INTRODUCTION

Over twenty years of reports and articles from government, business, think tanks and the media have drawn attention to the science, technology, engineering and mathematics (STEM) learning problem. This issue of Policy Insights is informed by a literature and policy review undertaken by the authors in 2017, as well as by the key messages of the ACER 2016 Research Conference, ‘Improving STEM Learning: What will it take?’

Set against Australia’s desire for strong, comprehensive and equitable STEM education is evidence that our education systems are not up to the challenge. Recent results of national and international tests show a continuing decline in performance by Australian students. There are concerns that we do not have sufficient teachers who are qualified to teach STEM subjects. While the curriculum is being modified in an attempt to address changes in STEM, including the introduction of a Technologies curriculum, there is concern that the Australian Curriculum is packaged in discrete disciplines and is not future-facing.

The companion policy and literature review outlines the complex context related to STEM learning and focuses on student outcomes, the teacher workforce and the curriculum. The review sheds light on possible policy directions in each of these three areas, and examines lessons from other countries. STEM education is a broad enterprise that starts in early childhood education, continues through the years of schooling and extends into tertiary education supported by contributions from extra-curricular and enrichment activities, science centres and museums. However, the focus in this Policy Insights is on primary and secondary schooling.
TO INVESTIGATE QUESTIONS RELATED TO CHANGE IN STEM LITERACY AND CURRICULUM REQUIRES AGREEMENT ON EXACTLY WHAT IS MEAN BY STEM. IT APPEARS STEM EDUCATION EITHER HAS SEVERAL DIFFERENT DEFINITIONS (BLACKLEY & HOWELL, 2015; ENGLISH, 2016; ROSICKA, 2016; SIEKMANN & KORBEL, 2016; WALL, 2016), OR IT ENCOMPASSES A CONTINUUM OF CONCEPTS UNDER THE ROOF OF WHAT SIEKMANN AND KORBEL (2016) REFER TO AS THE ‘HOUSE OF STEM’.
STEM EDUCATION POLICIES

Hoyle’s keynote address to the 2016 Research Conference presented an overview of 30 years of STEM education policy in the United Kingdom. It described a rich set of policies and programs, many of which have been evaluated, and most of which involved partnerships between government, education providers, scientific and learned bodies, charities and employers. Hoyle’s list provides a starting point for other countries looking at policy interventions to address STEM literacy challenges. The initiatives have been categorised as follows:

<table>
<thead>
<tr>
<th>Students</th>
<th>Teachers</th>
<th>Curriculum</th>
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<tr>
<td>Selection of senior STEM subjects</td>
<td>Quality of science teachers and lecturers</td>
<td>STEM curriculum development</td>
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<td>Focus on performance in senior secondary</td>
<td>STEM specialist teachers</td>
<td>Coordination of ‘a vast array of curriculum enrichment’</td>
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<td>Choosing careers</td>
<td>Continuing professional development for teachers</td>
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<tr>
<td>Equity initiatives addressing gender and ethnic representation</td>
<td>National STEM Learning Centre and Network</td>
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AUSTRALIAN STEM SCHOOL EDUCATION STRATEGY 2016–2026

On 11 December 2015, the 10-year National STEM School Education Strategy 2016–2026 was endorsed by Australian education ministers. The rationale was that ‘a renewed national focus on STEM in school education is critical to ensuring that all young Australians are equipped with the necessary STEM skills and knowledge that they will need to succeed’ (Education Council, 2015, p. 4).

The Strategy centres on two goals:
- to ensure all students finish school with strong foundational knowledge in STEM and related skills
- to ensure that students are inspired to take on more challenging STEM subjects.

To meet these goals, there are five strategies for action:
1. increase student STEM ability, engagement, participation and aspiration
2. increase teacher capacity and STEM teaching quality
3. support STEM education opportunities within school systems
4. facilitate effective partnerships with tertiary education providers, business and industry
5. build a strong evidence base.

Since then each Australian state and territory government has initiated some form of STEM education policy, and initiated programs that range across the three priorities of student outcomes, teacher workforce and the curriculum (Timms, Moyle, Weldon & Mitchell, 2018). The National Innovation and Science Agenda (Australian Government, 2015) funding supports additional early learning and school-based initiatives.
HOW CAN THE SCHOOL SECTOR MAKE A DIFFERENCE?

