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Optimising STEM education in WA schools

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Optimising STEM Education in WA Schools

Part 2: Full Research Report



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The cover photograph is of a wooden sculpture about science, human creativity and how we discover the true nature of life by applying scientific research to the world around us. The sculpture was created by Professor Efraim Rodriguez Cobos of the University of Barcelona.

Disclaimer

The views expressed in this report do not necessarily represent the views of the Department of Commerce or the Technology and Industry Advisory Council. The authors accept responsibility for the views expressed and all errors and omissions in this report.

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Executive Summary and Recommendations

Context

Education in science, technology, engineering and mathematics (STEM) is a powerful and productive driving force for economic growth. A strong STEM education system provides the essential underpinning of an innovative and scientifically literate culture that:

- develops the capabilities for individuals to function effectively within a science and technology based society;
- provides an ever widening range of career opportunities; and,
- builds the productive capacity required to drive a prosperous economy and enhanced well-being in an increasingly competitive world.

The STEM education pipeline begins in our schools, therefore there is widespread and deep concern about the unsatisfactory status of STEM education in WA primary and secondary schools. This concern is also evident at the national level where Professor Ian Chubb, Australia's Chief Scientist, has made a strong call for action in Australia to increase the number of STEM graduates to drive innovation and economic growth.

The imperative for WA is to support the development of our school students' STEM capabilities and interest in further education and careers in STEM.

Purpose

The purpose of the *Optimising STEM Education in WA Schools* project was to:

- identify the status of STEM education in WA schools;
- identify STEM education challenges, and the needs of students and teachers;
- identify the range of organisations supporting STEM education, the initiatives supported and barriers to providing support; and,
- make recommendations for optimising STEM education.

Methodology

The project was conducted in three phases:

- Phase A involved an analysis of literature and available research data.
- Twenty informants drawn from the three education sectors, four teacher professional associations and three significant STEM education service providers were interviewed in Phase B.
- In Phase C, interviews were conducted with representatives from 19 industry organisations that are significant supporters of initiatives to optimise STEM education in our schools.

A set of key findings emerged from the analysis of the data forming nine themes. These themes are described more fully in the body of this report.

Findings

The research revealed:

- declining achievement and negative attitudes towards STEM subjects amongst primary and secondary school students; Year 4 TIMSS achievement data for science and mathematics, and PISA data for 15 year old students in science and mathematics reveal declining performance relative to comparator countries; and, there is significant concern about the very low proportion of Australian and WA students reaching advanced benchmarks of achievement;
- declining participation in academically demanding STEM subjects at the senior secondary level; the average number of science subjects taken by WA Year 12 students declined from 1.42 to 0.66 between 1986 and 2012; the average number of mathematics subjects, that contribute to an ATAR, taken by WA Year 12 students declined from 0.92 to 0.69 between 1992 and 2012;
- strong negative impacts of social disadvantage on achievement, attitudes and participation in STEM subjects;
- concern about the availability of teachers with requisite STEM expertise;
- the substantial challenges resulting from out of field teaching and the requirements of the new Australian curriculum;
- the absence of integrated strategies to build and strengthen the capacity of the STEM teaching workforce;
- the importance of STEM skills and qualifications to industry, and the consequences of specific shortages;
- the diverse nature of initiatives providing support to STEM education, their uneven delivery to schools, and the willingness of industry to increase current support for STEM education; and,
- the barriers to optimising industry support for STEM education, and the strategies developed by education service providers to counter them.

A set of recommendations and suggested actions has been developed to address the concerns about the status of STEM education in WA schools. The recommendations are listed below and the accompanying explanations and suggested actions are explained in the body of this report.

Recommendations

1. Enhance the capability of the existing STEM education workforce through developing mechanisms for more co-ordinated, systematic and sustained provision of discipline-specific teacher professional learning, mentoring and resource development.
2. Provide incentives to attract additional high quality applicants into pre-service education in areas of STEM teaching shortages, currently mathematics, physics and technology education.
3. Collect data about the qualifications of those currently teaching Year 7-12 science and mathematics and those entering the profession.
4. Establish an Industry-STEM Education Consultative Group to generate higher levels of industry engagement in STEM education, increased collaboration between industry and education service providers in the delivery of STEM education initiatives, and create greater awareness of the range of initiatives being implemented.

5. Enhance the capacity of STEM education service providers to deliver discipline-specific teacher professional learning and curriculum resources needed by science, mathematics and technology teachers.
6. Develop holistic approaches to raising aspiration and opportunity for high quality STEM education in disadvantaged schools in the metropolitan area and regional centres.
7. Provide enhanced career education to students, parents, teachers, career guidance officers and school leaders to increase awareness and understanding of the importance of STEM education and the opportunities available through STEM-based careers.
8. Enhance the infrastructure and technical support required for a high quality science and technology education.
9. Projects initiated as outcomes of this report should be formally evaluated and include a dissemination strategy.

This study and its outcomes provide a compelling case for concerted action to address the current status of STEM education in our schools. The dimension of the problems requires the participation and collaboration of all key stakeholders and a proposed mechanism to achieve this is also described in this report. A summary report (Part 1) is also available as a separate document.

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Background and Context to the Study

Introduction

Numerous international and national reports published in recent years have indicated the importance of Science, Technology, Engineering and Mathematics (STEM) industries in underpinning current and future national economies (Australian Industry Group, 2013; International Technology Education Association, 2009; Moyle, 2010). In an Australian context, and more closely a Western Australian context, the future employees of STEM and STEM-related industries are currently students in this state's formal education system. There exists an imperative to support the development of our students' STEM skills and knowledge to ensure an adequate supply of appropriately qualified personnel for the STEM workforce.

The Australian Curriculum does not provide for Engineering to be studied as a separate discipline. For this reason, the focus of the report will be upon the disciplines of Science, Mathematics and Technology.

The Need for STEM Graduates

A range of evidence has emerged about the quality of science education and the number of students studying science that has raised concerns about Australia's capacity to generate the Science, Technology, Engineering and Mathematics (STEM) graduates needed to address the economic, social and environmental challenges facing Australia. In 2006, 35% of graduates in all geographic regions of the world were from science and engineering fields (physical, biological, mathematical, computer, agricultural, social and behavioural sciences and engineering) whilst in Australia there were 29% which was lower than the United States (32%), Canada (33%), the European union (34%), Singapore (51%), China (53%) and Japan (63%) (National Science Board, 2010a). Over the period from 1998 to 2006 in Australia, the number of graduates from all fields increased from 125 000 to 172 000 and the proportion of science and engineering graduates increased from 25% to 29%.

There have been strong calls for action in Australia (Office of the Chief Scientist, 2012) to increase the number of STEM graduates to drive innovation and economic growth.

Professor Ian Chubb, Australia's Chief Scientist has argued that:

Policies are emerging around the world that focus on STEM and seek to grow the supply of graduates with the skills and knowledge developed through a quality education in the STEM subjects. The reason is straightforward: the world's dependence on knowledge and innovation will grow and not diminish and to be ahead in the race, a community needs the skills to anticipate rather than follow.

No action by Australia would see the gap between our capacity and those of others widen further. In turn that would see us as followers not anticipators and restrict our opportunities to develop a high technology, high productivity economy (Office of the Chief Scientist, 2012, p. 6).

This view is also supported by the 2013 Australian Council of Learned Academies report (Marginson, Tytler, Freeman & Roberts, 2013) which argues that “in Australia, in reality the STEM economic policy agenda is largely driven by the need to lift the general quality of the *supply* of human capital as well as enlarge the high-skill group capable in research, commercialisable innovation and effective response to technological change” (p. 13).

Purpose of STEM Education

Science

In Peter Fensham’s (1985) seminal essay on science curriculum, he critiqued curricula that focussed only on the needs of the 20% of the cohort that needed preparation to be future science professionals and introduced the mantra of ‘science for all’. Later reviews (e.g., Goodrum, Hackling & Rennie, 2001; Millar & Osborne, 1998) argued that the main focus of science curricula for primary and lower secondary schooling should be the development of scientific literacy of all students so that they could participate effectively in science and technology dominated cultures. This theme is continued in the new F-10 Australian Curriculum which provides opportunities for students to develop:

an understanding of important science concepts and processes, the practices used to develop scientific knowledge, of science’s contribution to our culture and society, and its applications in our lives ..., and ... to develop the scientific knowledge, understandings and skills to make informed decisions about local, national and global issues and to participate ... in science related careers. (ACARA, 2012c, p. 3)

In the Australian Curriculum for senior secondary science there is a stronger focus on the preparation of the professional scientist and for science-related careers: “Studying senior secondary Science provides students with a suite of skills and understandings that are valuable to a wide range of further study pathways and careers” (ACARA, nd., p.1).

Australia’s Chief Scientist argues that “we need to ensure that the school sector maximises interest and provides opportunities for all students to study high quality mathematics and science leading to careers in those disciplines and in engineering” (Office of the Chief Scientist, 2012, p. 6). The US National Science Board (2010b), however, has made a call for a stronger focus on the most talented students: “we must renew our collective commitment to excellence in education and the development of scientific talent. Currently, far too many of America’s best and brightest young men and women go unrecognized and underdeveloped, and, thus, fail to reach their full potential. This represents a loss for both the individual *and* society” (p. 1).

As we in Western Australia prepare for the implementation of the Australian Curriculum for F-10 and senior secondary science, there is a need to balance the requirement of scientific literacy for all students and the development of those with talents in science for future roles as science professionals and innovators.

Mathematics

According to ACARA (2013a) “learning mathematics creates opportunities for and enriches the lives of all Australians... It develops the numeracy capabilities that all students need in their personal, work and civic life, and provides the fundamentals on which mathematical specialties and professional applications of mathematics are built” (p. 3). The focus of the Australian Curriculum: Mathematics is on developing refined mathematical understanding, fluency, logical reasoning, analytical thought and problem solving skills. These capabilities enable students to employ mathematical strategies to make informed decisions and solve problems efficiently.

The curriculum anticipates that all students will benefit from access to the power of mathematical reasoning, and learning to apply their mathematical understanding creatively and efficiently. Students are encouraged to become self-motivated, confident learners through inquiry and active participation in challenging and engaging experiences.

The National Numeracy Review (Coalition of Australian Governments, 2008) provided a “stocktake of research-based evidence about good practice in numeracy and the learning of mathematics” (p. vii). The review revealed that:

the mathematical knowledge, skill and understanding people need today, if they are to be truly numerate, involves considerably more than the acquisition of mathematical routines and algorithms... Students need to learn mathematics in ways that enable them to recognise when mathematics might help to interpret information or solve practical problems, apply their knowledge appropriately..., choose mathematics that makes sense in the circumstances, make assumptions, resolve ambiguity and judge what is reasonable (p. xi).

In a report prepared in consultation with the Australian Council of Heads of Mathematical Sciences, Rubinstein (2009) argued that “Australian mathematics and mathematics education are in a dire state” and that “without concerted action, there is little prospect for turning the situation around” (p. 1). According to Rubinstein:

Mathematics isn’t just important. It is a critical skill that every Australian citizen should be able to develop in order to improve their lives and the lives of those around them. Mathematics enables technological innovation in our world. It is elemental to all forms of commerce. It is the foundation upon which all sciences and all areas of engineering depend (p. 1).

Technology

The purpose of technology in Years F-12 is to develop students’ technological literacy, that is, to enable them to use, manage, assess and understand technology (The International Technology Education Association, 2009).

Specifically, the Draft Australian Curriculum: Technologies aims to develop students’ knowledge, skills and understandings so that they are able to:

- Be creative, innovative and enterprising when using traditional, contemporary and emerging technologies;
- Select and manipulate appropriate technologies, resources and systems when designing and creating;

- Evaluate technologies processes to identify and create solutions to problems;
- Design, plan and create technologies solutions; and
- Engage confidently with technologies and make appropriate decisions that relate to the impact of their use on the future (ACARA, 2013b).

Under the Draft Australian Curriculum: Technologies umbrella, Digital Technologies forms one component and Design and Technologies forms the second component.

The teaching and learning emphases of the Draft Australian Curriculum: Technologies are upon developing technological literacy, knowledge and understanding of a range of technologies, and an understanding of technology processes.

School Achievement Data

Science

There are three key indicators of the status of science achievement for Australian students: the TIMSS data which reports international comparisons of student achievement for Year 4 and 8 students which has a focus on content mastery; the PISA data which reports international comparisons of 15-year old students' scientific literacy; and, the Australian NAPSL data which reports on the scientific literacy of Year 6 students.

The 2007 TIMSS data (Thomson, Wernert, Underwood & Nicholas, 2008) shows that Australia scored above the international mean, however, Australia's science achievement is slipping – our Year 4 students were significantly outperformed by eight countries including most Asian countries, England and USA, and our Year 8 students' mean score was significantly lower than in 2003 and we were significantly outperformed by 10 countries. The 2011 TIMSS data (Martin, Mullis, Foy & Stanco, 2012) shows that our Year 4 students were significantly outperformed by 18 countries and our Year 8 students were significantly outperformed by nine countries. These data show that at the Year 4 level both the standard of achievement and our international ranking have fallen between 2007 and 2011, whilst performance at the Year 8 level is stable. The proportion of Australian students reaching the advanced benchmark of performance is of concern. At the Year 4 level only 7% of Australian students reached the advanced benchmark compared with 40% for Singapore; and, at the Year 8 level 11% of Australian students reached the advanced benchmark compared with 40% for Singapore. It should also be noted that in 2011 at the Year 4 level there was no difference between the mean performances of males and females, however, at the Year 8 level, males significantly outperformed females.

The 2006 PISA data shows that Australian 15-year olds were only significantly outscored on measures of scientific literacy by three countries, however, in 2009 we were outperformed by six countries (Thomson, De Bortoli, Nicholas, Hillman & Buckley, 2010) and by seven countries in 2012 (Thomson, De Bortoli & Buckley, 2013). In 2012, there was no significant difference between male and female mean scores. Indigenous student mean scores were equivalent to two and one half years of schooling lower than non-Indigenous students. The gap between the highest and lowest socioeconomic quartile was equivalent to two and one half years of schooling. The gap between metropolitan and provincial schools as equivalent to half a year of schooling and the gap between metropolitan and remote schools was equivalent to two years of schooling. The strong impact of

social and economic disadvantage on performance is reflected in the wide spread of scores achieved by Australian students in the 2012 PISA assessments. Fourteen per cent of Australian students achieved Levels 5 and 6 and were considered top performers compared to 27% for China and 23% for Singapore. Thirteen per cent of Australia students achieved below Level 2 and were considered low performers compared with 2% for China.

The NAPSL data (ACARA, 2013c) shows that almost half (49%) of sampled Australian Year 6 students did not reach the proficient standard in 2012. WA improved its mean score and ranking amongst the eight jurisdictions from seventh in 2006, to fourth in 2009 and second in 2012; however, 44% of WA students did not reach the proficient standard. There were no significant differences between performances of males and females in 2012, however, the gap between the performance of non-Indigenous students and Indigenous students was large and statistically significant and there is no evidence of the gap being closed between 2003 and 2012.

These data indicate that science education achievement in Australia is above international means, however, our performance is slipping relative to other countries and in absolute standards on some measures. We are significantly outperformed by our South-Eastern Asian neighbours who are our trading partners and competitors in knowledge-based products and services. On the Year 6 NAPSL data, WA is now ranked fourth in Australia and almost half of Australian students do not reach the proficiency standard. The data show a large disparity between the performances of students of high and low socioeconomic status, between Indigenous and non-Indigenous students, between students of metropolitan and remote geolocation, and between males and females on Year 8 TIMSS assessments.

Mathematics

The TIMSS data also provides a benchmark for comparing the mathematical achievement of students across different countries. At the Year 4 level, Australia was ranked 14th behind Hong Kong, Singapore, Chinese Taipei and Japan, followed by a group of seven European countries and the United States. All of these countries achieved a significantly higher average score than Australia. Nevertheless, Australia's achievement score was above the international average and significantly higher than that of 20 countries, including Sweden and New Zealand. At the Year 8 level, Australia was once again ranked 14th. Nine countries achieved significantly higher scores than Australian students: Chinese Taipei, Korea, Singapore, Hong Kong, Japan, Hungary, England, the Russian Federation and the United States. Australia's performance was not significantly different from the TIMSS scale average (Thomson et al., 2008). Of particular concern is the decline in mathematical achievement between 1995 and 2007, during which Australia's performance fell from being significantly above the United States and England to significantly below them (Brown, 2009).

The 2011 TIMSS data shows that at Year 4, Australia's ranking fell from 14th to 18th and we were significantly outperformed by 17 countries, however, at the Year 8 level Australia improved its ranking from 14th to 11th and we were significantly outperformed by six countries. Australia's mean scores at both Year 4 and 8 levels were not significantly different from 2007 so standards have remained static. There were no significant differences between the mean scores of males and females on the Year 4 or Year 8 assessments. A matter of concern is the low proportion of Australian students reaching the advanced benchmark: 10% of Year 4 Australian students reached the advanced benchmark compared with 43% of Singapore students; and, 9% of Australian Year 8

students reached this benchmark compared with 49% of students from Chinese Taipei. The data also show that 10% of Australian Year 4 students and 11% of Year 8 students failed to reach the low (lowest) benchmark (Mullis, Martin, Foy & Arora, 2012).

PISA also provides a measure of mathematical literacy in 15-year old students. While Australia scored significantly higher than the OECD average, Australia was significantly outperformed by eight countries in 2006 (Thompson & De Bortoli, 2008) and by 17 countries in 2012 (Thomson, De Bortoli & Buckley, 2013). Australia's mean mathematical literacy performance has declined significantly between 2003 and 2012.

Further exploration of the 2012 PISA data reveals that Australian males performed significantly higher than Australian females. Indigenous students scored significantly lower than non-Indigenous students, with the differences being equivalent to up to two and one half years of schooling. Students who attended schools in metropolitan areas outperformed students from schools located in provincial areas, who in turn outperformed students who attended schools in remote regions. The gap between the highest and lowest socioeconomic quartile was equivalent to two and one half years of schooling (Thomson, De Bortoli & Buckley, 2013).

Examination of the NAPLAN data between 2008 and 2012 reveals an increase in the mean numeracy scores for Australian Year 5 students, and a decrease in numeracy scores for Year 7 students. At the national level, between 93.3 and 93.9% of Australian students met the minimum standard for numeracy in 2012. Figures for WA reveal that the mean numeracy scores of Year 5 and Year 9 students have increased significantly between 2008 and 2012. In 2012, WA ranked fifth of the eight jurisdictions in numeracy at the Year 3 and Year 5 levels, and fourth at the Year 7 and Year 9 levels. The performance of non-Indigenous students was significantly higher than that of Indigenous students at all year levels (ACARA, 2012a).

These data reveal a modest and declining international ranking in maths achievement, and concerns about the low percentage of Australian Year 4 and 8 students reaching advanced benchmarks of achievement, and the impact of socio-economic and gender factors on achievement.

Technology

There are no national or international assessment data available to provide a picture of student achievement in Technology.

School Factors Impacting on Achievement and Transition to Tertiary Studies

The latest report from the Longitudinal Surveys of Australian Youth identified the school factors that influenced students' tertiary entrance score and transition from school to university studies (Gemici, Lim & Karmel, 2013). The report concluded that "young people's individual characteristics play a much stronger role with respect to university enrolment than the characteristics of their schools" (p. 9). However, when individual attributes have been accounted for, the three most important school-related variables influencing TER score are "school sector (Catholic and independent schools have higher predicted TERs than government schools), gender mix (single-sex schools have higher predicted TERs than coeducational schools), and the extent to which a school is academically oriented" (p. 9). Academic orientation of a school relates to the parents expectations that the school will perform well academically.

Student Attitude Data

Science

The 2009 NAPSL tests (ACARA, 2010) included a survey which assessed Year 6 students' attitudes towards science. There were indicators of students' perceptions of the importance of science and interest in science. Eighty-two per cent of the sampled students strongly agreed/agreed that *Science is important for lots of jobs*, while 76% strongly agreed/agreed that *I think it would be interesting to be a scientist* and 74% strongly agreed/agreed that *I would like to learn more science at school*. However, the survey data also revealed that 40% of students have the opportunity to study science in their class less than once a week and a disturbing 21% reported that they studied science hardly ever.

The 2006 PISA study included measures of 15-year old students' attitudes towards science and the data show that Australian 15-year olds' attitudes towards science are not positive (Thomson & De Bortoli, 2008). Australian students' perception of the value of science was below the international mean and students from only three of 57 countries (Netherlands, Finland and Korea) had a lower interest in learning science than Australia. Australian students' rating of enjoyment of science was also lower than the international mean. The international Relevance of Science Education (ROSE) study shows that the human development index correlates negatively with interest in learning science and technology (Sjoberg & Schreiner, 2010) and interest in having more science in the curriculum is lowest amongst western developed countries, especially girls.

These data sets show that Australian Year 6 students have positive attitudes towards science, however, our 15-year olds have developed quite negative attitudes and this is common to other western developed nations.

Mathematics

In 2007, TIMSS included a three-item measure of Students' Positive Affect Toward Mathematics (PATM). At an international level, students generally had very positive attitudes towards mathematics, with 72% of Year 4 students obtaining a high score on the PATM index. In Australia, 66% of Year 4 students obtained a high score on the PATM index, representing a significant decrease of seven percentage points since 1995. Internationally, 54% of Year 8 students obtained a high score on the PATM index, compared to just 34% of Australian students. These TIMSS data suggest that Australian Year 4 and 8 students have less positive attitudes towards mathematics than students from other countries (Thomson et al., 2008).

Student attitudes towards mathematics and problem solving were addressed in the 2003 PISA study. While Australian males reported higher levels of interest and enjoyment in mathematics than females, the overall results did not differ from the OECD average. Australian students scored higher than the OECD average on the instrumental motivation index, indicating stronger beliefs in the value of learning mathematics for external reasons, such as getting a job. In addition, Australian students had a higher self-concept in mathematics than the OECD average, with males having a stronger self-concept than females (Thomson, Cresswell & De Bortoli, 2004). Given that the PISA data were gathered from 15 year olds, many of these would have been Year 11 students who have recognised the importance of maths for university admission and would have a better understanding of the value of maths that the younger students sampled for the TIMSS assessments.

Technology

The 2011 National Assessment Program ICT Literacy (ACARA, 2012b) measured levels of confidence and skill development of students in Years 6 and 10 with regard to using information and communication technologies. Included in the assessment instruments were items that measured students' interest and self-efficacy in using ICT. On the item *I use a computer because I am interested in the technology*, 65% of Year 6 students strongly agreed/agreed while only 59% of Year 10 students strongly agreed/agreed. On the item *I like learning how to do new things using a computer*, 87% of Year 6 students strongly agreed/agreed and 77% of Year 10 students strongly agreed/agreed. At both year levels, students' overall interest and enjoyment in working with computers was significantly higher for males than females.

With regard to students' self-efficacy (confidence) in being able to perform a range of ICT tasks without assistance, there were no significant differences between males and females at Year 6 level or at Year 10 level. There were, however, significant differences between year groups with Year 10 students showing an increased level of self-efficacy compared to students in Year 6.

Enrolment Data for Senior Secondary Science, Mathematics and Technology

Various types of indicators have been used to analyse and report participation rates in senior secondary science, mathematics and technology. Annual enrolment numbers in each subject is the simplest index but does not reflect changes in the size of the Year 12 cohort. To illustrate, over the last 30 years there have been reported increases in the raw numbers of students participating in senior secondary science subjects. Yet when the corresponding increases in the overall Year 12 cohort are taken into account the actual percentage of students enrolled in these subjects has declined or at best remained the same (Lyons & Quinn, 2010). For this reason a useful index for analysing participation rates is the percentage of Year 12 students enrolled; expressing the number of students enrolled in specific subjects as a percentage of the number of students in Year 12. This, however, does not take account of the changes to the spread of ability in the Year 12 cohort since it became compulsory for students to remain in education or training until the end of Year 12. For this reason, the percentage of the 17 year-old population enrolling in subjects is a valuable measure.

Another issue to be noted in reviewing reports of participation rates is the range across the nation and across the years in the label or title given to the senior secondary subjects studied by students. For example, some reports included Human Biology participation rates with Biology and the range of mathematics subjects are categorised by some as high, intermediate and low level.

Science

From 1992 to 2011, data show that there has been a dramatic fall in the percentage of Australian students studying science in Year 12; from 94.1% participation to 51.4% (Goodrum, Druhan & Abbs; 2011). This decline in participation rates is evident in the three science subjects with the largest enrolments; Biology, Chemistry and Physics. The ACER report (Ainley, Kos & Nicholas, 2008), which focussed on student participation in science, mathematics and technology and drew on DEEWR data collected from all Australian States and Territories, reported trends in specific science subjects from 1991 to 2007. These were:

- Participation in Biology had declined from 1991 (35.9%) to 2003 and then stabilised to 2007 at 25%.
- Chemistry participation declined (23.3% in 1991 to 18% in 2007).
- Physics participation rates declined (20.9% in 1991 to 14.6% in 2007).
- Psychology enrolments peaked at 9% in 2006 but fell to 8.5% in 2007.
- Geology and Earth Science had a participation rate of 1%.
- Participation in the 'other' sciences (e.g. integrated science) remained reasonably constant, but increased slightly to just over 8% in 2007.

It was evident in the Victorian Auditor-General report (2012) titled, *Science and Mathematics Participation Rates and Initiatives* that there was a similar decrease in enrolments in the fundamental or enabling sciences in Victoria from 1995 (43%) to 2011 (39%), to that evident nationally. It was reported that in 2011, 60% of Year 12 students in Victoria studied one or more science subjects but only 39% studied Biology, Chemistry or Physics. The difference had been made up by a growth in Psychology, which was reported to potentially 'mask' the drop in enrolments in traditional sciences. Overall, the percentage of Victorian Year 12 students participating in science had increased over time but participation in the enabling sciences and mathematics had declined.

To further analyse participation rates and trends, it was considered useful to review combinations of science subjects taken by students. Taking multiple science subjects in Year 12 provides an indication of students' orientation and future career pathways. Based on the *Longitudinal Surveys of Australian Youth* (LSAY) data, Ainley, Kos and Nicholas (2008), reported the most common science subject combination was Chemistry and Physics. Importantly, the trend since 1990 was a substantial decline in the percentage of students studying two or more science subjects in Year 12.

These trends should be contextualised within broader social and educational issues. For example, Lyons and Quinn (2010) asserted that the reported national decline in the proportion of students taking Biology, Chemistry and Physics should be rationalised within a similar decline in many traditional subject areas such as Economics, Geography and History. They further concluded that the decline in science enrolments was likely to be due to a changing context for subject choices that included a greater range of subject options. As an outcome of student surveys, they also identified the following contributing factors linked to the decline in participation in senior secondary science subjects:

- Difficulty in perceiving of 'self as scientist'.
- Perceived decreased usefulness of science subjects, as many university courses no longer require the enabling sciences (and mathematics) as an entry prerequisite.
- Failure of school science to engage a wide range of students.

Furthermore, it was consistently reported that there was an association between participation in Year 12 science subjects and variables such as earlier mathematics achievement, socioeconomic background, gender, school sector and location. For example, Ainley, Kos and Nicholas (2008) reported:

- Students in the highest mathematics levels in Year 9 were more likely to participate in senior secondary Chemistry and Physics. The association with Biology was weaker and appeared non-linear.

- Participation rates in the enabling sciences were greater for students from high socioeconomic backgrounds. There was, however, a weaker association with Biology.
- Male Year 12 students were more likely to study Physics than Biology. Females were more likely to study Biology. Generally, males and females were equally likely to study Chemistry.
- Students whose parents were from non-English speaking backgrounds were less likely to study Biology than those whose parents were from an English speaking country.
- There was a slightly higher participation rate amongst city students in Chemistry and Physics and a slightly higher participation in Biology from country students.

There is further evidence of demographic variables impacting on students' participation in Physics and Chemistry from School ICSEA data (Australian Curriculum, Assessment and Reporting Authority, 2012). The ICSEA (Index of Community Socio-Educational Advantage) is based on parents' occupation and education level with measures of remoteness, per cent Indigenous and language background other than English for the community in which the school is set (ACARA, 2012). The mean score for ICSEA is 1000. The Western Australian data presented in Figure 1 shows that there is a strong relationship between participation in Physics and Chemistry and ICSEA. A very large majority of Physics and Chemistry students attend schools of above average ICSEA. Students from higher ICSEA bands are more likely to participate in Physics and Chemistry and more students across all ICSEA bands study Chemistry than Physics.

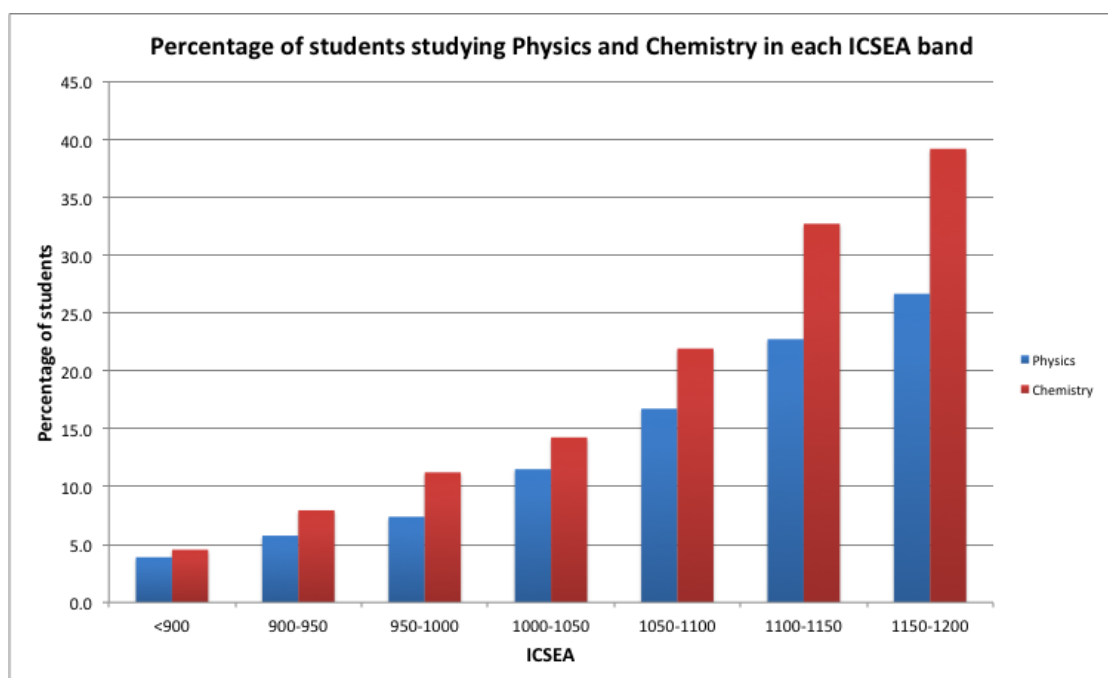


Figure 1: Percentage of WA students studying Physics and Chemistry in each ICSEA band

WA science participation rates

To conduct a meaningful analysis of WA students' participation in science subjects, it is necessary to consider the size of Year 12 cohort which has doubled over the period 1986 (11 321 students) to 2012 (22 476 students), and the participation rate of males and females. Absolute numbers of student enrolments in each subject are of interest, however, the percentage of students in the Year 12 cohort must also be considered. It is to be expected that with the shift from Year 10 to Year 12 as the end of compulsory schooling, the nature of the Year 12 cohort has changed considerably and

now includes a much wider range of academic ability and capacity to be successful in the traditional academic subjects. The Year 12 full-time student cohort has expanded from 45% of the 17 year-old population in 1986 to 71% in 2012 (Australian Bureau of Statistics, n.d.).

Table 1 reports participation data for the years 1986 and 2012 for science subjects.

