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Participation of women in Engineering: Challenges and productive interventions

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Executive Summary

Building science, technology, engineering and mathematics (STEM) skills in students at all school levels is essential to building the next generation of engineering workers and engineering skills. Despite more than two decades of initiatives, the under-representation of women in engineering has been a longstanding concern in Australia. This is related to concerns about levels of participation in engineering overall, and to current concerns about attitudes to and participation in STEM subjects and career pathways generally, and for women in the natural and physical sciences and higher level mathematics at school, university and the workplace. This review analyses factors affecting the participation of women in engineering, covering the full extent of the STEM pipeline across the schooling years but focusing particularly on girls' exposure to and engagement with engineering across those years.

There are four main factors identified in the literature influencing STEM participation of women:

- Gender stereotypes, which include the belief that science and maths are masculine subjects and as a consequence, people often hold negative attitudes to women in 'masculine' STEM careers.
- Women, from early childhood to adulthood, encounter social-psychological barriers to participating in the STEM fields. For example, parents often believe that boys are more interested and capable in STEM subjects and that STEM subjects are more difficult and less important for girls than boys. This can be interpreted in terms of girl's identity development where images of work in STEM do not match with girls' views of meaningful personal futures.
- There are small numbers of women in STEM leadership roles, for example, in academic leadership positions, who could encourage and support women's participation.
- The perceived nature, organisation and career pathways of STEM fields of study and employment are barriers for women's participation in STEM. For example, young people lack a clear understanding of what engineering and technology careers entail.

Within this broader STEM area, there are a number of factors specific to participation of women in engineering that have been identified in this review.

- Negative images about engineering study and careers, and self-perceptions that draw female students (who have ability in mathematics and science) to prefer medicine, veterinary science, and architecture.
- There are strong gender disparities in some of the influences which motivate study in engineering. For example, female students were significantly less influenced by 'enjoying knowing how things work' or 'enjoying building stuff'.
- Careers advisers in many schools are not adequately supporting female students who might consider engineering.
- The lack of growth in the number of female high school students studying pre-requisite subjects (e.g., higher level school maths and physics).
- There are masculine biases in engineering curriculum, assessment methods and the learning environment.

- Women academics in engineering are disadvantaged by family responsibilities, reduced mobility compared with male academics, the role of research, teaching and administration in appointments and promotions, lack of career planning, lack of mentors and networking and direct discrimination and prejudice.

This review found that the barriers and opportunities relating to women's participation in engineering occur at all points along people's education and work pathways, from early engagement with STEM activities and interests in the early years and primary school through educational experiences in secondary school leading to subject choices, to the experiences of women in university engineering courses and then in the workplace. Each point in this trajectory presents different needs and opportunities that could form the basis of productive interventions. Allied to this, the specificity of productive interventions will change with age. The review suggests that particular types of intervention could provide promise of successfully establishing attitudes and aspirations, and engagement, at different points along the age continuum. These are noted below, and diagrammatically represented, broken into the three broad dimensions of curriculum and pedagogy, mentoring and role models, and structure and context.

1. Promotion of activities in the early years that are exploratory and engaging, that focus on interest and confidence with spatial, scientific and mathematical competence.
2. Primary and lower secondary school curriculum activities / resources that link science and mathematics with socially progressive purposes and that employ inquiry and problem solving pedagogies. This would ideally involve working closely with teachers.
3. Scientific and design challenges for upper primary and secondary students, that focus on topics of interest to girls (rather than traditional male-centred car and bridge type challenges) and present role models and career information that open up identity possibilities for girls.
4. Links between scientists and engineers, and schools, which provide positive female identity role models for students along the schooling continuum.
5. Engineering/design activities and topics in the upper schooling years together with role models and career advice, which provide attractive identity futures for girls at the points of choice at year 10, 11 and 12.
6. Strategies to encourage upper secondary school students to enrol in subjects important as prerequisites in engineering, such as intermediate and advanced mathematics.
7. Targeted provision of female mentors and role models during engineering degrees, and in the workplace.
8. Opening out of university engineering curricula to allow more choice and diversity for female students, to combine engineering technical aspects with subjects that provide social purposes. This may include shifting to more inquiry-oriented and values-focused pedagogies.

Workplace

Tertiary

Secondary school

Primary school

Early years

Curriculum and pedagogy

*Emphasizing intellectually challenging learning activities that are directly connected to real world problems

Using complex civic issues and their consequences as broader context for teaching STEM subjects

Designing engineering courses to have less content and include more attention to social, political and ethical aspects

Focusing on hands-on classes and project-based learning

*Curriculum resources reflect the identity needs of female students (include topics that include societally relevant work and narratives of women and non-stereotypical STEM careers)

*Including engineering experiences within the curriculum, including outreach programs.

Increased focus on inquiry-based science and problem-based mathematics

Working with teachers to promote the discussion of values, and social uses of mathematics and science

*Focus on engaging early interest in exploratory science and mathematics activities

Mentors and role models

* The most effective interventions involve women in engineering leadership positions providing mentoring support and role modelling to women engineers

*Mentoring through gender-specific programs with female engineers, working as mentors and role models to address stereotypes of the engineering workforce.

This can involve collaboration between university and networks of engineers

Bringing together young women and successful female STEM professionals to provide an authentic understanding of STEM careers, and access to female role models

Career advice to include a) a focus on the creative and imaginative nature of STEM and offering diverse opportunities, b) how engineers contribute in improving society and c) the earning potential and marketability of STEM skills.

For younger students, increasing awareness of work in STEM as an identity possibility.

Structure and context

Maternity pay and provision for paternity pay and leave, incentives to return to work, flexible working hours, child care provision, and support for family mobility. Promoting more women to leadership positions.

Promoting a generic role for engineering degrees.

Offering flexible course structures

Scholarships and fellowships for female students and researchers in engineering

Encouraging girls to select higher level mathematics options.

Working with parents and parent groups to promote a) valuing of mathematics/science as opening future possibilities for their daughters, b) informed decisions in subject choice, c) informed advice on careers and d) confidence in girls' ability to succeed and prosper in STEM

*For parents of early years children, engaging them to become involved in and enthusiastic about STEM activities.

Introduction

Engineering-related studies and occupations depend on science, technology, engineering and mathematics (STEM) skills that are developed at school levels. Building STEM skills in students at school levels is therefore essential to building the next generation of engineering workers and engineering skills. Despite twenty years of initiatives the under-representation of women in engineering has continued in Australia (Godfrey & Holland, 2011). This review analyses factors affecting participation of women in engineering, covering the full extent of the STEM pipeline across the schooling years but focusing particularly on girls' exposure to and engagement with engineering across those years. The other focus for the review will be successful interventions that encourage females into the STEM workforce, and particularly the engineering pipeline.

The review team has considerable experience in this area, covering research on participation in STEM across the schooling and university years, experience with engineering education over a number of decades, and a network of contacts in these areas. The literature search strategy employed consisted of two parts:

- A literature search using key words. A series of keywords was generated that were refined through team consultations as the search proceeded. Using these keywords library databases were searched for journal articles, books and reports. The databases consulted include A+ Education, Proquest Education Journals, Proquest Dissertations and Theses, PsycINFO, British education index, Ebook library, Education Research Complete (EBSCO), Educational Resources Information Center (ERIC), Expanded Academic ASAP, Google Scholar, Web of Science (ISI), Deakin University Library Catalogue and Monash University Library Catalogue. These searches were supplemented by Google searches using the same keywords, and searches of government and industry group sites for reports and papers.
- Using a network of engineering educators in Australia to identify key issues and innovations focused on gender participation, both in Australia and internationally, that are represented in formal and informal literatures (such as internal and working documents, course outlines, evaluations).

An Endnote library was developed to help citation and manage literature. The team members, on a regular basis, communicated and consulted electronically and through face to face. The draft documents were circulated to team members for further comment and refinement. Gender is a central issue in any consideration of the participation of females in engineering. This report acknowledges that many people identify their gender in more complex ways than simply female or male, but the full consideration of gender diversity and its relation to engineering education and the engineering workforce was beyond the scope of this report.

Participation in STEM – global issues

Science, technology, engineering, and mathematics (STEM) are widely regarded as critical to the national economy (Fensham, 2008). A recent report, published by the Office of the Chief Scientist (2012b), noted that STEM disciplines

> provide enabling skills and knowledge that increasingly underpin many professions and trades and the skills of a technologically based workforce. They are the disciplines that help us to understand the natural world, and enable us to build a constructed world in which we apply what we know to improve the lot of human-kind. They are seen as part

of the essential path to a future that is broadly socially, culturally and economically prosperous. (p. 12)

Concern about Australia's ability to be competitive in the global economy has led to a number of calls to action to strengthen the pipeline into these fields (Office of the Chief Scientist, 2012b). Recent studies in regards to the Australian students' participation in post-compulsory science and mathematics subjects reported that the proportion of enrolments in mathematics and science in Year 12 has decreased over the years (Ainley, Kos, & Nicholas, 2008; Goodrum, Druhan, & Abbs, 2011; Kennedy, Lyons, & Quinn, 2014).

Goodrum et al (2011) reported that the percentage of students studying science in Year 12 decreased from a height of 94.1 % in 1992 to a low of 51.42 % in 2010. During this period, the proportion of Year 12 students taking physics, chemistry and biology fell by 31 %, 23 % and 32 % respectively. In a recent study, Kennedy et al (2014) have collected raw enrolment data from the education departments of each of the Australian states and territories from 1992 to 2012 and analysed the trends for each of the science and mathematics subjects. Figure 1 presents participation rates of students as a percentage of the enrolled cohort.

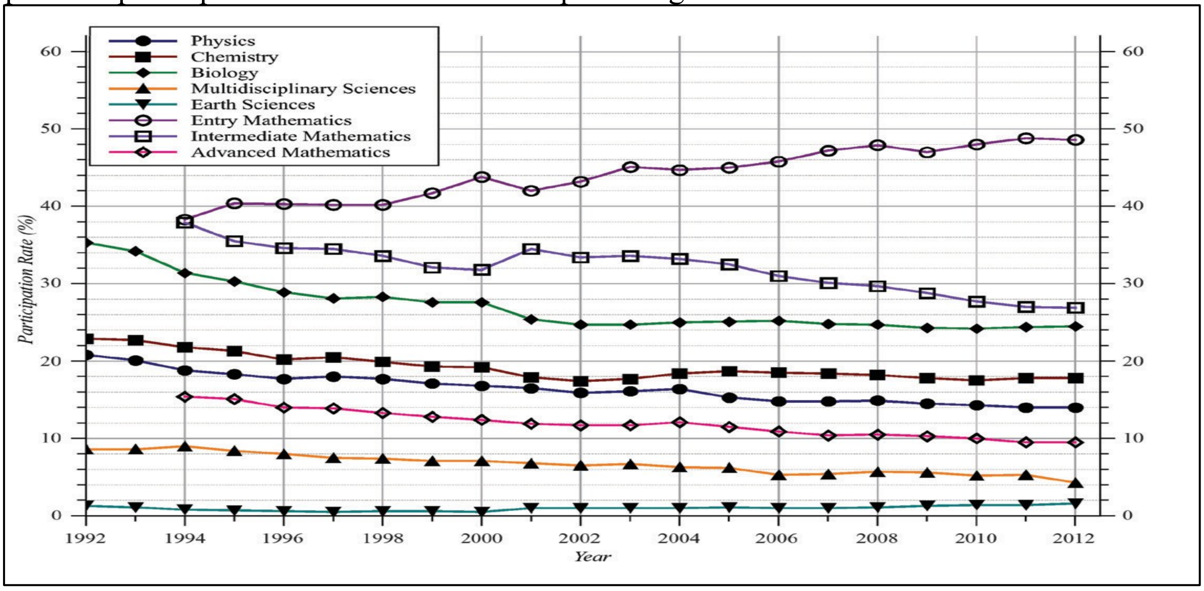

Figure 1. Participation rates for science and mathematics subjects, 1992-2012 (Kennedy et al., 2014, p. 39)

The Figure 1 generally shows declines in rates of participation for most of the science and mathematics subjects. While Biology has remained the most popular science subject throughout this period, the proportion of students enrolled in Biology declined from around 35 % in 1992 to around 25 % in 2012. The proportions of students enrolled in Physics, Chemistry and Multidisciplinary Sciences declined by around 7 %, 5 % and 5 % respectively between 1992 and 2012. Throughout the period, Earth Sciences have attracted the fewest enrolments of all the mainstream Science courses and the participation rates in this subject have been reasonably stable.

