Productive partnerships: Advancing STEM education in Western Australian schools

A report to the Science Education Committee of the Western Australian Technology and Industry Advisory Council (TIAC):

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Executive Summary

In the context of the introduction of the Australian curriculum and national teacher standards, and a future outlook of unprecedented prosperity, Western Australia is in a unique position to shape its own future in science and innovation. However, to maximise the potential benefits that science and innovation can bring to the State, it is essential to develop and implement a strategy for strengthening science, technology, engineering and mathematics (STEM) education support for early childhood, primary and secondary school students and their teachers.

Formal STEM education for students is the responsibility of the Government, the Catholic education system and the independent schools sector which, together, constitute the *formal* education system. In addition, there is a wide range of STEM education providers *external* to the formal education system. They include Federal and State Government agencies, statutory bodies, professional organisations, universities and private companies. These external providers make an important contribution to STEM education in Western Australia and there is a unique opportunity to leverage their efforts to even greater effect.

The Technology and Industry Advisory Council (TIAC) commissioned this study with the primary aim of identifying: the external STEM providers; their contributions to STEM education; and, the attributes that determine their optimum effectiveness within the formal education system. This report, and its supporting volume, is based largely on a pilot survey of STEM teachers, stakeholders and external STEM education providers. It is also informed by a comprehensive assessment of the relevant literature. The findings indicate opportunities for stakeholders to strengthen both the formal and external components of STEM education in Western Australia, and to build more productive partnerships between them. They lead to four recommendations to capture those opportunities:

Recommendation 1
Develop and implement a cross-sectoral strategy for improving STEM educational outcomes for all students in early childhood, primary and secondary school settings, especially in the core areas of the Australian Curriculum: science inquiry skills; science understandings; science as a human endeavour; mathematics content; and, mathematics proficiency.

Recommendation 2

Develop short and long-term strategies to develop the expertise of teachers in STEM education of early childhood, primary and secondary school students, including:

- *providing support for STEM teachers through professional learning opportunities and high quality resources;*
- *developing supportive partnerships with external STEM education providers;*
- *further developing STEM teacher undergraduate programs; and,*
- *attracting high level STEM graduates to the profession and retaining them..*

Recommendation 3

Develop a searchable database of both formal and external STEM providers that documents the activities and resources available to inform and assist STEM teachers and parents.

Recommendation 4

Develop and implement strategies to strengthen the partnership between the State's formal STEM education system and the external STEM education support providers, including stronger engagement of the relevant professional organisations, with the aim of:

- *increasing STEM resources closely aligned to the national curriculum;*
- *providing new learning and development opportunities for STEM teachers; and,*
- *providing teachers and their students with real world examples and experiences of science and innovation at work.*

Implementation of these four recommendations will bring continuing improvement in STEM education and materially assist the State to optimise the economic and social benefits of science and innovation over the long term.

Strengthening STEM education in Western Australian schools

Australia's newest Nobel Laureate, astronomer Brian Schmidt, said recently[1]: *nations rise and nations fall on the outcomes of science and education. Improvements in our lives are largely due to technology powered by science and education*. Significantly, he added: *The future for Australia is indeed bright—but it is not guaranteed. Capitalising on Australia's opportunities will not just happen, it requires strategic science and education policies that adapt to a changing world. And Australians will have to be willing to make significant changes in how they go about their business*.

His words apply equally well to Western Australia, where a firm foundation in science and mathematics in our schools and an outlook of unprecedented prosperity, provide a unique opportunity to strengthen our future and lead the nation in science and innovation. However, this will not happen without stronger support for science, technology, engineering and mathematics (STEM) education for early childhood, primary and secondary school students and their teachers.

Science and mathematics are two of the four curriculum areas most generally included in STEM education. In 2010 and 2011 there were modest increases in the numbers of students taking WACE examinations in Physics, Chemistry, Biological Sciences, Human Biological Sciences and Earth and Environmental Science. The overall percentage has also increased in mathematics; however, there has been a decline in the percentage taking the 'higher' mathematics courses[2]. In science, government school students in Years 5, 7 and 9, performed as well in 2010 as they did in 2009 in the Western Australian Monitoring Standards in Education assessments. In 2011, WA students showed the most improvement in the National Assessment Program Literacy and Numeracy tests[3]. While our current STEM results are encouraging, we cannot afford to become complacent. A cohesive strategic plan is required to further develop the STEM pathway from early childhood to primary and secondary schooling. Such a strategy will benefit tertiary and VET education, the workplace and community well-being.