Table 1: Number and percentage of the WA Year 12 cohort for each science and technology subject for 1986 and 2012, and percentage of subject candidates who are female

Subject	1986			2012		
	Number	Percentage of Year 12 cohort ^a	Per cent female	Number ^b	Percentage of Year 12 cohort	Per cent female
Biology	3 366	30	53	1 715	8	65
Human Biology	5 045	45	74	4 290	19	68
Chemistry	3 233	29	37	4 809	21	46
Physics	3 129	28	29	3 585	16	30
Physical Science	820	7	43			
Senior Science	343	3	31			
Geology/EES	120	1	8	285	1	45
Integrated Science				165	0.7	49
TOTAL	16 056	1.42 subjects per student		14 849	0.66 subject enrolments per student	

Notes. ^a These data refer to the Year 12 cohort which is defined as the full-time Year 12 students who are eligible to graduate at the end of the year. This is a subset of the total 17 year-old population of WA at that time. ^b The number of students in 2012 refers to those who completed two units and sat examinations for the subject at Stages 2+3 and for whom the examination scores may contribute to the student's ATAR. For some subjects there are also significant numbers of students who completed the subjects at Stage 1.

These data show that in WA the overall number of students participating in science subjects has declined; the numbers of students studying Biology and Human Biology have declined whilst the numbers in Chemistry, Physics and Earth Science have increased. As a percentage of the Year 12 cohort participation has declined in all subjects except for Earth Science.

In 1986, on average, each Year 12 student took 1.42 science subjects and this has declined to 0.66 subjects per student in 2012. Female participation rates vary strongly between disciplines: more females than males study biological sciences, while more males than females study physical and earth sciences. The greatest disparity between male and female participation rates exists in Physics and this has changed little between 1986 (28% female) and 2012 (30% female). It should be noted

that Chemistry has made the strongest growth in absolute numbers of student enrolments between 1986 and 2012 and that the female participation rate has risen from 37% to 46%. Enrolment numbers and female participation rates have also increased for Earth and Environmental Science compared to those for Geology.

Mathematics

To establish a general overview of the participation trends in Australian senior secondary mathematics, it was necessary to classify subjects into categories, due to the diversity of nomenclature used to label these subjects in Australia and changes across the years. In the literature, classifications are typically based on the intended purpose of the subject rather than the content (Ainley, Kos & Nicholas, 2008). For example:

- i. *Advanced or specialised mathematics*: Leading to tertiary studies in which mathematics is an integral component.
- ii. *Intermediate mathematics*: Leading to tertiary or further studies in which mathematics content is minimal.
- iii. *Fundamental mathematics*: Subjects which do not provide suitable mathematical content for any tertiary studies.

Participation rates in advanced or specialised mathematics subjects have declined in all States and Territories from 1991 to 2007. For example, in Western Australia in 1992 there was a participation rate of 13.9% in Calculus which dropped to 7.7% by 2007 (Ainley, Kos & Nicholas, 2008). Nationally there was a general decline in participation in advanced mathematics. Overall, there was an uneven decline throughout the '90s, a period of stabilisation from 2001 to 2004 and then a continuing decline from 2004 to 2007. There was no evidence at this time to suggest the trend had reached its lowest point. It is suggested that part of the reason for this decline was that advanced mathematics was no longer a pre-requisite subject for a range of university courses.

A range of reports presented a national trend toward greater participation in fundamental level mathematics courses which was matched by a corresponding decrease in participation in advanced and intermediate level mathematics subjects. To illustrate, Barrington (2006) as cited by Ainley, Kos and Nicholas (2008) reported the following participation rates:

- Increased student participation in Year 12 fundamental mathematics; 37% in 1995 to 46% in 2004.
- Decreased student participation in Year 12 intermediate mathematics; 27% in 1995 to 23% in 2004.
- Decreased student participation in Year 12 advanced mathematics; 14% in 1995 to 12% in 2004.

It is evident that the trends described by Barrington have continued. The DEEWR statistical collection of national enrolments in mathematical subjects from 2001 to 2007, showed there was a continuing decline in participation in the advanced mathematics subjects, a larger decline in participation in intermediate mathematics and a rise in participation in other mathematics (Ainley, Kos & Nicholas, 2008).

Further evidence of these trends can be found in more recent data from Victoria and NSW. The Victorian Auditor-General report (2012) stated that in 2011, 78% of Year 12 students in Victoria studied one or more mathematics subjects, however, the proportion of students studying high or advanced mathematics subjects was declining. From 1995 to 2010 the proportion of students studying one of the three Victorian Year 12 mathematics subjects rose from 68 to 78% but this increase was only in the least difficult option. The proportion of students taking advanced or intermediate mathematics subjects had in fact dropped.

Examining the NSW senior secondary mathematics participation data raised further concerning trends. In 2001, 9.5% of Year 12 students had no mathematics subjects; one-third of these were male and two thirds female. In 2011, this figure was 21.8%, with the same ratio of male to female students (Mack & Walsh, 2013). Gender influence on mathematics participation was further highlighted in the 2012 Secondary Education Statistics, from the WA School Curriculum and Standards Authority. The absolute number and percentage of males participating in the intermediate level of mathematics (Stage 2) is slightly lower than females. However, this trend is reversed in the advanced levels of mathematics (Stage 3 and specialist). There is a clear trend over time for more males to study harder mathematics than females in Western Australia.

Table 2: Number of WA candidates and percentage males sitting mathematics examinations 2010-2012 by subject

Year	Maths Stage 2		Maths Stage 3		Specialist Maths Stage 3	
	# candidates	% male	# candidates	% male	# candidates	% male
2010	5094	43.1	3570	60.6	1611	73.0
2011	3564	41.3	3488	59.2	1396	69.6
2012	4079	43.5	3749	58.9	1490	71.1

In addition, analysis of mathematics/science subject combination choices made by NSW senior secondary students 2001-2011 showed a substantial decline in the proportion of students undertaking at least one mathematics and one science subject and this trend was stronger for female students (Mack & Walsh, 2013).

- In 2001, 19.7% of boys and 16.8% of girls from the corresponding Year 8 cohort went on to study a mathematics/science combination in Year 12.
- In 2011, only 18.6% of boys and 13.8% of girls went on to study mathematics/science combination in Year 12.

Demographic factors have also emerged as significant variables impacting on students' participation in post compulsory specialist (Stage 3) mathematics. School ICSEA data from 2012 show that far more Western Australian students living in the metropolitan area participate in Stage 3 specialist mathematics than their peers from regional and remote communities. There is also a strong relationship between ICSEA band and participation in specialist mathematics (Figure 2). A large majority of specialist maths students attend above average ICSEA schools.

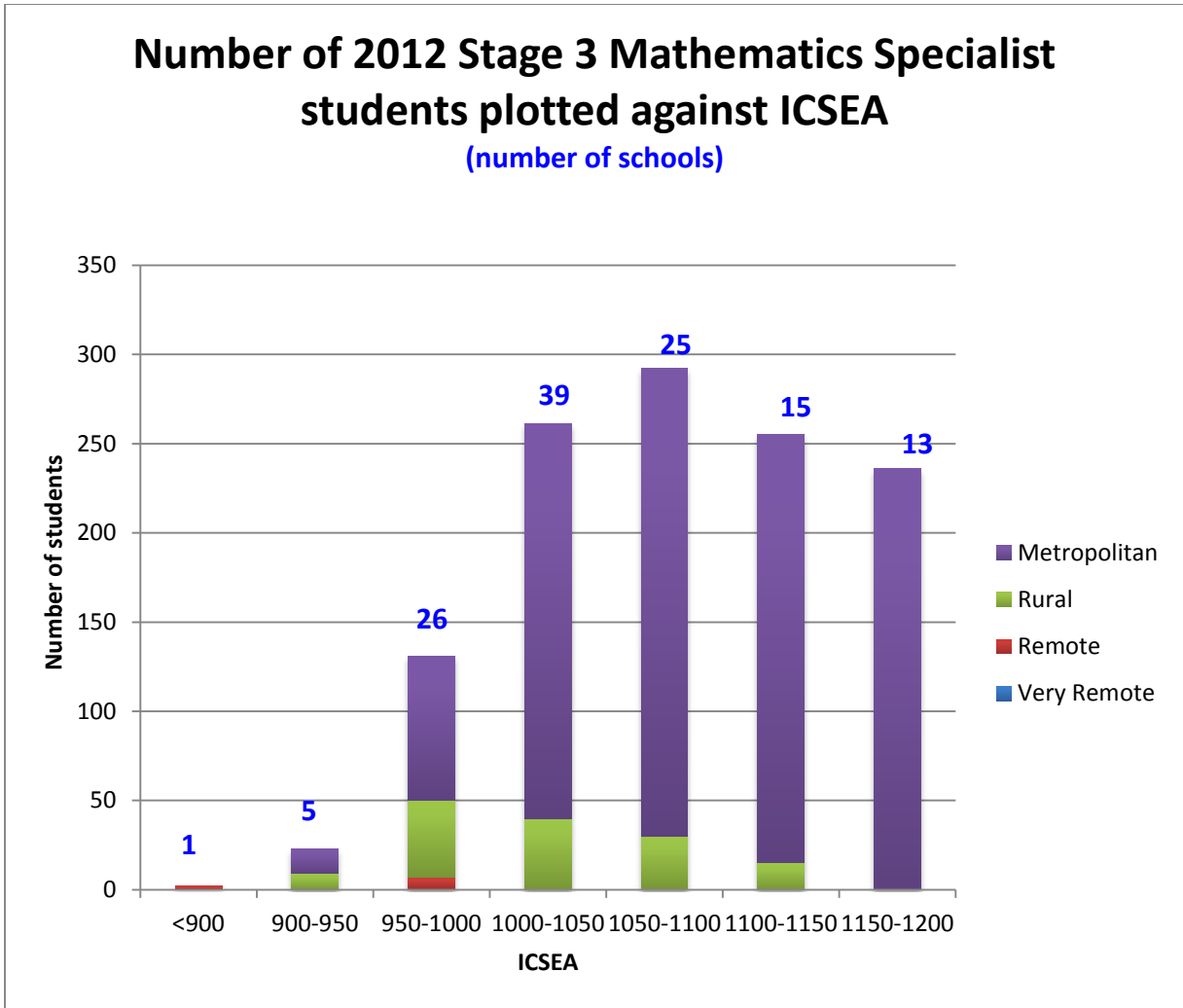


Figure 2: Numbers of WA students studying 2012 Stage 3 Specialist Mathematics by ICSEA band

WA mathematics participation rates

The data for WA students’ participation in mathematics subjects are reported in Table 3. These data show that between 1992 and 2012 the average number of maths subject enrolments per Year 12 student declined from 0.92 to 0.69; and, the proportion of Year 12 students studying the highest level mathematics subjects declined from 15% for Calculus in 1992 to 7% for Stage 3 Specialist Maths in 2012.

Table 3: Number and percentage of the WA Year 12 cohort for each maths subject for 1992 and 2012, and percentage of subject candidates who are female

Subject	1992			2012		
	Number	Percentage of Year 12 cohort ^a	Percentage female	Number ^b	Percentage of Year 12 cohort	Percentage female
Discrete Maths	6 961	44	54			
Applicable Maths	5 202	33	43			
Calculus	2 344	15	31			
TOTAL	14 507	0.92 subject enrolments per student				
Stage 2 maths				5 516	25	56
Stage 3 Maths				8 536	38	41
Stage 3 Specialist Maths				1 544	7	29
TOTAL				15 596	0.69 subject enrolments per student	

Notes. ^a These data refer to the Year 12 cohort which is defined as the full-time Year 12 students who are eligible to graduate at the end of the year. This is a subset of the total 17 year-old population of WA at that time. ^b The number of students in 2012 refers to those who completed two units and sat examinations for the subject at Stages 2+3 and for whom the examination scores may contribute to the student's ATAR. For some subjects there are also significant numbers of students who completed the subjects at Stage 1.

Technology

Similar to mathematics, describing national participation trends in technology is problematic due to the diverse nomenclature used to describe the wide ranging senior secondary subjects included in this field. Ainley, Kos and Nicholas (2008) used five clusters to report participation trends: information (computer) technology; technical studies; food and home science; hospitality; and agriculture. These trends were;

- Information technology student participation increased from 20% in 1996 to 25% in 2001. However, it decreased to 14% in 2007.
- Technical studies student participation increased from 8% in 1991 to 13% in 1992. Participation rates then remained fairly constant but an increase to 16% occurred in 2007.
- Hospitality studies student participation increased significantly from less than 1% in 1996 to 6% in 2007.

- Food and Home Science student participation rates increased from just less than 5% in 1991 to 8% in 2007.
- Agriculture student participation rates have remained low at 2% but relatively stable from 1991 to 2007.

Overall, participation rates in the information technology area were stronger amongst males than females by a ratio of two to one, and in technical studies by a ratio of four to one (Ainley, Kos & Nicholas, 2008).

In Western Australia, Vocational Education and Training (VET) programs were introduced in 1997 to maintain students' engagement with post-compulsory secondary schooling. Participation in Year 11 and 12 VET programs has increased from 35% in 1997 to 39% in 2011 (School Curriculum and Standards Authority, 2011). This growth correlates with the raising of the school leaving age for WA students to 17 in 2006. Specifically in 2011, 34.2% of Year 12 students in Western Australia participated in VET programs.

To contextualise the senior secondary VET participation trends described here, participation trends in apprentice and trainee directions are also included (National Centre for Vocational Education Research, 2013).

- The number of apprentices and trainees in-training increased nationally by 6.9% from 2011 to 2012.
- The number of apprentices and trainees commencing also increased by 8.2% from 2011 to 2012; of this trades commencement increased by 1.7% and non-trades commencement increased by 11%.
- Specifically, in WA there was an increase in commencements of 25.3% from 2011 to 2012.

WA technology participation rates

Applied Information Technology (AIT) which focusses on the uses of information technologies commenced in 2008 and its enrolments peaked in 2009 at 7% of the Year 12 cohort, and since then have declined. In 2012 AIT enrolled 1043 Year 12 students (5% of the Year 12 cohort) with 42% of these being female. Computer Science and Engineering Studies are both relatively new subjects and are attracting quite modest enrolments from Year 12 students (see Table 4) and it should be noted that they have particularly low female participation rates. Computer Science replaced the earlier subject of Information Systems which was offered between 1997 and 2008. Information Systems enrolments peaked in 2002 and at that stage attracted many female students who comprised 37% of enrolments. In 2012 Computer Science has fewer enrolments overall and only 2% of these are females. In 2012, overall enrolments in the technology subjects of AIT, Computer Science and Engineering Studies have declined to a modest 1782 Year 12 Stage2+3 subject enrolments which represents only 8% of the Year 12 cohort.

Table 4: Number and percentage of the WA Year 12 cohort for each technology subject, and percentage of subject candidates who are female

Subject and year	Number and year	Percentage of Year 12 cohort ^a	Percentage female	Number ^b	Percentage of Year 12 cohort	Percentage female
				2012		
Applied Information Technology	1414 (2009)	7	45	1043	5	42
Information Systems	763 (2002)	4	37			
Computer Science				443	2	15
Engineering Studies				296	1	4
TOTAL				1782	0.08 subject enrolments per student	

Notes. ^a These data refer to the Year 12 cohort which is defined as the full-time Year 12 students who are eligible to graduate at the end of the year. This is a subset of the total 17 year-old population of WA at that time. ^b The number of students in 2012 refers to those who completed two units and sat examinations for the subject at Stages 2+3 and for whom the examination scores may contribute to the student's ATAR. For some subjects there are also significant numbers of students who completed the subjects at Stage 1.

The participation rate data for science, technology and mathematics subjects raise a number of concerns. The greatest amongst these are that a significant proportion of Year 12 Western Australian students are studying no WACE science subjects and studying no mathematics subjects which places limits on their further education and career prospects. Without scientific and mathematical literacy, these students will lack the general science and technology understandings and capabilities to participate effectively in a science and technology dominated society. Given the huge increase in the size of the Year 12 cohort, despite the broadening of the ability range amongst the cohort, the number of students capable of successfully completing WACE science and maths subjects at a level that supports a tertiary pathway must have increased whilst the numbers studying these subjects has declined in science and increased slightly in maths. Computer Science and Engineering Studies are attracting very few students overall and almost no females. Given the criticality of a combination of science, technology and maths capabilities for innovation, the declining participation rates and the relatively low numbers of students completing high level science, maths and Computer Science places limits of the capacity for innovation in the WA economy and our capacity to address the social and environmental challenges facing our State.

It should be noted that the data sourced from SCSA reveals that there are significant numbers of Year 12 students completing Stage 1 STEM subjects. At Stage 1, students do not sit an examination

and their marks do not contribute to their ATAR. The largest numbers of Stage 1 semester long units completed by Year 12 students in 2012 were in Mathematics (12 235), Integrated Science (3 371) and Earth and Environmental Sciences (267). In 2012, the Year 12 cohort completed a total of 31 192 semester long units of mathematics at Stages 2+3 compared with 12 235 units at Stage 1. Stage 1 units therefore represented 28% of mathematics enrolments. In 2012, the Year 12 cohort completed a total of 29 698 semester long units of science at Stages 2+3 compared with 3 990 units at Stage 1. Stage 1 units therefore represented 12% of science enrolments. It is likely that to some extent these enrolments represent students' under-aspiration and a missed opportunity to complete more challenging studies and a better academic preparation for life.

The participation rates have been calculated based on the cohort of full-time Year 12 students who are eligible to graduate on completion of their studies. In 1986 the Year 12 cohort comprised 11 321 students or 45% of the 17 year-old WA population which was 25 153 persons (Australian Bureau of Statistics, n.d.). In 2012 the Year 12 cohort of students comprised 22 476 students or 71% of the 17 year-old WA population of 31 490. The proportion of full-time students in the 17 year-old age group had increased due to changes in the ages and requirements of compulsory schooling. When participation rates are calculated based on the cohort of 17 year-olds they are lower than for the figures based on the Year 12 cohort. For example:

In 1986, there were 1.42 science subject enrolments per Year 12 student and only 0.63 science subject enrolments per 17 year-old. In 2012, there were 0.66 Stage 2+3 science subject enrolments per Year 12 student and 0.47 science subject enrolments per 17 year-old; and for mathematics, there were 0.69 Stage 2+3 maths subject enrolments per Year 12 student and 0.50 maths subject enrolments per 17 year-old.

Undergraduate

Decreases in the proportions of students enrolled in university mathematics, physics and chemistry courses since 1990 have been reported in several documents (Brown, 2009; Dobson, 2007; Rice, Thomas & O'Toole, 2009; Royal Australian Chemistry Institute, 2005).

Data provided by Ainley, Kos and Nicholas (2008) show enrolment trends for three STEM areas of study, as numbers and proportions of the total Australian enrolment, for commencing undergraduate students for the period 2001 to 2006.

Table 5: Australian commencing undergraduate enrolments in broad fields of education 2001-6

Fields	2001	2002	2003	2004	2005	2006
Natural and physical sciences	18 488	17 825	17 708	18 292	17 692	17 611
	10.4%	10.1%	10.6%	11.0%	10.1%	9.6%
Information technologies	12 474	11 553	9 950	8 224	7 023	6 171
	7.0%	6.6%	6.0%	5.0%	4.0%	3.4%
Engineering and related technologies	11 170	11 114	10 898	10 655	10 619	11 046
	6.3%	6.3%	6.5%	6.4%	6.0%	6.1%

There have been declines in the numbers and proportions of undergraduate enrolments in natural and physical sciences and information technologies. With the exception of 2006, that decline is mirrored by the enrolments in engineering and related technologies. More importantly, over that six-year period, the undergraduate enrolments across these STEM fields have declined from 23.7% to 19.1% of the Australian cohort.

These data are consistent with the observations made about the limited numbers of STEM graduates from Australian universities. Data collated by the Department of Industry, Innovation, Science, Research and Tertiary Education (DIIRSTE) shows an overall continuing decline in university completions in STEM related fields, nationally and in WA. In some areas the number of students completing a STEM related university qualification has increased but when these figures are considered relative to the total number of students completing across all disciplines, the actual percentage has decreased. The most significant declines in absolute and percentage terms are in the areas of Information Technology and Agriculture and Environment related studies. These trends are evident generally across Australia and also in WA university completions. Yet, not all fields show a decline in completions. There has been a significant increase in completions from health related university courses both nationally (2001: 13.06% to 2011: 16.83%) and in WA (2001: 14.52% to 2011: 20.14%). The health field represents a growth area in terms of university STEM participation.

Table 6: Undergraduates and postgraduate domestic university student completions by discipline and year for all Australian universities and WA universities

Discipline	Number and Percentage	Australia		WA	
		Year			
		2001	2011	2001	2011
Natural and Physical Sciences	#	12,930	15,508	1,309	1,871
	%	8.59	7.83	9.83	9.70
Information Technology	#	8,301	4,532	625	328
	%	5.52	2.29	4.70	1.70
Engineering and Related Technologies	#	7,845	9,391	686	1,148
	%	5.21	4.74	5.15	5.95
Agriculture Environmental and Related Studies	#	3,580	3,279	402	347
	%	2.38	1.66	3.02	1.80
Health	#	19,654	33,323	1,933	3,883
	%	13.06	16.83	14.52	20.14
Other	#	98,193	131,992	8,357	11,704
	%	65.24	66.65	63	61
Total	#	150,503	198,025	13,312	19,281

Notes.1. Source: Department of Industry, Innovation, Science, Research and Tertiary Education (DIIRSTE) Higher Education Statistics Data Cube (uCube) which is based on the student and staff data collections. 2. Input perturbation has been applied to these data, whereby small random adjustments have been made to cell counts. These adjustments do not impair the utility of the tabular information.

The following university completion trends, within specific subject areas, are evident in the full DIIRSTE data set.

- The percentage of university completions in Natural and Physical Sciences has declined from a high of 8.14% in 2005 to a low of 7.5% in 2009, with a slight recovery evident in 2011 (7.83%). In W.A., there has also been a decline, however, in this state there is a larger percentage (9.7%) of completions in Natural and Physical Sciences than nationally.
- National completions in IT reached a high in 2002 (6.05%) and then steadily declined to a current low in 2011 of (2.29%). This trend is also evident in W.A with the lowest recorded completion rate in 2011 at 1.7%.
- Engineering and related technologies completions have steadily declined nationally. However in W.A, completion percentages have fluctuated slightly but there has been a slight increase over time (2001: 5.15% to 2011: 5.95%).
- Agriculture and Environment related studies have consistently declined over time at both the national (2001: 2.38% to 2011: 1.66%) and WA state level (2001: 3.02% to 2011: 1.8%).
- University completions from Health related fields have consistently increased over time at both the national (2001: 13.06% to 2011: 16.83%) and WA state level (2001: 14.52% to 2011: 20.14%).
- The percentage of students graduating in non-STEM fields of education has fallen from 2001 to 2011 by 2% in WA whilst increasing approximately 1% nationally.

Teacher Education

Teachers are fundamental to the effectiveness of our education system and the quality of learning outcomes has a significant impact on innovation within society broadly and on the economy. Indeed, the Grattan Institute (Jensen, 2011) argues that “Improving teacher effectiveness would have a greater impact on economic growth than any other reform before Australian governments” (p. 4). There are two key issues relating to the teaching workforce: an adequate supply of appropriately qualified teachers; and, the quality and effectiveness of those teachers.

Supply and Demand for Graduate Teachers

There is currently an oversupply of primary school teachers Australia-wide and there have been calls to increase the entry scores for teacher education. In WA, there is particular concern regarding a potential large over supply of primary teachers and a serious shortage of secondary teachers in 2015 as Year 7 students move into secondary state schools and the half cohort moves out of Year 12.

Australian teachers and school leaders were surveyed in 2010 (McKenzie, Rowley, Weldon & Murphy, 2011) and this revealed that the average age of primary teachers was 42 years and 45 years for secondary teachers. More teachers are female than male (81% primary and 57% secondary). Not all primary teachers had received tertiary training in teaching methods: in mathematics, 57% had not; in science 41% had not; and in computing 22% had not. The teachers averaged 8-9 days of professional learning in the previous year and needed further support with assessment and engaging students in learning. Other data show that large numbers of teachers leave the profession in the first few years, however, this report noted that one in six teachers had returned to the profession after having previously resigned. At the start of the 2010 school year, 8.5% of secondary schools reported an unfilled vacancy for a mathematics teacher and 7.2% had a science vacancy.

Teacher Qualifications

Most teachers in Australian schools have completed four years of tertiary education, either as a Bachelor of Education or as a BA/BSc with a Graduate Diploma of Education. More recently, and particularly in the eastern states in response to expectations of the Australian Institute for Teaching and School Leadership (AITSL) and teacher registration bodies, teachers with a BA/BSc are required to complete a two-year Master of Teaching to qualify for entry to the profession. As at 2010, seven per cent of primary teachers and 11% of secondary teachers held a master or doctoral qualification (McKenzie, Rowley, Weldon & Murphy, 2011).

Ainley, Kos and Nicholas (2008) provided data related to Australian secondary teacher qualifications as shown in the table below.

Table 7: Australian secondary teacher qualifications

Field of Teaching	Percentage of teachers with 2 or more years of tertiary study in the field	Percentage of teachers with 3 or more years of tertiary study in the field
Biology Yrs 11-12	85	78
Chemistry Yrs 11-12	87	73
Physics Yrs 11-12	76	60
General Science Yrs 7/8-10	44	38
Mathematics Yrs 11-12	81	66
Mathematics Yrs 7/8-10	64	53
Information Technology Yrs 11-12	53	40
Information Technology Yrs 7/8-10	31	24

These data suggest that a significant number of lower secondary maths (36%) and science (56%) teachers are teaching with less than two years of tertiary study in the subject. At the Year 8 level, the 2011 TIMSS data show that 55% of the sampled Australian science teachers had a major in science and science education, compared with 23% for Korea, 37% for Singapore and 54% for England. Of the sampled Australian Year 8 maths teachers, 37% had a major in mathematics and maths education, compared with 55% for Chinese Taipei.

Harris and Jenz (2006) surveyed all secondary schools in Australia to determine the qualifications of those teachers teaching mathematics. They received responses from 30% of all Australian secondary schools. Three out of four schools reported difficulty in recruiting suitably qualified maths teachers. Of those teaching Year 11 and 12 maths 75% had a maths major. Twenty-three per cent of lower secondary maths teachers had studied no more than first year maths and one-third had not completed any studies of maths teaching methods.

McConney and Price (2009) indicate that “there is a much higher incidence of teaching out-of-field in poor communities, rural and remote schools and metropolitan schools considered ‘hard to staff’” (p. 89) and this is a major contributor to the relative underachievement of students in these schools. This Western Australian study also noted that out-of-field (OOF) teaching was more prevalent in IT than maths or science teaching at the Year 11-12 levels. Research in the USA (Ingersoll, 2003) indicates that OOF teaching is far more common in ‘high poverty’ schools than ‘low poverty’ schools, in small school compared with large schools, and in Years 7-8 compared with Years 9-12. An interesting finding of this study is that small private schools had the highest levels of OOF teaching and large private schools the lowest levels of OOF teaching.

Pre-service training for primary teachers covers a broad base of subject areas in preparation for teachers being generalists in primary classrooms. Frequently, this leaves science content knowledge

and, for some, mathematics content knowledge underdeveloped. This underdeveloped knowledge results in a lack of confidence when teaching the subject area and professional learning is needed to supplement teachers' knowledge base. Surveys of Western Australian primary teachers in 1983 and again in 2003 indicated that about 20% of teachers felt *'not very confident'* to teach science (Rennie & Goodrum, 2007). Angus, Olney and Ainley's (2007) study of Australian primary schools found that only 18% of primary teachers believed they had all the expertise they needed to teach science while 35% believed that had all the expertise they needed to teach mathematics.

The 20011 TIMSS data reveals that only nine per cent of sampled Australian Year 4 teachers had a major in primary education and a specialisation in science, compared with 54% for Germany. Fourteen per cent of the sampled Australian Year 4 teachers had a major in primary education and a specialisation in mathematics, compared with 54% for Singapore.

Teacher Professional Standards

The Australian Institute for Teaching and School Leadership (AITSL) has established a set of seven professional standards that define the knowledge and competencies required by teachers at different levels: graduate, proficient, highly accomplished and lead teacher (AITSL, 2011). The standards relate to the following domains:

- Standard 1: Know students and how they learn
 - Standard 2: Know the content and how to teach it
 - Standard 3: Plan for and implement effective teaching and learning
 - Standard 4: Create and maintain supportive and safe learning environments
 - Standard 5: Assess, provide feedback and report on student learning
 - Standard 6: Engage in professional learning
 - Standard 7: Engage professionally
- (AITSL, 2011, p. 5)

For each standard there are a number of focus areas, for example:

Focus area	Graduate	Proficient	Highly Accomplished	Lead
.1 Content and teaching strategies of the teaching area	Demonstrate knowledge and understanding of the concepts, substance and structure of the content and teaching strategies of the teaching area.	Apply knowledge of the content and teaching strategies of the teaching area to develop engaging teaching activities.	Support colleagues using current and comprehensive knowledge of content and teaching strategies to develop and implement engaging learning and teaching programs.	Lead initiatives within the school to evaluate and improve knowledge of content and teaching strategies and demonstrate exemplary teaching of subjects using effective, research-based learning and teaching programs.

(AITSL, 2011, p. 10)

These standards will form the basis of recognising and certifying teachers as highly accomplished and lead teachers, and for accrediting teacher education courses. Increasingly, Australian governments are focussing on teacher effectiveness as ways of improving education outcomes. Effective teachers are the key to improving student learning, with teachers accounting for around

30% of the variance in student achievement (Hattie, 2003). A recent New South Wales Government report cites research that shows that the top 10% of teachers in the country could achieve in half a year what teachers in the bottom 10% of effectiveness take a full year to achieve (NSW Department of Education and Communities, 2013).

Status of the Disciplines and Visions for School Curriculum

There have been a number of national reviews of the status of STEM subjects within the Australian school systems. These reviews have highlighted areas of concern and the need for reform of the implemented curriculum.

Science

Goodrum, Rennie and Hackling's (2001) review of Australian science education indicated that the implemented science curriculum was not sufficiently relevant or engaging for secondary students and there was a need for ongoing professional learning for primary and secondary teachers.

Science in primary schools is generally student-centred and activity-based. When students move to high school, many experience disappointment, because the science they are taught is neither relevant nor engaging and does not connect with their interests and experiences. Disenchantment with science is reflected in the decline in science subjects taken by students in upper secondary school. Many science teachers feel undervalued, under-resourced and overloaded with non-teaching duties (Rennie, Goodrum & Hackling, 2001, p. 455).

Goodrum et al. (2001) made a call for a national approach to curriculum, an inquiry oriented curriculum and professional learning support for science teachers. The Australian Government's response to their report was to fund the national primary science professional learning program *Primary Connections*, and subsequently to fund the secondary science professional learning program *Science by Doing*.

Russell Tytler's (2007) call for a re-imagining of science argued for a more inquiry-oriented curriculum that gave children greater agency in their learning. Political consensus emerged supporting the development of a national curriculum for STEM subjects and this work is ongoing through ACARA. The national F-10 science curriculum (ACARA, 2011) does have a strong inquiry focus and a focus on science as a human endeavour which can support the contextualisation of learning. Tytler et al.'s (2008) review highlighted the need for capturing student interest and engagement with science in the late primary-early secondary years and argued for interventions targeted to this age group so that they can be retained in the STEM education pathway through Years 11 and 12 when science becomes non-compulsory.

Goodrum, Druhan and Abbs' (2011) review of the status of Year 11 and 12 science reveals that courses are primarily designed for university preparation and are therefore content laden, perceived to be conceptually difficult, abstract and taught in traditional transmissive ways. The perceived abstractness and difficulty of Physics and Chemistry are likely to be factors that will deter some students from electing to study them in Years 11 and 12, and the traditional instructional approach may have a negative impact on students' interest in science and the further study of science at university level. Goodrum, Druhan and Abbs (2011) argue that we should improve students'

experience of Years 7-10 science so that more students continue to study science in Years 11-12, and that teachers are provided with quality resources and professional learning so that the implemented curriculum is reformed.