Data relating to mathematics subjects show that, Entry Mathematics has been the most popular subjects over the years. The proportion of students enrolled in Entry Mathematics has risen by around 11 % between 1994 and 2012. On the other hand, Intermediate Mathematics displays the opposite trend to Entry Mathematics. The proportion of students enrolled in Intermediate Mathematics has fallen by 11 % in this period. Advanced Mathematics has followed a similar trend to Physics and to some extent Chemistry. The proportion of students enrolled in Advanced Mathematics declined from around 15 % in 1994 to a low point of 9 %

in 2012. As intermediate and advanced mathematics are considered important for engineering tertiary study, decreasing participation in these higher mathematics subjects would impact on the engineering pipeline. The low participation of secondary school students in the STEM subjects is thus of concern to engineering-related industries as low levels of student engagement with advanced mathematics and sciences restrict the numbers of students with STEM skills that can articulate into tertiary engineering courses.

Similar to the declining participation in advanced mathematics, Australian students' performance in international assessment has also decreased (Thomson, De Bortoli, & Sarah, 2013). As Thomson and her colleagues reported, Australia's mean mathematical literacy performance declined significantly between PISA 2003 and PISA 2012 by 20 score points on average. Specifically, the PISA mathematical literacy score declined from 524 in 2003 to 514 in 2009 to 504 in 2012. There has been a significant decline in the performance of Australian top performers, average performers and low performers. Between PISA 2003 and PISA 2012, the proportion of Australian low performers significantly increased and the proportion of Australian top performers significantly decreased (by 5% in each case). As mathematical literacy reflects the capacity to draw upon mathematics in new contexts to interpret data and solve problems rather than just reproduce taught procedures, this decline in performance for secondary students is likely to have repercussions for their later participation in STEM-related higher education and career pathways.

As might be expected, reports on participation in university science courses indicate a flow-on effect from school enrolment trends. A recent report by the Office of the Chief Scientist (2012a) analysed enrolment trends of Australian domestic students in STEM-related fields. Figure 2 is adopted from this report. It presents proportion of enrolments in these fields.

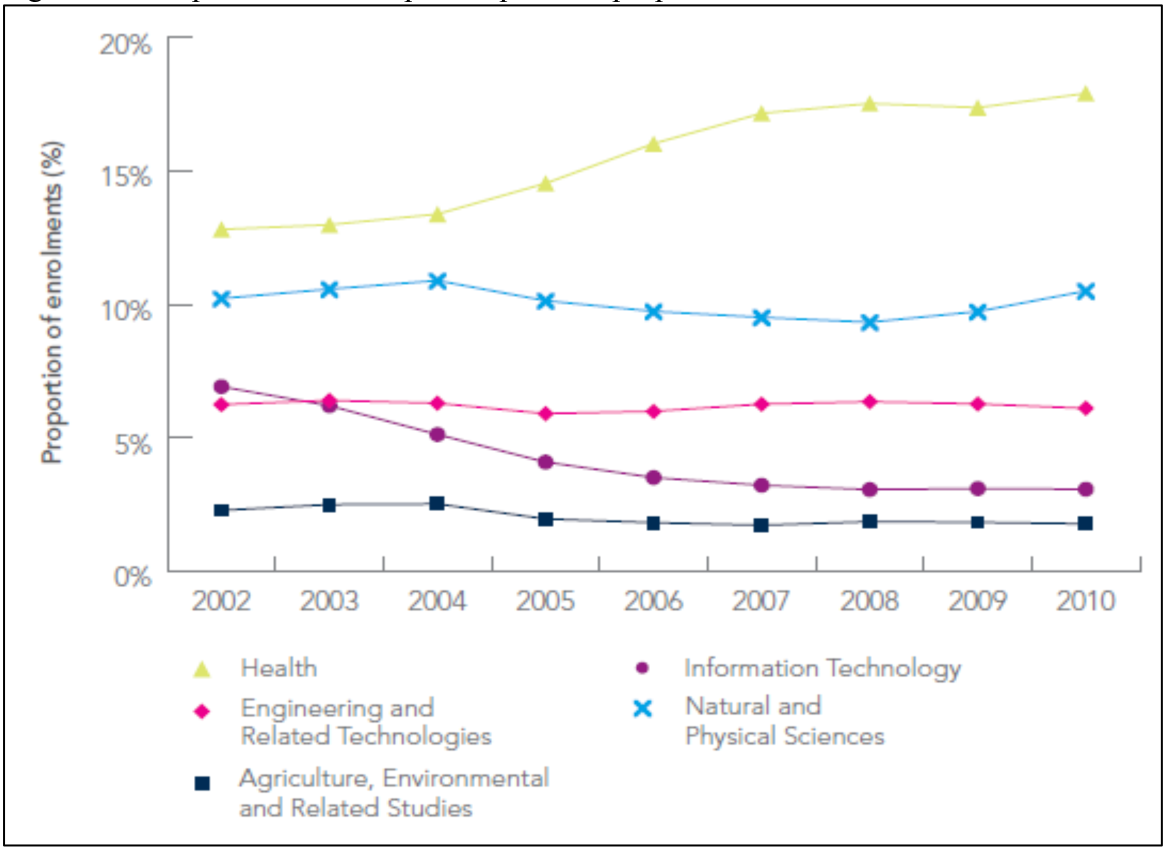

Figure 2. Commencing domestic bachelor's (pass and graduate entry) enrolments: STEM-related fields of education (Office of the Chief Scientist, 2012a, p. 71)

As the Office of the Chief Scientist reported, for the period 2002-2010, commencing domestic undergraduate enrolments increased overall by 23.6 %. In terms of undergraduate participation in STEM in the year of 2010, commencing enrolments in (a) Health represented around 18 %, (b) Natural and Physical Sciences represented 10.5 %, (c) Engineering represented 6.1 %, (d) Information Technology represented 3 %, and (e) Agriculture and Environment represented 1.7 % of all commencing undergraduate enrolments. Figure 2 shows that while enrolments in the Health sciences have increased over that period, as a proportion of total enrolments, enrolments in the Natural and Physical Sciences, and Engineering remained relatively static. Thus, the expansion of participation in tertiary education did nothing to address the historical shortfall in these areas. Further, enrolments in Information Technology, and Agriculture and Environment decreased by around 50 % and 4 % respectively.

Most developed countries appear to be experiencing similar enrolment trends to Australia at the high school or tertiary level of education. Declines in student participation and interest in science has been the focus of a recent European report, Science Education in Europe: Critical Reflections (Osborne & Dillon, 2008). This report highlighted how European countries, particularly, France Germany, the Netherlands, Sweden and the UK, were facing a decline in student interest and participation in STEM. As cited in Lyons and Quinn (2010), Barmby, Kind and Jones (2008) reported a 41 % fall in the number of students going on to study Advanced-level physics between 1985 and 2006, while Denholm (2006) reported that in Scotland enrolments in physics and chemistry declined by 15.1 % and 8.4 % respectively between 2001 and 2006. Lyons and Quinn also reported that New Zealand, Canada, Israel, Japan and Ireland are also observing a declining trend in student participation in STEM.

Some developing countries, on the other hand, have made progress in regards to increasing student participation in STEM, particularly in female participation in engineering. Turkey, for example, has been successful over the past 75 years in moving from being a society with almost no female participation in engineering to proportions higher than those currently found in the USA or Europe (A. Smith & Dengiz, 2010). In Turkey undergraduate women engineering students comprised nearly 22 %, graduate women engineering students were 32 %, and women academics in engineering were about 28 %. In India, there has been a tremendous increase in the enrolment of women in undergraduate engineering education, particularly in the computer-related fields (Gupta, 2012). Matthews (2014) reported how some Arab countries have seen a rise in female engineering students. For example, in Jordan female participation in engineering is 35.4 %. When graduates in engineering, manufacturing, and construction were counted together, women accounted for 43 % in Brunei, 36 % in Algeria, 34 % in the United Arab Emirates, 29 % in the West Bank and Gaza, and 27 % in Lebanon. Similarly, in Malaysia, a Muslim-dominant country, female participation in undergraduate engineering courses is 35.7 %. It is clear that, given the right contextual and cultural conditions, participation of women in engineering can markedly increase.

Issues in school STEM education

Bybee (2013) argued that a key issues in school STEM education is that its purpose is often not clear to the stakeholders of education, and that this creates ambiguity about the role of STEM education. He stressed that individuals, such as teachers, curriculum developers and the policy makers at the local and national levels would have general agreement on the purpose of STEM education. He proposed that the purpose of STEM education for all students in school is to promote STEM literacy, which refers to an individual’s:

- knowledge, attitudes and skills to identify questions and problems in life situations, explain the natural and designed world, and draw evidence-based conclusions about STEM-related issues;
- understanding of the characteristic features of STEM disciplines as form of human knowledge, inquiry, and design;
- awareness of how STEM disciplines shape our material, intellectual, and cultural environments; and
- willingness to engage in STEM-related issues and with the ideas of science, technology, engineering, and mathematics as a constructive, concerned, and reflective citizen.

(Bybee, 2013, p. 5)

Tytler (2007), in his Re-imagining Science Education report, outlines four major elements in the crisis of contemporary school science education:

- students developing increasingly negative attitudes to science over the secondary school years
- decreasing participation in post-compulsory science subjects, especially the physical sciences and higher mathematics
- a shortage of science-qualified people in the skilled workforce
- a shortage of qualified science teachers

Figure 3 illustrates how these aspects are linked and how they impact on science education.

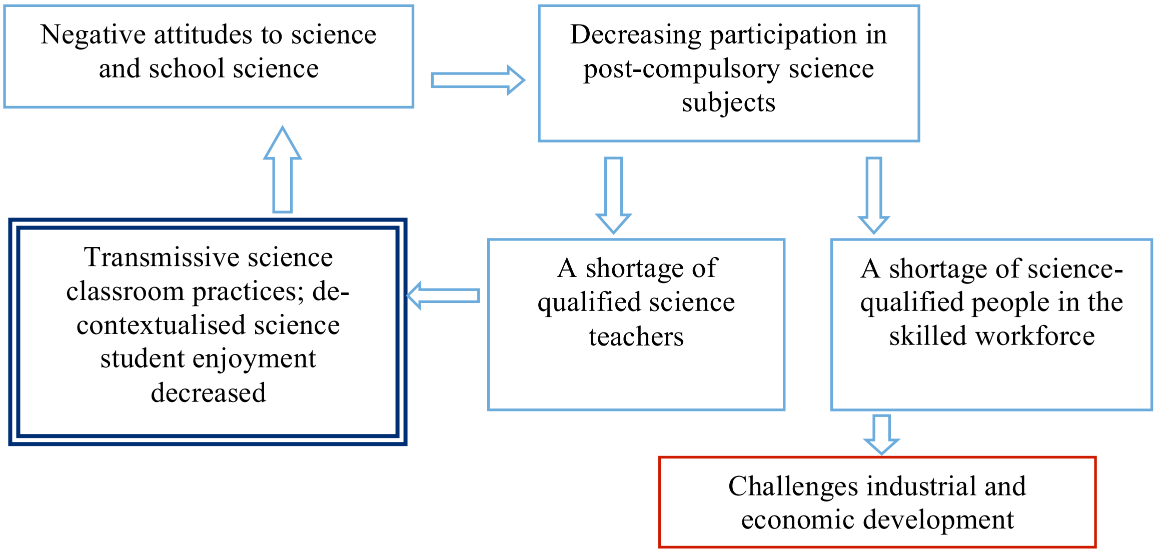

Figure 3. Major elements in the crisis of contemporary school science education and their implications. The Figure is drawn from the ideas discussed in Tytler (2007) and Fensham (2008).