There are many reasons why STEM education is important, but two are foremost: firstly, to prepare future STEM workers; and secondly, to increase the numbers of citizens who understand how science and technology are applied and work in real life settings. When considering the preparation of future STEM workers, the 2009 TIAC document, *Managing Western Australia's economic expansion: The need for people and skills*[4], has indicated the State's increasing need for skilled workers. Given the comparative advantage that WA enjoys in minerals, energy and

agriculture, the importance of the health sector, and the accelerating application of science and innovation in almost all areas of the economy, many of these skilled jobs will be in areas strongly underpinned by STEM.

Those graduating students who choose careers and professions unrelated to STEM will be citizens in a world dominated by science and technology. They will need to at least appreciate and understand the role of STEM if they are to optimise their own, and the State's, social and economic well-being.

The comparative strength of science and mathematics in our schools does not guarantee a future of increasing commitment to science and innovation. However, the introduction of the Australian Curriculum from 2013 onwards provides an important opportunity for STEM education in Western Australia. Preparation for senior school science courses in Physics, Chemistry, Biology, and Earth and Environmental Science and for Mathematics courses, will be reflected in the K-10 curriculum. By embracing, effectively implementing, and building on the new curriculum, the formal education system in Western Australia can strengthen both the perceptions of, and engagement with, STEM education by teachers and students alike.

Nevertheless, a curriculum change will not be sufficient. Investments in enabling support, including professional development and resources, will be required for optimum outcomes. Such investments are more likely to occur when there are productive partnerships between the formal education system and the external providers.

Many nations are now grappling with the need for improvement of STEM education. Indeed, the UK has a national STEM centre and an online STEM resources database[5]. The US has recently conducted a national workshop on STEM education, under the auspices of the National Academies[6]. The European Commission has set up a Mathematics, Science and Technology Cluster to develop STEM education[7]. In 2010, 67 national STEM educators from 15 countries were brought together to develop action plans to support STEM education in Asia[8].

Clearly, developed and developing nations agree that STEM education is important for future prosperity and well-being of the nation and its citizens, yet few of these nations share the current level of prosperity, nor the very positive economic outlook, that exists in Western Australia. Now is the time for Western Australia to invest more strongly in STEM education.

Recommendation 1
Develop and implement a cross-sectoral strategy for improving STEM educational outcomes for all students in early childhood, primary and secondary school settings, especially in the core areas of the Australian Curriculum: science inquiry skills; science understandings; science as a human endeavour; mathematics content; and, mathematics proficiency.

Apart from formal curriculum content, the skills and experience of the teachers play a key role in implementing such a strategy. In the shorter term, much can be achieved by strengthening support for existing STEM teachers through internal and external provision of resources and high quality professional learning. Providing opportunities for real world engagement of teachers and students in examples of science and innovation at work will also be important. Over the longer term, the more strategic issues of improving teacher education, preparation and retention, will need to be addressed.

Engaging STEM teachers: The key

Teachers are the key to strengthening STEM education. In developing a strategy for STEM education in Western Australia, we can draw on experience both here and overseas.

The substantial body of STEM education reports, summarised in the supporting volume, highlights the complexity of STEM education. Nevertheless, the report by the National Research Council in the US cited earlier[6] noted evidence that suggests effective STEM education builds on students' early interests and their views on what they know. It also engages them and provides experiences which sustain their early interest. In other words, context is important.

