Engaging students in STEM-related subjects. What does the research evidence say?

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Introduction

Considerable evidence exists regarding the declining number of students selecting science from Year 10 into Years 11 and 12 (Ainley et al., 2008; DEST, 2006; Fullarton et al., 2003) in Australia, with less research exploring student transition between secondary and tertiary study. Importantly, the phenomenon that we are experiencing is not unique with many OECD countries facing similar difficulties in terms of student participation and engagement in the enabling sciences in the secondary years of schooling (i.e., physics, chemistry and mathematics) (Osborne & Collins, 2001; OECD Global Science Forum, 2006; Sjøberg & Schreiner, 2005). Evidence of this emerging international concern was tabled and discussed during a meeting of the OECD attended by 17 delegations from western countries in 2005.

Trying to meet the variety of needs of our students is difficult. For example, in attempting to address a science for all agenda (Fensham, 1985) we need to allow all students the opportunity to develop a designated level of scientific literacy (Goodrum et al., 2001; Osborne, 2006) by the time they complete compulsory schooling (i.e., Year 10 in Australia). As defined by the OECD (2006: 12) scientific literacy refers to:

An individual's scientific knowledge and use of that knowledge to identify questions, to acquire new knowledge, to explain scientific phenomena, and to draw evidence-based conclusions about science-related issues, understanding of the characteristics of science as a form of human knowledge and inquiry, awareness of how science and technology shape our material, intellectual and cultural environments, and willingness to engage in science-related issues, and with the ideas of science, as a reflective citizen.

However, in achieving this goal it is critical that we also meet the needs of our high-achieving students who may be interested in pursuing careers in science. Clearly, if we are to cater for this diversity of students we require a differentiated curriculum that ensures engagement with scientific contexts that are meaningful for the range of students (Rennie & Goodrum, 2007) we teach in our classrooms.

In this paper, we identify a range of factors impacting the choices students make in relation to science and mathematics. These factors emerge from a review of the science education literature that has accumulated over the last thirty years. Hence, what is represented here is a synthesis of evidence about this critical area based upon educational research, not anecdotal communications or reports. Unfortunately, it is not possible to refer to all the literature but access to any of the literature cited in this paper will lead to more examples of research that helps unpack the complexity of this critical educational issue.
Factors impacting student choices in STEM areas

The Commonwealth Government’s independent *Review of Teaching and Teacher Education* (DEST, 2003) identified a number of national issues for Australia in relation to science, technology, engineering and mathematics (STEM) education including:

- a decline in the proportion of students who complete Year 12 studies in physics, chemistry, biology and advanced mathematics;
- insufficient numbers of well-trained and highly able teachers in science, technology and mathematics;
- a disinclination among primary school teachers to teach science, exacerbated by primary teachers’ relatively low levels of interest and academic attainment in science and mathematics;
- teaching that does little to stimulate curiosity, interest, problem-solving, and depth of understanding; and
- students who do not do well at school (including a large proportion of Indigenous students) who often leave at the minimum permitted age.

In a recent report entitled *Opening up pathways: Engagement in STEM across the primary-secondary school transition* the extent of the issue appears even more extreme with latest research suggesting that the “life aspirations for the majority of students are formed before the age of 14” (Tytler et al., 2008: viii). A review of this report along with other science education literature identifies a range of factors impacting student choices around STEM that align within four broad categories: Students, Teachers, Parents, and Other. A synthesis of the major factors highlighted in the science education literature is provided in Figure 1.

Based upon this extensive bank of literature we know that the *Student-related* factors focus around ‘identity’ with students needing to build a perception of themselves as competent STEM practitioners (Archer et al., 2007; Tytler et al., 2008). Intricately linked to this notion of identity are factors around student achievement (Goodrum et al., 2001; Hattie, 2003; McPhan, 2008), attitudes and motivation (Lindal 2003; Lyons, 2006), and interest (Panizzon & Levins, 1997). Reports from the *Relevance of Science Education (ROSE)* project (Schreiner & Sjøberg, 2007; Sjøberg & Schreiner, 2005), also raise gender differences as another influential variable for particular countries. While Australia was not actually included in the ROSE project, data from the Program for International Student Assessment (PISA) for 2006 identified no overall gender differences for Australian students in terms of their scientific literacy. However, males significantly outscored females for mathematical literacy for PISA 2006 (Thomson & De Bortoli, 2008).