Shortages of qualified science teachers and science-qualified professionals have different implications. As Fensham (2008) has argued, in the 21st century, science-qualified people are recognised everywhere as key players in ensuring that industrial and economic development occurs in a socially and environmentally sustainable way. Therefore, a shortage of these professionals has serious implications for the economy of all countries and on the health of their citizens. On the other hand, the shortage of qualified science teachers will impact on the quality of science classroom practice, and hence the enjoyment and learning of science by students, and this in turn will lead to a drop in numbers taking up science, and going into science teaching. Tytler (2007) explored the dimensions of this crisis, arguing that the problem lay in a mismatch between the science curriculum, contemporary practice in science, and the lives and interests of students in post-industrial societies. Evidence from TIMSS and from the Relevance of Science Education (ROSE) study shows that positive student attitudes to science negatively correlate with the degree of industrial advancement of countries, and that decreasing participation in STEM is a particular problem for post-industrial societies (Tytler, 2014).

The crisis elements in science education presented above are also relevant to mathematics (Forgasz, 2008; Forgasz & Leder, 2011), and point to a significant problem with student engagement with STEM subjects generally. Williams (2006) explored student engagement in mathematics in the middle years, and found that even in classes with recognised good teachers, there was little evidence of high-level intellectual and affective engagement with mathematics and where it did occur, it was upon the initiative of the student rather than as an explicit intention of the teacher.

Goodrum et al (2011) argued that the decrease in the number of students studying senior science and mathematics is associated with failure to engage students in science in lower secondary. Lyon and Quinn (2010), however, argued that the decline in student participation in STEM subjects were likely to be a consequence of both the academic and career aspirations of students and the associated diversification of curriculum offerings that included the introduction of alternative and vocational courses. The following section sheds lights on how the school STEM education has failed to stimulate student interest and engagement in STEM subjects.

Factors affecting engagement of students in science and mathematics in school, and STEM career pathways

Research suggests that school science education is often found inadequate to stimulate student interest and engagement in science. A large body of science education literature has discussed these inadequacies from students' perspectives.

Student attitudes to STEM

TIMSS 2011 data (Australian Mathematical Sciences Institute [AMSI], 2014) illustrated that 33 % of Year 8 Australian students do not like science. This picture was found to be more severe when students were asked about how they value science. 44 % of Year 8 Australian students expressed that they do not value science.

There have been both local and global concerns about the increasingly negative response to science from students across Years 7–10. A number of Australian studies over the last two decades have shown a general decline in students' interest and enjoyment of science across the compulsory secondary school years, with a particularly sharp decline across the primary to secondary school transition (e.g., Goodrum, 2006; Goodrum, Hackling, & Rennie, 2001; Lyons, 2006b; Rennie, Goodrum, & Hackling, 2001; Rosier, Banks, & Australian Council for Educational Research, 1990). Speering and Rennie (1996) noted, it is in these years that attitudes to the pursuit of science subjects and careers are formed; therefore this decline in interest in science in the early years of secondary school is particularly of concern.

Speering and Rennie's (1996) longitudinal study mapped the transition between primary and secondary school in Western Australia from the students' point of view in the context of science teaching and learning. Using a mixed methods design, this study found a considerable change in the organisation of the school, the curriculum and the teacher-student relationship during this transition. Students in this study, especially the girls, expressed their dissatisfaction with the teaching strategies used in their secondary science classrooms. They rated the teacher-student relationships of their primary school higher than that of the secondary school, and considered that it was regret for them to lose the close teacher-student relationship of their primary school years. They also viewed that science in secondary school was not what they had expected, and that may have long-term implications for their subject and career choices.

Reviewing the results of the Australian attitude data from the TIMSS 2002 survey, Thomson and Fleming (2004) reported that the percentage of high level of student self-confidence in science dropped from 66 % to 49 % between Year 4 and Year 8 students. In a similar vein, the percentage of students reporting that they like science 'to some extent' dropped from 87 % to 67 % between Year 4 and Year 8. An analysis from a gender perspective showed that while there was no difference between males and females in enjoyment of learning science at year 4, at Year 8, females appeared to enjoy learning science less than males. There was only 36 % of Year 8 students who reported that they liked science 'a lot' and this figure was almost half that of the international average.

There have been a number of such studies and reports over the last few years both nationally and internationally that have traced students' increasingly negative attitudes to science over the middle years of schooling and the associated decrease in student participation in post-compulsory science. There have also been some studies that specifically reported how students' viewed their school science experiences less positively than that of their experiences of science outside school. For example, in the UK, Bennett and Hogarth (2009) developed and used the *Attitudes to School Science and Science* questionnaire to explore students' views about school science and science outside school. Adapting the Views on Science-Technology-Society (VOSTS) approach (Aikenhead & Ryan, 1992), this questionnaire explored students' views regarding school science through their responses to science lessons, individual subjects within science, teacher effects and the importance of science in the curriculum. At the same time, the questionnaire explored students' views of science outside school through their responses to science as presented in the media, reading about science, careers in science, the misrepresentation of science, and personal and impersonal responses to science. This study found that students viewed their school science experience less positively than science outside school.

The studies mentioned above reported decreasing student interest in school science. In addition to this, we need to understand students' perceptions of the nature of school science and the factors determining their engagement with it as an interesting subject or a potential career. Such understanding is needed if we are to find fresh ways forward for the development of a science curriculum that would engage more students to study it and encourage pursuing a science-related career.

Factors affecting student attitude to STEM

Recently, three separate qualitative-dominated studies have sought to understand student disenchantment with school science, and what can be done about it. The three studies were from the UK (Osborne & Collins, 2000a, 2001), Sweden (Lindahl, 2003) and Australia (Lyons, 2006b). These studies were similar in that they were substantially interview-based and dealt with students in the years in which they made choices about their future studies.

Osborne and Collins (2000a, 2000b, 2001) qualitatively explored 16-year-old students' views about the kinds of scientific knowledge, skills or understandings they need for dealing with everyday life, interesting and valuable aspects of the curriculum, and desirable future curriculum content. Osborne and Collins argued that as their research sought insights into the experiences, views and beliefs of pupils, the data required were essentially qualitative; and they adopted the method of focus groups. This study elicited the following key findings of the students' perspectives:

- Though science is a prestigious and important subject to students for their career aspirations and to be considered educated individuals, they find difficulty in making connections between school science and their everyday lives.
- Science curriculum is content-dominated, overloaded and examination-driven, with too much repetition and too little challenge for students. Much of the science content (particularly from chemistry) is abstract and irrelevant to contemporary needs and their everyday lives. For many such topics, students perceive the instrumental value is only for passing an exam. Moreover, this curriculum requires too much copying and provides few opportunities for discussion.
- Amongst the sciences, biology has more relevance to personal life. Topics on astronomy and space, and contemporary scientific and socio-scientific issues are found interesting by all students.

Osborne and Collins argued that students' school science experiences as summarised above, are the product of a content-dominated and examination-driven curriculum. As students' exam scores are regarded as a determinant of school achievement and teacher competence, an overloaded content-dominated curriculum leads teachers to rush their students through the science disciplines. In such a classroom, students are often involved in simply copying science ideas that the teacher presents. This teacher-centred practice often fails to make a connection between school science and students' everyday lives (Osborne & Collins, 2000b), and as a result students find difficulty in relating school science to their lives.

Lindahl's (2003) longitudinal study tracked 80 students from upper primary school to the point of choosing their senior school subjects. This study found students' dissatisfaction to the lack of opportunity for personal opinion and expression in science that was caused by the narrow range of transmissive pedagogies used in their science classes. Students were also not attracted to the smell of the laboratory, texts dealing with facts and abstract concepts and teachers who did not laugh. In this study there were a number of academically strong students with an interest in science as presented in popular media, who rejected school science as something very different. Lindahl also found the importance of early exposure to science-related careers, in that students tended to be consistent in their intended career choices from primary school, yet many students had no idea what career option a study of science could lead to.

Australian students also had similar kinds of experiences of their school science. For example, Lyons (2006b) found three major aspects that characterise Australian students' perceptions of school science, as reported below.

- Transmissive pedagogy: Students viewed school science as a teacher-centred and content-dominated subject, in which they passively receive science content transmitted from expert sources.
- Decontextualised content: Students mostly viewed the school science content as irrelevant to everyday life and boring.
- Unnecessarily difficult: Based on their own experience of junior physical science courses and from the comments by teachers, parents, seniors and peers, students anticipated senior physics and chemistry courses as being difficult.

A recent study, commissioned by the Office of the Chief Scientist in Australia (Goodrum et al., 2011), sketches a similar picture of Australian Year 11 and 12 science education from students' and teachers' views that include: overcrowded content-laden curriculum; traditional transmissive pedagogy used in science classes, and rushed timetable with limited resources. For instance, both students and teachers viewed that Year 11 and 12 science is constructed to prepare students for university study with a large amount of theoretical and abstract content with little room for flexibility from either the teacher or student.

Lyons (2006a) examined the implications of the experiences of school science reported by students in Australia (Lyons, 2006b), the UK (Osborne & Collins, 2000a, 2001) and Sweden (Lindahl, 2003). As Lyons argued, students' experience of school science as teacher-centred content transmission may have a number of consequences for students' engagement with science: first, many students may not perceive this transmissive approach as good for understanding science concepts; second, this approach may frustrate students regardless of whether they think the topic itself interesting, and third, this approach leaves a narrow scope for in-depth discussion among students. Further, such transmissive pedagogy, by implication, suggests that laboratory environments are predominantly teacher-directed rather than inquiry-oriented, as evident in many educational contexts (Fraser, 1994; Goodrum et al., 2001). Such teacher-directed laboratory environments may fail to sustain students' interest in science practical activities (Braund & Driver, 2005; Cleaves, 2005). Moreover, unengaging, decontextualised science curriculum lacks the capacity to make school science meaningful in students' everyday lives (Lyons, 2006a) and may result in declining student interest in science (Aikenhead, 1996; Aikenhead, Barton, & Chinn, 2006; Fensham, 2006; Leach, 2002; Logan & Skamp, 2008).

Lyons further identified conditions, which persuaded students to choose physical science after compulsory school years: (a) supportive relationships with members of their family, and one of (b) parents who emphasised the strategic value of formal education or (c) family members advocating or supporting an interest in science. Most students with all three conditions in place chose physical science. Lyons also found that students taking physical science had higher levels of self-efficacy, in that they felt confident in their capacity to undertake and succeed in what are perceived as difficult subjects. In the literature self-efficacy relates to confidence in one's ability to succeed, and this can be a general quality, or relate to particular endeavours. Lyons, from the student narratives in his interviews identified this quality as being instrumental in the decision to take difficult science subjects. He explained these findings in terms of 'cultural and social capital' associated with supportive family relationships and family views that were aligned with school science. Based on these findings he provided a model, as in Figure 4, which illustrates the congruence between characteristics of school science and family worlds found among the science proficient students choosing physical science subjects.

Bourdieu's construct of cultural capital has been drawn on by Adamuti-Trache and Andrews (2008) to show the pervasive influence of family education level and values pertaining to education in influencing choice of STEM subjects. Blenkinsop and colleagues (2006) point out that the known link between family socioeconomic status and student career choice operates through the promotion of self-efficacy by parents with belief in their children's capabilities, and expectations of their academic achievement.

Lyons argued that it would be wrong to think of the diminishing numbers in post-compulsory science in terms of students being drawn away by more attractive options, or by a lack of career prospects. He concluded that the low intrinsic value of school science and the attrition of its strategic value contributed to the disinclination of students to choose physical science courses in the senior school.

Similar attitudes from students towards their mathematics teaching and learning have also been reported. TIMSS 2011 data (Australian Mathematical Sciences Institute [AMSI], 2014) illustrated that Year 8 students in Australia are not as fond of mathematics as their international counterparts; 45% of Australian Year 8 students do not like mathematics, compared to 31% internationally. Australian students do however value mathematics – much more than science, which is valued much less than the international average.