STEM education reports note overwhelmingly that teachers are the key in this STEM engagement process. According to this US National Research Council report[6], teachers need to be supported by a number of elements, including: *a coherent set of standards and curriculum, teachers with high capacity, a supportive system of assessment and accountability, adequate instructional time, and equal access to quality STEM learning opportunities.*

Many of these elements have been echoed and supported by STEM teachers in Western Australia in their responses to the pilot survey conducted as part of this report and summarised in the

supporting volume. For example, the results from the survey indicate that the two most important attributes of initiatives to support STEM education are: *be linked and relevant to the curriculum*; and, *update and develop teachers' knowledge of the topic.* These essential elements can be provided from both within the education system, and also by external initiatives to support teachers and students. Both sources are currently available to STEM teachers in Western Australia; however, the pilot survey indicates widely varying teacher awareness of their availability. In addition, there is limited evidence of evaluation of the effectiveness of external STEM education initiatives. Clearly, there is scope for significant improvement. A lack of teaching time was also commonly cited by respondents as a barrier to engaging in STEM education initiatives. This is a response that also needs to be addressed.

National standards for teacher preparation, including the preparation of STEM teachers, are being developed[9]. If adopted, many of these standards will meet key needs identified by a number of stakeholders, such as the Australian Science Teachers Association, the Australian Association of Mathematics Teachers, and the Australian Council of Deans of Science in the many reports summarised in the supporting volume.

In addition to the *preparation* of STEM teachers, the issue of teacher *retention* also needs to be considered. This is especially true for Western Australia, where the resources sector has attracted teachers away from the profession. To motivate and retain good teachers will require a number of strategies, including high-quality professional learning.

Primary school teachers require special assistance in the area of science understanding and skills. Evaluation of the *Primary Science Project* in the WA Education Department[10]noted that it takes a number of years to develop the knowledge and skills for effective STEM teaching, a conclusion that points to the need for more sustainable initiatives, rather than 'fixed term' projects. Western Australia requires a sustained commitment to longer-term, professional learning if it is to optimise STEM education.

Early childhood education teachers may not have strong STEM backgrounds and therefore will benefit from productive partnerships with STEM qualified teachers. They will also benefit from the support of external providers and materials such as the recent *Planting the seeds of science* materials[11].

Recommendation 2

Develop short and long-term strategies to develop the expertise of teachers in STEM education of early childhood, primary and secondary school students, including:

- *providing support for STEM teachers through professional learning opportunities and high quality resources;*
- *developing supportive partnerships with external STEM education providers;*
- *further developing STEM teacher undergraduate programs; and*
- *attracting high level STEM graduates to the profession and retaining them.*

Engaging external STEM education providers

As noted above, early childhood, primary and secondary STEM education is the responsibility of the State Government, the Catholic education system and independent schools sector. This formal education is offered to all students and the curriculum is moving to the Australian Curriculum. However, there is also a wide range of activities and resources offered through external STEM education providers. This external sector makes an important, and welcome, contribution to STEM education in Western Australia.

External providers range from the outreach activities of Federal and State Government agencies, universities and statutory organisations, such as Water Corporation, the Museum, and the Zoo; to the activities of a variety of independent bodies and some private sector companies, such as Scitech, CSBP, City Councils, the Gravity Discovery Centre and Earth Science Western Australia. A more comprehensive list is included in the supporting volume.

This study was initiated with the primary aim of identifying these external STEM education providers. It also aims to identify the views of STEM teachers about which attributes will optimise the effectiveness of external supporting initiatives. It is based largely on a pilot survey of STEM teachers and stakeholders, and informed by a comprehensive assessment of the relevant literature, summarised in the supporting volume. The study has also investigated the objectives and activities of a number of the external STEM education providers. Detailed results are included in the supporting volume.

The results clearly show that external STEM education providers in Western Australia offer a rich source of STEM learning opportunities. The more effective providers offer activities and

resources aligned with the curriculum and are also prepared, where possible, to visit schools. Their offerings span the whole range from K-12 and collectively, they address the three strands for science within the new Australian Curriculum. For example, *science inquiry skills and science understandings* are being addressed in external support for science subjects such as biological sciences, chemical sciences, earth and space sciences, and physical sciences. There is also significant support for *science as a human endeavour*. Whilst the focus of external STEM education providers is on metropolitan schools, several extend their activities into rural, regional and remote schools.

Given the rich diversity of external STEM education offerings, it was surprising that some STEM teacher survey respondents were not aware of the opportunities to access resources and support. Their response may reflect communication channels within some individual schools; however, regardless of the reason, it is important that all STEM teachers know about the numerous opportunities to access external STEM education resources and support.

