing students' interest in and attitudes towards science" (p. 42).

Science teachers educating students at Years 7-10 hold a special position of influence because these are the "formative years for the development of science attitudes among students. Students need teachers who are enthusiastic, motivated, well trained and confident in the subject areas they teach" (Office of the Chief Scientist, 2012, p. 55). Teachers' "influence on reinforcing or challenging gender stereotypes to young people cannot be underestimated" (Kiwana et al., 2011, p. 3).

The Universities Australia (2012, p. 1) report concluded that "study respondents consistently identified teachers with both passion and subject knowledge as important contributors to their career aspirations and choice of university subjects. Teachers who were perceived as boring or lacking in subject knowledge had strong negative effects on career aspirations and subject choices." These findings were echoed by Anlezark et al. (2008, p. 6) who found that "having good science teachers in high school is seen as an important motivator" for students.

Teachers "should appreciate that they often have a greater impact than they imagine on students' decisions about choosing STEM courses and careers" (Lyons et al., 2012, p. iii). Lyons et al. found that good teachers were rated as the most important individuals in students' "decisions to take STEM courses; more important than parents and peers. This finding was consistent with earlier research showing that Year 10 students rated their science teachers as having the greatest influence on decisions about taking science in Year 11" (p. iii). Female students "were significantly more inclined than males to regard personal encouragement from teachers as very important in their decisions to take STEM courses" (p. vi).

Motivational teachers engage girls in STEM. Inspirational teaching "is undoubtedly the key to the quality of our system, and to raising student interest to more acceptable levels. It is the most common thread running through the responses in every country where the issue has been assessed in any detail" (Office of the Chief Scientist, 2012b, p. 7).

The influence of families

Universities Australia (2012, p. 2) found that "parental encouragement into STEM for students is not time specific but occurs from before starting school to before starting university". Archer et al. (2012, p. 882) also determined that "the family plays an important role in helping to shape students' engagement, aspirations, and achievement/attainment in science". Moreover, "parental attitudes to science were found to be more closely related to children's science aspirations than general parental involvement in child's schooling or general parental aspirations" (p. 888). Therefore "supporting families to see science as a 'conceivable' and potentially desirable career option could provide a useful impetus and/or pillar of support for any nascent interest in science among children" (p. 905).

Two studies have found that mothers are particularly influential for girls. Leaper, Farkas and Spears Brown (2012, p. 278) determined that girls' maths and science motivation was associated with both mothers' and peers' support. Leaper et al. also reported that "girls tended to have stronger maths/science motivation if they had previously learned about feminism" and endorsed gender equality (p. 279). Lyons et al. (2012, p. vi) found that "females were significantly more likely than males to rate mothers as very important in their decisions to choose a STEM course".

While parental level of education, socio-economic status, and a family's socio-structural location are all important determinants of a girls' educational success, there are specific findings for STEM aspirations. A family's attitude to "science and their encouragement and fostering (or not) of science in their everyday family life (as constituted for instance through pastimes, activities, leisure consumption, TV, books, topics of conversation, social networks) seem likely to be more important influences on student science aspirations" (Archer et al., 2012, p. 888). Archer et al. also noted that it was important for families to make STEM a "thinkable", possible and realistic career for their children. Consequently "science was not 'just another subject'; it suffused all aspects of family life, such as daily topics of conversation, leisure time, and family activities and joint interests" (pp.890-891).

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The influence of careers advisors

The advice that girls are given from careers advisors at school may not be as important as that given by families and peers, but it is still influential in their career decision making process. Anlezark et al. (2008, p. 6) found that school "careers advisors are perceived by young people as more influential in steering young people away from, rather than into, STEM careers". Kiwana et al. (2011, p. 1) identified that "careers information, advice and guidance is still reinforcing gender stereotypes". Goodrum et al. (2011, p. 53) also noted from their research that adults had "actively discouraged some students, including interested and able students… from selecting science courses because of the perception that science subjects were difficult and time demanding."

The timing of formal careers and subject advice for students is also important. Universities Australia (2012, p. 1) stated that "high school students need to be made aware of the career opportunities afforded to STEM graduates at an earlier age, rather than in just Years 11 and 12".

Lyons et al. (2012, p. ii) recommend the establishment of a "comprehensive online resource for Careers Advisors, parents and students providing useful, reliable, and current advice on STEM courses and careers". Similarly, Schmidt, Hardinge and Rokutani (2012, p. 25) stated that "school counsellors would benefit from taking the necessary steps toward adopting and integrating… STEM initiatives into their work". STEM professional development for careers advisors would assist students "in career exploration and enhance data-based decisions for increasing mathematics and science interest" (Schmidt et al., 2012, p. 33).

Rowan-Kenyon et al. (2012, p. 10) suggested that school counsellors should engage parents "in the various aspects of the career development process, beginning early in a child's formal education". Childhood and adolescent "experiences influence choices, including career choices, made later in life. Intervention early in this trajectory is therefore critical" (p. 10).

Influencing high-achieving students

Careers advice is especially important for high-achieving students who "form the major labour supply for STEM occupations" (Anlezark et al., 2008, p. 6). High-achieving girls are often strong in multiple disciplines. Ceci, Williams and Barnett (2009, p. 218) found that women with "high math competence are disproportionately more likely to have high verbal competence, allowing for a greater choice of professions" (p. 218).