A great deal has been written in the past decade on the importance of STEM to Australia’s future. This commentary typically singles out education and training as the key to addressing the challenges identified. While it is not up to education to bear the entire responsibility and cost of increasing STEM capacity on behalf of the nation’s businesses and industries, there is a need for coherent, joined-up policy that includes school education. The following section discusses three specific areas in which the school sector has its strongest chance of making a difference, namely to student outcomes in STEM, the STEM teacher workforce and STEM curriculum.

CHALLENGE 1: IMPROVE STUDENT OUTCOMES IN STEM

Australia’s performance on national and international assessments in mathematics, science and ICT has not changed in one to two decades. Figure 1 summarises student performance on national and international assessments in mathematics, science and ICT.

POLICY INITIATIVES TO IMPROVE STUDENT OUTCOMES

Widespread improvement of student outcomes in STEM cannot be achieved through a single intervention. It will require a strategic combination of approaches, each carefully evaluated.

SMART MONITORING

In mathematics in Australia, we see achievement gaps between students from different socioeconomic backgrounds persist across year levels (Masters, 2015). Unfortunately, Australia only conducts a sample assessment in science at primary school Year 6 and then uses PISA as its measure for secondary school, so we cannot examine how the achievement gaps for science persist over time.

The kinds of skills that need to be learned and applied in STEM are complex. While conventional assessments of multiple-choice and written response items can assess knowledge and some of the skills, they are limited. It can be hard to assess science inquiry skills, the ability to write code or the application of engineering principles, using static assessment items. Full appraisal of these skills can only be achieved through practical assessments or through the use of technology via simulations and other interactive assessments. A promising avenue is to embed assessments into the learning materials to provide continual feedback to learners and summaries of progress to teachers in what has been called ‘third generation assessments’ (Bennett, 2015). This approach has the capability of measuring core skills in science and producing reliable and valid formative and summative assessments (Quellmalz, Timms, Silberglipt & Buckley, 2012).
### Challenges in Improving STEM Learning in Australian Schools

| Year 3 | **Numeracy** | No change in average performance between 2008 and 2017.¹ |
| Year 4 | **Mathematics** | No change in average performance between 2007 and 2015. |
|        |                | 30% did not achieve the proficient standard for Australia in 2015.² |
| Year 5 | **Numeracy** | Slight increase in achievement between 2008 and 2017 but no change in the number of students working at or above the national minimum standard.³ |
|        | **Science** | No change in average performance between 1995 and 2015. |
|        |                | 25% did not achieve the proficient standard for Australia in 2015.² |
| Year 6 | **ICT literacy** | Average performance was significantly lower in 2014 than in 2011, although similar to 2005 and 2008. |
|        |                | 45% of students did not meet the proficient standard.⁴ |
| Year 7 | **Numeracy** | No change in average performance between 2008 and 2016.¹ |
| Year 8 | **Mathematics** | No change in average performance between 1995 and 2015. |
|        |                | 36% did not achieve the proficient standard for Australia in 2015.² |
| Year 9 | **Science** | No change in average performance between 1995 and 2015. |
|        |                | 31% did not achieve the proficient standard for Australia in 2015.² |

**Figure 1** Summary of student performance on national and international assessments, by year level

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¹ NAPLAN (ACARA, 2017a)  
² TIMSS (Thomson, Wernert, O'Grady & Rodrigues, 2017)  
³ NAP Science (ACARA, 2017b)  
⁴ NAP ICT (ACARA, 2015)
### Challenges in Improving STEM Learning in Australian Schools


<table>
<thead>
<tr>
<th>Subject</th>
<th>Key</th>
<th>Notes</th>
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<tbody>
<tr>
<td><strong>Mathematics</strong></td>
<td><strong>Performance declined significantly in 2015 compared to 2012 results. In 7 states (except Victoria), average scores declined significantly between 2003 and 2012.</strong></td>
<td>- 45% of Australian 15-year-olds did not meet the nationally agreed minimum standard in mathematics in 2015, compared to 42% in 2012 and 36% in 2009.5</td>
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<tr>
<td><strong>Science literacy</strong></td>
<td><strong>Australia has shown a significant decline in scientific literacy performance between 2006 and 2015.3</strong></td>
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<tr>
<td><strong>ICT literacy</strong></td>
<td><strong>Average performance was significantly lower in 2014 than in all previous cycles.</strong></td>
<td>- 48% of students did not meet the proficient standard, compared to 34% in 2011.4</td>
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<td><strong>Mathematics</strong></td>
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<tr>
<td><strong>Physics</strong></td>
<td><strong>Year 12 students studying physics declined from 21% in 1992 to 14% in 2012.</strong></td>
<td>- Three quarters of students studying physics in 2012 were male.7</td>
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<tr>
<td><strong>Chemistry</strong></td>
<td><strong>Year 12 students studying Chemistry declined from 23% in 1992 to 18% in 2012.7</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Biology</strong></td>
<td><strong>Year 12 students studying biology declined from 35% in 1992 to 25% in 2002 but enrolment has been relatively stable since.</strong></td>
<td>- About two thirds of students are female.7</td>
</tr>
</tbody>
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**Key**
- Large decrease
- Small decrease
- No change
- Small increase
- Large increase