Mathematics

The National Numeracy Review (COAG, 2008) found that an unacceptable proportion of Australian students were not achieving acceptable levels of proficiency. Many students lack confidence with mathematics, do not see its personal relevance and are unlikely to continue studying it voluntarily. Rubinstein (2009) concluded that “Australian mathematics and mathematics education are in a dire state” (p. 1), noting that demand for graduates with substantive training in mathematics has outstripped supply in recent years.

The Australian Curriculum: Mathematics aims to ensure that students are confident and creative users of mathematics who recognise the connections between areas of mathematics and other disciplines (ACARA, 2013). The curriculum seeks to help students become self-motivated, confident learners through inquiry and active participation in challenging and engaging experiences. These aims will only be realised if students are supported in their learning by enthusiastic and capable mathematics teachers. However, only 68% of Year 11 and 12 mathematics teachers have received three or more years of tertiary education in mathematics (AMSI, 2012) and there are continuing concerns about shortages in the supply of mathematics teachers (McKenzie, Rowley, Weldon & Murphy, 2011).

Technology

In a comprehensive study of technology in Australian primary and secondary schools, Williams (2000) found that the status of the discipline was very low and that the provision of resources and professional learning for teachers did not provide sufficient support. Since then, there has been an enormous growth in new digital technologies and this has had an impact on the learning area. Despite this, Williams (2011) indicates that technology continues to be marginalised in STEM discussions, with science and mathematics given greater attention. The International Technology Education Association (2009) argues that technology needs to have a greater importance in the primary and secondary school curricula.

The literature indicates that learning approaches in schools need to be authentic and inquiry-, project- and problem-based. They need to be contextualised and linked to students’ real lives in meaningful ways. Activities also need to utilise the richness of technology-based environments as a means of enhancing the authenticity of learning experiences (Moyle, 2010; Spendlove, 2011). At a state level, the Education and Health Standing Committee (2011) endorses the use of digital technologies to support student-centred and inquiry-based learning activities, however, indications remain that the teacher is a crucial component in developing learning based on their use of such technologies.

What Research Says About Quality Teaching and Pedagogy

The Australian Institute for Teaching and School Leadership (AITSL, 2011) argue that:

The National Professional Standards for Teachers (the Standards) reflect and build on national and international evidence that a teacher's effectiveness has a powerful impact on students, with broad consensus that teacher quality is the single most important in-school factor influencing student achievement. Effective teachers can be a source of inspiration and, equally importantly, provide a dependable and consistent influence on young people as they make choices about further education, work and life (p. 1).

Hattie (2003) explains that after a student's prior knowledge which accounts for 50% of achievement variance, it is the quality of teaching which is the most influential factor accounting for 30% of the variance. From a meta-analysis and conceptual synthesis across previous studies he identified five dimensions of teaching excellence. Expert teachers can:

1. identify essential representations of their subject drawing on rich content and pedagogical knowledge;
2. guide learning through productive classroom interactions within supportive classroom climates;
3. monitor learning and provide feedback that promotes further learning;
4. attend to affective attributes through demonstrating a passion for teaching and learning and showing respect for students; and,
5. influence student learning outcomes by setting challenging tasks and promoting students' self-efficacy, and both surface and deep learning.

Impacts of Australian Curriculum

A summary of the anticipated impacts of the Australian Curriculum on the teaching and learning of science, mathematics and technology is provided as Appendix 1.

Key Findings Emerging from an Analysis of the Research Literature

Achievement in and attitudes towards STEM subjects

1. International comparisons of science and mathematics achievement show that in terms of absolute standards and international ranking, despite being above the international mean, Australia's performance has declined.
2. Very few Australian Year 4 and 8 students (<11%) reached the TIMSS advanced benchmark of performance in science and mathematics.
3. National testing of students' numeracy and scientific literacy show that the performance of WA students is improving in absolute terms and in comparison to other states, however, nearly half of Year 6 students failed to meet the proficient standard for scientific literacy.
4. National testing shows that Australian Year 6 students have positive attitudes towards science, however, 40% reported they studied science less than once per week.

5. International comparisons show that Australian 15 year olds' perceptions of the value of science are below the international mean and only three of 57 countries had lower interest in studying science than Australia.
6. Australian Year 4 and 8 students' positive affect towards mathematics was lower than the international mean
7. National assessments of Year 6 and 10 students' attitudes towards using ICTs reveal that Year 10 students had less interest in computer technology than Year 6 students but had higher self-efficacy with using ICTs than Year 6 students. Students' enjoyment and interest in working with computers was significantly higher in males than females.
8. International and national test data reveal that socioeconomic, Indigenous and geolocation factors are strongly affecting achievement in science and mathematics.

STEM education participation rates

9. There has been a dramatic fall in the percentage of Australian Year 12 students studying a science subject between 1992 (94%) and 2011 (51%).
10. Despite a doubling in the size of the Year 12 WA cohort between 1986 and 2012, there has been a decline in the number of science subject enrolments. In 1986 the average Year 12 student enrolled in 1.42 science subjects; this reduced to an average of 0.66 subjects in 2012 i.e., many students are now studying no Stage 2 or 3 science in Year 12.
11. There has been a national decline in mathematics participation rates in Year 12 advanced and intermediate mathematics courses.
12. Despite a large increase in the WA Year 12 cohort between 1992 and 2012 (43%) the maths participation rate has declined from an average of 0.92 maths subject enrolments per student in 1992 to 0.69 in 2012 i.e., many students are now studying no Stage 2 or 3 maths in Year 12.
13. There has been a significant number of Year 12 students enrolling in Stage 1 courses which do not contribute to an ATAR. In 2012, 13% of science and 39% of maths unit enrolments were in Stage 1 courses.
14. Computer Science and Engineering Studies are attracting very few students overall and almost no females.
15. Participation in WA VET programs increased from 35 to 39% between 1997 and 2011 with the increase in school leaving age.
16. There are strong socioeconomic and gender influences on participation in Year 11-12 science and maths e.g., only 17% of physics students attend schools with a below average ICSEA score; while in 2012 56% of Stage 2 maths students were female and 29% of Stage 3 specialist maths were female.
17. Undergraduate enrolments in STEM fields of education declined from 24% to 19% between 2001 and 2006.
18. Between 2001 and 2011 Australian undergraduate and postgraduate completions for: natural and physical science and for engineering and related technologies increased in numbers but decreased slightly as a percentage of all graduates; and, for information technology and for agriculture and environmental studies there were large declines in numbers and as percentages of all completions.
19. Between 2011 and 2011 WA undergraduate and postgraduate completions for: natural and physical science and for engineering and related technologies increased in numbers but

natural and physical science decreased slightly as a percentage of all graduates while engineering increased its percentage; and, for information technology and for agriculture and environmental studies there were large declines in numbers and percentages of all completions.

Teacher supply and qualifications

20. A large proportion of lower secondary science and maths teachers have less than two years of tertiary study in the discipline, and many have not studied teaching methods for the subject. At least one quarter of Year 11-12 maths teachers do not have a major in the discipline and three out of four Australian schools in a recent survey reported difficulties in recruiting suitably qualified maths teachers.
21. There is a much higher rate of out-of-field teaching in low socioeconomic, rural and remote and hard to staff schools compared with other schools.
22. More than half of Australian primary school teachers report that they do not have all the expertise they need for teaching science and maths.

Consultation with the Education Sectors, Teacher Professional Associations and Education Service Providers

Purpose and Approach

The purpose of the consultation was to elicit information from key informants about initiatives to enhance STEM education that have proved effective, gaps and challenges in STEM education, and potential new initiatives that might address key gaps. In most cases one-hour individual semi-structured interviews were conducted by a member of the research team. However, in some cases it was more appropriate to interview a small group of representatives from an organisation. All interviews were recorded on a digital audio recorder and transcribed verbatim.

A total of 20 participants were interviewed. The sample comprised three groups:

1. Science, maths and technology consultants, or former consultants, from the three education sectors: the Department of Education, the Association of Independent Schools of Western Australia and the Catholic Education Office.
2. Presidents and/or executive officers of the teacher professional associations that support teachers from science, maths and technology disciplines: the Science Teachers Association of Western Australia, the Mathematical Association of Western Australia, the Design and Technology Teachers Association, and the Educational Computing Association of Western Australia.
3. Selected significant STEM education service providers: Scitech, CSIRO and Earth Science WA.

There is a large number of organisations that provide STEM education services to WA schools; these include Scitech, ESWA, CSIRO, the Gould League and agencies attached to government departments such as the WA Museum, The Perth Zoo and Kings Park. To better understand the role of these service providers, three organisations, Scitech, ESWA and the CSIRO were invited to participate in interviews. It was beyond the scope of this project to conduct a comprehensive review of all education service providers and their programs.

Analysis of the interview transcripts identified themes relating to: STEM education initiatives that have proved effective which were implemented by the education sectors themselves or provided by the professional associations or education service providers; gaps in provision and challenges for STEM education; and, new initiatives that could be implemented.

Effective STEM Education Approaches and Initiatives Implemented by the Education Sectors

The education sector participants who identified effective initiatives tended to focus on those that have been implemented on a national or state-wide basis and have been sustained over a period of time to have an impact on culture and practice.

Early Years Science: An integrated approach

The *Early Years Learning Framework* (EYLF) has contributed to developing teachers' awareness of inquiry skills and their place in the early years' science experience. An integrated approach to addressing all learning areas has included science. An inquiry approach to early childhood science aligns with the desired outcomes of the EYLF and develops fundamental skills leading to those expressed in the Australian Curriculum.

With the current focus on literacy and numeracy due to NAPLAN testing there is an even greater need for teachers to be aware of curriculum integration pedagogies. That is, *"if we have to put our emphasis on literacy and numeracy then...how can we do literacy and numeracy through science"* (S7, interview 22/5/13). In light of the current focus on literacy and numeracy in schools, this comment highlights potential benefits from an integrated curriculum approach to science education. This is an underlying principle of the Australian Academy of Science resource *Primary Connections*, which links literacy with science. An example of an early years' integrated resource produced in WA is *Planting the Seeds of Science*. This resource includes science activities in an integrated program of art, technology, language, mathematics and music (S7, interview 22/5/13). Similar resources are available from commercial publishing companies and have been used to inform professional learning initiatives in Early Childhood Education.

Primary Connections

Primary Connections is a primary science teacher professional learning program supported with curriculum resources developed by the Australian Academy of Science which linked to the Australian Curriculum for Science. *Primary Connections* has worked well in WA as it has engaged teachers and resulted in more science being taught in primary schools than ever before. It is a highly scaffolded teaching resource and has been supported with structured professional learning materials and trainers. It was noted that *"there's been a lot of dedicated work in primary in particular on hands-on, minds-on, engaging, you know, trying to really develop students' inquiry, asking questions, investigating"* (S8, interview 30/5/13).

Research has demonstrated that when teachers are supported with *Primary Connections* curriculum resources and professional learning there are significant improvements to their confidence and self-efficacy for teaching science, they report improvements to their teaching practice and they spend more time teaching science (Hackling, Peers & Prain, 2007). Large scale assessments have also demonstrated positive learning outcomes for students studying with *Primary Connections* trained teachers. Students from *Primary Connections* classes achieved significantly higher mean scores on literacies of science and for processes of science than students from comparison classes (Hackling & Prain, 2008). Small scale case studies have also demonstrated strong conceptual growth for students studying in *Primary Connections* classes (Hackling et al., 2007). Further evaluations have confirmed statistically significant conceptual growth for students taught by teachers supported with *Primary*

Connections curriculum resources and professional learning (Hackling & Bowra, 2012). The Australian Academy of Science has received further funding from the Australian Government to continue the development and implementation of the program.

Primary Science Project

The *Primary Science Project* (Department of Education) used the Primary Connections resources for training of science curriculum leaders in schools. These people were positioned as trainers or mentors for other teachers in their school or school clusters. Support for the program included the comment, *“As a result of that project we’ve got a number of fantastic leaders in primary science education across the State in every district”* (S8, interview 30/5/13). The Project provided very strong support and mentoring for teachers implementing primary Connections in their classrooms.

Teacher Development Schools

The teachers trained as curriculum leaders through the Primary Science Project are now contributing to the implementation and running of DoE *Teacher Development Schools* across the state. It is a whole school approach and the structure of the program is determined within the school. For example, *“they run professional learning sessions, they invite local school teachers in, they show how they set things up in the school as a practice, so people can come in not only for a standard professional development hour or two hour but they can also come in and watch what’s happening in the class and see how people are delivering lessons, how’s the whole school process that’s been put in place to ensure sustainability of that particular science initiative”* (S8, interview 30/5/13).

This model has extended into regional areas where some online interactions have been included to support more remote groups. Other schools have focussed on showcasing the science facilities in the school and managing science equipment and resources. One lighthouse school has established a science room, with materials and equipment storage facilities and it has an education assistant to manage materials and re-stock consumables. Some large networking events have been coordinated by Teacher Development Schools. As an example, *“there might be 100 teachers come to school development days, organised conferences and they will come and provide workshops and talk to large groups”* (S8, interview 30/5/13).

The success of these primary science initiatives required the commitment of time, resources, professional learning and on-going support from a facilitator. The support of a curriculum leader was reported to be integral to these programs. As evidence, *“a lot of the success of those projects and other ones is to have an ongoing commitment that there’s someone checking how they’re going and they don’t feel that they’ve been left alone, with no help”* (S8, interview 30/5/13).

SPICE: A contextually relevant resource

The *SPICE* project was established as a partnership between the Department of Education and the Centre for Learning Technology at UWA to develop digital curriculum resources and professional learning support to enrich the secondary science curriculum. The strength in the SPICE resources was reported to be in the local relevance of the contexts provided in the teaching materials. A science co-ordinator commented, *“I see the SPICE strength (in) picking, the local context, the WA context, finding out aspects of the science and really doing examples well and helping teachers get science into current times with what is relevant”* (S8, interview 30/5/13).

An evaluation of the SPICE program conducted by Hackling and Bowra (2011, p. 3) concluded that:

The SPICE resources are of high quality. They support student-centred and inquiry oriented learning experiences and maximise the affordances provided by modern digital technologies to engage students with multimodal and interactive representations of science set in authentic and contemporary science research contexts.

Teachers gave high ratings of how well SPICE PD met their interests and needs, the quality of presenters and the facilitation of professional learning, and access to presenters for follow-up. Teachers considered SPICE events to be valuable personal enrichment experiences which built their interest and enthusiasm for science teaching.

The linking of high quality digital curriculum resources to professional learning provided on school sites at no cost to schools seems to be key success factors.

Getting It Right Numeracy

This program *“sought to improve student achievement in mathematics in primary schools by building the expertise of a specialist teacher who worked shoulder to shoulder collaboratively identifying students’ learning needs and planning activities to move kids forward”* (S9, interview 9/5/13). An evaluation of the Getting it Right Numeracy strategy undertaken by Meiers et al. (2008, p. 2) for ACER concluded that:

This collaborative work enhanced the understandings, confidence and teaching skills of the Specialist Teachers and their colleagues. It made a definite impact on the capacity of teachers to select, apply and develop diagnostic, formative and summative student assessment strategies and instruments so that they were better able to focus on individual learning needs.

The strategies that were deemed to be particularly useful were: modelling a whole lesson for the teacher to observe; modelling a strategy for the teacher to observe for part of the lesson; and collaboratively teaching the whole lesson with the classroom teacher. The evaluation found that the *“amount of time classroom teachers worked collaboratively with a Specialist Teacher had important effects across a range of outcomes – efficacy, sustainability, student attitudes, teaching practice, curriculum and knowledge”* (Meiers et al., 2008, p. 3).

The training provided to the Specialist Teachers was deemed to be pivotal to the success of the strategy and helped to build a considerable body of numeracy teaching expertise in government schools in WA. The program was judged to have *“had the most impact when the Specialist Teachers worked collaboratively with classroom teachers, when their work was focussed on individual student outcomes, and when the school supported a collegial culture”* (Meiers et al., 2008, pp. 2-3).

Participants interviewed noted that *“the admin has to be 100% behind the project”* (S20, interview 22/5/13) and that in cases where *“principals actively, formally and informally supported it, it worked really, really well”* (S4, interview 15/5/13).

First Steps in Mathematics

First Steps in Mathematics was identified as another highly successful initiative. Participants acknowledged that the *“First Steps in Mathematics resources, they’re still very much used within our schools”* (S9, interview 9/5/13) and *“No doubt it’s had impact. No doubt whatsoever”* (S14, interview 24/5/13). One of the reasons cited for the success of the initiative was its strong research base, which has *“had a strong influence on the development of other resources... particularly in the primary years”* (S9, interview 9/5/13). Other factors that were identified as contributing to the success of the program included schools setting targets for improvement, a sustained program of teacher professional learning aimed at *“developing teachers’ own knowledge and also building an understanding of the diagnostic maps from First Steps”* (S9, interview 9/5/13). Another key element of success was the support of school leadership whose *“actions showed that the program was important and the specialist teacher’s work was important, and they weren’t seen just as a support teacher”* (S9, interview 9/5/13).

Many participants were concerned that the initiative was prohibitively expensive, and that the expertise developed by specialist teachers has a limited lifespan within the education system. Their comments included:

That was a huge project... and it’s too expensive to run. (S14, interview 24/5/13)

The lifespan of that sort of legacy in the system is probably only about five years. (S9, interview 9/5/13)

Furthermore, while the program was successful in primary schools, the model did not appear to transfer well to the secondary context:

There were all sorts of issues... I don’t think heads of department or the people choosing the people actually understood the role... I think they thought that this was going to be someone who would come into the school and withdraw their weak kids and solve their problems for them. (S9, interview 9/5/13)

Principals as Numeracy Leaders

This project was implemented in AISWA schools and supported primary school principals to understand the big ideas of mathematics and how to design, implement and evaluate a whole of school numeracy development program. This project was based on the success of the Principals as Literacy Leaders project which acknowledges that the success of any initiative *“revolves around the leader making the time and providing the resources”* (S14, interview 24/5/13) and having the knowledge of what the research evidence shows is best practice.

Making Consistent Judgements

Subject 11 explained that the widespread making consistent judgements professional learning rolled-out by the Department of Education had provided valuable opportunities for discussing examples of student science, maths and technology projects and other work samples. This professional learning program enabled teachers to see a wide range of student projects and to develop an understanding of standards. This enhanced teachers’ capacity for making consistent assessments and gave them ideas about projects that could be included in the curriculum at their own schools.

Effective STEM Education Approaches and Initiatives Implemented by the Teacher Professional Associations or Education Service Providers

STAWA Primary Science Workshops

The Science Teachers Association of Western Australia (STAWA) has run a series of three professional learning workshops in primary science. Facilitators unpacked the Australian curriculum with participants, provided classroom ready activities as examples and required teachers to conduct an action learning cycle in their classroom and report back at follow-up workshops.

STAWA Student Learning Resources

In upper secondary, the Science Student Learning Resources Grants Program (WA Gov.) enabled STAWA to initiate the Physics and Chemistry Course of Study Curriculum Development Project. This project has provided teachers and students with lab and problems resources matched to the new curriculum. Student books were developed that helped support the teacher to deliver laboratory work with Science as a Human Endeavour (SHE) contexts and included background information and resources. Professional learning workshops were included on the curriculum with specific workshops on new content knowledge. There was a 100% uptake by schools in the first year. The resources went to all Year 11 and 12 teachers and students. Almost all Year 11/12 students are using the STAWA resources. It cost \$250 000 to produce 4 Year 11 and 12 Chemistry and Physics Lab/problems books. Teachers were provided with free copies at professional learning workshops and students purchased the resource as part of their book list (S12, interview 29/5/13).

Science Talent Search

STAWA's *Science Talent Search* is a competition that promotes science teaching and learning through creative project work. Entry categories include research investigations, inventions and science communication. This is a long standing science enrichment program for primary and secondary students. The program extends beyond the metropolitan area and includes co-ordinated regional judging events supported by STAWA networks and experienced teachers who are able to provide professional learning for their colleagues after school hours. The PD provided teachers with information on *"how to manage the projects that students do to enter, and as a result, there were broader and better entries into the Science Talent Search"* (S13, interview 20/5/13).

STAWA Future Science Conference

Future Science is an annual conference run by STAWA. The numbers attending the conference have gradually increased with 250 participants reported to consistently attend the event. Factors assumed to be contributing to the success are firstly, the need and desire for secondary science professional learning and then simply the timing of the event. It is held on a Friday, at the end of the year, after exams and Year 12 student have finished. This means there are no relief teacher costs to schools associated with teachers attending the conference (S12, interview 29/5/13). This is one teacher association conference that is attracting increased numbers of teachers, most other conferences struggle to attract viable numbers.

Industry Science Awards for Students

The STAWA *Industry Science Awards* were reported to be a cost effective approach to recognising students' science achievement and connecting schools with the industry representatives (S8, interview 30/5/13). Example initiatives were reported to extend beyond the funds given for the

awards to include industry staff going into the schools to make presentations. This cost effective initiative lead to awareness raising and partnerships. To illustrate, *“(They) committed their staff and their personnel to go to the school and to present the awards. And in discussions when they go to the school to present the award, “Oh, is this what’s happening in your school? Would you like a tour around? Would you like this? And Oh, I didn’t realise that,” and there might be the building of a friendship and relationship and partnerships, where people are willing to support and help their local community (S8, interview 30/5/13).*

Mathematical Association of Western Australia (MAWA) Professional Learning and Resource Development

After the last major syllabus change in the ‘90s, another successful initiative drew on the combined resources of MAWA, universities and the Department of Education to provide large scale professional development for teachers to *“get them up to speed with the new courses” (S22, interview 24/5/13)*. Another successful initiative has been the development of resources for teaching problem solving:

One of the things that MAWA’s found successful and has helped teachers in schools has been the provision of resources for problem solving and extension... Teachers still are not very good at teaching students to learn investigatively, are still not good at assessing students’ investigative ability. (S22, interview 24/5/13)

Engineers Australia Mentoring Program

Subject 5 identified a partnership with Engineers Australia had provided mentoring by new graduates to upper secondary students completing the Stage 3 Engineering Science course: *“this was about bringing the course into the real world so we arranged partnerships between new graduates from Engineers Australia to mentor Year 12 engineering studies students. In other words, mentor me through my project, but also come in and talk to me about what you’re doing at uni, and what is it, you know, will you go on a cadetship, that kind of thing. That was pretty good” (S5, interview 10/5/13).*

Technology Design Challenges

S16 identified some Design and Technology competitions that had provided valuable design challenges for students, such as the CO2 dragster completion and the Electric Vehicle Challenge, however the demands on teachers to offer support to small groups of students to enter these challenges without technician support limit the number of schools and students that participate.

Scitech Programs

Scitech is a not-for-profit organisation whose mission is to increase awareness, interest, capability and participation by all Western Australians in science, technology, engineering and mathematics (Scitech, <http://www.scitech.org.au/our-mission/notices/our-mission.html>). Approximately 3 million people have visited Scitech since its opening in 1988. 310 000 general public visitors and 60 000 school children visit the Scitech Discovery Centre annually at its West Perth base, with another 180,000 people experiencing Scitech via its travelling outreach programs.

Funding for Scitech's programs and services comes from grants from government, corporate sponsorship, admission and membership fees. The [Western Australian state government](#) provides approximately half of Scitech’s funding.

Scitech has been recognised with a number of international and Australian awards for the excellence of its programs, including:

- the creative science exhibit award at Asia Pacific Network of Science and Technology Centres conference in South Korea, in 2013;
- the ASTC Roy L. Shafer Leading Edge Awards in the Visitor Experience category for its Aboriginal Educational Program in 2012; and,
- the Australian Museum Eureka Prize for Promoting Understanding of Science through its Outreach program in 2009.

Although Scitech offers a range of programs and initiatives to the broader community, the work which impacts directly on STEM education in schools includes: teacher professional learning programs; outreach programs; competitions and curriculum enrichment; and, school visits to Scitech.

Professional learning

With professional learning *“our main aim is to build the confidence of teachers teaching science”* because we recognise that for most primary school teachers who teach all subjects *“science is the one that they have less confidence in their ability to teach”* (S40, interview 14/6/13). The aim is to support both in-service and pre-service teachers of science. The recent focus of professional learning has been helping teachers understand the new Australian Curriculum and how the inquiry and science as a human endeavour strands can be integrated into the science understandings strand. Scitech professional learning staff also take science lessons with classes to model approaches to investigating for the teachers. Mentoring programs have also been provided in regional centres such as Kalgoorlie, to support science teachers in their first and second year of teaching through workshops and building professional learning networks. The success of the PL programs is attributed to being needs focussed and including time for teachers to share their experiences. Time for teacher sharing has been highly valued by teachers and as a consequence of this, recent innovations have included sessions run at schools where teachers have an opportunity to showcase what they are doing. Typically schools pay for about a third of the full-cost of PL, and Scitech delivers PL to about 3 000 teachers each year (S40, interview 14/6/13). Evaluation data indicate that the Scitech professional learning enhances teachers’ confidence, pedagogical skills and content knowledge, and the resources they need for teaching science (Evans, 2006).

Outreach

Scitech’s Outreach program is a major initiative that takes science to schools throughout Western Australia. Outreach involves *“science shows, activities, planetarium shows in school for primarily primary school students. These are about providing either a topic that a teacher is currently working on that they don’t have the equipment to be able to explore further. Often it’s also about enthusing or motivating the students towards a greater awareness of science, an appreciation of science ... So I guess the aim of them really is that post a visit that the students are going to be more engaged in science, thinking more about science and particularly one of the focus points for us, is understanding that science process so that beyond a visit, regardless of whatever the concepts that we’re talking about ... the students are thinking about predicting and experimenting and so on, and we’re building up those skills”* (S40, interview 14/6/13).

Part of the Outreach program is the Aboriginal Education Program (AEP) which has been visiting all regional and remote schools every second or third year providing sessions for the students and, at the end of the school day, professional learning workshops for the teachers. Evaluations of the AEP show that it has a statistically significant positive impact on students' "rating of their enjoyment of science, that they learn interesting things in science, curiosity about science phenomena and their rating of science as a favourite subject" (Hackling, Byrne, Gower & Anderson, 2012, p. iii). The AEP also provides an important source of professional learning for teachers in regional and remote schools, many of whom are in their first years of teaching. The teachers "gained increased confidence for teaching science ... they found the modelled lessons and the professional development provided to be highly valuable and had helped to improve their confidence to teach science" (Hackling et al., 2012, p. iii). The success of Outreach programs is attributed to their highly interactive nature and highly skilled science communicators who have "*a set of skills that's about how to actually engage people in this world of science ... it does create that environment where people feel comfortable about having a go and exploring what they don't know*" (S40, interview 14/6/13). There is a cost for schools accessing the Outreach program, though; it is heavily subsidised by corporate sponsors and government so ensure equitable access for all schools, however, remote.

Competitions and curriculum enrichment

Scitech also provides competitions and other curriculum enrichment activities such as Robo Cup which involves building and programming robots for a competition. The competition attracts 350 upper primary and lower secondary students each year who intensively engage with the project over an extended period of time. Scitech supports "*the competition and the learning that accompanies that competition, whether it be the hosting, the culmination event, using our event management experience there, right through to running workshops for teachers and/or students in how to get started with the equipment ... and a couple of graduates ended up winning the world championship ... in Mexico City*" (S40, interview 14/6/13). Enrichment activities are also provided for gifted and talented students through PEAC challenge days held at Scitech and Scitech GT which caters for 100 very bright Year 7 and 8 students and extends them with activities and guest speakers at Scitech and includes them in an online community.

Class visits to Scitech

The fourth significant focus for Scitech is bringing school students into the West Perth venue for a program that complements and supports the school curriculum. About 50 000 students visit Scitech as part of a school excursion with more primary than secondary students (in the ratio 4:1) being involved. Teacher surveys indicate that their purposes for the visits are to motivate and enthuse students, consolidate science taught at school and to illustrate concepts not easily taught in schools. The success of the visits is based on a semi-structured format which combines presentations and time to freely explore exhibits in an environment supported by skilled Scitech staff.

ESWA Resources and Professional Learning Support

Earth Science WA (ESWA) was established in 2003 and has been providing services to schools to support earth and environmental education for 10 years. The mission of ESWA is to strengthen earth science education within WA schools to meet the State's strategic needs (S41, interview 12/4/13). ESWA does this through "developing teaching and learning resources, providing professional development for teachers, presenting at schools and assisting with field experiences for students" (ESWA, <http://www.earthsciencewa.com.au>).

The initial focus of ESWA was *“the creation and implementation of earth and environmental science as a Year 11 and 12 subject in WA to replace the declining geology subject ... and then there was an understanding to really boost those numbers and get students involved was to get them right back in Kindergarten to year 10. So ... from there it has evolved into outreach, so going to schools, as well as hands-on activities to really enthuse the students. It was also classroom modelling for teachers”* (S41, interview 12/4/13).

ESWA currently offers a range of educational services which include:

- Curriculum resources to support earth and environmental education for Year 11 and 12 students which include: a text book, student activity resources with teacher guide materials, a field guide and other resources to support excursions.
- Curriculum resources are currently being developed to support implementation of the Earth and Space Sciences strand of the F-10 Australian Curriculum for Science. These will comprise student activity resources and teacher guide materials.
- Kits of fossils, minerals and crystals are assembled and made available for loan from metropolitan and regional centres. The kits are supported with student activity sheets and teacher guide notes.
- Teacher professional learning workshops provided for teachers at their schools or part of teacher professional learning programs or conferences organised by the education sectors and teacher professional associations.
- Guiding excursions for school students as a way of providing mentoring to teachers to help them develop the knowledge, skills and confidence to run their own excursions.
- Outreach to schools providing lessons for students and professional learning for teachers.
- Participation in community science awareness and engagement events, particularly in regional areas.
- Coordination of a guest speaker program which involves earth and environmental science professionals visiting schools to talk to students about science and their professional roles. Some training is provided to these speakers to help them communicate effectively with a student audience.
- A web page (<http://www.earthsciencewa.com.au>) that provides access to ESWA resources and links to other relevant web sites.

ESWA has proved to be a highly effective model for supporting and enhancing the teaching of earth and environmental science in schools across all sectors and throughout the State of Western Australia. Measures of impact and effectiveness include: the huge growth in the number of schools offering earth science studies in Years 11-12 (4 to 30) and the number of Year 11 and 12 students studying earth science (<50 to >800); and the large number of schools (400 in 2012) and students who have been supported and engaged with ESWA (6 000 in 2012).

There are a number of factors that have contributed to the success of ESWA. ESWA is engaged with and has the strong support of the resources industry, government agencies and universities, and these are represented on the ESWA Board. Companies in the resources sector provide sponsorship of ESWA and these funds sustain the positions of two project officers and the curriculum development, professional learning and outreach activities. The extent and quality of curriculum

resources which are activity based, engaging and closely aligned to the curriculum make them very attractive and useful for science teachers, many of whom have a limited earth science background.

The outreach and professional learning support are provided at a time and place which suits schools and at no cost. Providing professional learning at schools at times at which teachers do not need to be released from teaching breaks through the significant barrier of relief teaching costs which limit many teachers access to professional learning. Having resource development and professional learning conducted by two very competent and highly experienced teachers who have earned the respect of the profession is another key success factor. Their deep engagement with science teachers and teaching ensures that the resources and PD are accurately targeted to the needs of students, teachers and schools.

It should be noted, that although the three education sectors are strongly supported by ESWA and their students and teachers are the main beneficiaries of their services, they are not sponsors of the organisation which relies on resource companies and universities for its funding. Scitech and CSIRO work very collaboratively with ESWA and provide office accommodation for the project officers.

CSIRO Programs

Scientists and Mathematicians in Schools

The CSIRO operates the *Scientists and Mathematicians in Schools* program which has as its main focus to “*create and support long term partnerships between individual teachers and scientists and mathematicians, to give the teachers a real-life application of what they’re teaching in the classroom*” (S42, interview 2/8/13). The program was an initiative of the Australian Government’s DEEWR beginning with a pilot program in 2007 (Rennie, 2012). The scientists and mathematicians provide support to teachers and students through taking lessons, supporting small group activity in lessons, establishing science or maths clubs, providing mentoring for teachers and students and raising career awareness of students. There are currently about 160 partnerships in WA of which most are with primary schools and involve scientists (S42, interview 2/8/13). Not all of the partnerships are active. Many of the partnerships are with a particular teacher in a school, while others are more broadly based. Many of the scientists are recruited from companies that have community engagement programs; mathematicians are quite difficult to recruit.