Within the *Teacher* domain, evidence highlights issues around the traditional pedagogical approaches used by teachers (Goodrum et al., 2001; Peck & Barnes, 1999), perception of science and mathematics (Bennett et al., 2005; McPhan et al., 2008; Osborne & Collins, 2001), and the impact of meaningless and irrelevant curricula (Rennie & Goodrum, 2007; OECD, 2004) on student engagement (Fensham, 2000). However, one of the most significant areas of concern to emerge from research studies is that school science and mathematics is perceived by many students as being irrelevant and ‘boring’ (Goodrum et al., 2001; McPhan et al., 2008; Tytler, 2007). One means of addressing these issues is to move towards a ‘contextual’ approach to the teaching of science with a greater focus around the relevance of science to society using inquiry and investigative approaches (Fensham, 2000; Osborne, 2006; Rennie & Goodrum, 2007). Similarly, research in the mathematical fields recognises the importance of inquiry and investigation along with the need for students to develop higher-order and problem-solving skills (Barnes, 2000; McPhan et al., 2008; Williams, 2005).
In terms of Parental influence, studies demonstrate that high-achieving students in science and mathematics are particularly influenced by the career aspirations and achievements of their parents (Cleaves, 2005; Lyons, 2006; McPhan et al., 2008; Tytler et al., 2008). Clearly, parents are likely to play a central role in the development of their child’s identity beginning in the formative years. However, the wider community too plays a critical role in how STEM careers are perceived and valued. In developing countries, such as India and China, STEM careers are valued by society and parents resulting in students actively engaging in these careers as a means of improving their socioeconomic status to escape the poverty cycle (Lowell & Salzman, 2007). Hence, it is these countries that are currently experiencing an over-supply of citizens with qualifications in STEM-related fields while the OECD countries struggle to fill available positions.

It is important to conceptualise that these factors do not exist in isolation but interrelate to form a complex matrix that impact student choices in STEM over a period of time.
The complexity and interrelatedness of factors impacting student choices demonstrates that the development of any educational strategy to improve student participation and engagement in the STEM fields will require a multifaceted approach that targets major levers for change. Figure 2 provides an overview of these levers for change and an indication of how they fit into the framework of factors impacting student choice.

Public awareness of the role of STEM in society can have a broad influence on students, parents and wider society. However, many public awareness events often have a limited reach/penetration beyond those individuals who are already engaged or interested in STEM. Such events serve to direct the already engaged in a particular direction. What is needed is a broad public awareness campaign that increases the value of science and technology in the general culture. If those individuals who influence young people’s view of themselves (including parents, teachers, peers, etc) are engaged with science then more students are likely to engage and subsequently consider STEM-related education pathways and careers.
Parental engagement, particularly in their children’s science and mathematics education can be difficult to elicit if it does not already exist (Schreiner & Sjöberg, 2007). Yet, it is clear from the research that parents play a critical role in explicitly enthusing and supporting their children to value the contribution the STEM has in their lives beyond the implicit support given by general cultural value (as discussed above).

The expectation and admission processes to Further Education shapes the nature of senior secondary science and mathematics, which in turn has an influence throughout secondary and primary education. However, the transition of students from secondary school science and mathematics and into university or VET education is less explored even though there have been many discussions about broadening pathways to allow multiple access points for students (Tytler, 2008). Anecdotally, the mechanisms for university admission often pervert young people’s aspirations, decisions and choices.

Many students are not aware of the landscape of STEM Careers available to them and the pathways to these jobs. Without this appreciation it can be difficult for some students to make meaning of their science and maths education.

The Curriculum content is important in terms of engaging students and the underlying knowledge that they are expected to develop. However, more important as levers for change are the quality and nature of the assessment items and tasks (which also constitute part of the curriculum). This is because research demonstrates that what is assessed and how it is assessed provides the clearest indication of what is valued about formal education (Black & Wiliam, 1998; Cole, 1990; Hamilton, 2003).

The pedagogy implied by Quality Teaching is the most important lever for change in the short and medium term. Increasing the quantity of high quality science and mathematics teachers is an end into itself but is also crucially important for maximising impact at all other levels of education. In particular, there is a critical role for Faculties of Education and Science in universities to play in the preparation of future primary and secondary science and mathematics teachers.

Conclusion

Research in science education highlights a number of issues around student participation and engagement in the enabling sciences that are interdependent. However, there are in fact few programs based on research evidence that highlight a sequence of strategies for increasing student achievement, participation and engagement in the enabling sciences in senior secondary schools. In contrast, there appears to be much greater emphasis around strategies to enhance primary science education even though it has only been recently that we have seen widespread adoption of research-based programs, such as Primary Connections, by the various jurisdictions in Australia. If the kind of national action plan for change in the enabling sciences developed by Rennie and Goodrum (2007) is to be adopted and implemented across Australia, major work needs to be completed at a macro-scale with a focus around educational systems and their policies.
**Postscript**

The review presented here was used to inform the Premier's Science and Research Council’s Working Party on Science and Mathematics in South Australian Schools report entitled: *Engaging science and mathematics education – A five year strategy for South Australia* (2009).

**References**