It is high-achieving girls in particular who need STEM encouragement because they are easily led into careers where there are fewer gender inequalities. Ceci et al. (2009, p. 218) concluded "mathematics-capable women disproportionately choose non-mathematics fields and that such preferences are apparent among math-competent girls during adolescence." An OECD report found that girls who are "high-achievers in science may not expect to become engineers or computer scientists; they direct their higher ambitions towards achieving the top places in other science-related professions, such as those in the health field" (OECD, 2012, p. 3).

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Therefore single-sex schools can actively guide high-achieving girls to explore STEM opportunities. This may be "achieved through the better promotion of STEM careers in the early years of high school, and through the better training and education of careers advisors in informing students about STEM career opportunities" (Anlezark et al., 2008, p. 6).

4. STEM pedagogy and curriculum

Many researchers and educators have speculated that the reason why students are disengaging with STEM comes down to the basic content, curriculum and teaching of science and mathematics at school. One report found an "almost universal" student view is that "mathematics and science are seen as boring and not related to real life" (Office of the Chief Scientist, 2012b, p. 20). Obviously we want to remove classroom experiences described by Engineers Australia (2009, p. 2) "which do little to stimulate curiosity, problem solving, depth of understanding and continued interest in learning among students, or to encourage them to undertake advanced study in STEM at school and beyond."

STEM subjects in the curriculum

Several studies conclude that "what is required to increase STEM participation is to make school mathematics and science more relevant to daily life, present it on a personal level and make it more relevant" (Universities Australia, 2012 p. 2). This is hardly revolutionary.

There are massive curriculum changes occurring at the national level in many countries. Part of the motivation for these changes is the student lack of interest in STEM. Kiwana et al. (2001, p. 1) speculate that perhaps the number of compulsory subjects "studied at ages 14–18 [should] include mathematics and physics". Wilson (2013) agrees that maths and science should be mandatory subjects through till Year 12. Although science and mathematics are well represented in the choice of subjects, technology is not. Technology is often confined to the TAFE sector. In "too many schools, STEM is still mostly science and mathematics, taught separately with little or no attention to technology and engineering" (Hoachlander & Yanofsky, 2011, p. 60).

Partnerships, pathways and programs

New initiatives can positively influence girls. Building and sustaining partnerships "between schools, industry, business, research and higher education institutions… will enable us to expand knowledge of STEM subjects and career pathways among students, teachers and parents" (Government of South Australia, 2011, p. 7).

There are many examples of successful girls-only programs that encourage students into STEM. The Digital Divas program, which aims to get girls into technology, is highly appealing and successful (Fisher et al., 2012). Work experience can also be a STEM influencing time. Lyons et al. (2012, p. iv) found that 94% of their female sample groups said that work experience placements encouraged their decision to study STEM.

Conclusions

Several factors are irrefutable. Firstly, many girls are not engaging in STEM and this reflects a trend that has gained momentum over the past decade and shows little sign of stopping. Secondly, while girls' schools are encouraging girls into STEM in greater numbers than coeducational schools, there is still more work to be done. Thirdly, this topic is important and we must all continue to engage girls in STEM because STEM literacies are fundamental for innovation and economic growth (Engineers Australia, 2009, p. 1).

There are myriad problems and solutions. It is heartening to read the reports from Alliance member schools in this magazine who are actively engaging girls in STEM by: designing innovative STEM curriculum and pedagogy, providing female mentors, trialling STEM programs and partnerships, supporting innovative teachers, boosting girls' confidence in STEM, and hopefully engaging a generation of girls who will redress the gender imbalance in science, technology, engineering and mathematics.

This paper has outlined some common themes. It is worth considering Bell et al. (2009, p. 59) when they ask the question "Which girls?" Certainly *all* girls need to be encouraged from primary school with their spatial learning, with hands-on lessons which encompass the fundamental STEM skills and literacies. For this to occur we need blanket curricular and pedagogical approaches. All girls should be switched onto STEM and given the opportunity to study these subjects at the tail-end of secondary school and in the tertiary sector.

However, perhaps more targeted and specific approaches are necessary for high-achieving girls who show an aptitude for STEM but who are choosing not to engage with STEM. Specific programs, internships, mentorships and targeted intervention may be necessary for this group of girls.

Hill et al. (2010, p. 90) conclude that we must "spread the word about girls' and women's achievements in maths and science… The more people hear this kind of information, the harder it becomes for them to believe that boys and men are better in these areas". Girls' schools are in a unique and privileged position to spread the word and engage girls specifically in the subjects of science, technology, engineering and mathematics.

Abbotsleigh's 'playground of the mind' in an outdoor setting that provokes interest, curiosity and engagement in mathematical and scientific games and therefore thinking.

Where are the women in Australian Science?

www.austehc.unimelb.edu.au/wisa/wisa.html

Where are the Women in Australian Science provides information about women and the roles they played in the history of Australian science, technology and medicine from the earliest periods of European engagement to the present day.

The exhibition links to biographical, bibliographical and archival information held in the Encyclopedia of Australian Science database.

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