The teachers and scientists are provided with an information pack about the program, however, as yet there is no induction program to support the teachers and scientists to work out what strategies might be most effective ways of working together. Networking events are held at which teachers and scientists can share what they are doing within their partnerships. Rennie’s (2012) evaluation of the program revealed that there were benefits for students, teachers and scientists: “For students, perceived benefits include the opportunity to see practicing scientists and mathematicians as real people, to experience science with them, and to increase their own knowledge of contemporary science/mathematics”; teachers “enjoyed working with a scientist/mathematician and for teachers of science, especially in primary schools, enhancing the profile of the subject in their school and the ability to update their knowledge and practice were important benefits”; and, the scientists “appreciated opportunities to promote their subject in schools and more broadly to the public, and to interest students in science or mathematics-related careers” (pp. iv-v).

Lab activities

The CSIRO staff working out of Scitech offer two hands-on science programs: *CSIRO Lab* offered in the laboratory within Scitech; and, *Lab on Legs* which is an outreach program offered at schools. These programs are funded by CSIRO, Scitech and by corporate sponsors so that schools pay only part of the full cost of these programs. *CSIRO Lab* activities usually involve a set of stations at which students engage with different experiments related to a theme. One of the most popular *Lab on Legs* activities has a focus on forensic science for which “we send the teachers the crime scene and police report and the suspects’ profiles. Then we come along with all the evidence and show them how to actually do the investigations, but then how to analyse it” (S42, interview 2/8/13). Opportunities are being explored for three phase visits to schools to overcome “one of the weaknesses with the *Lab on Legs* and the *Lab* classes, it’s a one-off” (S42, interview 2/8/13).

In addition to these programs the CSIRO offers the CREST awards program for science investigation projects, publications such as *The Helix*, online science and maths newsletters, access to web content and TV programs such as *SCOPE* (<http://www.csiro.au/Portals/Education.aspx>).

Current Gaps and Challenges in STEM Education

The participants identified a wide range of gaps and challenges facing STEM education. These ranged from issues of an adequate supply of appropriately qualified teachers, professional learning needs, and issues related to resourcing which all contribute to a gap between the intended and the implemented curriculum. All participants were asked to identify challenges arising from implementing the Australian curriculum. The findings are reported for science, then maths and finally for technology education.

The intended curriculum and the implemented curriculum for science

As reported above, there are a range of quality science education resources available but programs are not always delivered in the manner in which they were intended. For example in primary schools, teachers’ limited pedagogical content knowledge in areas such as sequencing science concepts and conceptual building can result in one off activities being extracted and delivered from what was a well-designed learning sequence.

“Look at the current science programs and courses, they work pretty well. But it is how they are delivered that changed it and maybe it hasn’t turned out the way it was intended. The intended curriculum doesn’t matched the delivered curriculum” (S1, interview 10/5/13).

Low levels of knowledge in non-specialist science teachers

All interviewees described a gap or deficiency in many non-specialist teachers’ science content knowledge. They were reported to have limited understanding of the nature of science and awareness of science in everyday phenomena. *“They don’t know their science, so therefore they can’t recognise where science is in everyday things”* (S1, interview 10/5/13). This issue was particularly evident in the primary area and with non-specialist lower secondary teachers.

A particular theme in interviews was observations of Early Childhood teachers who generally lacked confidence in their ability to teach science. It was reported that Early Childhood teachers often didn’t recognise science in children’s play or in the learning environment. This was explained by a sector representative in the comment, *“there is a lack of confidence that what they’re doing is*

science, and I'll go into classes and I'll go into fantastic lessons where there has been wonderful work done around living things and observations and asking questions, which I think is absolutely perfect for early childhood, and they'll go, "Oh, but this isn't science," and I say, "What do you think science is?" (S8, interview 30/5/13). Again this appeared to be due to a limited understanding of the nature of science and inquiry skills.

Regional school inequities

Inadequate content knowledge amongst teachers in regional schools was raised by professional association representatives as an equity issue. This problem has been compounded as individual school programs vary in quality from school to school and there is no consistent approach. There continues to be regional school inequities with large numbers of inexperienced and non-science teachers teaching science in regional secondary schools (S12, interview 29/5/13).

Reduced time for extension activities and excursions

All representatives interviewed agreed that limited time was available for teachers to engage students with extension activities and opportunities for accessing science experiences outside the school. Pressures on upper secondary teachers to get through the content and to prepare students for external examinations had resulted in less time and or opportunities for enrichment or exploring science as a human endeavour. For example, *"just getting them out is really hard, especially in the upper groups, upper years that everybody wants their time to do their own subjects, and so to take them out for half a day or a day for a biology camp or to go and listen to a chemistry talk or something it's really difficult"* (S1, interview 10/5/13).

Limited reach of curriculum enrichment activities

There were many comments about the limited reach of many science enrichment activities. Extending beyond the curriculum was dependent on access to external expertise and teachers who are supported with material and technical resources within their schools. As a consequence, activities designed to extend the more able students such as the Science Talent Search and CREST were only available to some students in some schools.

Primary science specialists

In order to deal with an avoidance of science by some primary school teachers, primary schools have employed science specialists. There are reports of varying degrees of success with the specialist science teacher model. Largely, the impact of such programs has depended on the qualities of the specialist science teacher and the support of school leaders. A concern associated with the specialist science teacher model is the loss of curriculum integration opportunities. This is evident in the comment, *"I'd like to see every primary school teacher do science in their class so they can make the integration across the other learning areas"* (S1, interview 10/5/13). Sustainability is also a concern. If the specialist teacher transfers to a different school, the former school is left with no one teaching science.

Challenges of introducing the Australian Curriculum for Science

It was consistently noted by all interviewees that teachers need time to read and work through the Australian Curriculum to build understanding of its content scope and sequence, and what is required in relation to pedagogy and assessment. Teachers need support to unpack the Australian Curriculum documents and examples of how to implement it in the classroom. *"It's more important now that they understand the aims, the structure and the intent of the Australian Curriculum and*

follow that through” (S1, interview 10/5/13). The information and key messages being provided to teachers need to be consistent across all professional learning being provided.

Changes to expected pedagogy

Achieving scientific literacy through delivery of the Australian Curriculum requires the weaving together of the three sub-strands, science understandings, inquiry skills and science as a human endeavour into an intentionally crafted, holistic learning journey for students. The context of science as a human endeavour is intended to drive conceptual learning and development of inquiry skills. This pedagogical shift was reported as significant for many secondary science teachers (S12, interview 29/5/13) as it requires engagement with the SHE sub-strand and learning science through inquiry.

Increased content demands in primary science

A common theme across interviews was the increased content demands of the Australian Curriculum. It was anticipated that many teachers would struggle with the science content and the required conceptual understanding. Sector representatives who had analysed the Australian Curriculum and identified shifts and additions of content stated that, *“The depth and breadth that is required for the new content in primary is going to be a problem”* (S1, interview 10/5/13). It was also raised that there was an increase in the conceptual demands at the Year 6 and 7 year level, which was proving to be challenging for many teachers.

New content in upper secondary science

It was reported that the inclusion of new content in Australian Curriculum Physics and Chemistry courses requires up skilling of upper secondary science teachers and revision of existing texts, laboratory manuals and student problem books (S12, interview 29/5/13). For example, *“new content in chemistry such as “thin layer or gas chromatography is going to (create) equipment problems...and there are areas where teachers will have to up-skill or retrain because they won’t know it”* (S18, interview 30/5/13). There were also some concerns expressed about the new Australian Curriculum Biology course and repeated content in WA’s Human Biology course.

Including Science as a Human Endeavour

However, the area of greatest concern, from all levels of schooling, was reported to be the inclusion of Science as a Human Endeavour (SHE) in the Australian Curriculum. Teachers need resources and professional learning to understanding how to deliver SHE. This has been a particular challenge in the secondary school context and extends to Science Inquiry Skills (SIS) resourcing and pedagogy. This was explained in the comment, *“One of the biggest things with the Australian Curriculum is the idea of Science as a Human Endeavour and Science Inquiry Skills and the importance that has been placed on these compared to just straight learning content”* (S1, interview 10/5/13).

More specifically, it was reported that there are repeated references in the Australian Curriculum SHE sub-strand to emerging technologies such as nanotechnology and biotechnology. This requires teachers to take a broader and integrated approach to science content. This issue was highlighted in the comment, *“with biotechnology and nanotechnology, all that coming in, the students should be doing much more combined learning...they need to actually do it (science) in a contextual setting, which requires thinking about real problems”* (S13, interview 20/5/13).

Assessment and achievement standards

The Australian Curriculum is requiring teachers to look at existing practices and map assessment tasks to the national achievement standards. Interviewees consistently identified the audit process required as being challenging for many teachers. Questions being asked of teachers through professional learning were reported as “*What are you testing? Does it match what you taught and does it match with what is expected of the students in that particular year group?*” (S1, interview 10/5/13). Also, “*But how do you know that they (students) can apply that learning? How do you know that they’ve understood this? How do you know that they can investigate?*” (S8, interview 30/5/13)

In particular, assessment of SHE is a major area of concern for teachers. They are questioning how the sub-strand can be assessed, how much it should be worth and what level of detail is required (S12, interview 29/5/13).

Participants identified several factors which may have served to challenge the effectiveness of existing mathematics programs in Western Australian schools. Factors affecting teachers are discussed first, followed by factors affecting students and structural issues.

Teacher mathematical content knowledge

There was strong consensus that the mathematical content knowledge of teachers must be improved in order to better meet the needs of students and potential employers. Concerns were also raised about the number of teachers who are teaching outside of their main area. Comments included:

The biggest issue that we have is the actual teachers’ own mathematical knowledge and pedagogical content knowledge in mathematics. (S9, interview 9/5/13)

The content knowledge really is a great cause for concern... we have a lot of teachers out of field, they’re just filling up a load. (S20, interview 22/5/13)

Effective mathematical pedagogy

Participants suggested that teachers require support and training to overcome “*a fairly heavy dependence on textbook teaching*” (S2, interview 15/5/13). Participants attributed the over-reliance on textbooks to the amount of content to be taught, a lack of teacher confidence and external factors driving curriculum:

I think partly it’s because we’ve always had too much content to go through... I don’t think that we are focussing on the mathematics that the majority need. I think it’s very much driven by universities. (S14, interview 24/5/13)

Teachers feel too pressured to work their way through a set syllabus or curriculum... there is the lack of content knowledge of the teachers, lack of confidence, lack of awareness of recent developments in mathematical pedagogy, and external pressures to meet the outcomes of an externally driven curriculum like NAPLAN testing. (S17, interview 20/5/13)

Differentiation of instruction

It was also suggested that many teachers require additional training in order to effectively differentiate their instruction for the range of students in their class.

Teachers need to be empowered to help those that are in need, with remediation, intervention and to be ready to use extension for those that need extension. And I don't think teachers have those skills. (S22, interview 24/5/13)

There was strong consensus amongst participants that existing mathematics programs in Western Australian schools have focused on “*that general broad maths education for the majority of the population... sufficient for them to achieve the minimum standard*” (S9, interview 9/5/13). According to participants, existing programs have not encouraged students “*to do maths at the highest level they can manage*” (S20, interview 22/5/13) and that “*there's no problem-based learning or inquiry-based learning, no challenge-based learning, or the kind of problem solving that I would expect in those kinds of programs*” (S17, interview 20/5/13).

Participants also identified several groups of students for whom existing mathematics programs appear to have been less effective. For example:

We could certainly do better for our Aboriginal kids... The other group of kids that I don't think we've catered for particularly well are those that are able... I suspect there are kids in our classes that could be dealing with much more complex mathematics than they actually have opportunity to do... for some of those kids the opportunity to actually engage them and excite them and grab them is kind of lost a bit... (S9, interview 9/5/13)

Student attitudes towards mathematics

It was further suggested that many students have formed their impressions of mathematics by the upper years of primary school and that this “*affects how they respond to it at a high school level. And then hence obviously going into what they choose for Year 10, 11 and 12 and then tertiary stuff*” (S3, interview 10/5/13). Anecdotal evidence suggests that the reason many students choose to opt out of further studies of mathematics is because “*they've had a bad experience... there's been something there, usually a teacher, where they've had an experience that hasn't been pleasant.*” (S3, interview 10/5/13).

It was also acknowledged that a great deal of work needs to be done in order to change student perceptions of mathematics in order to appreciate its likely impact on their subsequent career choices:

We need to educate students about how they need to become informed about mathematics because it underpins what they're going to do. It may not underpin what they're going to do when they're 19 but it will when they're 25. That's the message that's not getting out there. (S20, interview 22/5/13)

Year 7 transition to secondary schools

It was also clear that bringing Year 7 students into secondary schools may highlight existing issues with a lack of teacher mathematical content knowledge. One participant noted that support from

specialist mathematics teachers was more likely to be available in a secondary context, although this was more likely to be the case in larger metropolitan schools.

I don't think that you can assume that because the kids are in a secondary context they're necessarily going to get someone that knows the maths. (S9, interview 9/5/13)

Challenges of introducing the Australian Curriculum for Mathematics

Participants were able to identify a number of specific challenges that were associated with the introduction of the Australian Curriculum. Participants did take care to acknowledge that some issues of concern (such as the lack of teacher mathematical content knowledge and increasing workloads), although widespread, have not arisen as a result of the Australian Curriculum:

The teachers out there do need support, but it's not because of the Australian Curriculum necessarily, it's because of their own readiness for teaching, their own content knowledge... Teachers have huge workloads... The rate of change at the moment is really quite considerable... Teachers are worried about their capacity to achieve everything that needs to be done, and to be able to do it well. (S20, interview 22/5/13)

Earlier introduction of mathematical concepts

Few participants perceived that the Australian Curriculum would significantly change the mathematical content that is delivered in Western Australian schools. One participant commented “there’s no new content per se” (S2, interview 15/5/13). Another participant suggested “the biggest shift is when students are being introduced to concepts... students are expected to deal with harder concepts at an earlier stage” (S20, interview 22/5/13). Participants saw this as a potential source of anxiety for teachers and students:

The challenge for us, I think, in Western Australia is that the levels in the Australian Curriculum are set slightly higher than what we had in Western Australia, and I think that is a difficulty because the research base from First Steps in Maths was actually showing that the kids weren't capable of learning these things at the ages suggested by the Australian Curriculum. (S4, interview 15/5/13)

Changes to expected pedagogy

A number of participants regarded the Australian Curriculum’s proficiency strands as potentially challenging for some teachers, as evidenced by the following comments:

The Australian Curriculum doesn't give you any examples of how you do it. (S3, interview 10/5/13)

Teachers think, “Oh, it's just working mathematically, I do that anyway.” They don't realise they need to change their assessment approach and their teaching approach to give students the opportunity to explain their understanding. (S20, interview 22/5/13)

Lack of confidence with technology for delivering the maths curriculum

Participants also suggested that many teachers may lack the confidence to use technology to deliver mathematical content in the way suggested by the Australian Curriculum, and that further research is needed to determine the most effective instructional practices. Comments obtained included:

I see an issue with people coming to grips with the use of technology in the teaching of mathematics... You've got to show the teachers that that content can be delivered in other ways. (S14, interview 24/5/13)

If you read the Australian Curriculum... the use of technology is inherent... it's in the delivery of the concepts, it's knowing when not to use technology as well... it needs some good research to see what is going to be effective and what isn't. (S22, interview 24/5/13)

The informants identified a wide range of significant gaps and difficulties with technology education in WA schools.

Appealing to both genders

It's *"really important to realise the potential for girls in computer science and certainly engineering and places like ... we need to create an environment that inspires kids, that lets them understand that there are jobs out there and career opportunities"* (S11, interview 13/5/13). Subject 15 noted that *"if we want to get a greater number of people graduating or moving through the curriculum area, we need to be able to appeal through to both genders, and the curriculum is not going to change to meet the genders, it's the pedagogical approaches"* (S15, interview 23/5/13). He explained that the didactic pedagogy typical of secondary schooling was a barrier to girls' involvement in higher level technology subjects as they favoured more inquiry and social engaged forms of learning.

Infrastructure

Subject 19 explained that *"the trouble with a lot of primary schools (is) their infrastructure is not up to scratch in some ways. They're now embracing mobile technology and they need to set up proper wireless infrastructure"* (S19, interview 23/5/13). Several of the informants (e.g., S19, S15) identified problems of inequities in the level of infrastructure and expertise across sectors and schools to support technology education.

Teacher supply and expertise for technology teaching

From a secondary perspective teacher supply, teacher expertise, pedagogy and curriculum time are concerns. Subject 11 explained that technology teachers need a strong background in science and mathematics in addition to technology disciplinary knowledge. This theme was developed further by Subject 5 who stated that *“Okay, so I think again, anecdotally, primary schools I’d say that, you know, lack of training and expertise for primary school teachers, and that is going to continue further down these other questions with regard to the Australia Curriculum requirements ... certainly gaps in teacher expertise in the areas, for instance, the engineering studies course, there’s a significant amount of maths and science in there; typically, design and technology teachers or technology teachers just don’t have that background. So typically they’ve had to partner with maths or science teachers for those stage two and stage three courses. So big gaps there at those higher-level type requirements”* (S5, interview 10/5/13).

The Design and Technology strand of the Technologies Curriculum has a stronger presence in secondary schools than Digital Technologies (S19, interview 23/5/11) and in the non-government sector staffing was not a problem as teachers could be recruited from government schools. Subject 19 also explained that many secondary computing teachers have gone into industry or are working in networking in the education system and have been lost from the classroom. Subject 16 highlighted the difficulty of staffing secondary technology programs in government schools and issues with teachers needing a diversity of expertise in areas such as programming, aspects of engineering which require strong physics and mathematics backgrounds, and the traditional craft skills. Recruiting design and technology teachers is one issue, however, as Subject 16 explained retaining them is a problem due to workloads and the lack of technical support for ordering materials, maintaining workshops and machines.

Lack of technical support for secondary technology

Subject 16 explained that *“with the changing of the EBAs and stuff like that, over the last few years and everything ... the D&T teacher has to do all their own procurement of resources, machining of materials, and once they’ve done all that, very rarely do they have the energy and the time to go and experiment and do something new, and incorporate that into their curriculum ... so the last 15 years or so, a lot of development has been stagnated ... simply because they don’t have that support mechanism that comes through with technicians”* (S16, interview 23/5/13).

Valuing of the technology learning area by school leadership

Subject 6 highlighted the importance of school leadership for the development and valuing of technology education in secondary schools: *“I think there is value that’s put into what happens in IT and T&E areas in a school is very much to do with the value leadership places on it; whether they show a genuine interest in it. And, unfortunately, in a lot of our schools because TEE and university entrance is the be all and end all of everything, and that’s the way the school markets themselves. There isn’t perhaps the encouragement given to the hands-on and the technical subjects in schools”* (S6 interview 22/5/13). Subject 11 indicated that opportunity for students to study technology was largely dependent on the way that school timetables are structured: *“I mean, you’ve got people in schools making decisions about what goes on the timetable ... deputies, principals, they bring their beliefs and values to the whole thing and don’t understand that the economic future of Australia is sitting in this sort of area”* (S11, interview 13/5/13).

Challenges of introducing the Australian Curriculum for Technology

Informants from the education sectors and professional associations all commented on the way in which the Australian Curriculum for the technologies learning area had been structured and represented. The Technologies curriculum comprises two strands; Digital Technologies, and Design and Technology. Subject 6 noted that computational thinking is a new content within the digital technologies curriculum and involved logical and analytical thinking. Subject 11 explained that the curriculum is laid out in two-year bands *“so you’ve got two years to cover your four contexts, and within those four contexts you need to be looking at a product, a service or an environment”* (S11, interview 13/5/13).

Interpreting the curriculum document

As the language of the new curriculum is likely to pose problems of interpretation into teaching programs, teachers will need professional learning opportunities to unpack the curriculum and in primary schools work out how to integrate it with science, mathematics and other learning areas.

New content and teacher expertise

Subject S19 thought that *“The expectations with the Australian Curriculum is much higher and our (primary) teachers just haven’t got the skills and the resourcing”* to teach the digital technologies strand. In the secondary context *“there’s not many teachers, ICT teachers, that understand programming, computation. They’ve gone out into industry or gone into networking and won’t come back into the classroom”* (S19, interview 23/5/11). Subject 15 also identified the cognitive demands of the Digital Technologies curriculum as a challenge for students and the language of the curriculum document as a significant challenge for teachers.

Subject 15 also identified social and ethical aspects of IT as challenges for teachers as they do not necessarily have the skills to deal with issues of software piracy, plagiarism and online bullying.

Key challenges include the provision of reliable infrastructure, support in interpreting the curriculum documents and more programming skills for our digital technology teachers. Subject 19 believes that the emerging technologies pose a particular challenge: *“it’s still very patchy in our schools, and it’s a matter of trying to, I guess, bring in the expertise and create partnerships with outside industry and community to provide the resources and the expertise to up-skill our teachers”* (S19, interview 23/5/11).

Lack of computer science teaching in lower secondary schools

Subject 6 explained that implementation of the new curriculum in secondary schools will pose difficulties for both teachers and students because the assumed prior knowledge developed in the primary and early secondary years will be missing. Subject 5 explained that the Australian Curriculum will require schools to develop new programs that will introduce Year 8 and 9 students to engineering, computing and multimedia and the digital arts. He explained further that teachers currently teaching WACE courses will need to develop new curriculum resources and programs for the new upper secondary Digital Technology courses.

Key Needs

A range of key needs in STEM education were evident across the interviews with sector and professional body representatives. The needs of STEM teaching were related to teacher quality, teacher professional learning, curriculum and assessment resources, providing for the diversity of students, technical support and career education.

Teacher quality

Consistent with the research literature (e.g., Hattie, 2003), there was unanimous agreement amongst participants from the Government, Catholic and Independent sectors and the professional association that the single most important influence on students' learning outcomes is the effectiveness of the classroom teacher. A comment which reflected this was:

I guess what students need, really, is effective teachers... The quality of education that a student gets is only as good as the teacher delivering it. (S20, interview 22/5/13)

It was acknowledged that there is a need for many teachers of science and mathematics to further develop their content knowledge. This is particularly the case for teachers who are teaching outside their area of expertise. A comment which exemplified this was:

I think we need a much stronger workforce in terms of content knowledge. (S20, interview 22/5/13)

Participants suggested that the process of building the mathematical content knowledge of the teaching workforce requires a patient and sensitive approach:

If you have the bigger goal of actually improving what happens and building people's capacity over time, they need access to people that know the maths, that are not going to intimidate them, threaten them, make them feel less of a human being by admitting that they don't know that maths, and that's a really important issue that stops people from engaging. (S9, interview 9/5/13)

In addition to mathematical content knowledge, teachers also require "pedagogy related to how students actually learn" (S17, interview 20/5/13). A number of participants suggested that teachers who lack confidence are more likely to develop an overdependence on 'textbook teaching'.

We can't continue to try and deliver the same sort of mathematics teaching that we did 20, 30 years ago which is unfortunately what's still happening. We have to change, we have to adapt, we've got a new breed of student, we've got research to assist us that teachers generally don't get to access. (S2, interview 15/5/13)

Other participants confirmed that there is a significant disparity between research and practice:

I see an enormous difference between what theory or research suggests is a darn good way for kids to learn mathematics, and how mathematics teaching is delivered in a classroom. I don't see much professional learning happening in inquiry-based approaches... and even fewer that are cheap or free to access. (S17, interview 20/5/13)

There was also strong consensus that the maintenance and development of a strong and effective teacher workforce requires ongoing access to quality professional learning initiatives and the support of school leaders. Given that teaching practice is determined by the teacher's beliefs and pedagogical content knowledge, effective teacher professional learning is that which challenges beliefs about effective pedagogy and develops both content and pedagogical knowledge.

Teacher professional learning

It was consistently stated that quality resources alone would not improve classroom practice or facilitate the transition to the Australian Curriculum. Staged and well-targeted professional learning was required that included opportunities for action learning such as trying out new ideas in the classroom with ongoing support and feedback. For example, a sector representative stated, *“all of the research shows that if we're going to have success in initiatives then professional learning has to be spaced, it's got to be regular, you've got to have some sort of action learning, and see what it can look like in a school. It's not a once-off”* (S8, interview 30/5/13).

All stakeholders interviewed identified a need amongst teachers for ongoing professional learning opportunities. This included familiarisation with the Australian Curriculum and assistance with unpacking its content. Teachers at all levels are needing PD on new science content, designing assessment tools, programming to accommodate the Science as a Human Endeavour strand and importantly pedagogical development in order to improve what is happening in the classroom. It was argued that *“there's enough evidence to suggest that by changing the description of the curriculum you still are not getting changes within the classroom. You have to provide teachers with new strategies, ideas in which they can develop science as a human endeavour as their context for delivering their course work, refocussing back, asking appropriate questions relating to ethics of the science that they're doing”* (S12, interview 29/5/13).

The importance of mentoring and professional science education networks was a strong theme emerging across all interviews. Mentoring and support networks were identified as increasingly important in the implementation of the Australian Curriculum as there had been decentralised curriculum leadership in a major WA education sector. It was suggested that experienced teachers should be linked up with graduate or early career teachers in a mentoring relationship (S13, interview 20/5/13).

Professional networks, school clusters and lighthouse schools were strategies that had successfully been used in the past for collegial interaction and professional learning. For example,

“Teachers need more opportunities to discuss what they're doing with like-minded others. With guidance, with an opportunity to talk to somebody who might be more experienced than they are” (S1, interview 10/5/13).

Participants also made suggestions about the focus of professional learning. Subject 6 identified the need to up-skill upper secondary teachers for the new digital technologies curriculum, as many existing teachers teach multimedia and lack the skills to teach computer science. It may require recruitment of new teachers as those teaching digital arts may not have the dispositions or knowledge required to teach computer science. Even those teachers with a programming background are likely to be familiar with procedural programming languages and not the newer object oriented ways of programming (S6).

Subject 16 identified PD as a priority for Design and Technology (D&T) teachers as many were older teachers who have mainly taught wood and metal work and need to learn about emerging technologies and how to integrate them into the curriculum. Subject 16 also indicated that D&T teachers often find it difficult to be released to do subject specific PD as the priority for the school is often addressing behaviour management or literacy and numeracy concerns, and it is rare for all the D&T teachers to be allowed to attend a PD together. Often one teacher is released who must come back and inform his colleagues after attending a workshop which tends to be ineffective. Similarly the professional associations are finding that attendances at conferences are dropping because of difficulties in accessing school funding and release. Subject 15 argued that schools need the ability to target individuals through performance management because teachers cannot remain relevant in the rapidly changing technology discipline unless they are continually refreshing their knowledge base. Professional learning for technology teachers is a high priority because of the rate of change in the discipline and that new technology is a driver of innovation. Subject 6 advocated for forms of professional learning that included a mentoring component from a curriculum leader within the school. Professional learning programs such as EPICT which provide training on new technologies and the associated pedagogies work best when linked to mentoring support. When summing-up Subject 15 identified five key needs in technology education: *“professional development, conferences and advocacy, linkages to industry associations and valuing the role of females”* (S15, interview 23/5/13).

One education sector supports teacher professional learning through regular network meetings, meetings of ICT curriculum leaders from school clusters, in school mentoring and by developing curriculum resources shared on an Australia-wide Scootle network (S19, interview 23/5/13). Video conferencing by consultants into workshops held at regional secondary schools is also providing access to PD for teachers in regional and remote schools (S19, interview 23/5/13).

It was acknowledged that the cost of teacher relief represents the single most significant barrier preventing teachers and schools from accessing professional learning as illustrated by the following comment:

You’re looking at over \$500 a day for a relief teacher and if you’re looking at extensive professional learning that’s a very costly exercise. (S20, interview 22/5/13)

While some participants advocated for the creation or expansion of online professional networks to support teachers, it was acknowledged that providing access to quality professional learning is inherently expensive:

[it] needs to be targeted, it needs to be quality, you know, world’s best practice, and you can’t do that unless you get the world’s best presenters/facilitators, and that costs money. (S22, interview 24/5/13)

Participants suggested that schools in regional or remote areas faced additional challenges:

Teacher relief is really, really difficult... For people to go into a PD in Fitzroy Crossing, for example, it takes them a day to get out of their school and a day to get back, so they lose their weekend. (S4, interview 15/5/13)

There are so many areas that could be dug into to make mathematical learning in an Aboriginal or Torres Strait Islander context so much more meaningful for those students. But those resources just don't exist at the secondary level. (S20, interview 22/5/13)

In addition to the cost of teacher relief, participants were also concerned about the cost of lost expertise when teachers are promoted, move schools, retire or leave the profession. Comments included:

The issue with investing is people that they move on, you know, that's the thing. (S9, interview 9/5/13)

A lot of good quality teachers will be retiring in the next five to ten years. (S20, interview 22/5/13)

Participants observed that ensuring students are provided with the best possible educational opportunities is a significant challenge for regional and remote communities. It was acknowledged that the recruitment and retention of a suitably qualified and experienced workforce is a challenge common to both education and industry. It was suggested that improving the educational opportunities offered to the children of industry workers may help to combat the perception that "I've got to get back to the city for Years 5, 6 and 7." (S14, interview 24/5/13). It was further suggested:

Imagine that you were able to set up some initiatives where you improve the teaching and learning that was going on, so the kids got the best possible education they could. At the same time you up-skilled your teachers, and maybe they got an extra qualification, Grad Dip or something. Imagine a school that was able to then say "All our teachers have a higher degree." (S14, interview 24/5/13)

Curriculum and assessment resources

The teachers should be consulted about their resource needs in bridging any gaps evident in the transition to the new Australian Curriculum (S12, interview 29/5/13). Yet, it was noted (S1, interview 10/5/13) that there was a large degree of reliance on science textbooks, particularly in lower secondary. Consequently, closer attention needs to be given to the interpretations of the Australian Curriculum presented in textbooks. It was reported that there is currently a gap in the content presented in texts and their alignment with Australian Curriculum.

The popular and widely used resources such as STAWA Physics and Chemistry laboratory manuals and student problem books need to be reviewed and suitably revised to align the content with the Australian Curriculum (S12, interview 29/5/13).

Resources need to be produced that present science as a human endeavour. There is a need for this support from Early Childhood through to Upper Secondary. Scenarios included should be relevant to students' everyday lives and the diversity of Western Australian contexts (S7, interview 22/5/13).

Teachers require professional learning in relation to assessment practices, especially in the SHE sub-strand. It was suggested that there be an *"online setup for the delivery of questions and quizzes"* (S12, interview 29/5/13). Currently available science assessment resources such as SEAR need to be reviewed, up-dated and aligned with the Australian Curriculum achievement standards. Teachers are requiring student work-samples as illustrations of the Australian Curriculum achievement standards from F to 10.

One participant suggested that it is important to acknowledge that not all students are destined for university study, and that there is a need to provide teachers with more resources and information about how the mathematics they are teaching can be applied to a range of contexts:

There's not enough information out there on the application of the mathematics... many of our children are not going to end up at university... we also need to show them that there's a mathematics application at this point here. (S14, interview 24/5/13)

Subject 6 explained that primary school teachers will need exemplar curriculum resources to show them how to integrate the new technologies content into the primary curriculum.

