Edith Cowan University
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Technology and Industry Advisory Council

# Optimising STEM Education in WA Schools

## Part 1: Summary Report


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**February 2014**

**Acknowledgements**

This project was funded by the WA Department of Commerce through the Technology and Industry Advisory Council. The research team would like to acknowledge the support of TIAC's Science Education Committee in framing the approach to this study:

Dr Jim Ross AM (Chair)
Alan Brien
John Clarke
Russell Dyer
Dr Pamela Garnett
Glenda Leslie
Dr Claire Patterson
David Wood

The research team would also like to acknowledge support from the School Curriculum and Standards Authority in providing school subject enrolment data.

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 Efraïm Rodriguez Cobos of the University of Barcelona.



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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 summary report. The full research report is available as a separate document that forms Part 2 of the project report.

# 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). The future employees of STEM and STEM-related industries in WA 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.

A range of evidence has emerged about the quality of science education and the number of students studying science that has raised concerns about our capacity to generate the STEM graduates needed to address the economic, social and environmental challenges facing us. In 2006, 35% of graduates in all geographic regions of the world were from science and engineering fields 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, 2010).

There have been strong calls for action in Australia to increase the number of STEM graduates to drive innovation and economic growth. Professor Ian Chubb, Australia's Chief Scientist has argued that: "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).

## Purpose

The challenge of identifying how we can increase the number of students studying STEM subjects and the STEM-capabilities of school and higher education graduates was the motivation for this project, *Optimising STEM Education in WA Schools*. The STEM education pipeline starts in our schools and it is recognised that most of the STEM education problems are situated at the primary and secondary school levels of education. The purpose of the study was to identify: the status of STEM education in WA schools; the challenges facing STEM education; the range of organisations supporting STEM education; the barriers to providing support; and, to make recommendations for optimising STEM education in WA schools.

## Approach

The *Optimising STEM Education in WA Schools* project was implemented 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; and, 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 and from these nine themes were developed, and recommendations and suggested actions have been made to address the unsatisfactory status of STEM education in WA schools.

## Major Research Findings

The research findings are presented here as a set of 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 in Part 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 whilst 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 proportion 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, 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 include 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: address the needs and gaps identified by teachers; are delivered through partnerships with an education service provider; provide mutually beneficial outcomes; are 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).

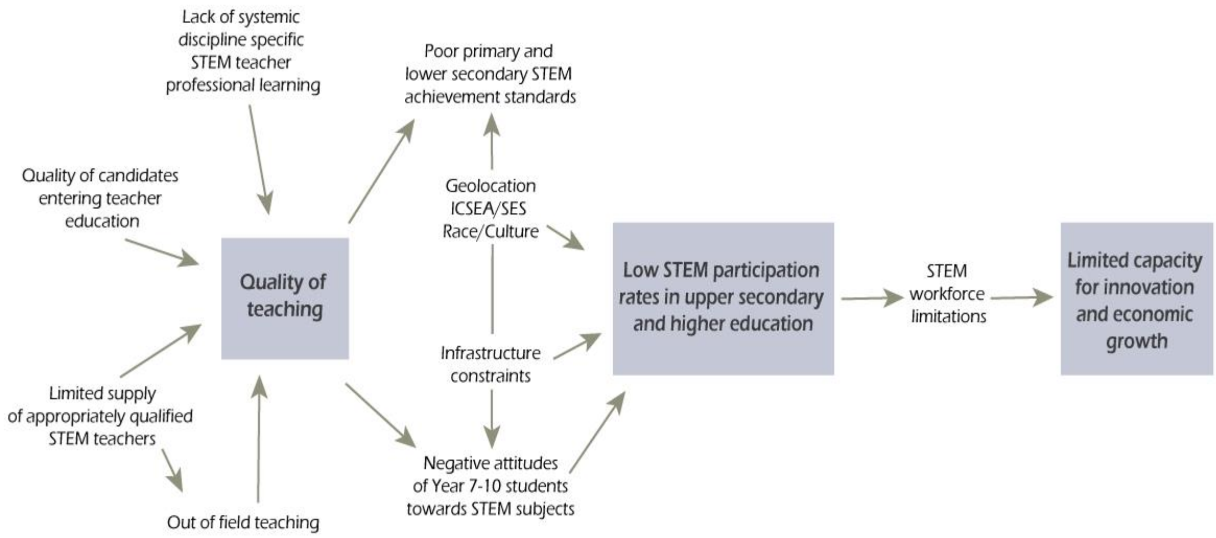
A wide range of participants indicated that a centrally collated source of information about STEM initiatives would be very useful to help disseminate information about STEM initiatives to schools and to key stakeholders. Many companies indicated that they would be happy to work through a service provider 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 1.

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.

Figure 1 Key school education factors limiting the development of a STEM capable workforce




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.

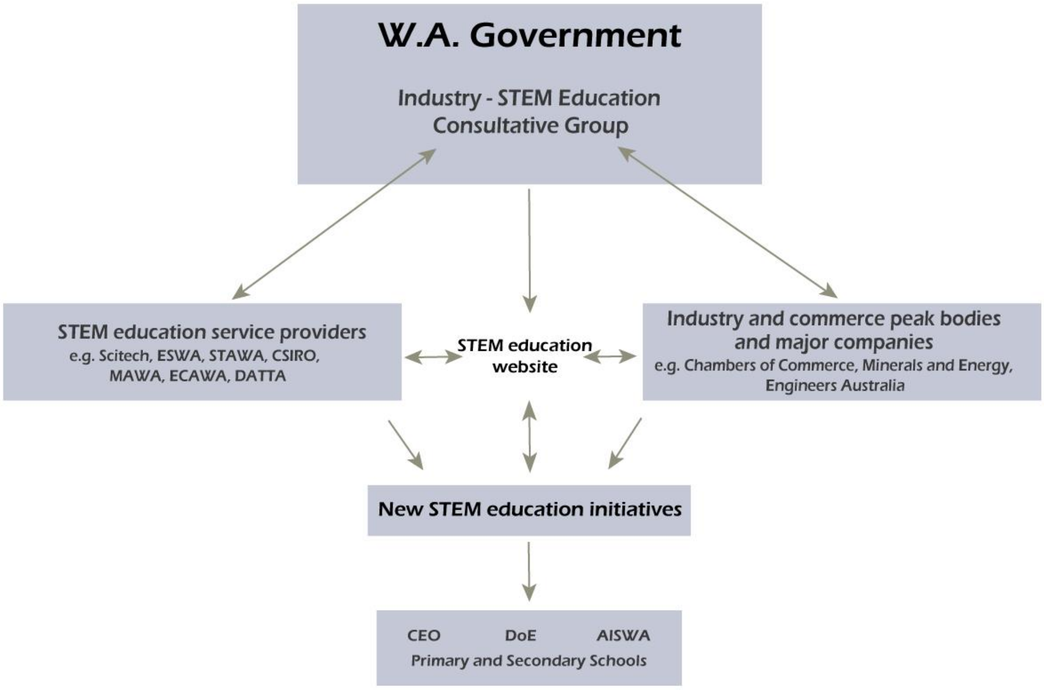
## A Model for the Coordination and Optimisation of STEM Education Support

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 2 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-third each basis, with possible additional Federal Government support.

**Figure 2. 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 though 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 with STEM teaching shortages, currently mathematics, physics and technology education.

Suggested action:

i. The WA Government provide HECS re-imbursement 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 actions:

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**: Projects initiated as outcomes of this report should be formally evaluated and include a dissemination strategy.

Suggested actions:

i. All tenders and contract 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 contracts 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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