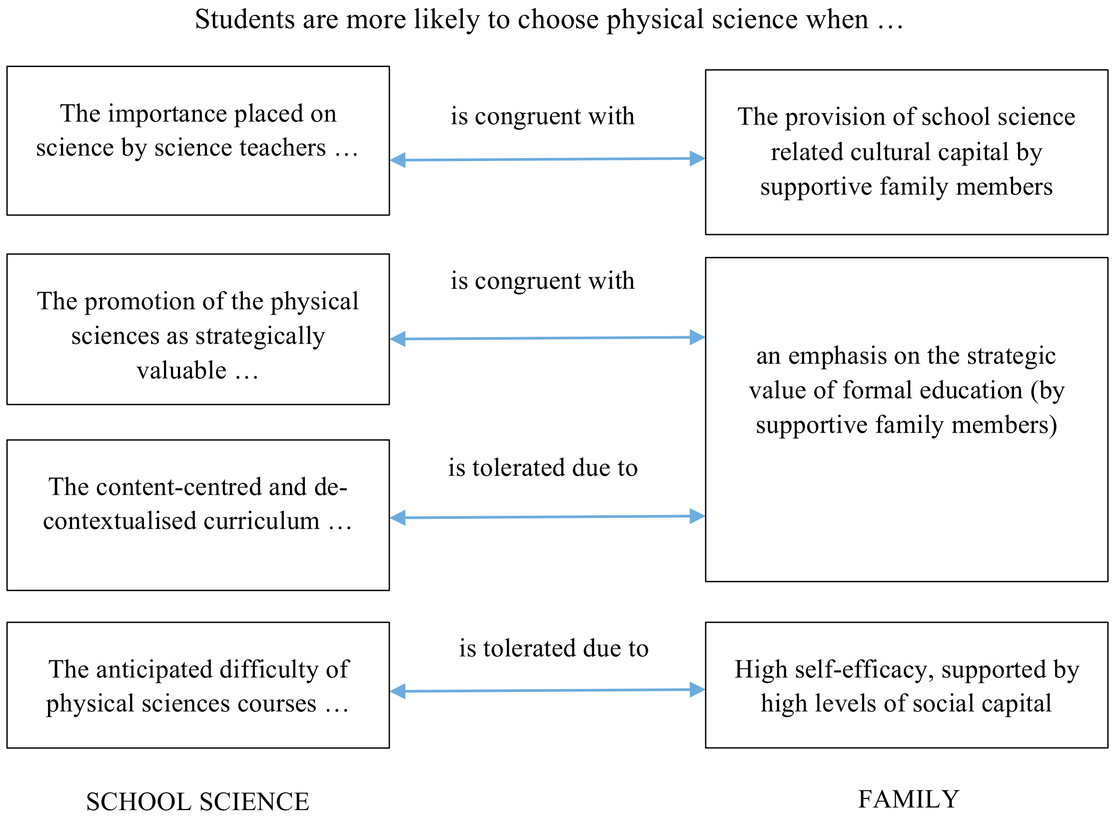

Figure 4. A model illustrating the congruence between characteristics of school science and family worlds found among the science proficient students choosing physical science subjects (Lyons, 2006b, p. 307)

As reported in Tytler et al (2008), many mathematics classes in Australia do not require thinking beyond memorising and repeating mathematical procedures and doing simple analysis. Also students are not required to reorganise knowledge to develop new ideas and consider the rationality of the mathematics they generate. These classroom practices indicate a minimal intellectual practice of mathematics learning. When students only memorise and repeat rules and procedures, rather than explore to develop mathematical ideas in mathematics classes, they lack control over their learning, and this eventually may contribute to a decline in their confidence, interest and participation in mathematics.

There is a persistent and ongoing decline in the percentages of Year 12 students taking advanced and intermediate mathematics. For example, Year 12 advanced mathematics enrolments have dropped by 22% from 2000 to 2012 and by 34% from 1995 to 2012 (Australian Mathematical Sciences Institute [AMSI], 2014). This trend is particularly severe for female students. For example, in the New South Wales school certificate, the proportion of girls who elect to study no mathematics after year 10 has tripled from 7.5 % in 2001 to 21.5 % in 2011 (Mack & Walsh, 2013). This declining enrolment of female students in mathematics, however, does not align with their attitudes towards mathematics, compared with male students. As compared with their male counterparts, Victorian Year 7-10 female students were perceived to enjoy mathematics more, to be more capable, and more likely to succeed, while boys were more likely to find mathematics boring and to need more help (Forgasz, 2001; Leder, 2001).

As pointed out above, one of the key reasons students are not attracted to science at the secondary school level is the way science is taught. A similar reason impacts on mathematics education. In regards to the data on mathematics teacher profiles and qualifications, AMSI reported that there are not enough teachers qualified (in terms of having methodology training in mathematics) to teach mathematics in Australian high schools.

- Only 60.4% of Year 7-10 teachers teaching mathematics have completed methodology training in the area, suggesting that nearly 40% of these teachers are not fully qualified. In Years 11-12 this percentage goes down to a (still very significant) 23.7%.
- Only 64.1% of Years 11 and 12 mathematics teachers had at least 3 years tertiary education in the field, down from 68% in 2007.
- Only 45.8% of Years 7 – 10 mathematics teachers had at least 3 years tertiary education in the field, down from 53% in 2007.

(Australian Mathematical Sciences Institute [AMSI], 2014, p. 11)

According to the 2011 TIMSS survey, 34% of Australian Year 8 students are taught mathematics by a teacher without a solid mathematical background, compared to the international average of 12%. In 2007, 10% of schools reported at least one unfilled vacancy for a mathematics teacher. This scarcity of qualified mathematics teachers leads to teachers teaching mathematics outside their field of expertise or, in acute shortages, teachers not fully qualified in mathematics being recruited to teach these subjects. It not surprising that the less qualified teachers would promote a teaching-learning culture in mathematics classes where students focus more on memorising and repeating rules and procedures, rather than exploring to develop mathematical ideas. As noted previously, such a culture would restrict students from developing control over their mathematics learning that would contribute to a decline in their confidence, interest and participation in mathematics.

In addition to the factors affecting student engagement in STEM subjects, as discussed in this section, there have been gender issues in STEM education that have hindered gender balance in STEM education.

Gender issues in school STEM education

In the USA, while girls and boys take math and science courses in roughly equal numbers in primary and secondary school, fewer women than men pursue these majors in post-secondary studies (Hill, Corbett, & St. Rose, 2010). Female participation in undergraduate engineering courses is less than 20 %, and importantly a decline in female participation in engineering is observed between 2001 (19.2 %) and 2011 (18.6 %) (National Science Foundation, 2012). Representation of women in the STEM field further declines at the graduate level and in the transition to the workplace. A similar picture of female participation in STEM is found in the UK (Zecharia, Cosgrave, Thomas, & Jones, 2014). Only about 20 % female students in UK are taking A-level physics and this percentage has remained the same in the past 20 years or more. Female participation in the STEM-related workplace is about 13 % of which 5.5 % are in engineering and this is the lowest proportion of female engineers in the European Union (EU) countries. In a comparison among the EU countries, Osborne and Dillon (2008) reported that percentages of female STEM graduates vary from 19.5% in the Netherlands to a maximum of 42% in Bulgaria, with an average of 31% across EU countries.

Kennedy and colleagues (2014) analysed gender-pattern of Year 12 Australian students' enrolment in science and mathematics courses between 1992 and 2012. This analysis indicates that Chemistry, Multidisciplinary Science and Earth Science have tended towards gender equality, while Physics, Biology and Advanced Mathematics have retained and in some cases strengthened their respective gender biases. Entry Mathematics has been the subject closest to the cohort norm in terms of equality of genders throughout the study. There have been around 26 males for every 25 female students taking Chemistry, 22 females for every 35 males taking Multidisciplinary Science, and nine females for every 10 males taking Earth Sciences. Physics has the largest proportion of male students and this proportion has become steadily larger. In 2012, around three male students for every female took Physics. In a similar fashion, there have been 14 females per 25 males taking Advanced Mathematics. On the other hand, Female students have consistently shown a preference for Biology over their male peers with around nine females for every five males. Entry Mathematics has traditionally had a slight female bias with 11 females per 10 males, while Intermediate Mathematics has had a slight male bias with eight females per 10 males. In the New South Wales school certificate, the proportion of girls who elect to study no mathematics after year 10 has tripled from 7.5 % in 2001 to 21.5 % in 2011 (Mack & Walsh, 2013). In addition, the proportion of female students participating in higher-level mathematics is declining at a greater rate than the proportion of male students. This declining participation in higher-level mathematics limits young women from pursuing in STEM careers (Forgasz & Leder, 2011).

Similar to declining participation, in Mathematics, Australian female students' performance in international assessment programs seems poorer compared to their male counterparts. For example, the PISA assessment 2012 shows that in mathematical literacy, males achieved a mean score of 510 points, which was significantly higher than the mean score achieved by females of 498 points, and this difference is equivalent to about one-third of a school year (Thomson et al., 2013). Also, female performance in mathematical literacy has decreased at a higher rate compared to males. Between PISA 2003 and PISA 2012, while the mean performance for males decreased by 17 score points on average, the mean performance for females decreased by 24 score points.

Sikora (2014) explored gendered patterns in the participation of school science subjects and in adolescent career preferences. In secondary schools, of the students drawn to science careers, boys are four times more likely than girls to be attracted to occupations related to physical sciences subjects such as physics, mathematics, engineering and computing, while occupations related to life sciences subjects appealed to twice as many girls as boys (Sikora, 2014).

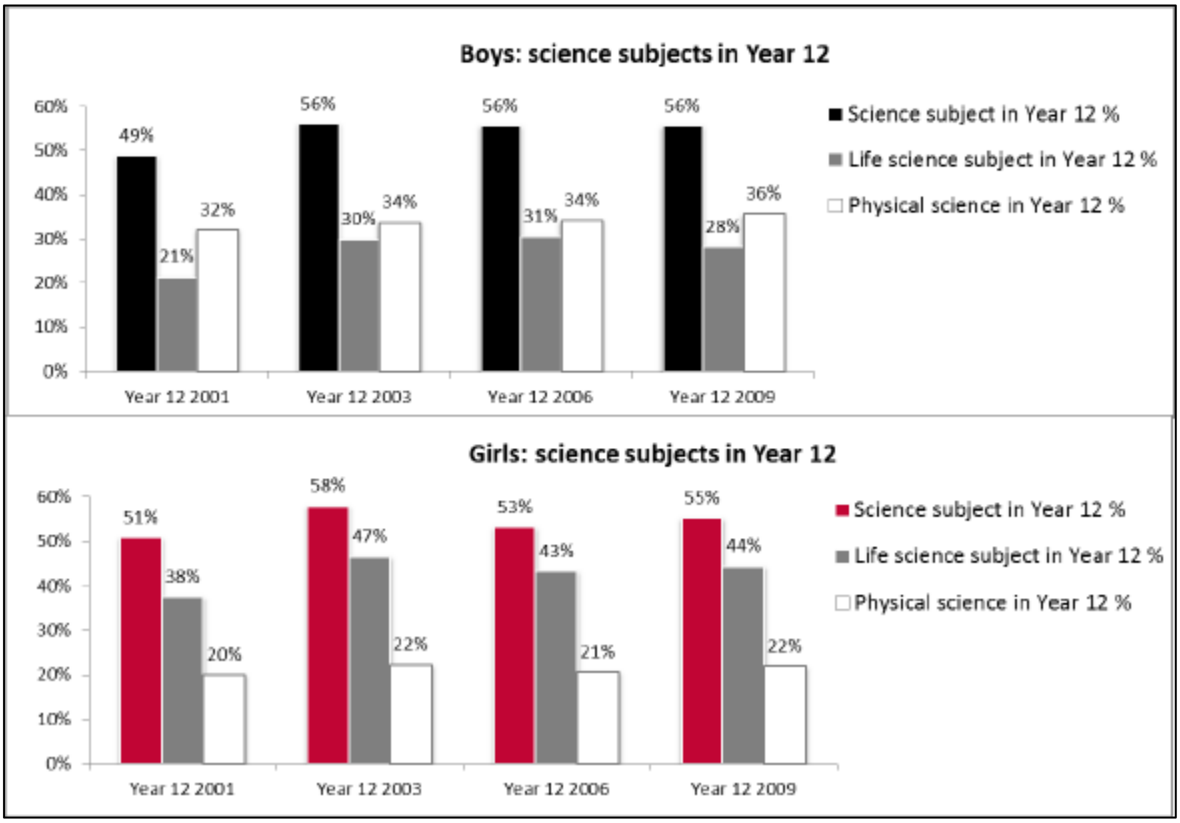

Figure 5. Students' participation in Year 12 science subjects by gender: 2001–2009 (Sikora, 2014, p. 14)

Figure 5 shows that students' choices of science subjects in Year 12 are segregated by gender. Boy students tend to take up physical science subjects in Year 12, while girl students like to take up life science subjects. Considering students' participation in tertiary science subjects, it was found that science at the tertiary level tends to be more strongly segregated by gender in the physical science subjects. In 2006, only 6 % female students participated in physical science subjects, compared with 31 % male students.