Student diversity

According to participants *"one of the current needs of teachers is being able to cater for differentiation"* (S4, interview 15/5/13). A number of participants commented that while many schools attempt to cater for differentiation in mathematics via streaming, research suggests that this approach is not particularly effective. Participants identified this as an area where further professional learning is required, as illustrated by the following comments: *"I suppose one of the difficulties is differentiation right across the board"*. (S9, interview 9/5/13)

Participants suggested that some students need additional time in order to develop mathematical ideas and understandings, and that these students may opt out of mathematics if they lack the fundamental skills required to access the curriculum. Comments included:

One of the things that happens in schools is that the time devoted to maths education is lost, it's reduced... Now for mathematics time on task equals learning. (S22, interview 24/5/13)

I think the biggest need for maths education is Years 7 to 10, because that's where we lose kids. And some of those we lose because they haven't left primary school with enough maths (understandings and skills) to access the curriculum, but really it's hard for the student and hard for the teachers to make up that gap. (S9, interview 9/5/13)

There was a common belief that there was a large range of resources and initiatives aimed at extending students interested in or excelling in science. However, a common view was that there is limited time in the school program to incorporate or access extension activities due to an overcrowded, content heavy approach to science in secondary schools. For example, *"If it's solar challenge, hydro challenges, there's thousands and thousands of competitions, investigations,*

applications that you can do, and the catch-cry has already been, we don't have time" (S8, interview 30/5/13).

For this reason it was recommended that extension resources and activities be carefully aligned to curriculum and this mapping was made clear to teachers. A desirable aim for extension activities was to provide depth in the curriculum and higher order thinking and reasoning opportunities, rather than simply increasing the breadth of topics covered. It was stated, *"Let's just not accelerate them, let's enrich it and let's get them some wonderful opportunities"* (S8, interview 30/5/13).

Participants expressed concern that many teachers are *"not too sure about what extension should be"* (S14, interview 24/5/13) and that *"what a lot of people see as extension and enrichment tends to be very abstract"* (S17, interview 20/5/13). There were also concerns that some teachers may lack the content knowledge required to provide appropriate opportunities for enrichment and extension and that opportunities for enrichment and extension have been lost as a consequence of the amount of content teachers are required to cover. Comments included:

If kids are going to get decent enrichment extension they need teachers who are on top of the concepts, who know where the F to 10 mathematical ideas are heading. (S17, interview 20/5/13)

A lot of enrichment has gone by the wayside, unfortunately. I think teachers are so worried about covering content that if it's a little bit out of the ordinary it doesn't happen. (S14, interview 24/5/13)

It was suggested that students require access to a broader range of opportunities for enrichment and extension, and that there is a need to ensure that these opportunities are made available to all students:

There needs to be a better continuum and accessibility of a broad range of enrichment and extension... I see enormous differences between what happens in urban schools and rural, regional and remote schools. And the further away from the city the fewer the teachers who can provide the extension and enrichment, and the fewer the resources that would accompany that. (S17, interview 20/5/13)

In terms of enrichment and extension for students, Subject 5 explained that competitions such as the Lego Robo Games and the Solar Car Challenge had been excellent for developing club type activities for a small number of enthusiasts, however, there is a need to mainstream these types of enrichment activities.

Support for managing equipment and IT networks

Primary school teachers are largely unsupported in managing science equipment and materials. Educational assistant time in this area could free up teachers' time and enable them to concentrate on the teaching and learning of science. As evidence, *"...if you can buy some education assistant time to help with setting up equipment and maintaining it and helping prepare material, that would be a big advantage."* (S8, interview 30/5/13)

Subject 16 identified technical support for digital technologies as key needs for both primary and secondary schools, and technical support for secondary Design and Technology. Subject 15

emphasised the need to maintain currency with computer hardware and software and adequate access to the internet without unnecessary constraints imposed by the SOE. Subject 6 also emphasised the need for robust and seamless technology to support ICT teaching in schools and for teachers to be given access to new software and hardware six months before they are rolled-out to students so they have an opportunity to familiarise themselves with the new products. Technical support is also a priority for secondary D&T as without technical support teachers have no time for special initiatives or for innovations in their curriculum and practice.

Career education and advocacy

Subject 11 had particular concerns about girls being encouraged to continue their technology studies through the upper secondary years and into university and that this needed to be addressed through career education. Participation data suggests that career education is also required to increase girls' participation in high level maths.

Subject 11 explained that there is a need to secure sufficient resources and time in the primary and secondary school curricula to address the technology education needs of society. Only a small proportion of primary teachers are technology enthusiasts who incorporate technology across the curriculum using real world problems as contexts for learning, whilst many give technology lip service. Subject 6 explained that primary *"schools have been doing bits and pieces but technology often comes under craft, if you like, art and craft. To do it properly you actually need space, you actually need resources. You need somebody who is informed about what it's all about."* (S6 interview 22/5/13). These views are consistent with the research findings of Angus, Olney and Ainley (2007), who surveyed primary school principals and teachers in 2006. Their data indicates that only 26% of principals thought that technology was addressed comprehensively in their school. Teachers reported that on average (K-7, n=564) they only taught technology for 14 minutes per week and only 13% indicated they have all the expertise they need to teach the subject.

There appears to be an issue arising from the focus on ICT general capabilities in Australian Curriculum that digital technologies are being integrated into other learning areas in a very shallow way and *"the field of study has been timetabled out as being unnecessary"* (S19, interview 23/5/11). Subject 6 also reported that primary schools are not teaching IT as a subject and this is also the case in secondary schools in Years 7-9. Subject 15 stated that digital technologies *"exists in schools for teaching literacy skills and multimedia skills, and your primary, as a tool to facilitate learning ... But when it comes to the computational analysis, the data management side, the discipline of computing, they don't see it as a relevant perspective to explore"* (S15, interview 23/5/13).

Subject 19 explained that *"because they don't have that dedicated time ... and it hasn't been treated as a field of study and they haven't got that prior knowledge or that foundation to get some depth and breadth. So when it comes to Year 11 and 12 like computer science, students haven't got the adequate background, and to be able to cope with the course"* (S19, interview 23/5/11). Subject 15 provided additional examples of this computing gap in the existing curriculum. Subject 16 explained the difficulties of attracting more able students into technology programs such as Year 11 and 12 Engineering when there is little teaching of programming or electronics in Years 7-10, and many students leave the course mid-way through Year 11 for a VET course. Several participants explained that there needs to be stronger advocacy for the place of technology in primary and secondary schooling.

New Initiatives to Optimise STEM Education

All participants were asked to identify new STEM education initiatives that should be implemented. Suggestions related to improving the supply of adequate numbers of appropriately qualified teachers, approaches to meeting the professional learning needs of the current stem teaching workforce, the provision of new curriculum and assessment resources, career education and advocacy for STEM education, and better co-ordination of STEM education initiatives.

Teacher supply

There is currently an undersupply of appropriately qualified mathematics, physics and technology teachers, particularly in government and hard to staff schools and the extent of undersupply is expected to increase in 2015. Teacher undersupply leads to a greater proportion of Year 7-10 STEM subjects being taught by out-of-field teachers. Subject 19 identified the need to develop more specialist secondary ICT teachers who have programming skills and indicated that their HECS fees may have to be paid to support them through their training or re-training. Several participants expressed concerns about the need for quality teachers and teaching in the transition years between primary and secondary schooling

One of the big things that's going to be needed is the retraining of a significant number of primary teachers to teach secondary maths. The middle school maths, in my view, is the biggest area of need. Students are lost to the senior courses because they have 'wasted their time' in middle school and have not been moved along. They have been kept busy but they haven't been extended to the point where they have the necessary background to do the higher maths in senior school. (S22, interview 24/5/13)

I also see a real issue with what I'm going to call the 'transition' years, particularly as we move Year 7s into high school. I know there's lots of teachers teaching outside of their area, and obviously some primary teachers are going to move in to secondary. (S14, interview 24/5/13)

The transition years represent the point in the STEM education pathway that attitudes towards science and maths learning decline dramatically; new initiatives are needed to enhance the quality of teachers and teaching in these years.

Teacher professional learning

Participants suggested that future STEM professional learning initiatives should seek to build on the established success of previous initiatives. There was strong consensus amongst participants as to the factors which have contributed to the success of existing professional learning initiatives: successful initiatives generally involve a strong research base; an action research component; support from school leadership; and, a sustained approach to mentoring.

Build on previous success

Participants suggested that new STEM professional learning initiatives should seek to build upon the success of previous/existing initiatives such as the systematic approaches taken by Primary Connections, the Primary Science Project, Getting it Right (Mathematics) and First Steps in Mathematics. While acknowledging the success of these large initiatives, participants suggested that smaller, more targeted initiatives may be in order "in the current climate" where it has become

increasingly difficult to roll out effective, system-wide initiatives and many schools “are picking off lots of commercial things around the place.” (S9, interview 9/5/13). Comments included:

There were some very good older initiatives that had some impact... take our First Steps in Mathematics, but not make it so big and bulky, and narrow it down. (S14, interview 24/5/13)

I don't think the answer's going to be as big as something like First Steps... (S3, interview 10/5/13)

Other participants observed that there has been a shift towards decentralising resources to individual schools in order to allow them to address their own particular needs, however, this is limiting the capacity of education sectors to implement systemic reforms.

Research based initiatives

According to participants, the size of an initiative was not as important as its research base. Participants suggested that most successful initiatives have been developed from a research background and that further research is needed to evaluate new initiatives. Comments obtained include:

Things like Primary Science Connections have a great base out of industry... it was done from a research background; there's pedagogy sitting underneath it... it gave teachers not only the professional learning, but the package of materials in order to deliver that. And I've never seen anything like that in mathematics, ever. (S14, interview 24/5/13)

Funding should be coming through a university so that there's a research quantum attached to it... I think it's important we are setting up objective measures of how these things work. (S17, interview 20/5/13)

Action learning and research

Participants suggested that in addition to having a strong research base, new initiatives should seek to involve teachers in the process of action research. This increases teachers' sense of ownership of the knowledge they develop, which can then be passed on to other teachers in the school.

Action research projects that involve teachers directly... I think that works wonders because the teachers themselves are getting up skilled and they can, as we suggested before, they can then pass that on to other teachers within their school. (S2, interview 15/5/13)

Mentoring and networks

Participants suggested that providing teachers with access to a mentor over a sustained period of time is an essential component of successful professional learning initiatives. The mentor may provide content knowledge expertise, research expertise, opportunities for modelling and team teaching, feedback and support for the teacher. The following comments illustrate this:

Having someone who's within the school, within the classroom, you know that mentoring shoulder to shoulder in the school. That's the best model, but that's the most expensive one as well. (S4, interview 15/5/13)

To get teachers to change what they understand a maths teacher does is really quite extensive in what it requires, because they've got to not only be shown, they've got to see it modelled, they've got to try it, they've got to get feedback on how they're going, they've got to try it again and gradually improve what they're doing... so that they can see the difference that they're making to the students by taking a new approach. (S20, interview 22/5/13)

A common view appeared to be that the most effective approach is to train one or two teachers who would be “*kind of pioneers who get enthusiastic*” and “*are encouraged to share the knowledge and help with the professional learning of the other teachers in the school.*” (S2, interview 15/5/13). However, it should be noted that these approaches have limited success.

A knowledgeable facilitator and collegial interactions are integral to resource uptake and the associated professional learning required for the Australian Curriculum to be delivered as intended.

For example, “*a group of real people who have then the ability to talk people through things, help them out, solve problems, tell them what they don't know.*” (S1, interview 10/5/13). This suggests that any new STEM initiative must include the ongoing support of a knowledgeable educator who is contactable, active in schools and with teachers' professional learning.

Support from school leaders

There was strong agreement that teachers require the support and encouragement of school leaders if they are to further their professional learning. Participants suggested that a more strategic approach to teacher professional learning will benefit schools by increasing the capability of their teaching workforce as a whole, while providing opportunities for teachers to further their own career development. In addition to encouraging teachers to access appropriate professional learning, school leaders should consider how they can ensure teachers are given the opportunity to utilise their newly-developed skills in the school context. The rapid adoption of emerging digital technologies (such as the iPad) was cited by several participants as a challenge for which many teachers are underprepared. A comment which exemplified this was:

Leadership is very well versed on what the AITSL standards are... If we're going to improve the teachers' professionalism, help them out, you know, don't just say, "Here you go, off you trot, good luck with your iPad." (S3, interview 10/5/13)

Industry supported training hubs

Subject 16 identified as a priority the development of an industry supported training hub approach to teacher professional learning for teachers of D&T. This would be based on training provided about new machines and opportunities to have initial training at the hub and then loan the machine with associated curriculum support materials so that they can be trialled in the teacher's school and showcased to the school community who might then support the purchase of the new machines. In the past this has worked with companies who sell new technologies providing a couple of machines to the hub and the training in how to use them. Similarly some schools could establish a training hub based on welding skills so that teachers from other schools could be trained at low cost.

Subject 5 emphasised the need to ongoing professional learning for teachers of technology because of the rapid change in technologies themselves – Windows 8, tablets and apps for example. To be

effective, professional learning needs to be continuing and ongoing with follow-ups after workshop sessions (S5, interview 10/5/13). AISWA works with schools to identify their professional learning needs and then develops workshops to address them which are delivered face-to-face in the metropolitan area, however, servicing regional and remote schools is a real challenge and requires a tour through the region and follow-ups using Adobe Connect Pro. Equity of access to professional learning is an issue, particularly for teachers in regional and remote areas.

Curriculum resources and leadership

With the introduction of the Australian Curriculum there is a need to refresh text books, develop additional curriculum resources for new content areas and develop assessment resources matched to the new content and expected standards. Subject 6 indicated that a high priority would be the provision of “resources, exemplars and models of work” and that the implementation of these resources should be supported with professional learning, mentoring and opportunities for reflection and review (S6, interview 22/5/13). Subject 11 indicated that curriculum resources that identify a context, pose a real-world problem, provide supporting resources including examples of the finished product and assessment materials are required in the technology learning area.

Given that the Australian Curriculum is a curriculum for all jurisdictions, Subject 15 argued for a national approach to the development and dissemination of curriculum resources using the Scootle network of Education Services Australia. This recommended action is consistent with recommendations of the Williams (2000) report to develop a “national online resource for primary and secondary technology educators that brings together and annotates exemplary programmes of professional development, curriculum resources, materials and competitions that address new understandings about technology education” (p. 14).

S6 also argued that developing capacity for curriculum leadership in the digital technologies area was essential: “Somebody who gets in there and walks the walk, talks the talk and won’t ask anybody to do it unless they’re doing it themselves.” (S6, interview 22/5/13). This comment reflects an emerging theme of the need for curriculum leadership at school and education sector levels.

Career education and advocacy

Participants argued that there is a need to challenge the common perception that “maths is only for some.” (S9, interview 9/5/13). It was acknowledged that this perception of mathematics makes it more difficult to attract funding for mathematical initiatives. One participant observed:

Lots of people don’t like mathematics, or they’ve had a bad experience... So maybe the initiatives might not be about mathematics per se, but more about some of the applications... You really need to get the expertise of the engineers, the electricians, the tradies so to speak... And I look at something like the Home Base, the Housing Industry Association, where they manage to get the plumbers and the electricians together. (S14, interview 24/5/13)

It was also suggested that competitions such as those run by the Mathematical Association of Western Australia (MAWA) have helped students come to view mathematics as “something that everybody can do” (S20, interview 22/5/13). Participants suggested that “science has done such a better job at selling itself than maths” (S9, interview 9/5/13). Another participant suggested:

We need to get people into schools talking to groups of students en masse... There aren't role models out there for students... It's got to be somebody cool. (S10, interview 5/6/13)

Given that attitudes towards mathematics decline sharply in the transition years, career education about mathematics is needed towards the end of the primary years.

Career education was identified as a critical need to open students eyes to ICT based workplaces to see that ICT careers are more than just programming: *"career development is fundamental for kids to help look at their learning, their life and their work basically in pathways, and they're more the richer for it."* (S19, interview 23/5/13)

The Big Day Out for IT which offers a career expo for Year 11 and 12 students to meet representatives from industry and learn about career opportunities is valuable but what is needed is career education and expos for Year 8 and 9 students; Year 11 and 12 is too late (S15). Year 8s and 9s need this information to help them make sensible subject choices in Year 9 and 10 as these will determine course options for Years 11 and 12 and ultimately post-secondary education. Subject 11 recommend an initiative that would promote studies of technology and explain how this links to studies of science and mathematics.

Technology education needs people who can champion the cause and advocate for career expos and sensible school timetabling that allows students to develop expertise across science, maths and technology (S15, interview 23/5/13). In terms of priorities S15 argued that online curriculum resources, PL for teachers and advocacy for the curriculum area in schools, on the timetable and for events such as career expos were important.

Similar findings were reported in the evaluation of the UK STEM Cohesion Program (National Foundation for Educational Research, 2011) which noted that *"The status and capacity of careers provision in schools, continued to give cause for concern. A lack of cohesion between STEM and careers activities in schools was noted, as well as senior leadership teams not prioritising STEM careers information and guidance"* (p. vii).

Centralised information and direction to STEM initiatives

There are a large number of STEM initiatives and opportunities for teachers and students but access to the full range of information can be a problem due to its dispersed nature. A centralised, online repository or website with hyperlinks to STEM initiatives and providers would allow more teachers and students to benefit from opportunities. However, the data needs to be searchable. For example, *"...some sort of filter or way of saying, "We're really interested but we'd like someone to come and speak as guest speakers." Or, "We're really interested but we want the kids to go out and do something." (Teachers) think of a type of involvement, and then have a look at what potential initiatives are out there. Maybe it could be focused around the key concepts and ideas."* (S8, interview 30/5/13)

Managing and administering initiatives funded by industry

There is a range of education service providers and professional associations who develop strong relationships with partner industries who provide financial and other resources to support STEM education in schools. This is a competitive space and no consensus emerged from the consultations

about a better way of recruiting the support of industry and making industry resourcing available to all providers. There was recognition of the valuable work of the providers and that some teacher professional associations need stronger administrative support and structures to make them more effective. It was recognised that each of the providers has strengths to support particular disciplines or education levels within the STEM domains.

Key Findings Emerging from Interviews with Education Sector and Teacher Professional Association Representatives

Successful STEM education initiatives

23. Science has been supported by a number of highly successful initiatives, however, maths and technology have been supported with far fewer initiatives.
24. The most significant initiatives implemented by the education sectors themselves were those with a widespread implementation such as *Primary Connections* curriculum resources and professional learning through the Primary Science Project, Getting it Right Numeracy, First Steps Mathematics and Making Consistent Judgements. A combination of ongoing professional learning, mentoring and curriculum resources contributed to their effectiveness, however, it should be noted that many of these initiatives are no longer operating.
25. Of the professional associations, STAWA has been the most effective in delivering initiatives to support teachers and to extend able students. Successful initiatives include teacher conferences, student learning resources and the Science Talent Search competition.
26. Scitech has established itself as a significant provider of primary science teacher professional learning, outreach to schools throughout the State, and a venue for class visits at which students can experience highly engaging and interactive activities. Scitech's impact and effectiveness are evident in the numbers of schools, teachers and students Scitech engages with, and through evaluations.
27. ESWA has established itself as the main provider of curriculum resources, teacher professional learning and mentoring support for teachers of earth sciences. Success is based on having two highly capable staff develop resources and supporting teachers in their schools at times and places that suit them, at no cost to schools. The large numbers of schools, teachers and students supported, and increased enrolments in Years 11-12 Earth and Environmental Science are key measures of impact.
28. CSIRO Education provides a strong link between the research and resources of CSIRO and schools. CSIRO has provided a number of STEM education enrichment initiatives including the Scientists and Mathematicians in Schools program, lab activities at the CRIRO lab within the Scitech Discovery Centre, outreach activities that take laboratory activities to schools, the CREST science awards scheme and content from their web site.
29. The effective STEM education service providers have all been successful because of their capacity to attract funding from industry and/or the education sectors to support initiatives.

Gaps and challenges in STEM education

30. There are gaps between the intended and implemented curriculum largely due to low levels of content and pedagogical knowledge and confidence of non-specialist early childhood, primary and lower secondary teachers of science, maths and technology.
31. The quality of teaching in the transition and early secondary years of schooling is compromised by the many out-of-field teachers and regional schools experience inequities in supply of appropriately qualified teachers and access to professional learning.
32. There was strong consensus that: maths education has focussed too much on general mathematics education to meet the minimum standards demanded by NAPLAN testing; too little focus has been given to encouraging students to study mathematics to the highest level they can manage; and, there has been too little problem or challenge-based and inquiry-based learning.
33. Enrichment experiences for students through excursions are limited by time constraints and risk minimisation issues, and extension initiatives tend to be limited to modest numbers of schools and students.
34. Introduction of the Australian Curriculum poses a number of challenges for science, maths and technology education. These include: integrating the science as a human endeavour strand into the inquiry and conceptual learning strands of science; increased content demand in the primary years and new content in secondary years for science and maths; developing new assessment strategies and tasks mapped to the achievement standards for each year group for science, maths and technology education; and, access to time in the curriculum for the implementation of technology education.

Key needs and initiatives for optimising STEM education

35. Participants identified as priorities, a number of key needs that must be met to optimise STEM education. These include: an adequate supply of appropriately qualified teachers, especially for Years 7-10; ongoing professional learning for in-service teachers; the development of additional curriculum and assessment resources; a capacity to cater for student diversity; support for managing materials, equipment and IT networks; and, carefully targeted career education.
36. Participants' suggestions for new initiatives for optimising STEM education focussed on: attracting more appropriately qualified STEM teachers and the retraining of others; appropriately designed and implemented teacher professional learning; curriculum resources and curriculum area leadership; career education and advocacy within schools for additional prioritisation of STEM education; and, improved coordination and dissemination of information about industry supported initiatives.
37. Key barriers to new initiatives were the high cost of teacher relief to attend professional learning (PL) and the difficulties of engaging teachers with online PL, and a significant challenge is providing access to PL for teachers in regional and remote locations.
38. Participants agreed that new professional learning initiatives need a strong research base, an action learning component, support from school leadership and mentoring support. National initiatives like Primary Connections or state-wide initiatives such as Getting it Right Numeracy and First Steps Mathematics are the most effective, however, given resource limitations smaller scale initiatives may be required.

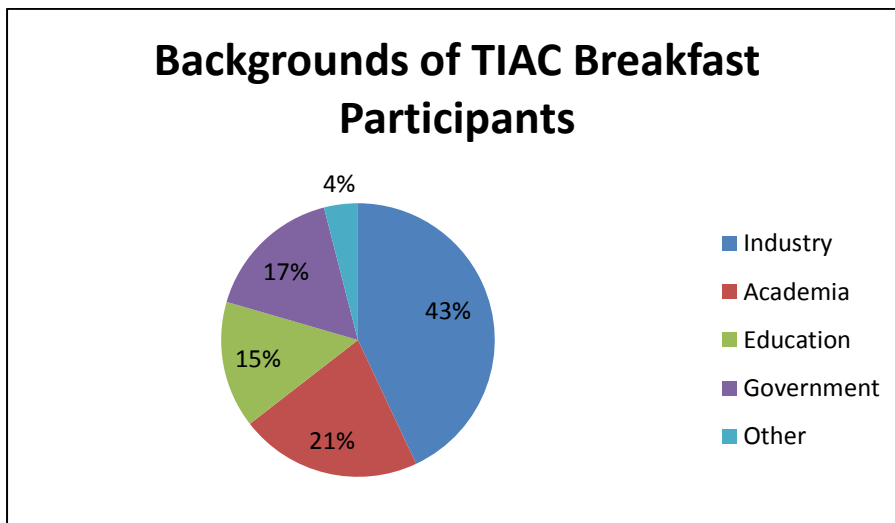
Consultation with Supporters of STEM Education

Purpose and Approach

The purpose of the consultation with industry supporters of STEM education was to elicit information from key informants about: STEM requirements of employees; initiatives that have been implemented to enhance STEM education; barriers to involvement with schools; and, ways of overcoming barriers to participation with schools.

The consultation process commenced in June 2013 and was facilitated by a breakfast function sponsored by TIAC and held on 25 June 2013 at which key stakeholders were provided with information about the current status and concerns with STEM education. The function hosted 79 participants nominated by the Science Education Committee (excluding members of the Committee and the research team) from organisations in WA considered to be key stakeholders for optimising STEM education in schools. The participants were drawn from industry, academia, education and government (see Figure 3).

Figure 3: Backgrounds of TIAC Breakfast Participants



Following a briefing on the issues confronting STEM education in schools, responses were collected from the participants via an interactive *Keepad* survey on a range of STEM education issues.

At the conclusion of the function, 25 industry participants indicated their willingness to be involved in follow-up interviews as a means of gathering further data and the Science Education Committee selected 13 of those participants for interview. In addition, the Chair of the Science Education Committee made personal contact with representatives from eight other industry organisations to recruit additional participants for the interview phase of the research.

Appointments were made to conduct structured 45-minute length interviews with 21 industry participants. Information letters, consent forms and interview questions were emailed to participants prior to interviews. Of the 21 industry participants contacted, one participant declined to be interviewed and another participant was advised by his organisation's Human Resources department not to participate.

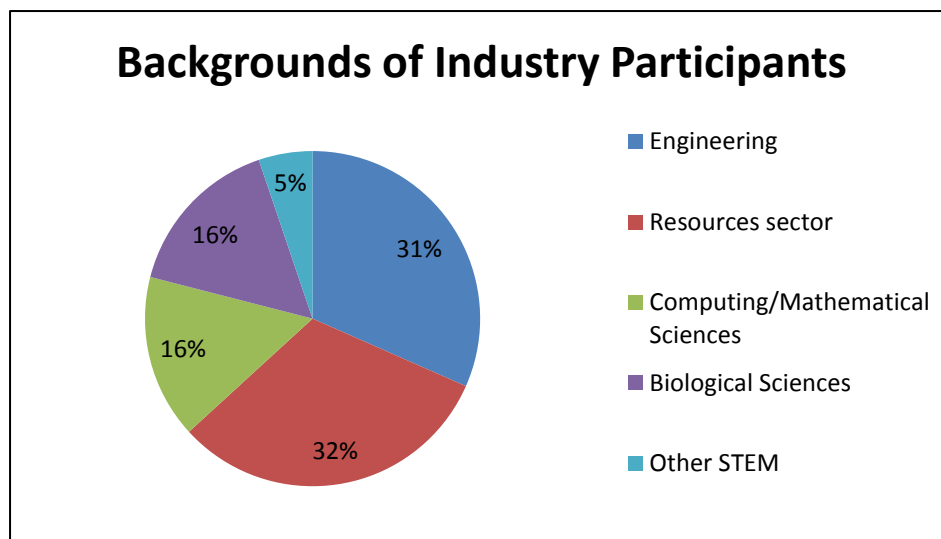
Structured interviews with 19 industry participants were conducted during August and September of 2013. Fifteen interviews were conducted face-to-face where it was practical to do so and four interviews were conducted via telephone. All interviews were audio recorded. Key information was recorded onto a template record sheet during the interviews and this information was elaborated when the interview recording was replayed to check details.

Demographic data for interview participants

Demographic data regarding the types and sizes of companies consulted with are reported in Tables 9-11.

The largest numbers of participants were drawn from engineering and resources companies, followed by participants from computing/mathematical and biologically-based companies (Table 4).

Figure 4: Backgrounds of Industry Participants



A large majority of the companies were significant, large (Figure 5) and international (Figure 6) companies with strong reputations.

Figure 5: Industries Consulted, by Size

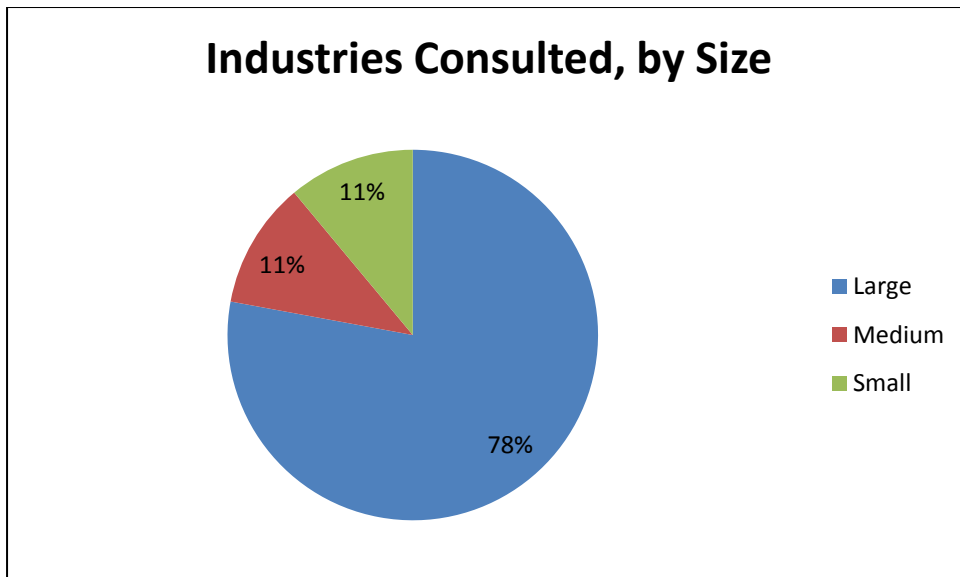
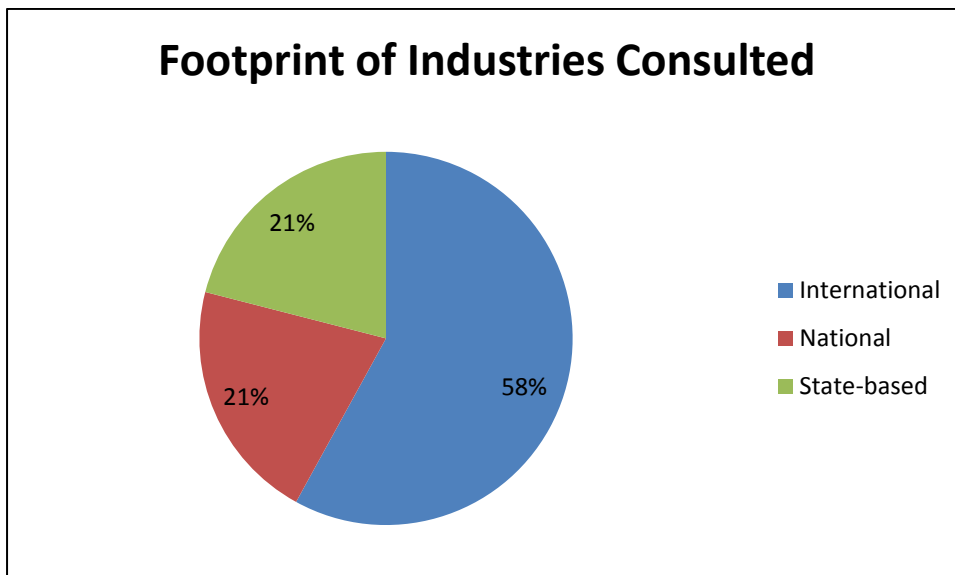


Figure 6: Footprint of Industries Consulted



Data Collected at TIAC Breakfast 25 June 2013

Data from the *Keepad* survey conducted at the TIAC breakfast were aggregated by the *Keepad* software and are reported here as simple descriptive statistics, question by question.

1. Extent to which participants' organisations have difficulty recruiting suitably skilled STEM graduates from WA:

Moderately or highly difficult	63%
Slightly or not at all difficult	21%
Not applicable	17%
2. Extent to which participants' organisations have difficulty recruiting suitably skilled STEM technicians from WA:

Moderately or highly difficult	56%
Slightly or not at all difficult	15%
Not applicable	29%
3. Whether the participants' organisations consider the future availability of requisite STEM skills in WA in their strategic planning:

Do	76%
Do not	24%
4. Whether the participants' organisations provide support for STEM education initiatives in WA schools:

Do	85%
Do not	15%
5. Whether the participants' organisations deliver STEM education programs or activities in WA schools:

Do	77%
Do not	23%
6. Whether the participants' organisations would be willing to consider providing additional support for STEM education initiatives in WA schools:

Willing	95%
Unwilling	5%
7. Extent to which participants' organisations would find it useful to have information about external STEM education initiatives collated and made readily available in a central location:

Useful or very useful	96%
Not useful	4%

These data revealed that the organisations represented at the breakfast understood the importance of STEM skills and planned for their development (Q3). Most of the organisations were actively supporting or delivered STEM education initiatives (Q4&5) and had a very positive disposition towards providing additional support for STEM education (Q6). Almost all participants indicated that a centrally collated source of information about STEM initiatives would be very useful (Q7).