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**Notes**

1 NAP ICT (ACARA, 2015)
2 PISA (Thomson, DeBortoli & Underwood, 2017)
3 Wienk 2015
4 Kennedy, Lyons & Quinn, 2014
5 PISA (Thomson, DeBortoli & Underwood, 2017)
6 Wienk 2015
7 Kennedy, Lyons & Quinn, 2014
EARLY INTERVENTION AND ACCESS FOR ALL

A study conducted in the United States by Morgan, Farkas, Hillemeier and Maczuga (2016) showed that science achievement gaps begin very early in life and persist over time. From a longitudinal study of over 7000 students, they found that some groups of students entering school were far less knowledgeable about the natural and social sciences than their peers. These general knowledge gaps strongly predicted poor performance through the first four years of school. The conclusion to their longitudinal study echoes Evans’ (2005) recommendation:

... policymakers and practitioners may need to increase the provision of early intervention efforts in science – particularly for at-risk populations – if science achievement gaps are to be narrowed or closed.

An Australian Government project that is working toward this is the Early Learning STEM Australia (ELSA) project. ELSA is a play-based digital learning program for children in preschool to explore STEM.

Females continue to be underrepresented in STEM-related courses and careers. Females’ motivation to pursue STEM in senior secondary can be determined by their exposure to STEM prior to and during school.

There is a need to get girls enthusiastic about STEM prior to and throughout their schooling. Female role models in STEM are one enabler; through school visits by women working in STEM, female STEM teachers and researchers. The University of New South Wales facilitates ‘Science 50:50’, which engages girls through school visits, online resources, facilitating mentoring experiences and access to STEM facilities on-campus.

The Office of the Chief Scientist’s STARportal (2017) links to a multitude of clubs and challenges for students interested in robotics, coding and engineering. The majority of these are extension activities offered out of school hours to engage participants who generally have an existing interest and capacity to pay. Policymakers and providers face a dilemma in scaling these kinds of initiatives to ensure equitable access.

The real challenge is to invest in creating the same level of engagement and excitement about STEM as part of the standard program in all early childhood centres, in all schools across the community, for all students.

The opportunity to be directed towards STEM should not depend on access to extracurricular enrichment activities.
SPECIALIST STEM SCHOOLS

Across Australia, the introduction of specialised STEM schools has been one policy aimed to increase student engagement in STEM and provide a targeted education, following a path taken by other countries. According to American researchers Erdogan and Stuessy (2015), specialised STEM schools have been around for over 100 years and they fall into three categories:
1. selective STEM schools
2. inclusive STEM schools
3. schools with STEM-focused career and technical education.

In Australia, examples of specialist STEM schools include the John Monash Science School in Melbourne – associated with Monash University; the Queensland Academies – Science, Mathematics and Technology Campus (QASMT), which has credit arrangements with the University of Queensland; and the Australian Science and Mathematics School established on the Flinders University campus in Adelaide in 2003 (Bissaker, 2014).

A recent example of the establishment of schools with STEM-focused career and technical education can be seen in a $128 million program to construct ten Tech Schools on TAFE and university campuses across Victoria (Department of Education and Training Victoria, 2017).

Another way to encourage students to specialise in STEM is to create a career academy – what has been described as a ‘school-within-a-school’. About 2550 high schools in the United States have created career academies and some focus on STEM subject areas. The career academies are multi-year programmes with integrated academic and career technical content organised around broad career themes (Institute of Education Sciences, 2006). There are existing Australian schools with specialist STEM programs in several states and territories, with a new $100m STEM and health science focused school planned to open in Adelaide in 2019.

COMMUNITY CONNECTIONS

Student and teacher interest in STEM is one of the challenges facing schools. Strategies that focus on engagement with ‘real-world’ STEM can contribute to increased levels of motivation through informal learning opportunities. A plethora of programs exist that promote this connection with industry, with STEM-related institutions, and involvement in community initiatives. These include citizen science activities, coding clubs such as CoderDojo, and challenges such as the STEM Video Game Challenge.