To ensure that this information is readily accessible and available to all STEM teachers, a searchable database of external STEM education providers and their activities and resources is required. Such a database will help to ensure that individual organisations providing external support and resources do not operate in a vacuum, engage in collaboration and avoid overlap. A comprehensive list of STEM education providers is included in the supporting volume.

Recommendation 3
Develop a searchable database of both formal and external STEM providers that documents the activities and resources available to inform and assist STEM teachers and parents.

Partnering to strengthen STEM education

Partnering with community and industry organisations provides an opportunity to develop stronger and more productive partnerships between the formal education system in Western Australia and external providers of support and resources. If this opportunity is seized, it will benefit all STEM teachers and students in the State and will strengthen our future in science and innovation. However, effective outcomes will require encouragement and facilitation.

Some external STEM education providers currently achieve very effective outcomes as a result of close consultation with teachers and the formal education system. As a result, their resources and activities are closely linked to the curriculum and teacher feedback, and they provide school visits where possible. A searchable database will also enable all external STEM providers to learn from the examples and experiences of the more successful initiatives, and thus improve their contributions to teachers and students.

In line with the State Government's Economic Audit Committee report, *Putting the Public First*[12], the proposed approach will foster cross-sectoral collaboration across the Department of Education, the Catholic Education Office and the Association of Independent Schools. TIAC is well placed to provide the leadership needed to achieve more effective and productive interaction between the formal, school-based, STEM education initiatives and the wide range of external initiatives.

A key aspect of effective STEM education is the evaluation of supporting programs and initiatives. STEM partnerships will be strengthened if the external STEM education support providers objectively assess the aims and effectiveness of their programs. For example, one evaluation criterion could be: *How effectively are the external STEM provider initiatives contributing to the State Government's strategy for STEM education in Western Australia?*

The partnership between the formal STEM education system and the external STEM education providers can also be strengthened by closer engagement of the State Divisions of the relevant professional organisations. There are several professional organisations that are closely linked to the sciences in the Australian Curriculum: physics; chemistry; biological sciences; and earth and environmental science; as well as mathematics, technology and engineering. Invariably, these organisations share current concerns about the need to strengthen STEM education in Western Australia. They also recognise the increasing importance of science and innovation to the State. These organisations can become a bridge, by encouraging and assisting some external STEM education providers, or be a direct participant in supporting STEM education. In addition, many of their members provide a direct link to the numerous companies that are also concerned about STEM education, both in a generic sense and also in relation to their future workforce and its level of skills.

Whilst there are many productive possibilities to strengthen STEM education in Western Australia, the key elements will always be: provision of resources closely aligned to the

curriculum; new learning and development opportunities for the teachers; and opportunities to engage teachers and their students in real world examples of science and innovation at work.

Recommendation 4

Develop and implement strategies to strengthen the partnership between the State's formal STEM education system and the external STEM education support providers, including stronger engagement of the relevant professional organisations, with the aim of:

- *increasing STEM resources closely aligned to the national curriculum;*
- *providing new learning and development opportunities for STEM teachers; and*
- *providing teachers and their students with real world examples and experiences of science and innovation at work.*

Towards a more scientifically and technologically literate Western Australia

Strengthening science and innovation in Western Australia is essential if the State is to capitalise on its current fortunate circumstances and ensure a future characterised by enduring prosperity and social well-being. However, these aims will not be achieved without a significant and sustained strengthening of STEM education in our schools. A strategic plan is required and this report, the underpinning literature review and the pilot survey, highlight four key components and a number of specific objectives:

1. **Students:** improve student participation in, and their understanding and enjoyment of, STEM;

2. **Teachers:** strengthen the expertise of teachers in STEM through a combination of short and long term initiatives that will:
   - provide support through professional learning opportunities and high quality resources;
   - enable supportive partnerships with external STEM education providers;
   - further develop STEM teacher undergraduate programs; and
   - attract high level STEM graduates to the profession and retain them.