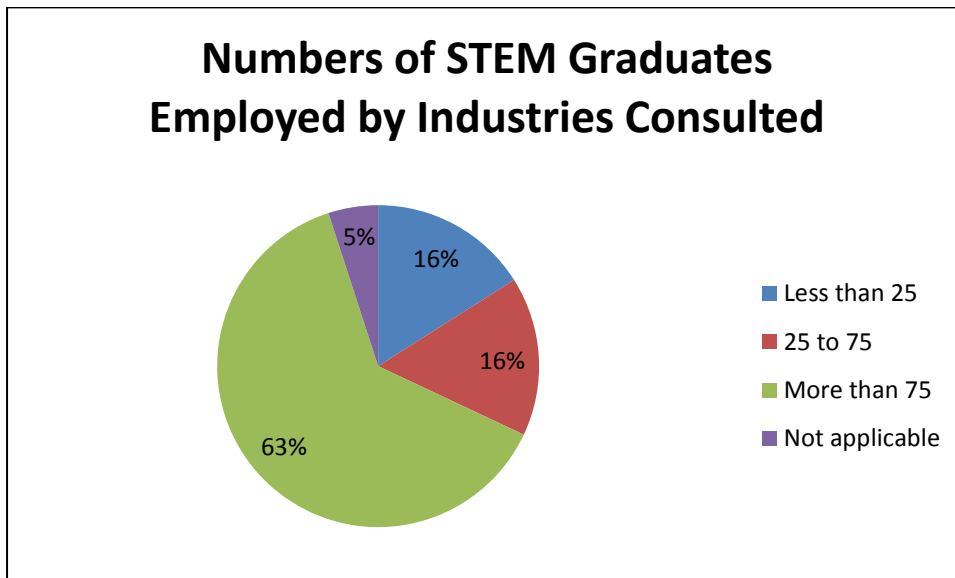
A small majority of participants reported that their organisations experienced moderate or high difficulty in recruiting suitably skilled STEM graduates and technicians from WA. In the follow-up interviews, it was noticeable that this sub-set of participants, many of whom were drawn from large and prestigious international companies reported less difficulty in recruiting STEM qualified staff as

they had well established strategies in place that made them employers of choice and ensures a strong stream of applications for employment.

Number of STEM graduates and technicians employed by companies consulted

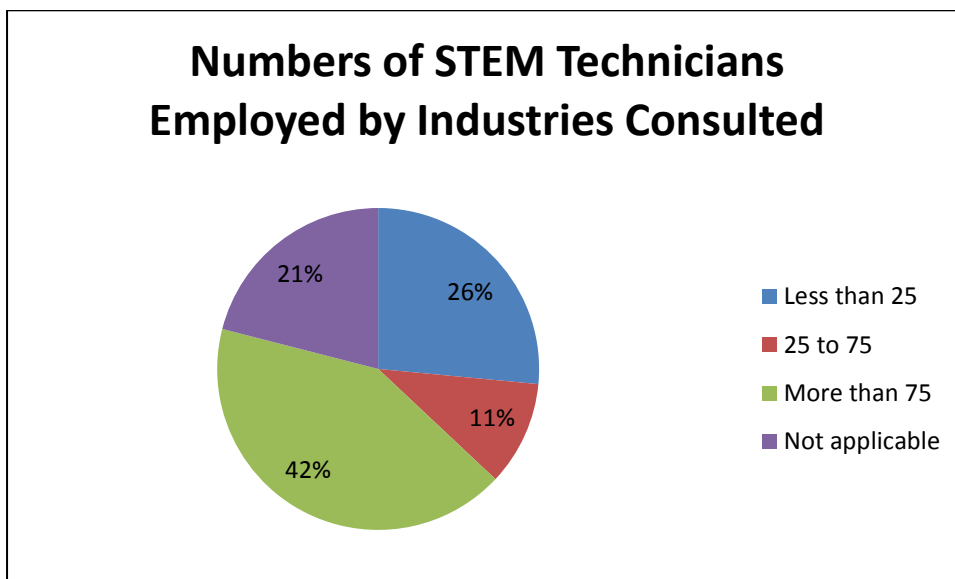
Given that most of the companies were large, they employed large numbers of STEM graduates. A majority (63%) employing more than 75 (Figure 7).

Figure 7: Numbers of STEM Graduates Employed by Industries Consulted



There was a bimodal distribution in the pattern of employment of technicians with many (42%) employing large numbers (>75) and another group employing less than 25 or indicating it was not appropriate for their enterprise; this group comprised (47.5%). The companies employing large numbers of technicians were typically in the resources sector whilst those employing few technicians were in engineering, IT and finance which only required IT technical support for their ICT systems.

Figure 8: Numbers of STEM Technicians Employed by Industries Consulted



STEM skills required by industry

Interviewees identified a range of specific STEM skills required within their industry. The STEM content fields and skills raised reflected the diversity of the participating industry groups. There was a general emphasis on the various types of engineering and this cut across the mining, technology and medical industries. Engineering skills were highly valued (e.g. civil, mechanical, chemical, electrical and electronic) from both university and TAFE pathways (e.g. Technicians – electrical and electronic). To illustrate,

“For me, it’s a fluorescent neon sign in front of me going science, technology, engineering, maths; that’s what [this organisation] is all about: application.” (S9, interview 5/8/13)

In addition, the following science subject specialisations were identified as essential by the industry representatives:

- Chemistry
- Earth sciences / Geosciences / Geology / Geophysics
- Metallurgy (minerals testing and metallurgical testing)
- Environmental sciences / Agricultural science
- Marine sciences
- Genetics
- Medical and health sciences
- Biotechnologies

Mathematical competencies were generally valued by the industry representatives and in particular by industries dealing with data and statistical analysis. The following skills were specifically stated:

- Statistics
- Mathematical modelling
- Bioinformatics (statistics and data collection)

Computer science and IT skills were identified as valuable across industry types and essential to software developers. There was evidence of increasing demand for people with programming skills and competencies across a range of computer software. Finding employees at the intersection of computer software handling skills and statistical expertise was identified by an interviewee as particularly problematic.

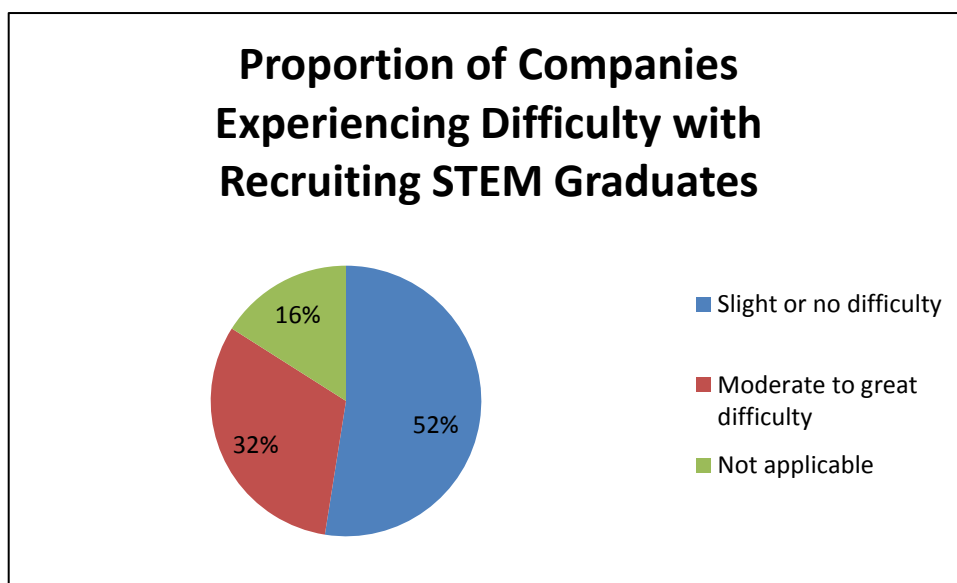
The following general capabilities were also identified by the interviewees as essential to their industry:

- Practical and job-ready
- Outcomes focussed
- Spatial thinking
- Analytical skills
- Inquiry and problem solving skills
- Creative thinking
- Masters and PhD level qualifications

Recruitment issues in STEM related industries

Most of the industry representatives interviewed found employing STEM graduates manageable because they had implemented a range of recruitment strategies. For example, there was evidence of a move towards international recruitment across the diverse industry groups, which is not surprising given that more than half of the companies had an international footprint. Other companies worked very closely with university faculties and some had implemented cadetship programs. Given the status and prestige of many of the companies they were employers of choice. It would be expected that smaller companies would experience greater difficulty in recruitment of appropriately qualified and experienced staff. As would be expected, the more specialised the skills the more difficulty industry groups had recruiting graduates. An overview of the relative level of difficulty in recruiting STEM graduates is presented in Figure 9.

Figure 9: Proportion of Companies Experiencing Difficulty with Recruiting SYEM Graduates



The degree of difficulty experienced in recruiting graduates was related to the area of STEM specialisation required by the industry. To elaborate and differentiate across the diverse industries, comments are made and supported by interview quotes in four areas; engineering, resource sector, computing and mathematics, and biological, which includes medical and agricultural sciences.

1. Engineering

A major mining group in WA was reported to have had difficulty recruiting suitably qualified engineers (process, mechanical and electrical) and that the standard of applications did not always meet industry requirements. Their representative said, *"We have had to go internationally at times. It's just the number of people available with the qualifications. We generally get a decent quantity of applications, but the standard of applicants has not always been sufficient to fill the positions. On occasions we've left positions unfilled because we've been unable to source a suitable candidate."* (S21, interview 16/8/13)

Another major national company reported difficulty recruiting system engineers and as such invested in training-up graduates from other specialist areas to be proficient in systems engineering. Specifically, *“We do employ a lot of systems engineers – they are hard to find. Sometimes we take other brands of engineers and train them up to be systems engineers. The graduates in WA are largely slanted towards the resource sector.”* (S23, interview 9/8/13)

Some highly specialised industries are recruiting internationally or interstate as WA Universities do not offer courses in the required field. For example, *“We don’t train them (naval architects) in WA at the moment so we’re sourcing graduates from Tasmania. But we generally have no problem recruiting due to the company’s profile and job opportunities in ‘sexy’ high tech projects.”* (S22, interview 8/8/13)

A large engineering company reported having minimal difficulty recruiting graduates as they had invested heavily in building strong ties to university engineering faculties. Their representative explained, *“They have developed a strategy of engaging closely with university programs and have got to the point where they are an employer of choice for engineers.”* (S26, interview 6/8/13)

One higher education institution related some difficulty in attracting suitably qualified and experienced engineering academics. They generally drew from an international pool and were in direct competition with the resource sectors in WA. Their representative stated, *“We draw from an international pool. Our positions are very specialised. It’s not like we’re going into the regular job market. No actually where we have difficulty is in particular disciplines where we’re competing with industry...Mining engineers are really hard to appoint, petroleum engineers are really hard to appoint. And of course we do have trouble keeping our graduates and getting them into PhD programs. Some of its straight money as we have to compete with industry – that’s our biggest challenge.”* (S28, interview 7/8/13)

2. Resources Sector

An Australian professional association for the oil and gas industry reported no significant recruitment issues as currently the sector *“has the resources to draw graduates and offers diverse career paths and opportunities.”*(S32, interview 22/8/13). In support of this assertion a major petroleum company’s representative stated, *“We have the drawing power of a large multinational company with diverse career paths and opportunities but there may be potential shortages as new projects come online.”*(S31, interview 30/8/13)

Recruiting internationally and building strong relationships with universities had also ensured efficient recruitment of graduates in the mining industry. A major mining group in WA was reported to be *“recruiting graduates from all over the world and has partnerships with all WA universities to ensure a good supply of employees.”* (S24, interview 14/8/13). Partnerships with universities were also a part of a major petroleum company’s recruitment strategy. Their representative stated, *“We have structured recruitment, we have partnerships with Tier 1 universities so we actively go out and recruit. We also offer internships – we have a high rate of conversion – between 90-95%. Where we struggle is taking on more experienced hires – people who are mid-career.”* (S25, interview 15/8/13)

3. Computing and Mathematics

Graduate recruitment in the areas of computing and mathematics is far more problematic. Australia’s leading geographic information system specialist’s representative stated, *“The drop in IT*

graduates is frightening. The combination of IT and GIS (Geographic Information System) skills is as rare as hens' teeth." (S37, interview 5/8/13). Similarly, mathematics graduates with skills in data analysis and statistics are difficult to recruit. A WA data analysis company director explained, "Graduate recruitment is a continuing problem. There are few suitable Western Australian candidates applying. Auckland University graduates have been appointed." (S36, interview 7/8/13)

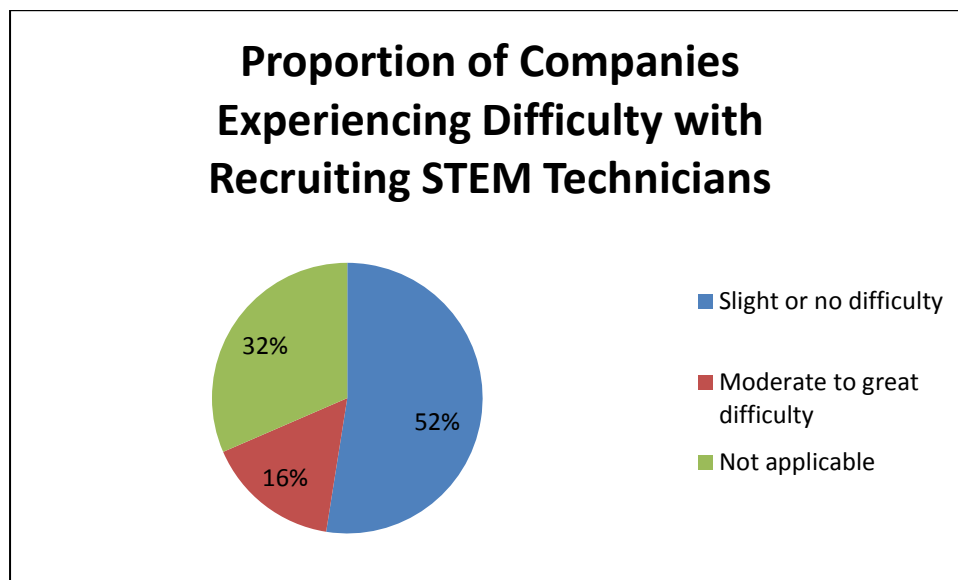
4. Biological: Medical and Agricultural Science

A representative from a significant health research institute in Perth explained "fellowships are used to recruit students...We have quite a few international people who come to us. We sometimes have more students than we have spaces." (S27, interview 14/8/13). A representative from another medical research facility in Perth also reported recruiting graduates internationally. She stated, "I get the sense that researchers need to recruit a little bit further than just our own backyard." (S29, interview 5/8/13)

In the fields of environmental and agricultural science there has been some degree of difficulty recruiting graduates as for example those with an agribusiness background have been "sourced from the eastern states now that Muresk has closed" (S39, interview 16/8/13) and mining service companies have had to "recruit overseas for environmental scientists who can do environmental impact assessments." (S39, interview 16/8/13)

When changing the interview focus to the recruitment of STEM technicians, it was mostly reported by the industry representatives as unproblematic. The overall summary of the interviewee' response to the level of difficulty experienced recruiting technicians for their industry is summarised in Figure 10.

Figure 10: Proportion of Companies Experiencing Difficulty with Recruiting STEM Technicians



To elaborate, a major engineering company representative reported "No difficulty recruiting technical staff but they are mainly contracted on a project basis which is not really a career pathway." (S34, interview 28/8/13). This experience was similar in another engineering company

whose representative stated, *“They employ experienced technicians only and can source them from the local market.”* (S26, interview 6/8/13)

However, a university engineering faculty was reported to have difficulty keeping laboratory technicians as *“industry is going to pay them more. We retain the existing ones but we can’t replace them because we’re competing in an explosive market; they leave for the mining sector.”* (S28, interview 7/8/13)

Alternatively, a representative from a medical research institute related difficulty in recruiting technicians *“due to the highly specialised nature of the field.”* (S27, interview 14/8/13)

Industry’s rationale for offering STEM support

The participating industry representatives recognised that they could take a significant role in STEM education and contribute to building the capacity of their industry by working in collaboration with the education sectors. For example, an industry representative from a major mining company stated *“We want to make sure that people are well skilled for the future and we also want to make sure the nation is well educated.”* (S24, interview 14/8/13)

Specifically, there were two main themes in the rationales articulated by the interviewees for their industry’s involvement in STEM initiatives; future employees for STEM industry and demonstrating good corporate citizenship.

Firstly, investment in STEM education initiatives were viewed by the participants as ensuring there are future employees for the industry. For example a technology company representative stated, *“Part of our responsibility is engaging with research organisations, universities and schools and trying to support students. Ultimately the end goal is that we get really good students coming, or good graduates coming, into the organisation.”* (S38, interview 1/8/13)

Secondly, investment in STEM initiatives enables the industry partner to demonstrate good corporate citizenship. There is evidence to show companies sponsoring and supporting community initiatives that contribute to developing positive public relations. For example *“They have a well-developed, philosophy of building human capacity in the community in ways that will have a positive impact on the business...”*(S24, interview 14/8/13). Demonstrating responsible corporate citizenship is a part of public companies’ social obligation. For example, one of the industry representatives stated, *“As an ASX listed company you have various obligations.”* (S34, interview 28/8/13)

Good corporate citizenship also has an underlying economic rationale for some industry groups. An engineering company representative stated, *“If you’re shown to be a good social member of the community and a good citizen then in general terms if you’re looking for that support from government, from institutions... then theoretically you could argue that by setting yourself up to be a participant, may make other elements provide a benefit in that respect.”* (S34, interview 28/8/13)

The educational level or context of interest for Industry groups when targeting STEM initiatives varied, with some industries working with universities only and others active in primary and secondary schools. A common trend in industry STEM initiatives was to target universities and university students as this provided the quickest and most obvious return on the investment as it

translated directly to the recruitment of graduates into the company. For example, *“Their target audience is universities and tertiary providers from which they can source graduates.”* (S21, interview 16/8/13). A representative of the resource sector explained, *“when we get involved in universities, one of the angles is getting people to consider our industry as a potential career...when we get involved at that point, we’re not really influencing kids to go into the science and engineering area as such, we’re just influencing which industry they choose to head into after they’ve already made that choice.”* (S21, interview 16/8/13)

Yet, this same industry representative was questioning if simply targeting university level STEM education was the answer to ensuring the future supply of employees. They stated, *I know there have been discussions in recent times, in the last 6-8 months, about how we can encourage ... is this sufficient to be targeting students at university level or should we be targeting students at a younger age to encourage them to pursue that career path in the first place?* (S38, interview 1/8/13)

It was noted by other interviewees that there are many points along students’ educational journey at which they can exit from STEM education. A participant representing the minerals and energy sector stated, *“What we try to do with our policy advocacy and education and careers initiatives is to try to keep the pipeline from primary school to employment in our industry as full as possible up to decision points. There are the risks associated along the way that we try to address through our initiatives.”* (S35, interview 14/8/13). Another resource company representative explained, *“What you’re trying to do when you get involved with the school students is encourage them to go to uni and to do the science and the engineering related degree. You broaden or deepen the pool of people you have to select from later on.”* (S21, interview 16/8/13)

Industry’s contribution and involvement with STEM-related initiatives

The major resource companies in WA have contributed substantial sums of money to informal STEM education initiatives. For example, *“the company has a community investment fund which has contributed \$40M in WA over the past 12 years with a focus on health, education, the environment and the arts”.* (S24, interview 14/8/13). In addition, valuable and diverse types of contributions have been made from a range of STEM related industries.

1. Types of Initiatives

The types of STEM initiatives supported by industry have varied and ranged from significant cash funding to the donation of time and professional expertise. The nature of industry involvement is summarised in Table 8.

Table 8: Contributions to STEM-related initiatives by participants' companies

Nature of support	Number (n)	Proportion of total (%)
Providing mentors	11	24.4
Providing visiting speakers	9	20
Provision of resources	6	13.3
Supporting career expos	6	13.3
Cash to fund PD or resource development	4	9
Hosting class visits	2	4.5
Other (includes providing student awards, scholarships, networking opportunities)	7	15.5
Total	45	100

Examples of the various types of STEM initiatives undertaken or supported by industry are provided in the following section. This is not intended as a comprehensive list but rather illustrative of the various types of STEM initiatives supported by industry.

(i) Mentors

Industry groups are providing various mentoring opportunities to university and high school STEM students. There are also some mentoring opportunities for high school STEM teachers

- “Beijing Bound” is a mentoring program that involves industry staff working with Year 11 and 12 students to develop science projects which go through rounds of competitions and hopefully qualify for the final in Beijing.
- Internship program in a resource industry that provides university students with a project and a technical coach. Many interns are sent overseas for a period e.g., Bangalore, Kuala Lumpur, Houston.
- Industry Practicum Experience for 3rd Year university students in mathematics that provides students with mentoring and client project experience.
- Work experience for high school students with a leading agricultural company which can lead to an opportunity for students to take a 12 month gap year prior to doing their degree in Agricultural science.
- Engineers provide mentoring to teachers in their company’s partner school (specialist engineering high school) and plan for a 5-year relationship.

(ii) Visiting speakers

Industry groups are providing STEM guest speakers and visiting lecturers to public events, high schools and some primary schools.

- Science Café coordinated by Scitech during National Science Week involved guest speakers from various STEM industry groups. The reported focus was on career path development for high school students.
- ESWA education coordinators visit schools and run hands on activities with students
- STEM industry employees have been visiting lecturers in universities
- Women in engineering go out and speak to Year 11 and 12 students in girls' schools and promote pathways in engineering.
- An agricultural company sent staff out to local primary schools.

(iii) STEM competitions

Competitions for high school and university students have been sponsored by industry groups and some have involved mentoring from STEM professionals. Resources, prizes and judging have also been contributed by industry.

- Resource industry funding has been used for the Robocup competition, which is conducted in collaboration with Scitech and a university. This involved 300-400 students designing and building a robot for a competition.
- Beijing Bound science project competition
- BioGenius. Included a series of activities and provided mentors to students for 6 months assisting in the design and running of a project before the students competed internationally (US).
- WA Junior Mathematics Olympiad for lower secondary school students.
- National Spatial Technology in Schools Competition which is coordinated in WA by a project officer in the WA Land Information System office of Landgate. Students develop skills of working with spreadsheet data, geolocation data and transforming into a map representation. *“Software has been provided to some schools and colleagues have been providing mentoring to teachers and students in secondary schools. It has a small reach but high impact.”* (S37, interview 5/8/13)

(iv) Science exhibitions and interactive activities

A range of science exhibitions and interactive displays have been funded by industry groups. The development of the exhibitions has been informed by STEM industry professionals.

- Innovations Central in City West (Scitech). Floor space dedicated to a focus on innovation
- Exhibitions at Questacon – The Imagination Factory, which also spent six months at Scitech. The exhibition facilitated exploration of weight, measurement and movement.

(v) Career expos

The resource industry and engineers are contributing funds, speakers and resources to career expos

- STEM awareness festivals held in Kalgoorlie and in Karratha. These are two-day events which focus on science, careers and opportunities in local companies.
- Annual oil and gas industry conference/career expo where 40-50 Year 10 students listen to guest speakers etc.
- Minerals and energy sector contributes to career expos such as ‘Get into Mining’, which is a two-day careers expo for Year 10s at Central TAFE each year
- Regional STEM expos at Esperance and Goldfields sponsored by the minerals and energy sector

- Engineers contribute to career expos at universities.
- Science Café coordinated by Scitech during National Science Week involved guest speakers from various STEM industry groups.

(vi) Student awards and scholarships

STEM industry groups are providing postgraduate scholarships or funding for PhD or honours projects.

- A major WA engineering company provides scholarships at UWA and Curtin University. To date there are about 240 recipients of these scholarships working within the industry. They are also a major sponsor of Engineers Australia.

(vii) Teacher professional development

A range of industry groups are funding professional development for STEM teachers.

- Industry groups have made contributions to Scitech, which is the State's premier science exhibition and education centre. Funding from industry has enabled Scitech to deliver outreach engagement programs to students and professional development programs to teachers in rural areas of WA. Scitech Outreach visits all (*regional*) schools every second year providing activities for students and professional learning workshops for teachers.
- Minerals and energy sector have provided ongoing financial support in the area of Earth Sciences education-ESWA. They have funded curriculum resource development and teacher professional learning facilitators who run workshops for teachers. Schools are also assisted to run field trips.
- A medical research group in WA is also developing and hosting teacher professional development. The focus is on biotechnology and the medical research currently being conducted in the industry.

(viii) Provision of resources

Industry funds have been used to develop a variety of STEM education resources. Some of these resources are supported by professional development programs for teachers.

- Earth Sciences Western Australia (ESWA) is funded through industry sponsorship and produced a text book for the WA Earth and Environmental Science course. They produced the 'Field Guide to Perth and Surrounds' and engage with the education community through a website and social media. They make 'do-it –yourself kits' available to schools. Some ESWA resources are made available on the website and now with further funding from a major sponsor they have extended the scope from K to 12. Revision seminars are also run for Year 12 students.
- 'Better Beginnings' early literacy program through Library Board of WA and EDvance school leadership initiative with the Fogarty Foundation
- 'Biotechnology in a Box'. University collaboration where equipment is loaned to schools. The program is popular and kits are booked out in advance. Secondary school teachers and technical staff are provided with the equipment needed to explore new content of the Australian Curriculum.
- 'Networking Academies' is a software resource and training program provided by a technology company. They provide students and teachers with access to a learning management system that supports the development of ICT skills and systems thinking in different domains of work

and industries. Students at secondary level can study and gain recognition for endorsed study through WACE.

- Web-based resources such as 'Oresome' are a national collaboration and curriculum package.
- 'People for the Futures' – a careers education website which gives person profiles, outlines different roles in the industry and features 150 different occupations.
- 'SPICE' secondary science curriculum resources produced in collaboration with industry and university science faculty.
- Major engineering company has supported teachers to develop curriculum for the Year 11-12 Engineering Studies program. Employees of the company provide expert input into developing activities, learning outcomes and a text book.

(ix) Hosting class visits

Site visits are hosted by some industries. The focus has been mainly on secondary and tertiary students.

- Scitech and the CSIRO laboratory host school visits
- BioDiscovery lab hosts visits for secondary school students. The NextGen program will be run with visiting students. The education director stated, *"I am building in mathematics, computer science and applied technology aspects so students will have a STEM experience."*(S29, interview 5/8/13)
- ALCOA sites have high school and university students coming through. However, site visits are weighted more towards the tertiary sector.
- InterGrain has a number of schools which come to visit their facilities.
- ESWA support and facilitate school excursions in collaboration with high school teachers to a range of sites such as Dryandra, Darling Scarp and Swan Coastal Plain.

(x) Funding for community projects

Banks are in some cases providing grants or matched funds to those raised in schools or by the community for STEM related initiatives.

- A major WA bank supports environmental science Landcare projects in some primary and secondary schools. There is a focus on land care and sustainability. They provide grants to schools to support projects.

(xi) Specialist STEM Secondary School

Industry has supported specialist programs in secondary schools by providing funding, curriculum support resources, guest speakers and mentors.

- Specialist Engineering Program at Governor Stirling Senior High School, from Year 8 through to Year 12 provides engineering curriculum and experiences with an academic and vocational stream. This is offered in partnership with collaborating engineering companies and a university engineering faculty.
- A peak resource sector representative body supports the Minerals and Energy Academy at Southern River College in Gosnells.

2. Factors contributing to success

The industry representatives interviewed identified factors they believed made their company's STEM initiatives successful. Yet, in most cases there were no clearly defined measures of effectiveness or success. That said, there was evidence to suggest that the largest organisations represented did have defined visions, strategies and objectives against which they related factors for success. For example, a resource sector representative stated, *"We have a Board that oversees the program and a team that works with partners to develop strong proposals with a small number of capable partners...We've looked at our strategy and the objectives of why we do what we do and hooked it back into the business of the business ... We reviewed our strategy for community investment and we still believe education is key."* (S24, interview 14/8/13). There was evidence of clear strategic planning underpinning some companies' strategies.

Four broad themes were identified by interviewees as contributing to the success of their company's STEM initiative(s):

- Committed staff
- Targeting of identified needs
- Collaboration
- Tangible outcomes such as resources.

To elaborate, one resource sector representative stated, *"Getting our industry employees involved and getting them out there and getting our grads involved, getting our innovation guys with their 'tefal' heads on, getting them interested and engaged in it."* (S24, interview 14/8/13)

A significant factor emerging was the power of strategically targeted curriculum resources coupled with well supported professional learning for STEM teachers. One industry representative stated,

"ESWA is the best example of this sort of work. They've been very good at picking the right people at every stage. The current people running it are the best teaches in the world. That is very important if you are modelling to teachers with classroom practice; writing materials as well, and they have the capacity to travel to areas of need. They go to the country and remote areas." (S35, interview 14/8/13)

This example highlights the strategy adopted by the larger companies who support effective STEM initiatives, they work through a well-established education service provider such as ESWA, Scitech or a teacher professional association.

3. Cost and educational effectiveness

It was evident from the interviewees that STEM initiatives conducted or supported by industry were mostly not formally evaluated. This was reported to be too hard due to intangible outcomes or the longer term impact of some initiatives. Informal indicators were mainly used for inferring the cost effectiveness and educational impact of STEM initiatives. There was some evidence of targeted planning and project monitoring amongst some of the larger companies.

Targeted design and monitoring

There was some evidence of targeted project design and a measure of the number of students involved amongst the larger companies. For example, one major resource sector company, who is a

significant contributor, was reported to have a model in place for collecting baseline data every three years to monitor needs in the communities in which the company does business. Their representative stated, *“They have a well-developed, philosophy of building human capacity in the community in ways that will have a positive impact on the business, a policy of longer term major partnerships that deliver an impact. Scitech activity (we support) has touched a million children and will have a sustainable benefit.”* (S24, interview 14/8/13)

Earth Science Western Australia has undergone an evaluation process and data is available on the number of students, educators and schools engaging with the program. Repeat visits by schools have been noted and overall, there is a reported increase in the utilisation of the service.