Gender-based stratification of participation in STEM may have roots in the expectations of students prior to the curricular choices they make in upper secondary school. The OECD, in 2006, surveyed the career expectations of 15 year old students internationally. Across OECD countries, an average of 47.5 % of boys who anticipated a scientific career expected a career in engineering or computer science compared with 12.4 % of girls (Organisation for Economic Cooperation and Development (OECD), 2010). This gender difference is a bit higher in Australia, where only 8 % of the girls indicated an expectation of a career in computer sciences or engineering, compared with 46 % of the boys.

In Australia, aspirations of students at age 15 to enter careers in engineering or computing are below the OECD average, being 10.5 % for boys and just 1.2 % for girls, compared to OECD averages of 12.4 % and 1.6 % respectively (Organisation for Economic Cooperation and Development (OECD), 2012, p. 82).

Why is the under-representation of women in STEM fields an issue?

The under-representation of women in STEM fields may impact on the health of STEM study and workplaces in many ways. Marginson et al (2013), for example, reported following arguments in this regard:

1. In order to get better aligned, productive and relevant STEM research, it is important to get the gender balance in STEM aligned with the gender balance in the real world.
2. Participation of women promotes creativity and reduces potential bias which together help boost the quality of STEM research.
3. Gender equality in STEM education and careers are advocated on the grounds of equal opportunity, social justice, fairness and human rights.
4. As STEM research uses public funds to address peoples' common needs and issues, it is fair to adequately involve all subgroups of the population in the research process.
5. The STEM workforce is seen as an important factor to enhance human capital, which boosts national economic growth and international competitiveness. Women who are trained in STEM but who leave prematurely from a STEM-related career are wasted economic resources.

Given this significant and long-standing concern with the participation of women in STEM subjects and career pathways, there have been many studies examining the factors affecting this participation. The following sections examine findings concerning the barriers to women participating in STEM more generally, and then to Engineering in particular.

Women in STEM – Factors affecting participation

There are four main types of factor identified in the literature for STEM participation of women; gender stereotyping, social and psychological barriers, the lack of women in leadership roles who could encourage and support participation, and perceptions of the nature of STEM work. Some of these studies explicitly refer to engineering as part of the issue relating to STEM.

Gender stereotypes

Sikora (2014) reported that many of the barriers to the participation of girls in STEM education and STEM careers are rooted into culture and gender stereotypes. Surveying 1300 Swedish students Brandella and Staberg (2008) found that majority of the students perceived mathematics as a symbolically male domain. In particular, older students hold more strongly gendered views than younger, whereas boys in the science stream have the strongest beliefs of mathematics as a male domain.

Social-psychological barriers

Saucerman and Vasquez (2014) conducted a literature review to identify social-psychological barriers to STEM field participation for women, organized by developmental stages – from early childhood to adulthood. They found that in early years, without any conscious intention by parents, young girls receive less exposure to and understanding of mathematical and scientific ideas from their parents than boys. One possible reason for this practice, as reported, was parental beliefs that boys were more interested and capable in STEM subjects and that STEM subjects are more difficult and less important for girls than boys. Similarly, without conscious intention, teachers also convey gender stereotyped views regarding STEM education to the children in early years. Along with influences from parents and teachers, when girls move from childhood to adolescence, their self-perceptions and attitudes to STEM are also influenced by their peers and the media. As most media portray STEM as a male-dominated domain, it is not surprising that fewer females would perceive STEM as an area of interest. Parental expectation for careers plays a vital role in shaping career aspirations. For instance, mothers' expectations about whether their male and female children should have gender-stereotyped careers are significantly correlated with their children's gendered career expectations. When women enter STEM majors and careers, they may be prone to ‘prevention focus’ as a result of stereotype threat (a decrease in performance that can occur when there is an expectation that women will perform at a lower level than men) in either study environment or workplace environment. Prevention focus may manifest itself in the form of women ensuring that projects are completed on time, being well dressed-up, and minimizing work absences. However, this focus may restrict women from taking reasonable risks, negotiating promotions, and volunteering for projects – the practices exemplified by people who rise to the top of their chosen field or who show innovation and creativity.

Small numbers of women in leadership role

Small numbers of women influence and participate in senior roles on funding and other decision making bodies (Marginson et al., 2013), for example, in academic leadership positions. In the USA, while around 25 % of deans and department heads are women, in the STEM fields, this drops to nearly 5 % (McCullough, 2011). McCullough identified several issues responsible for this low representation that included discrimination, prejudice and bias against women; family obligations; lack of role models and mentors; different leadership styles and expectations of leaders, and societal double binds.

The perceived nature, organization and career pathways of STEM

As reported by Marginson et al. (2013) the perceived nature, organization and career pathways of STEM fields of study and employment are a barrier for women’s participation in STEM. For example, young people lack understanding of what engineering and technology careers entail. The Engineering workforce study (Australian Workforce and Productivity Agency, 2014) reported that the low status of engineering as a profession and poor perceptions of engineering careers have been problematic in most western economies. This is attributed to a number of factors, including the lack of understanding about engineering as a career and the inability of the engineering profession to sell the value of its work and social contribution. This is true of primary school students’ perceptions of STEM work, identified by Lindahl (2003) as a significant barrier to the early formation of career intentions, as well as problems with perceptions at the point of later subject selection, as will be outlined below. There are also significant gender effects relating to the way STEM and engineering pathways are framed, that will be discussed in relation to gendered responses to STEM curricula.

Within this broader STEM area, there are a number of factors specific to participation of women in engineering that have been researched.

Women in engineering – factors affecting participation

In many developed countries, women participation in engineering is poor. For example, analysing gendered patterns of participation in post-compulsory STEM education in the context of the UK, E. Smith (2011) concluded that while female participation in science in general has increased, recruitment in engineering remains stagnant. A similar pattern is observed in Australia as well. As Dobson (2012) reported, during 2002-2009, the number of women in bachelor’s degrees in all fields of education increased by 20.7 %, the increase in the number of women in science courses was only 11.4 %. Moreover, women prefer Biological Sciences and Other Natural and Physical sciences subjects ahead of all others. Women’s representation in Mathematical Sciences and Physical Sciences were reported as “under-represented”. This is particularly the case in the Physical Sciences, in which the female presence was found to be less than one-third. Students commencing programs in engineering, manufacturing and construction constitute an average 15 % in tertiary education across the OECD countries, while in Australia it is only 9 % (Organisation for Economic Cooperation and Development (OECD), 2012, p. 358).

Godfrey and King (2011) studied recruitment and retention of women in engineering education and identified barriers to increasing the participation of women in engineering degrees. They argued that the main reason for the continued low participation of women in engineering is recruitment, rather than retention. This argument was based on the data showing that once women have enrolled in engineering, their retention was higher on average than their male counterparts. They identified the following barriers to female participation in engineering.

- Negative images about engineering study and careers, and self-perceptions that draw female students (who have ability in mathematics and science) to prefer medicine, veterinary science, and architecture.
- There are strong gender disparities in some of the influences which motivate study in engineering. For example, female students were significantly less influenced by ‘enjoying knowing how things work’ or ‘enjoying building stuff’.
- Careers advisers in many schools were not supporting female students who might consider engineering.
- The lack of growth in the number of female high school students studying pre requisite subjects (e.g., higher level school maths and physics).
- There are masculine biases in engineering curriculum, assessment methods and the learning environment.

Armstrong and Bellis (1993), as cited in Armstrong (1995), noted that women academics in engineering are disadvantaged by family responsibilities, reduced mobility compared with male academics, the role of research, teaching and administration in appointments and promotions, lack of career planning, lack of mentors and networking and direct discrimination and prejudice. In addition to these issues, there have been cognitive and social issues that disadvantage women in participating in engineering. For example, Hill and her colleagues (2010) identified a large gender difference in cognitive abilities in the area of spatial skills, which are considered as an important factor for success in engineering and other scientific field. As Sorby (2009) reported, according to Piagetian theory, an individual acquires spatial visualization skills through three distinct stages of development. In the first stage, children learn two-dimensional topological skills where they are able to discern an object’s topological relationship with other objects (e.g., distance between two objects, etc.). In the second stage, children acquire projective spatial skills, which involve “visualizing 3-D objects and perceiving what they will look like from different viewpoints or what they would look like if they were rotated or transformed in space” (p. 461). In the final stage, a person learns to combine projective abilities with the concept of measurement (e.g., area, volume, distance, translation, rotation, and reflection). Studies, suggested that individuals’ spatial skills can be improved with a simple training course within a short time. For instance, at Michigan Technological University, Sorby and Baartmans (2000) designed and implemented a successful 10-week course for first-year engineering students who had poorly-developed spatial skills[1]. This course was found to improve their spatial-visualization skills. More than three-quarters of female engineering students who took the course remained in the school of engineering, compared with about one-half of the female students who did not take the course. Continuing this project for a number of years, Sorby (2009) suggested that, when girls grow up in an environment, which promotes their success in science and maths with spatial skills training, they are more likely to develop their skills in STEM as well as their confidence and aspirations to take up a STEM related career. Based on Sorby's work, Hill et al (2010, p. 56) made the following recommendations to help young children, particularly girls, develop spatial skills:

- Explain to young people that spatial skills are not innate but developed.
- Encourage children and students to play with construction toys, take things apart and put them back together again, play games that involve fitting objects into different places, draw, and work with their hands.
- Use handheld models when possible (rather than computer models) to help students visualize what they see on paper in front of them.

In addition to perceiving science and maths as masculine subjects (Marginson et al., 2013), Hill et al (2010) pointed out that people often hold negative attitudes to women in "masculine" careers, such as engineering. People often judge women to be less competent than men in male-dominated jobs unless they are clearly successful in their work. However, when people find a successful woman in male-dominated job, they tend to dislike her. As both likability and competence are needed for success in the workplace, women in STEM fields often find themselves in a double bind that eventually decreases their job satisfaction.

Associated with the research into factors affecting participation of women in STEM and in engineering there have been numerous initiatives over many years aimed at increasing participation. The following section describes these initiatives under a number of headings that attempt to provide a framework to make sense of their diversity. The different approaches relate to both the types of approach and presumptions underlying them, and the place in the STEM/engineering education pathway the initiative focuses on – from the early years through to the workplace.

Attracting and supporting women in engineering – approaches globally

In a recent government commissioned report in the UK (Zecharia et al., 2014), it is argued that the main influences on students' decisions regarding studying STEM fall broadly into three categories that provide three mental checklist questions to students:

1. **Relevance of STEM** to sense of identity and future aspirations = *Is it for people like me?*
2. **Perceived actual and relative ability** in STEM subjects = *Do I feel confident?*
3. **Science capital or experience of STEM**, including formal and informal exposure to STEM subjects and careers through the curriculum, schooling, media, culture, family and personal connections = *Can I see the possibilities and pathways?*

Students get the information needed to answer to these questions from their wider society, family and friends, the classroom and the workplace. Stereotyping notions about women and STEM are present in the wider society, such that family and friends, the classroom and the workplace often convey messages to women that STEM is not their area. For example, while teachers are often not aware about stereotyping, in STEM classes they provide more attention to boys than girls and they hold lower expectations for girls in these subjects, and boys are more likely to dominate class interactions. This practice leads to girl students' increased sense of inadequacy in the subject and the growing belief that STEM subjects are difficult and not 'for someone like me'.