Improving student outcomes across the full range of STEM will take a combination of approaches. Four things that need to be addressed include:
- monitoring STEM learning skills more broadly over time rather than just testing knowledge in summative assessments
- developing early intervention programs to close the gaps that will otherwise persist over time
- encouraging broader participation through specialised STEM schools and career academies
- stimulating interest in STEM through accessible and affordable out-of-school activities.
CHALLENGE 2: BUILD THE STEM TEACHER WORKFORCE

The Organisation for Economic Co-operation and Development (OECD) (2012) and the Productivity Commission (2012) have noted the undersupply of science and mathematics teachers in Australia. Previous studies show that this is not a new problem (e.g. Department of Education, Science and Training (DEST), 2003; Eacott & Holmes, 2010; McKenzie, Rowley, Weldon, & Murphy, 2011; Stokes & Wright, 2007).

About 60 per cent of secondary teachers are women; however, in most sciences (except biology and general science), there are still greater numbers of male teachers, which is also the case for mathematics and computing/IT. In science and mathematics, a greater proportion of male teachers is retiring from the profession at the same time as the proportion of men entering it continues to decline. Male-dominated subjects are likely to suffer teacher shortages, especially in the context of a booming primary student population about to enter secondary schooling (Weldon, 2015).

Figure 2 shows that biology and general science are the most popular science specialisations for pre-service teachers; biology has almost twice as many final-year enrolments as chemistry, and over three times as many as physics (Weldon, Shah & Rowley, 2015).

Lack of teachers with subject specialisations leads to teachers teaching outside their specialisation, known as teaching out of field.

Out-of-field teaching is common in Australia (Queensland Audit Office (QAO), 2014; Weldon & Ingvarson, 2016).

According to Staff in Australia’s Schools (SiAS) data, 23 per cent of primary teachers have no tertiary studies in either mathematics or numeracy, and 26 per cent say they have no teaching method studies qualifications in either area.¹

Figure 3 illustrates the interplay of the challenges of shortages in the teacher workforce and the challenges from the lack of interest of students in STEM. Together the two sets of problems are reinforcing a downward spiral in STEM teaching and learning.

POLICY INITIATIVES TO BUILD THE STEM TEACHER WORKFORCE

Australia will not be able to deliver the STEM curriculum it envisages or raise student outcomes unless it has the qualified teachers to deliver it. But, to better target workforce policies to appropriate areas, we need to know where the issues lie. Teacher workforce data collection in Australia is limited and leaves considerable gaps in our knowledge. Universities have records of the subject areas in which teacher education graduates specialise. However these data are not routinely collected nationally.

¹ Additional analysis of SiAS 2013 data for this report (the SiAS 2013 report shows mathematics and numeracy separately) was not clear whether primary teachers who did not have teaching methods qualifications in mathematics did so in numeracy.
Primary students have not improved over time and a significant proportion do not achieve to expected standards, particularly in low SES areas.

Students with high ATARs are less likely to undertake a teaching qualification. Regional and rural students are less likely to undertake a degree.

Students in Year 7 show no improvement over time. Fewer achieve expected standards by Year 8. By Year 10, performance in mathematics and science is in decline.

Student performance in Year 7 shows no improvement over time. Fewer achieve expected standards by Year 8. By Year 10, performance in mathematics and science is in decline.

Many university science and engineering courses do not require advanced Year 12 subjects and there is evidence that easier Year 12 subjects are taken to improve ATAR outcomes.

Primary teachers have low levels of specialisation in STEM fields. There is little time in the curriculum for science.

Primary students have not improved over time and a significant proportion do not achieve to expected standards, particularly in low SES areas.

At secondary level, regional and rural schools may have difficulty recruiting quality teachers. Many mathematics and science teachers are out-of-field, particularly in Years 7–10.

Many university science and engineering courses do not require advanced Year 12 subjects and there is evidence that easier Year 12 subjects are taken to improve ATAR outcomes.
INCENTIVES TO QUALIFY AS A STEM TEACHER

Providing incentives is a common method to attract people to STEM teaching. Specialists in shortage subject areas are offered incentives to enter teaching. Schools that are hard to staff also use similar tactics. These can be financial incentives in the form of scholarships, payment of tuition fees or bonus payments for working in a location for a given amount of time (Weldon et al., 2015). Another incentive might be to offer a permanent or ongoing position – a guarantee of work.