An evaluation of SPICE resources was reported by one industry representative. They stated *“Students who did use SPICE resources did indicate that they did feel more engaged.”* (S29, interview 5/8/13). The cost effectiveness or impact on students STEM understanding was unclear from the representative’s comments. Similarly, a technology company did not have a sense of the cost effectiveness of their activities but reported that of those people using their software *“Over 100,000 have achieved some form of certification over the last 15 years in Australia.”* (S33, interview 5/8/13)

Informal indicators of impact

Most industry representatives interviewed related informal indicators of the STEM initiatives impact. One measure was the translation of mentoring to employment in the company. For example, *“Staff mentoring time has provided experience that has helped employment. Some of the mentored students became employed by the company.”* (S36, interview 7/8/13). Another resource company representative believed their mentoring program was effective as the *“Interns’ final projects are assessed.”* (S25, interview 15/8/13)

Another resource sector representative reported positive flow on benefits from the company’s investment in STEM initiatives in relation to community engagement but was unable to provide feedback on the cost effectiveness or educational benefits as no evaluations had been conducted. Their representative said, *“But if you talk about it in pure ‘profitable’ terms – it’s impossible to measure.”* (S31, interview 30/8/13)

Informal feedback from teachers in participating schools

Participation rates and uptake of workshops and site visits was used by some industries as impact indicators. One representative stated not really having a sense of the educational impact of their initiative but *“Schools come back to us frequently.”* (S39, interview 16/8/13). Participation was also used as an impact indicator for teachers’ professional development workshops. For example, *“There are an increasing number of applicants.”* (S29, interview 5/8/13). Informal feedback from teachers was also used as an indicator of the impact on students. For example, *“Feedback from the school has been very positive. One of the teachers said, ‘I didn’t realise that engineering was about this, this, this and this.’”* (S26, interview 6/8/13)

Too early or too hard to evaluate

A major resource sector company’s representative explained that it was thought to be *“Too early to assess impact as a commitment to a medium term length relationship is critical for success.”* (S26, interview 6/8/13). Others related *“It is very hard to quantify”* (S21, interview 16/8/13) and *“no formal evaluations have been conducted.”* (S38, interview 1/8/13)

In other areas it is the informal nature of the initiative itself that proves problematic for evaluation. For example, *“it’s been more individual scientists – so far. Certainly dollar value – it’s probably impossible for us to put on.”* (S27, interview 14/8/13). One industry representative commented that the impact of their initiatives was unclear as there was *“no clear philosophy, policy or strategies for sustainability and impact.”*(S30, interview 15/8/13). A major industry contributor of funds to STEM initiatives stated, *“The investment that we made was a seven figure sum – a large sum. But I’m not sure how you would measure the cost effectiveness – there’s a massive lead time. How do you know that that might have affected some kid’s career?”* (S23, interview 9/8/13)

There was evidence to suggest the industry representatives were aware of a need for more formal evaluation strategies, both formative and summative in nature. Evaluation could be used to inform project design and strategically target initiatives to key areas of need. For example, the effectiveness *“has been discussed but not researched, and no evaluations have been conducted at this time “I am aware that giving money does not always provide the most educational impact, but am unsure of the most effective way to get involved.”* (S38, interview 1/8/13). In the medical area a representative stated, *“It can be a cluttered space – not necessarily an effective cluttered space. Where do we fit in to that so we’re not stepping on toes and that we’re not doubling up? That’s the key I think.”* (S27, interview 14/8/13)

Involvement in STEM initiatives does raise awareness of the importance of industry partnerships in education. *“Having been immersed in that job (STEM initiative), I think it has really heightened my awareness of the importance that we need to be far more focused on the process and looking at 21st century learning environments and what the reality is especially when it translates out there to the real world.”* (S29, interview 5/8/13).

Barriers to Industry Participation in School Initiatives

Interviews with company representatives revealed a number of barriers to participation in school-based STEM initiatives. The barriers were grouped into categories based on the themes that emerged from the interviews. Each of the categories is elaborated upon below.

Time

Industry representatives identified time as the most significant barrier to their participation in STEM education initiatives. Although many organisations allocate time (or funding) which staff may use for the purpose of community engagement, participation in STEM education initiatives usually requires more time than the company can provide. Limited time and capacity appeared to be particularly significant barriers for small businesses. For example:

The biggest single barrier is simple. It’s time. We’re a small business. There’s a limit to how much time we can devote to something. (S36, interview 7/8/13)

While many staff working in STEM-related professions were keen to support STEM education initiatives, businesses were most concerned that optimum use was being made of staff time, as the following comments illustrate:

If we’re going to build a relationship we want to make sure it’s the optimal for both sides... it’s the effective use of the contact time. (S27, interview 14/8/13)

There's always an issue of time. There's so much all of us could be doing and we still have a day job. (S22, interview, 8/8/13)

Some companies also found that the public can be suspicious of corporate motivations in relation to their support of educational initiatives. For example:

We are seen as a private enterprise... that this is us trying to push our brand. It is very important to get the message that this is a corporate social responsibility program. We are not making any money from it. (S33, interview 5/8/13)

Structural and Administrative Challenges

The lack of flexibility in school timetables and the administrative challenges of making contact with schools, establishing partnerships and complying with legal requirements were also cited as barriers to participation in school-based STEM initiatives. A number of company representatives admitted that they are “unsure how to engage with schools” (S38) and “would not know how to work directly with schools” (S35). Time spent on administrative tasks was not considered effective use of company time and the lack of a suitable service provider to liaise between companies and schools was seen as a barrier to participation in STEM initiatives. For example:

Schools work between about 8:30 and 3:00 – business work before and after that. (S34, interview 28/8/13)

What we don't have time for is setting up the contacts in the first place. The administrative side is the biggest barrier. That becomes really frustrating and stops you doing it. (S21, interview 16/8/13)

People can also be a little scared by the Working With Children provisions. (S28, interview 7/8/13)

Preferential Engagement with Universities

Company representatives suggested that engaging with universities is easier than engaging with schools. For this reason, many companies focus their efforts on engaging with universities, which is seen as having a more immediate pay-off:

We have rationed our time more towards the university level where the pay-off is more obvious and the contacts are easier. (S36, interview 7/8/13)

Looking back from the business world – our focus is on attracting bright graduates and we sort of take the view that it's someone else's job to get them there (to university). (S22, interview 8/8/13)

Company representatives also suggested that there has not been a need to engage with schools while a sufficient supply of university graduates has been available:

We haven't needed to target high schools as plenty of university graduates have been available to us... perhaps we don't know how to engage with those demographics. (S38, interview 1/8/13)

Nevertheless, engaging with universities presents other issues for companies, such as negotiating the ownership of intellectual property:

There's a little bit of a barrier with engaging with tertiary staff. The criteria they are measured against are not well-aligned with actually working with us. They're focused on research papers rather than trying to do something that helps us. (S21, interview 16/8/13)

Working with universities and CSIRO and other government bodies, contracting and IP clauses tend to be sticking points that slow things down. (S25, interview 15/8/13)

Lack of Coordination

The need for a more coordinated approach was suggested by numerous participants, particularly in view of geographical considerations. For example:

There are certain schools around the place which are in danger of being "loved to death". There is no coordination. There are so many organisations that go out there. Initiatives need to be better coordinated, planned and organised. (S28, interview 7/8/13)

Perth is very centralised. Getting out to some of the outlying schools – needs time, commitment and availability. (S34, interview 28/8/13)

Company representatives seemed to agree that better coordination of STEM education initiatives would help foster collaboration between schools and ultimately benefit more students. For example:

I'm not sure whether doing something at one school is the right way to do things. (S36, interview 7/8/13)

We would like to develop a few schools to act as hubs that might offer training to other schools in their region. (S33, interview 5/8/13)

Lack of Curriculum Knowledge

A number of organisations were keen to use their own resources to develop STEM education initiatives, but needed input from specialist science and mathematics educators in order to do so. For example:

We want to do this, but we want to do it right. It's a lack of knowledge on our part as to where we fit in the curriculum. We've had meetings with science teachers and they're very enthusiastic but they don't have time (as a body) to do that. Support from education experts would be great. (S27, interview 14/8/13)

Overcoming Barriers to Industry Participation in School Initiatives

Company representatives made various suggestions as to how the barriers to participation in school-based STEM initiatives could be overcome. The suggestions have been grouped into categories based on the barriers that were identified in the previous section.

Time

Company representatives suggested that participation in STEM education initiatives was “*more a time commitment than a financial commitment*” (S38, interview 1/8/13). Participants suggested that “*establishing a social responsibility agenda*” (S22, interview 8/8/13) would provide a mandate for companies to commit time and resources to “*programs focused on developing human capital*” (S33, interview 5/8/13). Another participant likened supporting STEM education initiatives to parents volunteering time to support junior sporting clubs:

The connection between business and schools is parents and children. How do junior football clubs survive? It's all voluntary. If you were thinking about how you could recruit young engineers or mathematicians, it's the passion of the people because they want their kids to follow that path. (S35, interview 14/8/13)

Structural and Administrative Challenges

Participants also suggested that providing administrative support would “*improve the communication flow with schools*” (S23, interview 9/8/13). In addition to making it easier for companies to work with schools, the provision of administrative support ensures that the best possible use can be made of staff time. Comments included:

Certainly businesses don't have time to do all of the organisation. Administrative support gives us value for money by making the time work effectively. (S22, interview 8/8/13)

Preferential Engagement with Universities

Meeting the increased demand for STEM graduates will require an increase in the number of primary and secondary students entering the STEM pathway. One industry representative suggested that there is a need to “*develop the idea that education is a continuum that doesn't end at Year 12*” (S28, interview 7/8/13). Another industry representative advocated a long-term approach, suggesting that their company was “*open to working with individual students over a period of several years*” (S2, interview 8/8/13). Despite this, many companies are “*looking for short-term benefits*” and are “*not interested in engaging with primary schools*” (S38, interview 1/8/13).

Lack of Coordination

There was unanimous agreement that improved coordination and dissemination of information about STEM education initiatives would “*definitely help companies to build relationships with schools*” (S38, interview 1/8/13). It was suggested that working through a service provider would facilitate improved communication with schools, “*better publicising of events e.g., guest speakers and career expos*” (S34, interview 28/8/13) and the potential for companies to “*pool resources for projects that extend beyond a small footprint*” (S26, interview 6/8/13). Working in collaboration with a service provider would also enable participation in STEM education initiatives to be seen “*as a genuine corporate social responsibility program rather than as a marketing exercise*” (S33, interview 5/8/13).

Lack of Curriculum Knowledge

It was suggested that working in collaboration with teacher professional associations would enable companies to overcome their lack of specialist curriculum knowledge.

Other Suggestions

Company representatives made several other suggestions as to how to overcome barriers to participation in STEM education initiatives. These included working with parents who are *“one of the most influential groups of people and a major source of advice for their children”* (S23, interview 9/8/13) to raise their awareness of careers in STEM-related fields. It was suggested that there is also a need to *“provide PD for teachers and school career advisors, so that they are better informed about careers in engineering and STEM”* (S22, interview 8/8/13).

Industry Support for Future School Initiatives

Company representatives indicated that their organisations were prepared to support STEM education initiatives in a variety of ways. These included providing cash to fund PD or resource development, providing resources, hosting class visits, providing guest speakers, providing student mentors, contributing to career expos, providing scholarships and sponsoring exhibits (at Scitech and Questacon). Comments which exemplified this included:

We're open to all of the above. We're looking for the best value for money. There would be more value to business if there was a social responsibility agenda... a real business imperative to be seen to be doing it. (S22, interview 8/8/13)

All of the above. We provide support materials, we host classes, we go out into schools. Mentors - maybe not so much. Of course we have open days. (S28, interview 7/8/13)

Companies were also more likely to support STEM initiatives that could be run in partnership with an experienced service provider. One company representative suggested that *"we would consider it seriously if structure was given to a program"* (S38, interview 1/8/13). Other participants suggested that *"collaboration is absolutely paramount"* (S29, interview 5/8/13) since it allows companies to *"work with organisations that can provide support or recommendations to assist us"* (S35, interview 14/8/13). The timing of school-based STEM initiatives must also be sufficiently flexible if full use is to be made of the available resources, with one company admitting that *"while we're not at capacity at the moment, we couldn't have lots of students at once"* (S39, interview 16/8/13).

Cautions to Future Involvement in Initiatives

A number of companies, however, appear to be proceeding with caution, suggesting that they intend to consolidate or reduce their commitment to STEM education initiatives due to resource limitations. For example:

The climate that we're in is probably driving us to contract a little bit. (S21, interview 16/8/13)

There's no further plans from the Perth office due to resource limitations. (S37, interview 5/8/13)

Key Findings Emerging from Interviews with Representatives of Industry and Commerce

The demand for STEM capabilities

39. Representatives from academia, education, industry and government who attended a breakfast function recognised the significance of STEM education, planned for its development, provided support for STEM education initiatives and indicated a willingness to provide further support.
40. There was a wide range of engineering and science skills required by the industries consulted and engineering skills from all engineering disciplines and from university and TAFE pathways were highly valued, as were skills from geoscience disciplines, chemistry

metallurgy, environmental science and agriculture, marine sciences, medical and health sciences, genetics and biotechnology.

41. Skills relating to mathematical modelling, statistics and bioinformatics were in high demand and low supply.
42. Computer science, programming and IT skills with specialist software packages were required across all industry sectors. Combinations of software skills and disciplinary knowledge such as statistics and GIS were problematic to source.
43. Employers were also seeking general capabilities that included inquiry and problem solving skills, creative thinking, spatial and analytical skills and dispositions such as being outcomes focussed, practical and job-ready.
44. Many of the large and international companies experienced only slight difficulties recruiting appropriately qualified staff for non-specialist roles as they had strategies in place to ensure a supply of staff. These included close relationships with university faculties, cadetships and sourcing staff from overseas. Smaller companies would be expected to experience greater difficulty with recruitment and universities experience difficulty recruiting engineering academics and technicians.

Current STEM education support initiatives

45. Most companies who supported STEM education initiatives were motivated by ensuring a future supply of appropriately qualified future employees and to demonstrate good corporate citizenship. Many industry supported STEM initiatives are targeted at university students as this provides the quickest and most obvious return on investment as it translates directly to the recruitment of graduates into the company, however, other companies recognised the need to support primary and secondary schooling as they recognised the losses that occur along the STEM education pathway.
46. The most common forms of STEM education support included mentoring, visiting speakers, providing resources, supporting career expos, providing cash to fund teacher professional learning or curriculum resource development, sponsoring competitions, hosting class visits and funding scholarships.
47. Successful STEM education initiatives were focussed on needs and gaps identified by teachers, were delivered through partnerships with an education service provider, provide mutually beneficial outcomes, delivered by committed people, sustained over a period of time and often involve a combination of teacher professional learning supported with curriculum resources.
48. Many of the smaller initiatives lacked any formative or summative evaluation.

Addressing the barriers to supporting STEM education

49. The most common barriers to the involvement of companies in supporting STEM education include staff time, the complexities of working directly with schools, lack of school curriculum knowledge and concerns about lack of coordination leading to duplication and gaps.
50. Many of the barriers to involvement could be addressed by better coordination, administrative support, and working in partnership with education service providers who understand how schools work and have the specialist curriculum knowledge.

51. Representatives from academia, education, industry and government who attended a breakfast function indicated that a centrally collated source of information about STEM initiatives would be very useful.
52. When asked about support for future STEM education initiatives many companies would be happy to work through a service provider and would support funding PD or resource development, providing resources, hosting class visits, providing guest speakers, providing student mentors, contributing to career expos, providing scholarships and sponsoring exhibits. However, several companies would proceed with caution in the current climate of contraction in the resources sector.

Discussion and Recommendations

The purpose of the study was to identify: the status of STEM education in WA schools; STEM education challenges, gaps and needs of students and teachers; the range of organisations supporting STEM education, the initiatives they support and barriers to providing support; and, to make recommendations to provide direction for optimising STEM education. Evidence was gathered through reviewing the current international and Australian literature and available data regarding STEM education, interviewing representatives from the education sectors and education service providers, and representatives from a range of organisations from industry and commerce. From these multiple sources of data, key findings were generated which relate to nine themes.

Theme 1: Declining achievement and negative attitudes towards STEM subjects

The performance of Australian Year 4, Year 8 and 15 year-old students on international measures of science and mathematics achievement is either declining or static whilst other countries improve, and far too few students reach advanced benchmarks of achievement (Key Findings 1 & 2). On these international measures only 7-11% of Australian students reach the advanced benchmark of achievement compared with 40-50% in countries such as Singapore and Chinese Taipei. We are significantly outperformed by our South-East Asian neighbours who are our trading partners and competitors in knowledge-based products and services. Socioeconomic/ICSEA status, gender and Indigenous status strongly affect achievement in science and mathematics (KF 8) which suggests there is a lack of equity in access to a quality STEM education.

Although WA primary school students are improving their numeracy and scientific literacy rankings relative to other Australian jurisdictions, nearly half of Year 6 students fail to reach the scientific literacy proficient standard (KF 3). Australian Year 4, Year 8 and 15 year-old students have less positive attitudes to studying science and mathematics than many other countries (KFs 5 & 6) and although our primary school students have quite positive attitudes towards science this positive affect becomes quite negative in secondary school (KFs 4, 5 & 6). Although there is a strong international trend to negative attitudes towards STEM education in secondary students from Western developed countries (Sjoberg & Schreiner, 2010), Australia performs particularly poorly compared to similar countries. Such negative attitudes are likely to impact on students' continued participation in STEM education in senior secondary and tertiary education.

Theme 2: STEM education participation rates

There has been a significant and continuing decline in the number of Australian and WA Year 12 students studying science and mathematics subjects at an academic level that enables further education in STEM fields at university (KFs 9, 10, 11 & 12). There have been changes in the size and composition of the Year 12 cohort resulting from changes to the school leaving age and requirements for compulsory education or training in WA; and, significant changes in the range of upper secondary course offerings and university admission and prerequisite requirements. These changes and student course counselling practices in schools have seen a large shift in WA Year 12 enrolments towards subjects that have low academic standards and do not support further education in STEM fields (KFs 10, 12 & 13). The socioeconomic/ICSEA and gender factors that have negative impacts on students' science and mathematics achievement in primary and lower secondary schooling also have a strong influence on WA Year 12 students' participation in high level science and mathematics subjects, and very few females study technology subjects (KF 16). The

COAG Reform Council Report (2013) makes strong links between Indigeneity, socioeconomic status and geolocation, and the proportion of young Australians who achieve a Year 12 or equivalent education standard, and those who go on to be fully engaged in work or study. Maintaining students in high level STEM education through to Year 12 enhances their opportunities for gaining full-time and rewarding employment. A significant proportion of Year 12 Western Australian students are studying no WACE science subjects and no mathematics subjects which places limits on their further education and career prospects. Without scientific and mathematical literacy, these students will lack the general science and technology understandings and capabilities to participate effectively in a science and technology dominated society.

Australian undergraduate enrolments in STEM fields have declined in absolute numbers in the last five years despite an increased university population; and, domestic undergraduate and postgraduate completions in STEM are fairly static or declining with the most significant declines being in IT and agriculture and environment sciences (KFs 17, 18 & 19). Health science is the one STEM field of university education experiencing strong growth in completions. In WA, the proportion of completions in IT and Agriculture and Environment Science have reduced by 50%.

Theme 3: Teacher supply and qualifications

Teachers are fundamental to the effectiveness of our education system and the quality of learning outcomes has a significant impact on innovation within society broadly and on the economy. In WA, there is particular concern regarding a potential serious shortage of secondary teachers in 2015 as Year 7 students move into secondary state schools and the half cohort moves out of Year 12.

Given that teacher quality is fundamental to the quality of teaching and learning, there is great concern that a majority of Australian primary teachers report that they do not have all the expertise they need to teach science and mathematics. Furthermore, and a large proportion of lower secondary mathematics and science teachers have less than two years study in the discipline; many are teaching out of field (KFs 20 & 22). At least one quarter of Year 11-12 mathematics teachers do not have a major in mathematics and three out of four schools in an Australia-wide survey reported difficulty in recruiting suitably qualified mathematics teachers (KF 20). Marginson et al. (2013) state that “out of field teaching in science and mathematics is especially high in Australia compared with other countries” (p. 23). North American data show that the rate of out of field teaching is much higher in low socioeconomic, rural and remote and hard to staff schools (KF 21) which may be an important factor in the lower levels of achievement and participation in Year 12 advanced science and mathematics subjects in those schools in WA. Anecdotal data suggest that out of field teaching is a problem in hard to staff WA schools, however, this assertion is somewhat tentative given the lack of data regarding WA teachers’ qualifications, particularly for those teaching science, mathematics and technology in Years 7-10.

Theme 4: Successful STEM education initiatives and providers

The most successful STEM education initiatives have been those emanating from national or state levels having a large reach and combining teacher professional learning with mentoring and curriculum resources, and a strong research base (KF 24). It should be noted that many of these initiatives which had widespread implementation and impact are no longer operating and there is a need for new initiatives which have a large footprint and are sustained over time.

There is an extensive range of education service providers that deliver STEM education initiatives to schools. They include government agencies, professional associations, industry, universities and private providers and four examples are discussed below. Of the professional associations, the Science Teachers Association of WA has been the most effective providing conferences, teacher professional learning, student learning resources and competitions (KF 25).

Scitech has developed great infrastructure and resources that largely service primary science education through teacher professional learning, outreach to rural and remote schools, supporting student enrichment activities and hosting visits to its West Perth site with an extensive array of interactive exhibits (KF 26). Earth Science WA (ESWA) has been most effective in supporting the development of senior secondary earth and environmental science through developing the curriculum resources required by teachers and providing teacher professional learning at schools, at no cost. Their work is extending down through lower secondary education to support the implementation of the earth sciences strand of the Australian Curriculum for Science (KF 27). CSIRO Education's main contribution to science and mathematics education is to coordinate professional scientists and mathematicians' engagement with schools in mentoring roles and providing laboratory activities on site at Scitech or out in the schools (KF 28). Each of these successful STEM education service providers have been effective through forming partnerships with schools, having the expertise needed to work with schools and support teachers, forming collaborations with government and industry partners who fund their activities, and having the administrative, business and education acumen to develop quality programs and sustain them over time with a wide reach (KF 29).

Theme 5: Gaps and challenges in STEM education

There is a gap between the intended and implemented curriculum because of non-specialist and out of field teaching, particularly in the early, primary and transition years to secondary schooling (KFs 30 & 31). The lack of content and pedagogical knowledge of generalist and out of field teachers compromises the quality of teaching and learning and may be a significant factor in the poor science and mathematics achievement standards in the primary and transition years, and the decline in attitudes towards science and mathematics in the early secondary years (KF 31). Furthermore, the large numbers of inexperienced and out of field teachers teaching in regional secondary schools is likely to be associated with the lower levels of participation in senior science and higher level mathematics in these schools.

There are concerns that mathematics teaching has focussed too much on meeting minimum standards and not enough on extending the middle and top range students, and there has been too little challenge and inquiry-based learning (KF 32). Much work needs to be done in order to change students' perceptions of mathematics in order for them to appreciate its likely impact on their subsequent career choices.

Compared to science, there have been far fewer mathematics and technology professional learning and curriculum resource development initiatives. There is a need to strengthen the mathematics and technology teacher professional associations to enhance the delivery of professional development programs for teachers.

The implementation of the Australian curriculum poses challenges for science, mathematics and technology education at both primary and secondary levels. The Australian curriculum introduces new content, and in some subjects, introduces abstract concepts at an earlier age. Teachers will need professional learning support and new curriculum resources to teach the Australian curriculum effectively. One of the most significant challenges of the Australian curriculum is to develop and match assessments to new learning outcomes and standards (KF 34). Marginson et al. (2013) argue that this is an opportunity to develop assessment regimes that support the commitment to problem solving and inquiry-based approaches to teaching and learning.

Theme 6: Initiatives needed to optimise STEM education

The most fundamental initiative required is a set of integrated strategies for building the capacity of the STEM teaching workforce. These strategies need to address the requirement for: an increased supply of appropriately qualified secondary mathematics, physics and technology teacher graduates; retraining of existing teachers to fulfil these roles; ongoing professional learning; and, curriculum resources to support professional learning programs and to support the implementation of the Australian curriculum. New professional learning initiatives need to have a strong research base, grow out from past successful initiatives, involve action learning, be ongoing and be supported by mentoring and strong school leadership (KFs 35, 36 & 38).

Key barriers to implementing professional learning initiatives are the cost of relief teachers, the difficulty of engaging teachers in online professional development and servicing the needs of regional and remote schools (KF 37), however, it should be noted that ESWA, SPICE and Scitech outreach provide models that show how these barriers can be addressed. There is a need to strengthen the capacity of teacher professional associations to deliver STEM education initiatives.

Theme 7: Industry demand for STEM capabilities

There is a wide range of engineering, science, mathematics and IT skills required by the industries consulted. Skills from all engineering disciplines were highly valued, as were skills from geoscience disciplines, chemistry, metallurgy, environmental science and agriculture, marine sciences, medical and health sciences, genetics and biotechnology. Although none of the employers explicitly indicated that they needed physics expertise, physics is clearly an enabling science required to develop applied capabilities related to engineering and other sciences. Skills relating to mathematical modelling, statistics and bioinformatics were in high demand and low supply. Computer science, programming and IT skills with specialist software packages were required across all industry sectors. Employers were also seeking general capabilities that included inquiry and problem solving skills, creative thinking, spatial and analytical skills and dispositions such as being outcomes focussed, practical and job-ready (KFs 40, 41 & 42).

Large and international companies experienced only slight difficulties recruiting appropriately qualified staff for non-specialist roles as they had developed close relationships with university faculties, cadetships and sourcing staff from overseas to ensure a supply of appropriately qualified staff. Greater recruitment difficulties were experienced by smaller companies and by universities seeking engineering academics and specialist technicians (KF 43).

Theme 8: Current STEM support provided by industry and other organisations

Many organisations drawn from industry, academia, education and government are actively supporting STEM education initiatives and are positive about providing additional support. They also

acknowledge the value of a centrally collated source of information about STEM initiatives. Most companies which support STEM education initiatives are motivated by ensuring a future supply of appropriately qualified future employees and to demonstrate good corporate citizenship. Many of these initiatives are targeted at university students as this strategy impacts directly on the recruitment of graduates into the company, however, other companies take a longer view and support primary and secondary schooling as they recognised the losses that occur along the STEM education pathway.

The most common forms of STEM education support included mentoring, visiting speakers, providing resources, supporting career expos, providing cash to fund teacher professional learning or curriculum resource development, sponsoring competitions, hosting class visits and funding scholarships. Successful STEM education initiatives: addressed the needs and gaps identified by teachers; were delivered through partnerships with an education service provider; provided mutually beneficial outcomes; were sustained over a period of time; and, often involved a combination of teacher professional learning supported with curriculum resources (KFs 44, 45 & 46). Many industry representatives indicated that they were motivated to increase their level of support for STEM education.

Theme 9: Addressing barriers to industry support for STEM education

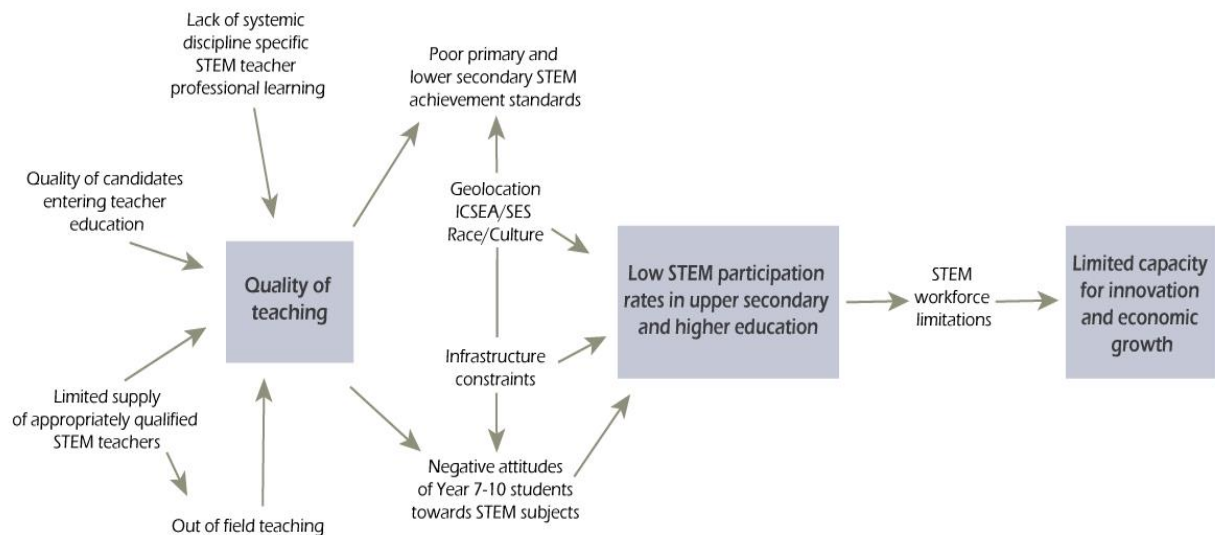
The most common barriers to the involvement of companies in supporting STEM education include: limited staff time given that these activities are not core business and often represent volunteering; the complexities of working directly with schools; lack of school curriculum knowledge; and, concerns about lack of coordination leading to duplication and gaps. It was suggested that many of the barriers to involvement could be addressed by better coordination, administrative support, and working in partnership with education service providers who understand how schools work and have specialist curriculum knowledge (KFs 48 & 49).

A wide range of participants indicated that a centrally collated source of information about STEM initiatives would be very useful to help disseminate information about STEM initiatives to schools and to key stakeholders. Many companies indicated that they would be happy to work through a service provider as this would address many barriers to participation. They indicated that they would support the existing range of initiatives i.e., funding professional development or resource development, providing resources, hosting class visits, providing guest speakers, providing student mentors, contributing to career expos and career education, providing scholarships and sponsoring exhibits. However, several companies would proceed with caution in the current climate of contraction in the resources sector (KFs 50 & 51).

Key School Education Factors Limiting STEM Education

Based on the evidence gathered, a summary of the school education factors limiting the development of STEM-capable school and university graduates is presented in Figure 11.

Figure 11 Key school education factors limiting the development of a STEM capable workforce



Fundamental to the development of a STEM capable workforce is the quality of teaching of STEM subjects in primary and lower secondary school. Teaching quality is compromised by the calibre of candidates entering teacher education and the limited supply of appropriately qualified STEM teachers which leads to out of field teaching, particularly in hard to staff schools. As indicated by the Grattan Institute report (Jensen, 2010), there is no other investment that can be made by governments that yields a greater return on economic growth than investment in the development of teachers' skills. Unfortunately, there has been a lack of investment in systemic discipline-specific teacher professional learning for teachers of STEM subjects. Effective professional learning focusses on discipline-specific knowledge and pedagogy, is supported with curriculum resources and mentoring, and is sustained.

Quality of teaching and learning is also influenced by a number of other variables such as geolocation, socio-economic status and race. Educational disadvantage increases with remoteness of location, low socio-economic status and proportion of the school population who are Indigenous, and it is these schools which are staffed by the least experienced teachers and often experience high levels of out of field teaching. The educational experience is also compromised by limitations in infrastructure such as lack of stable IT networks and technical support for STEM education, and science rooms in primary schools. This range of variables contributes to the poor achievement standards of primary and lower secondary students, the negative attitudes of Year 7-10 students towards learning STEM subjects and the low participation rates in upper secondary and tertiary STEM education. The lack of early career education about the importance of STEM education and the opportunities that arise from it also contributes to low participation rates. The limited numbers and quality of school and university graduates in STEM fields place serious constraints on Western Australia's capacity for innovation and economic growth.

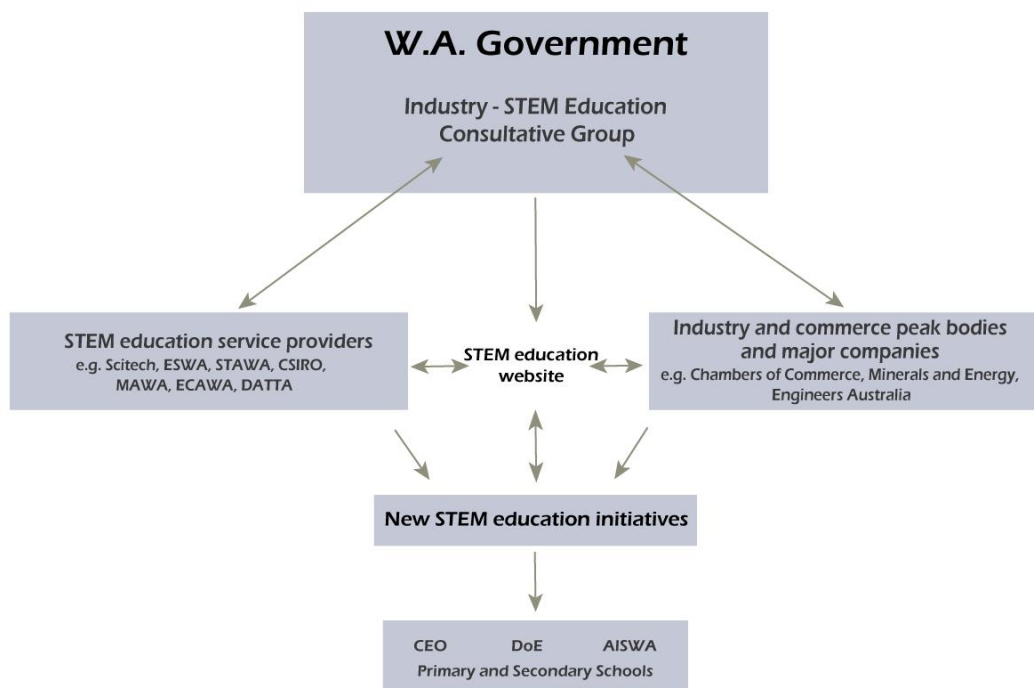
A Model for the Coordination and Optimisation of STEM Education Support

Currently the provision of resources and support for STEM education initiatives in Western Australia is both diverse and uneven with some schools and subjects being ‘loved to death’ whilst others are neglected. There is a need for stronger partnerships between government, industry and education for the harnessing of resources and optimisation of STEM education in WA schools. Figure 12 presents a model for the coordination of new STEM education initiatives that are required for the optimisation of STEM education.