3. **Resources and Support:** strengthen STEM teaching resources and support by developing a searchable database of both formal and external STEM providers that documents the activities and resources available to inform and assist STEM teachers, external providers and parents; and,

4. **Partnerships:** strengthen and broaden the partnerships between the State's formal STEM education sectors and external STEM education support providers to: increase STEM resources closely aligned to the curricula; provide new learning and development opportunities for STEM teachers; and provide teachers and students with real world examples and experiences of science and innovation at work.

The introduction of the Australian Curriculum provides an opportunity and a focus for developing and implementing a strategic plan built around these four components and their associated objectives. Nevertheless, experience elsewhere indicates that implementation will also require significant investment in enabling support for the curriculum to achieve its full potential, including professional development and resources. This investment can be shared through productive partnerships between the formal education system in Western Australia and the external STEM education providers and their supporters, including industry.

There is considerable scope to strengthen the partnerships between the providers of external STEM education support and the formal education sectors, and to broaden community and industry engagement. One example is by deliberately engaging the State Divisions of those professional organisations closely linked to the sciences in the Australian Curriculum, and also to mathematics, technology and engineering. Not only do they share current concerns about the need to strengthen STEM education in Western Australia, but they also provide a key link to the many concerned companies that do not have the connections to directly make a contribution.

Western Australia has the educational foundation and prosperity to become a leader in science and innovation, in a world where the global investment in R&D has almost doubled in the last eleven years (see page 22 of the education section of *The Australian* newspaper 23.11.11). Strengthening STEM education in our schools is the essential first step along the path to a better educated and more productive work force, a more innovative industry sector, and increasing community well-being.

This report concludes that this first step can be lightened by more effectively harnessing the important external contributions to STEM education in our schools. These important contributions from external organisations can be consciously broadened and deepened to the benefit of all stakeholders, and to the benefit of the State's future prosperity and well-being.

Terms

Taken from:
Towards a 10-year plan for science, technology, engineering and mathematics (STEM) education and skills in Queensland. Retrieved 27 October, 2011 from*:*
http://education.qld.gov.au/projects/stemplan/docs/stem-discussion-paper.pdf

Science is a process of inquiry. It involves questioning, predicting, hypothesising, investigating, gathering evidence, organising data, testing, refining, explaining and communicating. The practice of science has led to an evolving body of knowledge which continues to be built up over time and revised as new evidence comes to light.

Scientific literacy is defined by the Organisation for Economic Co-operation and Development (OECD) as the ability to use scientific knowledge and processes not only to understand the natural world but to participate in decisions that affect it.

Science education is the process through which people learn about science. Formal science education refers to the educative process that takes place in established educational institutions such as schools, training providers and universities. Science education relies on both content knowledge and pedagogy and seeks to balance the principle of scientific literacy against preparing students for more specialised science study or employment.

Technology is often used as a generic term for all the tools people develop and use that involve the purposeful application of knowledge, experience and resources to create products and processes that meet human needs. Technology deals with our usage and knowledge of tools and crafts and how we use them to control and adapt to our environment. It is a consequence of science and engineering and refers to material objects – such as machines, hardware or utensils – but it also covers broader themes, including systems, methods of organisation and techniques. Technology also includes an aspect of enterprise and market analysis.

Technologically literate people can understand the designed world, its tools, systems and the infrastructure to maintain them. They have practical skills in using tools and fixing simple technical problems, they use products appropriate to their needs, and they contribute to decision-making about the development and use of technology in environmental and social contexts. In particular, the use of information and communication technologies is vital in modern contexts.

Engineering refers to the application of scientific principles and the use of technological capabilities to convert natural resources into structures, machines, products, systems and processes for the benefit of society. The application of engineering has increased significantly and affects most aspects of our lives. Fields of engineering are diverse and include manufacturing, process and resources, chemical, mining, materials, automotive, mechanical, industrial, civil, construction, building services, geotechnical, ocean, electrical, electronic, computer, software, aerospace, maritime, environmental, biomedical and transport.

Mathematics is a way of viewing the world to investigate patterns, order, generality and uncertainty.

Mathematical literacy, according to the OECD, is an individual‘s capacity to identify and understand the role that mathematics plays in the world, to make well-founded judgments, and to use and engage with mathematics in ways that meet the needs of the individual‘s life as a constructive, concerned and reflective citizen.

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