This section presents an account of literature discussing approaches taken to attract and support women in STEM, in general, and engineering, in particular.

Age of engagement with STEM

There is considerable evidence that students make their broad career choices at an early age (Lindahl, 2003; Tytler, 2014; Tytler et al., 2008) implying that if girls are to be attracted into a STEM or engineering pathway attention needs to be paid to girls' perception of STEM work, and of science and mathematics subjects, in the primary school years and certainly during the early secondary school years.

The countries that are stronger in STEM have as a feature efforts to engage students with science experiences from an early age (Marginson et al., 2013). The Engineering and Technology Labour Market Study (Engineers Canada & Canadian Council of Technicians and Technologists, 2008) in Canada reported strategies to achieve diversity in the engineering profession through increasing underrepresented groups, including women. This study recommended starting STEM Programs in elementary school at least by grade 5 or 6.

There is an emerging literature on the importance of science and mathematics activities and experience in the early, pre-school years. The research shows that gaps in children's literacy and numeracy functioning, for instance, occur at an early age and can be apparent before children reach school years. The effect of family can be strong through these years, with children from financially disadvantaged families tending to have more learning problems and lower engagement compared to other children. The argument has been made, on this basis, that investment in early years education in general yields higher returns compared to investment in later childhood. With regard to STEM, a focus on positive dispositions and skills in mathematics and science through hands on, exploratory activities, and engagement of parents and carers within preschool programs are recommended as central to laying the groundwork for later engagement and competencies in mathematics and science.

Tytler (2014) reviews the literature on student identity in relation to science, to argue that this construct, which incorporates both psychological and social features of individuals' lives and aspirations, is powerful for describing and explaining students' choices of subjects and careers. Identity questions are of the type 'what type of person do I want to be?' and 'can I see myself as an adult engaging with engineering work?'. The identity perspective highlights the need to frame school science and mathematics subjects in a way that is congruent with the values and aspirations of girls, and the need to provide images and role models of work in STEM to which they can relate. Thus, curriculum, and role modelling, become important strands in strategies to increase the participation of girls and women in STEM and engineering. The middle years of schooling, from upper primary school through to Year 10, are important years for identity formation and hence prime years for targeted presentation of role models and supportive narratives. Strategies in the upper secondary through university years tend to be more specific in terms of career models and mentoring by successful female STEM professionals and engineers.

Curricula, pedagogies and teaching-learning culture in STEM

The literature identifies a range of issues and recommendations concerning curriculum content and values, and the way science, mathematics and engineering are taught, as relevant to participation in STEM.

At the school level

- The need for curriculum design and professional development that could generate greater teacher awareness about encouraging girls to consider STEM pathways (Marginson et al., 2013). The Interests and Recruitment in Science (IRIS) study (Lyons et al., 2012) found that first year female students in university STEM disciplines considered personal encouragement from their school teachers as an important factor in their decisions to take STEM courses. Hill and colleagues (2010) noted that girls' interest and achievements in maths are shaped by the environment around them. They pointed out that "when teachers and parents tell girls that their intelligence can expand with experience and learning, girls do better on math tests and are more likely to say they want to continue to study math in the future" (p. xiv). This approach was also found helpful to address negative stereotypes about girls' abilities in maths that measurably lower girls' performance in maths tests and their aspirations for science and engineering careers over time.
- Promotion of content, pedagogy and resources suited to the learning styles and preferences of girls as well as boys (Marginson et al., 2013). Curriculum resources should reflect the identity needs of the female students. Zecharia et al. (2014) argued that female scientists and engineers are not highlighted in society and this influences girls in the development of their identity; so it is recommended to include topics on women and non-stereotypical STEM careers into curriculum. Developers of curriculum and associated teaching resources in STEM courses should ensure these documents reflect the pre-eminence of personal interest and practical application among the many influences on students' decisions to choose university STEM courses (Lyons et al., 2012).
- There is advocacy of greater exposure of engineering in the school curriculum, and the promotion of engineering as a useful generalist degree course (Marginson et al., 2013). There is some argument that the term 'engineering' needs to be included in the school curriculum alongside or in place of 'technology' and 'science'. In a survey, Australian senior school students suggest integrating engineering experiences within the school curriculum (Australian Workforce and Productivity Agency, 2014). As they view it, benefits of such integration may include: helping them understand and appreciate how their learning in mathematics and physical sciences can apply to the solution of important real-world engineering problems, leading to better preparedness for senior subjects; and helping them appreciate the roles of the engineer in society.
- An increased focus on inquiry-based science, and problem-based mathematics throughout the curriculum was found important for engaging students in learning (Liston, Peterson, & Ragan, 2008; Marginson et al., 2013). Australian senior school students viewed that the inclusion of hands-on activities in real-world contexts are important for promoting their interest in STEM at secondary school level (Australian Workforce and Productivity Agency, 2014). As well, they expressed their interest in understanding how theoretical concepts learned in mathematics classes could be practically applied.

Outreach activities in schools

Australian students considered STEM-related outreach activities as important in their decisions (Lyons et al., 2012). Activities included the Science and Engineering Challenge, the

Siemens Science Experience, the Honeywell Engineering Summer School, Youth ANZAAS and the National Youth Science Forum. This finding leads towards developing and supporting effective outreach programs for Year 9-12 girls (Engineers Canada & Canadian Council of Technicians and Technologists, 2008; Lyons et al., 2012).

At the university level

- Armstrong (1995) commented that most engineering courses in Australia were overloaded with content and there was not enough effort put into identifying the key skills and knowledge needed in engineering and to use the students' time more efficiently. She criticized the prevailing belief that engineering students should devote many hours to study (between 48 to 70 hours per week). This belief often discourages women from studying engineering, as in reality they have to perform more family responsibilities than men (e.g., giving birth and taking care of children, etc.). She suggested that engineering courses should have less content and should include more attention to social, political and ethical aspects. She also advocated for joint degrees such as Arts/Engineering and Law/Engineering which allow a wider range of study.
- The prevailing pedagogy in engineering dictated by lectures, tutorials and laboratories needs to shift to problem-based learning, open ended assignments and more student control of the learning process (Armstrong, 1995; Godfrey & Holland, 2011). Klawe (2014) reported a successful case of an US engineering college, Harvey Mudd College, in which 56% of students receiving engineering degrees were women in 2014. Teaching-learning approaches in this college are dictated by hands-on classes that incorporate project-based learning.
- Knight, Mappen, and Knight (2011) reported an effort in the US college system to steer women to STEM majors through the Science Education for New Civic Engagements and Responsibilities (SENCER) initiative. In this approach complex civic issues and their consequences are used as broader context for teaching STEM subjects. This approach is grounded in the idea that women tend to prefer active and collaborative learning environments in which new material is contextualized into real-world situations. This study found that engaging women with learning activities that are both intellectually challenging and directly connected to real world problems contributed in increasing their interest in STEM fields.

Mentoring, career counselling and role models in STEM

Separate from suggestions concerning curriculum and pedagogy are examples of approaches to attracting and retaining girls and women in STEM fields that involve mentoring, the promotion of role models, and counselling about possible careers in STEM.

At the school level

- Bringing together young women and successful female STEM professionals (including scientists, engineers, mathematicians and computing specialists) to provide an authentic understanding of STEM careers, and access to female role models (Liston et al., 2008; Marginson et al., 2013; The Royal Society, 2014).
- Role models may include web-based presentations of narratives of STEM professionals, for instance, those on the Academy of Technological Sciences and Engineering [ATSE], and Science and Technology Education Leveraging Relevance [STELR] website (Marginson et al., 2013) and computer-based social models (Plant,

Baylor, Doerr, & Rosenberg-Kima, 2009). Details of computer-based social models are presented in Appendix 4.

- Peer to peer support between high school and primary students, or between tertiary and upper secondary students, through activities and science shows (Marginson et al., 2013).
- Creative partnerships with both government and non-government bodies need to be established to raise girls' confidence in STEM and their families' and teachers' expectations through showcasing non-stereotypical careers, female and non-traditional male role models and mentors (Zecharia et al., 2014).
- The advice given in school about engineering as a career requires improvement (WISE, 2014). Zecharia et al. (2014) recommended that career advice include earning potential and marketability of STEM skills focusing on the creative and imaginative nature of STEM having societal impact and offering diverse opportunities.
- Career counselling messages regarding engineering as a career, need to be revised and tailored for girls (Veenstra, 2012). For girls, the message should address how engineers contribute in improving society. This is a core value espoused by girls that figures prominently in their decision to elect for a career in engineering. Examples of such messages include "engineers make a world of a difference," and "engineering is essential to our health, happiness and safety." This recommendation aligns with Benderly (2010) demonstrating that girls, to a greater extent than boys, choose career paths they think will enable them to contribute to society, work with people and help others.

At the university level

- Active mentoring for female engineering students was identified as an important factor in increasing female participation in the engineering degrees at Harvey Mudd College (Klawe, 2014). This college has a collaboration with the Society of Women Engineers, which links women students to a larger network of professional and academic engineers dedicated to helping them succeed in engineering careers. This group plays a mentoring role for women engineering students. As these mentors are women engineers, they may be perceived by female students as role models in engineering.
- The literature suggests women attending engineering courses be mentored through gender-specific programs, such as "Women in Engineering" in Australia (Godfrey & King, 2011), and "Women in Science and Engineering" in the USA (Veenstra, 2012). As Godfrey and King (2011) noted, "Women in engineering" benefit faculties in a number of ways including: engaging women students in outreach, mentoring, peer tutoring and leadership roles; contributing to recruitment initiatives; providing alternative perspectives in faculty discussions, and demonstrating the valuing of women and establishing commitment to equity and opportunity for all. Details of this program are presented in the Appendix.
- A survey on Australian students shows that they view role models representing the diversity of the population as important, particularly for addressing stereotypes of the engineering workforce (Australian Workforce and Productivity Agency, 2014).

University policy and practice in relation to women in engineering

There is a range of structural and policy initiatives reported, that have been successful in attracting and retaining women in engineering at university level.

Support for female students

- Universities can reserve scholarships and fellowships for female students and researchers in engineering (Marginson et al., 2013). Universities should investigate sponsorship for part-time study scholarships for post graduate or retraining studies (Godfrey & King, 2011).
- Strategic reservation of funds for women to assist their study and establish themselves as researchers, and/or the allocation of greater points in funding selection processes to projects that include women researchers (Marginson et al., 2013).

University policy

- Godfrey and King (2011) recommended that the following issues regarding university policy need to be addressed:
    a. In all marketing and other engineering faculty publications, frame engineering as a field that requires a broad range of skills to attract a more diverse set of students to engineering. Consider widening admission criteria to attract all with the potential to succeed in engineering rather than specific subject criteria, and ensure the engineering curriculum supports the full range of students (p. 185).
    b. Proactively recruit qualified women to faculty positions and value contributions to gender inclusivity and equity in academic promotion (p. 185).
    c. Provide students and faculty with diversity training that explicitly addresses what constitutes sexual harassment and discusses how gender-biased remarks and jokes can impede learning amongst those targeted by such remarks (p. 185).
    d. Increase flexible delivery of post-graduate programs and courses and raise awareness of current offerings. Increase the provision of short courses or on-site collaborations (p. 189).
- Based on consultant reports of 23 countries, Marginson et al. (2013, p. 85) noted that universities and the professions in engineering and the technologies "might consider ways and means of strengthening the generic role of engineering degrees in professional labour markets, broadening the pathways between the study of engineering and employment in fields beyond professional engineering, including business and government. Such an approach would have implications for program design, marketing and student counselling".

Interventions at the level of the workplace

Facilitating female participation in STEM-related fields of work, particularly in engineering, requires workplace awareness and cultural change including: greater periods for any payments during maternity and paternity leave, incentives to return to work after periods of time away spent with family, flexible working hours, child care provision, and support for family mobility (Godfrey & King, 2011; Marginson et al., 2013).