It is proposed that the WA State Government establish an Industry-STEM Education Consultative Group. The Group, comprised of representatives drawn from: Government education and science portfolios; peak industry bodies and major companies; key education service providers; the three school education sectors; and, school principals would provide overall strategic coordination of the resourcing and provision of STEM education initiatives. This approach to building collaborations is consistent with the WA Economic Audit Committee’s (2009) call for the public service to work in partnership with industry and community organisations to maximise the effectiveness of service delivery.

Given the devolved nature of education funding, schools have access to funds to support teacher professional learning, however, to ensure widespread participation of schools in STEM professional learning, it is suggested that schools, industry and government each commit resources to support STEM initiatives, perhaps on a one-thirds each basis, with possible Federal Government support.

Figure 12 A model for the coordination and optimisation of STEM education support for WA schools



Consultation with industry indicates that companies are committed to supporting STEM education, however, education service providers are needed to effectively deliver STEM initiatives as they have the knowledge of curriculum, pedagogy and the culture and operation of schools. It is proposed that STEM education service providers be supported and strengthened to enhance their capacity to deliver the discipline-specific professional learning and curriculum resources required by teachers. In some cases, for example career education initiatives, there is a need for education service providers and industry groups to work together to deliver programs.

Recommendations have been made for actions needed to implement this model of STEM education optimisation.

Recommendations

The following recommendations and suggested actions target the factors that contribute to the unsatisfactory status of STEM education in our primary and secondary schools. They also aim to facilitate implementation of measures to optimise STEM education support and reverse the long term decline in STEM capability.

Enhance the capability of the existing STEM-education workforce

The unsatisfactory status of STEM education in WA schools will not change without enhancing the capability of the STEM education workforce. This requires action to enhance the capability of existing STEM teachers (Recommendation 1) and action to attract higher calibre candidates into teacher education (Recommendation 2).

Education is not reformed by the new teachers entering the profession. Reform is driven by school and curriculum area leaders who can change the culture of schools. Culture and practice are changed by teacher professional learning that is ongoing, coordinated and systematic. To be effective professional learning needs to address the needs of teachers, and the need most frequently identified at this time, is support to implement the Australian curriculum. Effective professional learning is based on the successes of past initiatives, has a strong research base and engages teachers through action learning and action research, is linked to curriculum resources and has a strong focus on discipline-specific content and pedagogy (Ingvarson, Meiers & Beavis, 2005). Marginson et al. (2013) also support this view that there is a need for “sustained discipline-specific professional development programs, focussed on pedagogical content knowledge and content knowledge” (p. 23) to enhance the capability of STEM teachers.

Recommendation 1: Enhance the capability of the existing STEM education workforce through developing mechanisms for more co-ordinated, systematic and sustained provision of discipline-specific teacher professional learning, mentoring and resource development.

Suggested actions:

- i. The WA Government lead the development of co-ordination mechanisms based on the model proposed in this report (Figure 2) to support more systemic provision of professional learning and development of curriculum resources. Implementation of this model requires the WA Government to establish an Industry-STEM Education Consultative Group.

- ii. The initial focus of STEM education initiatives should address the needs of teachers as they implement the Australian Curriculum for Science, Mathematics and Technology (i.e., exemplar assessment and curriculum resources) and the pedagogies required to engage the diversity of students in WA classrooms. Models and content of professional learning should be based on research and the strengths of previous initiatives that have been demonstrated to be effective.

Teacher supply

The research literature (e.g., Hattie, 2003; Jensen, 2010) clearly indicates that the variable with the greatest impact on student achievement is the quality of the teacher and his/her teaching. This was supported by the comments made by several of the study's participants who said that above all else, what students need is good teachers. The poor achievement standards and declining attitudes towards STEM subjects in the early secondary years, and the shrinking pipeline of STEM students through upper secondary and tertiary education will not be addressed until students in primary and lower secondary education are deeply engaged in STEM education by enthusiastic and well qualified teachers with sound content knowledge and the pedagogical skills needed to engage students in purposeful and productive learning. With the imminent transfer of Year 7 students from government primary schools to secondary schools, there will be increased pressure on the quality of the transition experience of students; a time when pedagogy changes dramatically and students' attitudes towards studying STEM subjects decline. Action needs to be taken to increase the calibre of candidates entering pre-service STEM teacher education and the supply of appropriately qualified graduate secondary teachers in key areas in which there is shortage and greatest out of field teaching, currently mathematics, physics and technology education. HECS reimbursement has been demonstrated to be an effective mechanism for attracting high calibre school leavers and graduates into teacher education.

Recommendation 2: Provide incentives to attract additional high quality applicants into pre-service teacher education in areas of STEM teaching shortages, currently mathematics, physics and technology education.

Suggested action:

- i. The WA Government provide HECS re-imburement for qualified graduate teachers who have a major in physics, mathematics, technology or computer science, after teaching for three years in WA schools.

Data about teachers' qualifications

This study had to rely on international, Australian and limited WA data to find the evidence to support the many anecdotal reports of teacher shortage and out of field teaching in STEM subjects at the secondary school level. Given the lack of any systematic collection of data about WA teachers' qualifications there is a need to put in place processes to collect data about existing STEM teachers' qualifications and those new STEM teachers entering the profession. These data are required to inform STEM education policy development and workforce planning.

Recommendation 3: Collect data about the qualifications of those currently teaching Year 7-12 science and mathematics and those entering the profession

Suggested action:

- i. The WA Government commission a comprehensive survey of Year 7-12 teachers to ascertain demographic data and qualifications of the science, mathematics and technology teaching workforce.
- ii. The WA Government require the WA Teacher Registration Board to keep a database of the qualifications of all teachers registering to teach in WA schools.

Optimising industry support for STEM education and dissemination of information about STEM education initiatives

Many organisations are supporting STEM education, most commonly through mentoring, visiting speakers, providing resources, supporting career expos, providing cash to fund teacher professional learning or curriculum resource development, sponsoring competitions, hosting class visits and funding scholarships. There is also a willingness to do more in the name of good corporate and social responsibility, and the challenge is how to more effectively harness this support and its potential.

There are opportunities to enhance the level of cooperation between companies through key industry peak bodies to generate initiatives with larger reach and impact, and to enhance cooperation between service providers. Strategies such as these have the potential to enhance the level of industry support and to use it more effectively. There is a need to establish a high level consultative group to build collaborations between government, industry, education service providers and the school sectors and to recruit resources from state and federal governments and industry to strengthen STEM education. To establish and maintain this group, and to ensure the continuity and sustainability of industry, service provider, and education sector engagement that will be essential to optimising STEM education, will require firm leadership from an appropriate government agency. This agency should also be responsible for future cross-sector educational projects and the associated grant programs.

A large proportion of participants drawn from companies and education service providers have remarked that the provision of STEM education initiatives occurs in a congested and contested space with some schools and subjects being 'loved to death' and others being neglected. There is a need to provide a centrally collated source of information so that all schools and service providers are aware of the range of initiatives being offered and who the key providers are.

Recommendation 4: Establish an Industry-STEM Education Consultative Group to generate higher levels of industry engagement in STEM education, increased collaboration between industry and education service providers in the delivery of STEM education initiatives, and create greater awareness of the range of initiatives being implemented.

Suggested actions:

- i. The WA Government identifies an appropriate agency that will establish, and be responsible for, an Industry-STEM Education Consultative Group to facilitate the involvement of education and science government portfolios, industry, service providers, education sectors and school principals to create the collaborations and resources needed to generate long-term STEM education initiatives with a large footprint.

- ii. The Consultative Group leads a process to develop a website that provides information about STEM education initiatives and directs students, teachers and parents to the relevant service providers; and, maintains the currency of the information.

Enhance the capacity of STEM education service providers to support teachers

A significant proportion of the discipline-specific professional learning and curriculum resource support provided to teachers of STEM subjects is currently delivered by STEM education service providers such as Scitech, ESWA and STAWA. The most successful STEM education service providers have the expertise needed to work with schools and support teachers, form collaborations with government and industry partners who fund their activities, and have the administrative, business and education acumen to develop quality programs and sustain them over time with a wide reach. They have also developed ways of addressing barriers to involving industry and schools and there is a significant opportunity for this expertise to be shared more effectively between service providers, particularly the teacher professional associations, to enhance their capacity to deliver more effective support to schools and teachers. The key service providers, such as the teacher professional associations linked to STEM subjects, will need to be supported and strengthened to enhance their capacity to deliver the discipline-specific professional learning and curriculum resources that are required by teachers.

Recommendation 5: Enhance the capacity of STEM education service providers to deliver discipline-specific teacher professional learning and curriculum resources needed by science, mathematics and technology teachers.

Suggested actions:

- i. The Industry-STEM Education Consultative Group reviews the STEM-related teacher professional associations to determine the resources and support needed to achieve the capacity building and the development of service delivery models required to strengthen the teaching of science, mathematics and technology.
- ii. The WA Government, through an appropriate agency and the input of the Consultative Group, provides resources to build the network of STEM education service providers and to strengthen the capacity of the teacher professional associations to more effectively develop and deliver teacher professional learning and curriculum resources in science, mathematics and technology.

Enhance equity and access to quality STEM education

Analysis of international, Australian and WA assessment data clearly demonstrate large and statistically significant gaps between the achievement of students from high and low socioeconomic status/ICSEA schools, between non-Indigenous and Indigenous students, and, in some subjects between males and females. There are also strong impacts of socioeconomic/ICSEA status, race, geolocation and gender on students' participation in technology, physics and advanced mathematics.

There is strong evidence to show that too many students are not being challenged and supported to attempt more than the lowest levels of mathematics in secondary schooling. Increasing the participation and achievement of these disadvantaged groups will be an important strategy to

increase the number of STEM graduates needed to drive the economy and address the social and environmental challenges facing WA. This view is supported by the ACOLA report (Marginson et al., 2013) which states that “by growing the proportion of students who stay in STEM, including women and low socio-economic status (SES) students, a nation expands the talent pool from which future STEM high achievers will be drawn” (p. 14).

Recommendation 6: Develop holistic approaches to raising aspiration and opportunity for high quality STEM education in disadvantaged schools in the metropolitan area and regional centres.

Suggested actions:

- i. The Industry-STEM Education Consultative Group review participation and performance data for WA schools with mid-range and below average ICSEA scores to identify schools and school clusters which have large under-participating and under-performing populations and target these for STEM education improvement plans.
- ii. The Industry-STEM Education Consultative Group develop a holistic collective impact model for STEM education improvement that addresses the needs of school leadership, teachers, students and parents to be implemented at school or school cluster levels.
- iii. Education service providers in partnership with industry identify ways in which curriculum resources can be contextualised and pedagogy changed to make STEM subjects, such as mathematics and physics, more relevant and attractive to a wider range of students.

Awareness of the importance of STEM education

Many companies and STEM education service providers have recognised the critical importance of raising STEM education awareness at community, parent, school leader, teacher and student levels. STEM education not only develops the capabilities required to function effectively within a science and technology based society, but also provides wonderful career opportunities for the individual and builds the capacity of Western Australia to drive an economy based on innovation.

Many excellent career education initiatives are currently focussed at tertiary and upper secondary levels and, as many researchers have argued (e.g., Tytler, 2007; Tytler et al., 2008), such interventions need to be earlier, in the upper primary and early secondary years. To develop STEM education awareness and a STEM education culture, a holistic approach is needed involving parents, students, teachers and school leaders. No change in school culture is possible without the support and leadership of the school leadership team. Career education is also needed to enhance students' aspirations to study higher level mathematics and science subjects.

Recommendation 7: Provide enhanced career education to students, parents, teachers, career guidance officers and school leaders to enhance awareness and understanding of the importance of STEM education and the opportunities available through STEM-based careers.

Suggested actions:

- i. Industry, working in collaboration with education service providers, deliver career education for Year 6-8 students and their parents emphasising the critical role of high level mathematics and science, and opportunities for girls in mathematics and technology.

- ii. Industry, working in collaboration with education service providers, deliver STEM career expos to enable students to engage directly with STEM professionals.
- iii. Education service providers deliver *Leadership for STEM Education* programs for leaders of secondary schools

STEM education infrastructure

Interviews with key personnel within the education sectors and teacher professional associations generated a body of evidence to indicate that the infrastructure needed to support a quality STEM education is lacking in many schools. Previous research (Hackling, 2009) has highlighted the need for enhanced technical support for secondary science education and this need is being addressed through the DEEWR funded *Science ASSIST* project managed by the Australian Science Teachers Association. This STEM research study demonstrates that there is a wider need encompassing support for IT networks in primary and secondary schools, primary science and for design and technology in secondary schools.

Some participants have raised questions about the need for specialist primary science teachers and science rooms. Given the commitment of Australian jurisdictions to the *Primary Connections* program with its evidence-based focus on integrating science with other learning areas, introducing a specialist science teacher would be counterproductive to this agenda. However, there is a need for curriculum area leaders in schools who can provide coordination and mentoring of less confident teachers of STEM subjects.

There is support for the development of science rooms in primary schools. Video based classroom research (e.g., Hackling, Murcia & Ibrahim-Didi, 2013) shows that middle and upper primary classrooms are congested with furniture and there is little space for group activity and movement. To be effective, teachers have to find ways of emptying the classroom of furniture or move into an open covered area within the school for science activities. This approach does not resolve issues of managing and storing equipment and materials. A science room with limited furniture and with storage facilities would provide an environment far more conducive to inquiry based and activity focussed science education in primary schools. Richard Johnson, the winner of the 2013 Prime Minister's Prize for Excellence in Primary Science Teaching, has demonstrated how valuable a specialist science room has been for building the culture of science at WA's Rostrata Primary School.

Recommendation 8: Enhance the infrastructure and technical support required for a high quality science and technology education.

Suggested actions:

- i. Each education sector develops science rooms and provides support for managing science materials in all primary schools.
- ii. Each education sector provides sector/district/school cluster level IT support for primary school IT networks.
- iii. Each education sector ensures that all secondary schools provide adequate technical support for science, IT and design and technology learning areas.

Evaluation of STEM education initiatives and dissemination of findings

It was quite evident from the consultations with industry supporters of STEM education initiatives and education service providers that many of the existing initiatives had not been subject to any formalised evaluation. Formative evaluations that are conducted concurrently with project implementation can provide valuable feedback to shape implementation strategies to maximise impact. Summative evaluations can provide measures of impact and also identify variables constraining and enhancing effectiveness of initiatives. University grant schemes established to enhance teaching and learning in universities require that all projects not only include an evaluation but also a dissemination strategy so that what is learned through the project is disseminated widely for uptake by other institutions. The same requirements should apply to the initiatives resulting from this report.

Recommendation 9: All projects initiated as outcomes of this report should be formally evaluated and include a dissemination strategy.

Suggested actions:

- i. All tenders and contracts let for projects as an outcome of this study include a fixed proportion of the funding for evaluation which should comprise both formative and summative components.
- ii. All tenders and contract let for projects as an outcome of this study include a fixed proportion of the funding for a dissemination strategy so that what is learned in each project is disseminated widely to maximise impact.

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Appendix 1

Appendix 1: Impacts of the Australian Curriculum

AUSTRALIAN CURRICULUM: SCIENCE FOR WESTERN AUSTRALIA

With the development and implementation of the Australian Curriculum there has been a wide range of State based consultations with science education stakeholders, which together with curriculum comparisons and mapping exercises has generated the feedback provided to ACARA and used to inform ongoing initiatives. There are emerging issues for Western Australia in transition to the Australian Curriculum Science.

Consultation and coordination of feedback for the Australian Curriculum

The Curriculum Council and now the School Curriculum and Standards Authority (SCASA) has coordinated Western Australian feedback to the Australian Curriculum, Assessment and Reporting (ACARA)

- The consultation involved teachers and consultants from across the sector/systems.
- The Curriculum Councils consultation with WA teachers included validation workshops for the achievement standards for F–10 science
- State representatives were nominated by the Curriculum Council 2011 to be part of national panels for the senior secondary courses in both science
- School Curriculum and Standards Authority (SCASA) replaced the Curriculum Council and started working in 2012 to ensure consistent information regarding the implementation of the Australian Curriculum was passed to schools through the relevant school sector/systems.
- SCASA implemented (2012) an Australian Curriculum Working Group whose role was to promote cross-sectoral discussions and to build agreement on issues relating to implementation of the Australian Curriculum in W.A.
- SCASA surveyed all schools in Western Australia (2012) to determine progress in implementation of the Australian Curriculum.
- The results of the survey are held within the Authority and are currently being used to inform future implementation planning and funding priorities.
- The Authority's Australian Curriculum Working Group has implemented a project involving approximately 150 teachers (Pre-primary to Year 10) working to develop illustrations of good assessment practise.
- SCASA is also coordinating W.A. teachers' involvement in a range of the Australian Curriculum, Assessment and Reporting Authority (ACARA) projects, including the ACARA F–10 Work Samples project which will improve the national collection of annotated students work.
- SCASA is currently working to adapt the AC senior secondary courses in Chemistry, Physics, Biology and Earth and Environmental Science for potential implementation as Year 11 WACE courses in 2015.

In addition, the Science Teachers Association of Western Australia (STAWA) aimed to elicit and document the views of WA teachers from all sectors regarding the Australian Curriculum F -10 and the Draft Australian Curriculum – Senior Science Subjects.

- Comments were collated and the resulting STAWA response was sent to ACARA on behalf of all members.

- The STAWA response to the Australian Curriculum F-10 Science and the general response to the Draft Australian Curriculum – Senior Science Subjects can be downloaded by members from the STAWA website, www.stawa.net.
- STAWA is currently coordinating a professional development program, that incorporates action learning (<http://www.acwa.wa.edu.au/>), aimed at facilitating teachers' work around the transition to the Australian Curriculum in Western Australian schools.
- This is a cross-sectoral initiative supported by WA Government funding.

F-10 Curriculum Comparisons

- A comparison of the Australian Curriculum (AC) and WA K-10 Syllabus Science was conducted by the Department of Education and published in February 2011.
- This is a comprehensive document and available to the public on the DoE website.
- A comparative mapping exercise was also conducted by AISWA

WA K-10 SYLLABUS	AUSTRALIAN CURRICULUM F to 10	Comments
Investigating	Science Inquiry Skills	Align closely
Communicating Scientifically Acting Responsibly Science in Society	Science as a Human Endeavour	<ul style="list-style-type: none"> • In the AC specific contexts are suggested as elaborations for each year level. • WA K-10 Syllabus did not provide levelled elaborations for these areas of the curriculum. • Communicating is included in the AC as a part of the Science Inquiry strand
Earth and Beyond	Earth and Space Sciences	<ul style="list-style-type: none"> • Science understandings included in both curricula are generally consistent. • Content previously implicit in the WA K-10 Syllabus has been made more explicit in the Australian Curriculum. • There is some new content included in the AC and the year level for a range of key understandings has been shifted down.
Energy and Change	Physical Sciences	
Life and Living	Biological Sciences	
Natural and Processes Materials	Chemical Sciences	

General differences

- The AC strand Science Inquiry Skills and the WA K-10 Syllabus Investigating outcomes align closely.
- There is further and more detailed elaboration of the nature of scientific inquiry evident in the AC sub strand Inquiry skills than in the WA Syllabus Investigating outcomes.
- There is a greater emphasis in the AC given to both collaboratively and individually investigating; and a range of investigation types (e.g. fieldwork)
- The AC Science as a Human Endeavour strand represents the greatest difference to the WA K-10 syllabus and is reported to be causing concern for teachers.
- There is more emphasis given in the AC Science curriculum to digital technologies for data collection and emerging technologies (e.g. biotechnology/nanotechnology).
- In lower secondary, the use of keys and models is more explicit in the AC than in the WA Syllabus.
- There is more of an industry focus in the AC Science as a Human Endeavour strand.
- The numeracy demands of science are made explicit in the AC and there is greater expectation at a younger age for mathematical skills (graphing patterns and trends, mass & volume).
- Fieldwork and assessing risk and ethical issues is more explicit in the lower secondary years of the AC.
- Content implicit in the WA K-10 Syllabus has been made more explicit in the Australian Curriculum. e.g. Force: push/ pull, friction, gravity and Energy: Heat, energy transformations and electrical circuits
- The year level for a range of key understandings has been shifted down.
- For example: WA Syllabus year 8 content has been moved into year 7 in the AC. The Chemical and Physical understandings (mixtures & separation techniques) represent the greatest change at this year level. The water cycle is also now included in AC year 7.
- For example: The AC year 8 biological understandings include content (body systems) previously included in year 9.
- For example: The AC includes light and sound waves and atomic radiation previously covered in year 10.
- For example: AC year 10 includes extension content from the WA Syllabus e.g. transmission of heritable characteristics, DNA, evolution and laws of physics.

Senior Secondary Curriculum Comparisons

- Senior Secondary Australian Curriculum Science currently consists of 4 subjects, Biology, Chemistry, Earth and Environmental Science, Physics
- ACARA reports that the final revised drafts of these documents were presented for Ministerial approval in December 2012.
- Drafts of the Year 11 and Year 12 courses of the Australian Curriculum science were released for public consultation in June 2012.

WACE COURSES	AUSTRALIAN CURRICULUM Yr 11 & 12 Courses	Comments
Biological Sciences	Biology	The AC Biology subject includes content from both the WACE Biology and Human Biology Course.
Human Biological Science		
Integrated Science		N/A
Earth & Environmental Science	Earth & Environmental Science	Inclusion of some new content Detailed comparison and mapping required
Chemistry	Chemistry	Inclusion of some new content Detailed comparison and mapping required
Physics	Physics	Inclusion of some new content Detailed comparison and mapping required
Psychology		N/A

Emerging issues for WA in the transition to the Australian Curriculum Science

1. At all levels, the Science as a Human Endeavour strand in the Australian Curriculum requires increased contextualisation of learning.
2. There is some new content in the AC Senior Secondary courses previously not in existing WACE courses. This has implications for both pre-service and in-service professional learning.
3. The AC Biology course combines content from both the WACE Biological and Human Biological Courses. Overlap and repeated content would occur in potential course combinations.
4. New AC content at the primary level will have implications for teacher training, professional development and resourcing.
5. New and more explicit understandings and inquiry skills stated in the AC Early Years could suggest pedagogical shifts that may include intentional teaching

AUSTRALIAN CURRICULUM: MATHEMATICS FOR WESTERN AUSTRALIA

The key challenges for WA appear to be:

1. New content at Senior Secondary level previously not in existing WACE courses
This will have implications for teacher training, professional development and resourcing.
2. New content at primary level previously not taught in primary years
This will have implications for teacher training, professional development and resourcing.
3. The emphasis on new pedagogies and increased contextualisation of learning
This will have implications for teacher training, professional development and resourcing.
4. Shortages of appropriately trained Mathematics specialist teachers at the lower secondary level

This will be exacerbated by the movement of Year 7 into high schools.

Potential solutions

1. Teacher training, professional development and resources can be drawn from interstate for the AC Senior Secondary content outside of WACE.
2. It is likely that training and professional development will be required for many primary teachers. This training and PD will need to focus on content not previously included in the primary curriculum. Existing lower secondary resources can be utilised to support teachers.
3. Where necessary, training and PD should reflect the changing emphasis to new pedagogies and increased contextualisation of mathematical content.
4. Increased supply of appropriately trained Mathematics teachers at lower secondary level to accommodate the Year 7 cohort and appropriate PD for teachers of Specialist Mathematics.

Curriculum Comparisons

- Some content has been shifted downwards so that students will be encountering material in Year 6 that was not previously in the primary curriculum.
- Much of the content that was taught in Year 8 is now taught in Year 7. This coincides with Year 7 students entering high schools.

F-10 Curriculum: Number and Algebra

- Students work with larger numbers at an earlier age
- AC content descriptions assume greater fluency with whole and decimal numbers
- Students locate negative numbers on a number line in Year 6
- Students add, subtract and divide fractions with unrelated denominators in Year 7
- Variables and algebraic expressions are introduced in Year 7. Algebra content in Years 8 – 10 is likely to be more demanding for most students
- More time will likely be required for students to learn how to apply the associative, commutative and distributive laws in Year 7

F-10 Curriculum: Measurement and Geometry

- AC gives greater emphasis to the use of familiar metric units
- AC doesn't specify content relating to the estimation of measurements
- Understanding angle is largely new content for Year 3
- Measurement of area and volume is introduced using grid paper and centicubes in Year 4
- Students construct angles using a protractor in Year 5
- Cartesian coordinate system is introduced using all four quadrants in Year 6
- Content relating to angles (Year 7) is likely to be more challenging for students

F-10 Curriculum: Statistics and Probability

- AC gives more emphasis to comparison of students' representations of data
- Students collect and organise data with and without appropriate technologies (Year 3)
- AC gives more emphasis to evaluating the effectiveness of data displays (Year 4)
- 0-1 probability scale is introduced in Year 5
- Students use digital technologies to conduct chance experiments (Year 6)
- Content includes mode and range (in addition to mean and median) and stem-and-leaf plots (Year 7)
- Students interpret the relationship between the median and the mean (Year 7)

Senior Secondary Curriculum

The Senior Secondary Australian Curriculum consists of four subjects, each of which comprises four units. Specialist Mathematics further develops the concepts introduced in Mathematical Methods and is the only unit **not** designed to be taken as a stand-alone unit.

- **Essential Mathematics** – prepares students for employment or further training
- **General Mathematics** – focuses on discrete mathematics (e.g., networks, growth and decay)
- **Mathematical Methods** – focuses on modelling, calculus and statistical analyses
- **Specialist Mathematics** – extends above concepts. Introduces vectors, complex numbers and matrices

The vast majority of content in Essential Mathematics, General Mathematics and Mathematical Methods is taught in the existing Stage 2 and 3 WACE: Mathematics and Mathematics: Specialist courses.

The AC **Specialist Mathematics** subject introduces some significant additional content in the areas of combinatorics, vectors, mathematical proof, trigonometry and algebra. These have been itemised below:

Unit 1	WACE Equivalent	Comments
Combinatorics	3A MAT 3.1.4 3C MAT 3.1.1, 3.1.2	Three-circle Venn diagrams Pigeon hole principle Identities associated with Pascal's triangle
Vectors in the plane	3A MAS 1.1-10 3B MAS 1.1-6	Define and use projections of vectors
Geometry		The nature of proof Circle properties and their proofs
Unit 2		
Trigonometry	3B MAS 2.2, 2.4 3D MAS 2.1	Find all solutions of $f((a(x-b)) = c$ Reciprocal trig functions Converting $a \cos x + b \sin x$
Matrices	3D MAS 1.1-9	
Real and complex numbers	3D MAS 5.2 3B MAS 6.1-6, 3D MAS 6.1-4	Prove irrationality by contradiction Proof by induction Prove divisibility results
Unit 3		
Complex numbers	3D MAS 5.2 3B MAS 6.1-6, 3D MAS 6.1-4	
Functions and sketching graphs	3C MAT 1.4.7	Factor theorem
Vectors in three dimensions	3C MAS 1.1-12	Vector equation of a curve Vector calculus
Unit 4		
Integration and its applications		Integration techniques
Rates of change and differential equations	3C MAT 2.1.2-3	Differential equations Slope fields of 1 st order de's Modelling motion
Statistical inference	3C MAT 3.3.2, 3.4.1-3	

DRAFT AUSTRALIAN CURRICULUM: TECHNOLOGY FOR WESTERN AUSTRALIA

At a national and state level, the decade between 2000 and 2010 saw a virtual dearth of reporting activity in the area of Technology. Reports published around 2000 indicated the inadequacy of support for teachers through a lack of curriculum resources and suitable, if any, teacher professional development. Indications were that the status of Technology was low.

In the decade since 2000 there has been an enormous growth in the availability and use of digital technologies on a global level. Reports published in recent years that reference technology discuss the implementation of digital infrastructure, which will ultimately support a ratio of one digital learning device per student in all classrooms to support teaching and learning. There have been no reports published in recent years that have evaluated the Technology area and minimal reports published that discuss its status and direction.

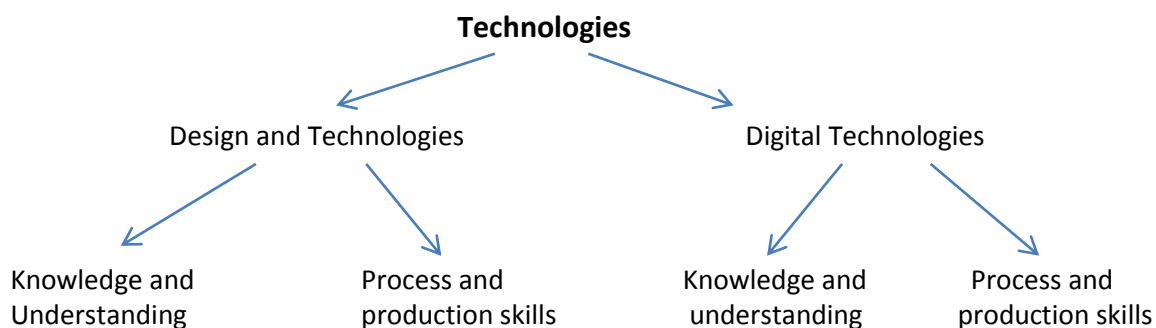
The Curriculum Framework

According to the Curriculum Framework the Technology and Enterprise learning area, as it was known as, involved “applying knowledge, skills, experience and resources to the development of technological solutions that are designed to meet the changing needs of individuals, societies and environments.” The learning area emphasised two aspects: processes; and solutions. The Curriculum Framework presented an explicit model of the technology process and emphasised that technology and enterprise involved the use of that process to develop solutions to problems or situations.

References to digital technologies were made under ‘Technology Skills’ which was one of seven Technology and Enterprise learning outcomes.

The Draft Australian Curriculum

As of February 2013, Technologies exists as a Draft Australian Curriculum. From F to Year 8, students will study two subjects under Technologies: Design and Technologies; and Digital Technologies. For Years 9 and 10, school authorities will decide whether students can choose to continue in one or both of those subjects. Each of the subjects Design and Technologies and Digital Technologies has two strands: knowledge and understandings; and process and production skills. This is shown as below.



The Draft Australian Curriculum emphasises the integration of knowledge and process. It also indicates that the intent of Technologies work is that it relates to the real world through students examining “the use, development and impact of technologies in people’s lives.”

Key Points

The Draft Australian Curriculum indicates two key components:

- Systems thinking and the creation of preferred futures. This relates to a consideration and concern about the impact of work on future generations.
- Project management. Students will be explicitly taught how to manage projects.

Appendix 2

APPENDIX 2: Organisations Consulted

Alcoa

APPEA

Chamber of Minerals and Energy of Western Australia

Chevron Australia

CISCO

Clough Engineering

CSIRO

Data Analysis Australia

Design and Technology Teachers' Association

Earth Sciences Western Australia

Educational Computing Association of Western Australia

ESRI Australia

Hatch Engineering

Intergrain

Kvaerner

Mathematical Association of Western Australia

Raytheon Australia

Rio Tinto Australia

Science Teachers Association of Western Australia

Scitech

Shell

SKM

Telethon Institute for Child Research

The Association of Independent Schools of Western Australia

The Catholic Education Office of Western Australia

The Department of Education Western Australia

UWA Engineering

Western Australian Institute for Medical Research

Westpac