Interventions at the level of society

Some developing (e.g., India, Turkey and Malaysia) and Arab countries (e.g., Jordan, Brunei, Lebanon, and United Arab Emirates) have made significant progress in increasing female participation in engineering (Gupta, 2012; Matthews, 2014; A. Smith & Dengiz, 2010). Common features in these countries are higher status (in terms of both societal and earning) of the engineering profession and increased family support. For example, a survey of women engineers from Turkey (A. Smith & Dengiz, 2010) found that family culture, knowledge about engineering and high status of engineering profession influenced women in choosing engineering. Women in this survey recognized that an important motivating factor for them was the satisfaction expressed by relatives who worked in engineering jobs and the lack of gender bias in their counselling interaction with these relatives. In their student life, relatives helped them clarify their career goals by explaining to them about the job prospects and description of engineering.

Concluding Remarks

The low rate of participation of women in engineering has been a longstanding concern in Australia. This is related to concerns about levels of participation in engineering overall, and to current concerns about attitudes to and participation in STEM subjects and career paths generally, and in particular for women in the natural and physical sciences and higher level mathematics at school, at university, and the workplace.

The continued existence of this issue despite decades of studies and initiatives indicates the problem is deeply embedded in cultural aspects of Australian life. The evidence for this is the higher general rates of participation in engineering in many countries, including Korea and China, and for women in engineering in many emergent economies such as Turkey and India. Even in countries with a more closely aligned economy and cultural history, such as Germany, the participation rates in Engineering are higher than in Australia. Part of this relates to education systems and the nature of choices offered to young people, and part seems to relate to the status of engineering as a profession. In developing economies in particular, engineers enjoy relatively high status.

Factors of a deeply cultural nature are hard to deal with in planning for change, and initiatives to tackle these would need to be at the broader policy level. However, there are many specific initiatives reported in the literature, in countries sharing many of Australia's problems in this respect and sharing similar education and industrial systems, that have generated insights into the key issues and that offer ways of reducing barriers to participation.

An important point to make is that the barriers and opportunities relating to women's participation in engineering occur at all points along people's education and work pathways, from early engagement with STEM activities and interests in the early years and primary school through educational experiences in secondary school leading to subject choices, to experiences of women in university engineering courses and then in the workplace. Each point in this trajectory presents different needs and opportunities that could form the basis of productive interventions. These will differ for different age groups and contexts.

Allied to this, the specificity of productive interventions will change with age. With primary school age students the issue can be cast in terms of a broad orientation to STEM as a potential interest and work orientation rather than targeting a career in engineering as such. This focus will play out largely in terms of orientation to the subjects of science and mathematics. As students approach university subject selection and enter university courses then the focus needs to shift to engineering specifically, and keeping students enrolled in subjects important as pre requisites, such as intermediate and advanced mathematics. Once students have chosen engineering, then interventions focus on keeping women enrolled and engaged in courses, then in the workplace.

Dimensions of intervention

The other pattern that can be discerned in the literature on engagement and participation of girls and women in engineering and STEM more broadly concerns three broad dimensions of students' and individuals' interactions with STEM subjects and STEM/engineering futures. These are:

1. Girls' response to curriculum and pedagogy. The literature is clear that curricula need to avoid the presentation of exclusively masculine images and should include topics that emphasise the societal relevance of science, for instance, and the social usefulness of mathematics. The pedagogies employed should be open, intellectually challenging, collaborative, inquiry-based and problem-based. The presentation of engineering should focus more broadly than on machinery and bridges, and include design as an important element of a large range of socially useful products and practices. In the early years this might include an exploratory, questioning orientation and opportunities to engage in hands on play in a resource rich environment.
2. The need for role models and mentors. This is an identity issue partly for addressing stereotypes of the male-dominated STEM workforce. At the school level this would involve not only exposure to narratives or direct experience of women doing STEM and engineering work, but also to information about the way engineering and STEM more generally can be offer rewarding challenges and career opportunities. At the university level successful interventions have involved women mentors working as part of the collaboration between the university and a larger network of professional and academic female engineers. In the workplace interventions with this focus involve women in leadership positions acting as mentors. At the university level, interventions involving mentoring / role modelling seem to have proven most effective as strategies for retaining females.
3. Structural / contextual factors that open up and encourage opportunities for girls and women to participate in STEM / engineering. Structural constraints include pressure on subject choice to increase ATAR scores, including pressures to take entry level rather than advanced mathematics. They may include gendered discourses and career information from teachers in school. Enabling structures may involve improved systems of support (e.g., scholarships and fellowships) at university, and increased awareness and cultural change in the workplace that promotes a more female friendly environment. A major structural policy strategy in other areas has been the imposition of quotas, or active advantaging of female candidates.

Figure 6 shows how these three broad dimensions relate to recommended initiatives at different points in an individuals' early years-to-school-to-work trajectory. In each case the most promising strategies are identified with *, based on reporting in the literature.

Planning for intervention

There is no research that explicitly compares intervention strategies, and given that interventions can be conceived of very broadly, with long -term aims, in earlier years of schooling, through to quite specific programs with short term outcomes at the engineering degree or workplace level, it is difficult to conceive of a metric that would allow such a comparison.

Given the evidence that students have substantially made identity-related choices about broad career directions by the age of 14, intervening before that age has the potential to yield substantive returns over the longer term. After the age of 14, attraction of girls into engineering is drawing on an increasingly restricted pool of potential candidates, due to both establish interests and expectations, and choice of pre-requisite subjects, particularly more advanced mathematics. But of course the metrics through which one might evaluate such interventions are inherently indirect, particularly for earlier age groups.

Part of the difference between early, broad intervention and later, engineering-specific interventions is the focus on different outcome types. One can think of such interventions as targeted directly at increasing the number of women engineers, or more broadly as targeting the general population to promote positive perceptions of STEM and engineering work generally – a broader STEM literacy aim. There is an argument that such an aim increases the potential pool of female engineering candidates, and also promotes a more positive environment for a technologically sophisticated society in which engineering can prosper (Marginson et al., 2013).

From the literature, one can discern particular types of intervention that provide promise of successfully establishing attitudes and aspirations, and engagement, at different points along the age continuum. These are discussed briefly below, and illustrated in Figure 6, broken into the three broad dimensions of curriculum and pedagogy, mentoring and role models, and structure and context.

1. Promotion of activities in the early years that are exploratory and engaging, that focus on interest and confidence with spatial, scientific and mathematical competence.
2. Primary and lower secondary school curriculum activities / resources that link science and mathematics with socially progressive purposes and that employ inquiry, problem solving pedagogies. This would ideally involve working closely with teachers.
3. Scientific and design challenges for upper primary and secondary students, that focus on topics of interest to girls (rather than traditional male-centred car and bridge type challenges) and present role models and career information that open up identity possibilities for girls.
4. Links between scientists and engineers, and schools, which provide positive female identity role models for students along the schooling continuum.
5. Engineering/design activities and topics in the upper schooling years together with role models and career advice, which provide attractive identity futures for girls at the points of choice at year 10, and 12.
6. Strategies to encourage upper secondary school students to enrol in subjects important as pre requisites in engineering, such as intermediate and advanced mathematics.
7. Targeted provision of female mentors and role models during engineering degrees, and in the workplace.
8. Opening out of university engineering curricula to allow more choice and diversity for female students, to combine engineering technical aspects with subjects that provide social purposes. This may include shifting to more inquiry oriented and values-focused pedagogies.

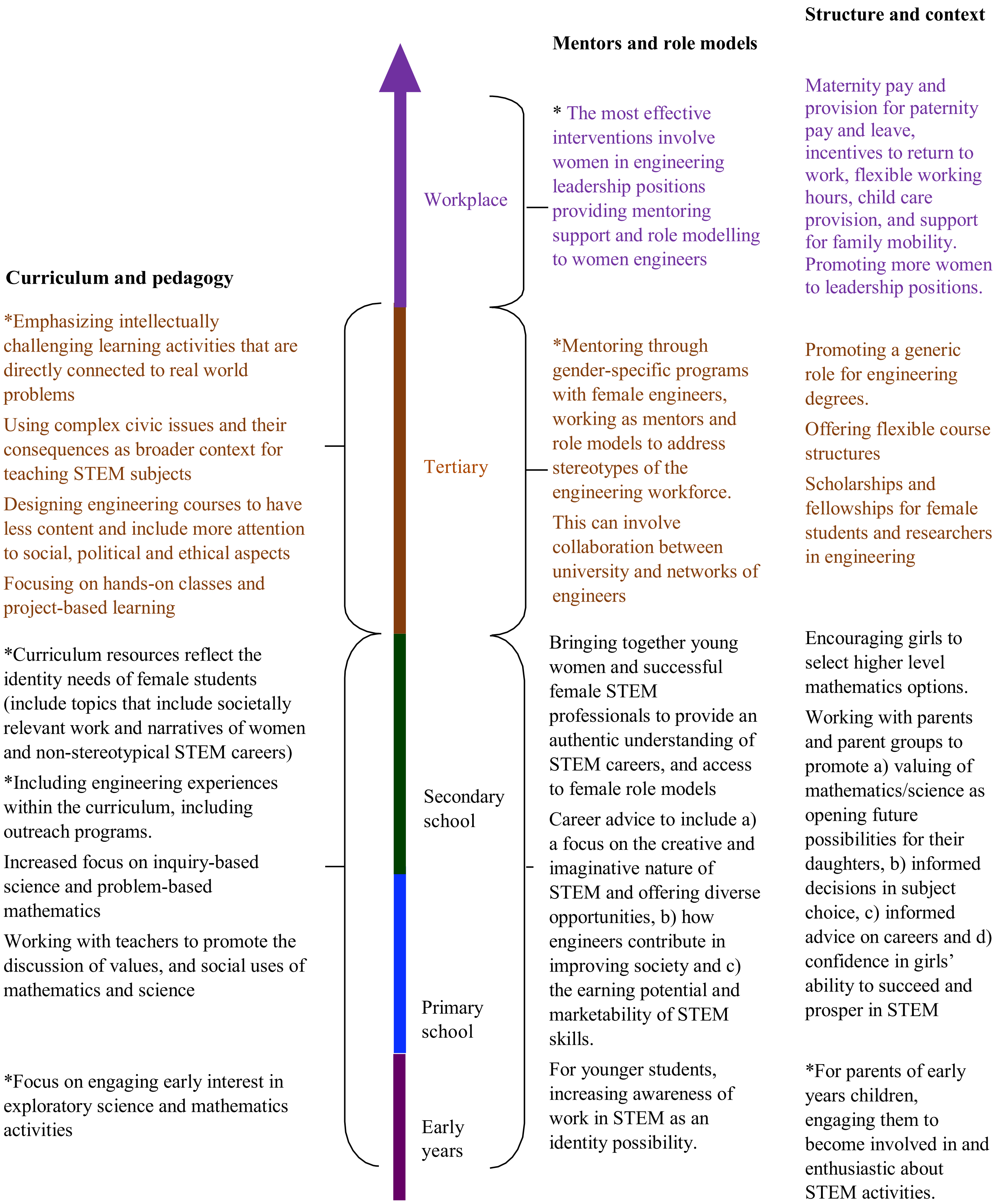

Figure 6. Engagement/participation trajectory for an individual women, and possible initiatives designed to open up STEM and engineering possibilities.

Metrics for intervention

There are detailed figures available in the public space on participation in engineering degrees, broken down by social categories including gender, which can be used to track the success of interventions. These are, however, broad indicators that lag behind in time, so that evidence of success of an intervention takes some time to emerge.

Currently, enrolment in engineering and related technology courses stands at 7.1% of the total degree cohort (Department of Education, 2014). This is low by international standards. Of this, 16% are female.

For interventions relating at the university level, metrics can relate to more restricted participation numbers and can be gathered over a shorter time scale. Both the University of New South Wales and the University of Queensland have female engineering enrolment of 20%, with UNSW targeting an increase to 25% by 2020, and UQ an increase to 30% by 2023. These are already high figures on the national scale, so that there seems room for improvement of female enrolments of 25-50% above current rates seem appropriate targets over a 10 year period. Historically, however, such increases have proved elusive.

Beyond enrolment and retention figures, valid and objective metrics are difficult to establish. For shorter term school level interventions that focus on attracting students and female students into engineering, or improving attitudes to STEM, possible metrics include:

- Metrics around choice of options in the middle years, or senior secondary subjects. These measures are rather fraught as indicators if applied within one setting, given the number of other variables that feed into changes in enrolment, such as chance differences in cohorts, the effect of particular teachers etc.
- Expressions of interest in continuing in these subjects, or in choosing a career in STEM. For the early years of schooling the metric would more appropriately relate to expressions of interest in STEM activities following an intervention.
- Participation rates in voluntary activities. This is a metric that is used for instance in projects that aim to recruit schools into innovative programs, with the assumption that choice to participate is an indication of the success of a program.

The literature often refers to a STEM 'pipeline' as a model for describing the dropping out of students from STEM contention at different points in their schooling. Thus, of the 100% age cohort beginning at birth, perhaps 40% have ruled out interest in pursuing STEM as a course or career by the end of primary school, a further 20% by entry to Year 11, and in terms of engineering, a further 30% at university entry and more again during an undergraduate degree and at point of entry into the profession. The pipeline figures would look different for women, compared to men. The metaphor is useful in highlighting the different points of choice that are critical for enlisting engagement with the idea of becoming a STEM professional, and the potential gains to be made by early interventions. It is misleading, however, on two counts. The first is the implied assumption that the only outcome worth pursuing is entry of people into professional STEM careers, rather than focusing attention on the enabling effects of having people exposed at all points to engagement with STEM, even if they eventually do not enter the STEM professional workforce. The second problem with the metaphor is its assumption of a linear process, whereas in reality there are pathways back into STEM and engineering through further education, for instance, which need to be part of the participation equation.

In summary, there are interventions across the spectrum of years that focus on engaging students, and females in particular, in STEM activities and STEM and engineering futures. At each stage the nature of the intervention is somewhat different, and the appropriate outcome measures and metrics are different also. But there are patterns of intervention that hold across those years, breaking into three broad dimensions. These potentially provide guidance as to what interventions are likely to prove influential.

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[1] At Michigan Technological University, all engineering majors take the Spatial Visualization Test during Orientation. This test measures the ability to visualize a three-dimensional object from different perspectives, and it identifies students who could benefit from additional instruction to improve their spatial visualization skills. Students who do not pass this test will be enrolled in a one-credit course, Introduction to Spatial Visualization, to help them further develop these skills. Topics include isometric sketching, orthographic projection, object transformations, 3-D coordinate systems, patterns folding to 3-D objects, and cross sections of solids. Source: http://www.mtu.edu/ef/

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Appendices

This review has described a range of initiatives designed to encourage females into the STEM workforce, and particularly the engineering pipeline. This section provides detail for a selection successful interventions both in Australian and international contexts, that are illustrative of a range of different approaches.

Appendix 1: Women in Engineering Programs

A number of Australian universities have initiated Women in Engineering programs to provide a range of support for female engineering students. For instance, the University of Technology, Sydney (UTS) initiated the Women in Engineering Program in 1981 to address the low rate of female participation in engineering (Holland, 2007). Strategies included in this program are communicating the opportunities of engineering as a course of study and a career to students; promoting the involvement of women in the course, in the Faculty and in research at UTS, and networking with professionals from engineering fields and professional and community organisations.

The recent Engineering Workforce Study (Australian Workforce and Productivity Agency, 2014) included two case studies representing successful implementations of a Women in Engineering program at the University of New South Wales and the University of Queensland.

Case 1: University of New South Wales

The University of New South Wales' Faculty of Engineering is actively recruiting women and has set a goal of boosting female enrolments to 25 per cent by 2020 (it is currently at 20 per cent).

The university's Women in Engineering Program aims to inspire girls to pursue engineering degrees and careers, support women studying engineering at the University of New South Wales, and celebrate the successes of female engineering graduates.

Engineering workshops and school visits

An important part of the Women in Engineering Initiative is raising the awareness of engineering as a potential career option among girls.

School groups are invited to attend day-long engineering workshops on campus throughout the year, several of which are tailored specifically for girls. In addition, schools can request a visit at their school, where students can hear about the diverse and interesting career options presented by an engineering degree and participate in an engineering-related activity in the class. Current engineering students take part in these visits so they can talk about their own experiences and provide positive role models.

Women in Engineering camps

The University of New South Wales has hosted two summer Women in Engineering camps for 20 to 25 exceptional female senior students from high schools across New South Wales, Victoria, South Australia and the Australian Capital Territory.

The students are immersed in a five-day program in January where they work with each other and with mentors including current students and academics on activities that showcase the diversity of engineering disciplines and applications. They participate in a number of networking events and site visits including a Sydney Harbour Bridge Climb.

Of the 12 participants who were starting Year 12 that attended the 2013 Women in Engineering Camp, nine enrolled in engineering at the University of New South Wales in 2014.

When asked how the camp helped with their career goals, these were some of the responses:

"It has shown me that girls can do engineering as well, and to a high standard! After meeting several women interested in the same type of engineering that I am, at the networking function, it has allowed me to get a different perspective, instead of always talking to men about it!"

"The camp has allowed me to fully understand what engineering is and has answered my questions about my career goals. Also, meeting like-minded women has further motivated me to pursue engineering."

"I feel that I have a much better understanding of the engineering schools at UNSW and have a better idea for what I would like to study in the future. It's been really inspiring to hear so many people at different stages of their engineering careers talk about how much they love what they do and how pivotal some of the changes they bring about can be."

Australian Workforce and Productivity Agency (2014, p. 107)

Case 2: University of Queensland

The University of Queensland's Women in Engineering program is a leader in Australia having recorded a significant increase in the incoming undergraduate engineering student cohort of 24.4 per cent in 2014, up from 21.2 per cent in 2013. This is the highest ever female intake at the University of Queensland and places the university well above the state, national and Group of Eight averages.

The program was established as a university-led, industry-funded initiative to address the gender disparity in engineering at both the tertiary and industry levels. The program's goal is to increase the total University of Queensland undergraduate engineering female enrolment from its current 20 per cent to 30 per cent by 2023.

Together with the University of Queensland, the program's industry partners, Rio Tinto, the Australian Petroleum Production and Exploration Association and the Australian Power Institute, are committed to sharing program findings with other tertiary institutions and industry so that greater female participation can be realised on a national and global scale.

The Women in Engineering program largely centres on its comprehensive high school outreach program. It introduces and inspires female high school students to consider engineering studies through on-campus and in-school interactive workshops, careers' events, expos and other high school outreach activities.

The Women in Engineering program also hosts two flagship events for high school students. The Engineering Futures Evening is for Years 10 to 12 female students and their teachers and parents. This event comprises guest speakers, networking and a student and industry expo. Another significant event is the Women in Engineering Explore Engineering Day for female Year 12 students. The day allows students to more deeply explore a range of engineering fields through interactive workshops.

In 2013, its first year of operation, the program directly engaged with over 600 female high school students from 47 Queensland schools. This is on track to increase in 2014.

As students transition from high school to university and throughout their University of Queensland student experience the Women in Engineering program supports and encourages them in order to retain the next generation of female engineers.

To this end, the program hosts several current student events for networking and industry engagement. It also has a Student Leadership Team, comprising 15 young women from different year levels and engineering disciplines, who represent the program at events for current and prospective students. By increasing connections with industry and other students, the program offers students opportunities to build networks that will benefit their future professional careers.

Source: Australian Workforce and Productivity Agency (2014, p. 108)

Appendix 2: Women in Engineering National Committee

The Women in Engineering National Committee, an initiative by Engineers Australia, coordinates a number of activities with each state and territory division's Women in Engineering committee, to promote the participation of women members of Engineers Australia. The Strategic Planning report for 2012/13 articulates the Committee's key initiatives under three themes: Attract, Retain/Support and Celebrate as below.

1 Attract
- 1.1 Continued development of the GirlTalk program including the CD, Go Girl brochure and toolkit including presentation templates, activity ideas etc. for implementation by the Divisions. Consideration should be given to a national sponsor
- 1.2 Develop strategic alliances with other organisations (i.e., Robogals, NAWIC, CELM)

2 Retain/Support
- 1.1 Position statements regarding Women in Engineering Issues.
- 1.2 Development of a Women in Engineering blue print to encourage diversity. Blue print needs to include an awareness of the issues facing women in engineering and good practice solutions implemented in industry.
- 1.3 Fit for purpose Personal Protective Equipment (PPE). Run trial within industry to obtain feedback on functionality.
- 1.4 Continued support of the Divisions in providing CPD and networking events especially encouraging the 2012 theme of the Year of Regional Engineering. (All)
- 1.5 Identification and nomination of female Fellows.
- 1.6 Development of a Fellows mentoring program. Framework to be developed initially.
- 1.7 Continued participation in Equal Rights Alliance (ERA) women in leadership projects.
- 1.8 Development of Industry Women in Engineering Survey.

3 Celebrate

3.1 Identification and nomination of female Honorary Fellows

3.2 Profiling of inspirational female engineers through website, social media and the EA Magazine.

3.3 Database of College awards and potential nominations.

3.4 Conference scholarships. Criteria to be developed and advertised to encourage paper submission.

3.5 Investigate development of an Engineering Excellence Award (EEA) for exceptional organisational diversity activities

Source: https://www.engineersaustralia.org.au

Appendix 3: Job shadowing

In the USA, Moriarty, Howe, and Yasinski (2013) examined effectiveness of a job shadow program for undergraduate women engineering students as a means of improving interest and persistence in engineering. The program was run by the Picker Engineering Program at Smith College. Job shadowing provided participant students with a workplace-based learning experience that included an opportunity to spend a day or two observing a professional engineer in the field. 14 students were selected to participate in this program based on a review of their application material, an essay that outlined their reasons for wanting to shadow, and their stated goals if selected for the project. Shadow participants created reflective interest statements, spent a day observing engineering professionals, and reported on their experiences at a panel presentation for their engineering classmates. In order to assess the impact of this job shadow program a mixed-methods research was conducted that included pre- and post- surveys, participant interest statements, participant reports, observations of participant presentations, and participant interviews. This research found that in general the job shadow experience had a positive impact on the participating students. In particular, it helped to improve confidence and provided new insights into what it would be like for them as women in the engineering workplace.

Appendix 4: Computer-based social models

In the USA, Plant, Baylor, Doerr, and Rosenberg-Kima (2009) studied the use of animated interface agents as social models for changing male and female middle-school students' attitudes toward engineering-related fields, their self-efficacy for these fields, and their math performance. This study reported an increase in girls' interest and utility beliefs in engineering, and self-efficacy and math performance after the girls were exposed to a 20-minute narrative delivered by a computer-generated female agent describing the lives of female engineers and the benefits of engineering careers. The narratives were designed to promote self-efficacy for engineering courses and to counteract stereotypes of engineering as lacking social responsibility and an unusual career for women, while emphasising "the people-oriented and socially beneficial aspects of engineering and included positive statements about students' abilities to meet the demands of engineering careers" (p. 211). Based on their findings, the researchers argued that interface agents may be used effectively as social models for influencing attitudes and beliefs and supporting performance.

Appendix 5: The Engineer Your Life Website

The Engineer Your Life (EYL) project, through a website (www.engineeryourlife.com), targeted female high school students, career counsellors/educators, and professional engineers to (a) increase their understanding of engineering, (b) inspire young women to explore engineering as a career option and (c) help adults encourage young women to investigate engineering opportunities (Paulsen & Bransfield, 2009, 2010). Within this project, data were collected from the participants over a period of three years. The final report of this project in 2010, found that EYL initiative has had a positive impact on the students, counsellors, educators, engineers and outreach partners who had participated in it. For instance, most of the students who viewed the EYL website indicated that the website helped them learn more about engineering (95.3% in Year 2 and 91.7% in Year 3), made them more interested in engineering as a career (87.9% in Year 2 and 77.8% in Year 3) and inspired them to take an engineering class in college (75.5% in Year 2 and 77.8% in Year 3). By providing resources for students and their student mentors, as found by Paulsen and Bransfield (2010), EYL has helped to encourage academically-prepared female students to consider a career in engineering.