Reports from England and Australia suggest that these incentives are generally successful, although there is little evaluation of the extent to which incentives attract teachers who would not otherwise have entered or returned to teaching.

BETTER DATA TO POWER BETTER POLICY

We need better data in order to target better policy in Australia, and better evidence on where the issues are. High quality teachers make a difference, that is, teachers who have a deep knowledge of their field and deep understanding and extensive experience of how to teach it. Some data are available, telling us:

- it is common for more experienced teachers to teach senior secondary level
- there is more out-of-field teaching at Years 7–10
- few primary teachers have a strong background or tertiary qualification in science or mathematics
- fewer teachers in STEM subjects graduate each year compared with English, social studies and health and physical education.

But we do not know where these teachers go, what they do or how long they stay.

Australia, like other countries such as England, has a history of using a variety of incentives to encourage participation in teaching. We need more data to understand where in the teacher supply pipeline we might best target such incentives, and data over time to enable us to gauge to what extent those incentives or policies are working. Options include targeting:

- school leavers with strong STEM results to undertake a STEM degree and then a teaching qualification
- STEM degree graduates to undertake a teaching qualification
- mature-age potential career changers from STEM areas to undertake a teaching qualification
- newly qualified STEM teachers to enter low SES schools, hard-to-staff schools and schools in rural and remote areas
- experienced STEM teachers to teach in low SES schools, or to teach younger students
- STEM teachers from overseas to teach in Australia (regional and low SES schools).

Some states have implemented a number of these targeted options. Sharing the impact and issues across jurisdictions is needed to determine effective longterm strategies.

Other options include policies that focus on strategies for:

- lowering the rate of students dropping out of STEM subjects at senior secondary level
- lowering the rate of Initial Teacher Education students who drop out of teaching degrees
- lowering the attrition rate of early career teachers.
CHALLENGE 3: RETHINK THE STEM CURRICULUM

A third element of the STEM education equation is the curriculum. The Australian Curriculum is not based on a modern conceptualisation of STEM. It is structured around discrete learning areas, and does not integrate explicit STEM learning progressions across the school years.

There are a number of challenges in planning STEM curricula.

First, if one embraces the concept of STEM as a meaningful interdisciplinary approach to learning, then schools should be addressing all parts of STEM. To date in Australia, the emphasis has been on the M (mathematics), which is reinforced by the choice in NAPLAN to assess all students in numeracy at Years 3, 5, 7 and 9. In contrast, science literacy and information and communication technology (ICT) literacy are only assessed in a sample of schools every three years. Also, ICT literacy assessments are given just to students in Years 6 and 10, while science assesses only Year 6. There is no curriculum or assessment of engineering.

The second challenge is choosing what to include from each discipline and where to place the emphasis. Each area of STEM comprises multiple sub-disciplines. Within science there are the traditional divisions of biology, chemistry, physics and earth sciences, but these can be fragmented into a multiplicity of sizeable fields. This complex pattern of disciplines and sub-disciplines applies to all four components of STEM.

A third challenge is that knowledge building proceeds at a tremendous rate across STEM and particularly in science and technology. Whole new sub-disciplines emerge quite rapidly such as bioinformatics, which was first used as a term in 1970 but has really taken off in the last two decades due to advances in genetic research, technology and mathematics.

A fourth challenge that is related to those already outlined is how to fit a modern and more inclusive version of STEM into an already crowded curriculum (Lloyd, 2013).

In summary, if STEM is to be truly implemented, curriculum designers will have to address how to ensure that all four parts of this challenge are addressed and cope with defining the knowledge and skills necessary for each discipline in a durable way that is able to accommodate future changes in disciplinary knowledge and scope. The designs will have to account for the limited space in the overall curriculum and assessment systems will have to reflect the breadth of STEM.
POLICY INITIATIVES TO RETHINK THE STEM CURRICULUM

DEVISE A NEW DEFINITION OF STEM CURRICULUM

To make progress on planning an integrated STEM curriculum, we need a new shared definition of what STEM is. Much of the academic literature addresses how STEM subjects are linked without providing a rationale as to why they belong together. A way to look at STEM is to define it as the set of disciplines that work together to understand and model the universe so that people can solve problems through harnessing and manipulating the world around them. Figure 4 represents the main linkages among the disciplines in this approach.

Shift to an emphasis on practice

In this model, the major focus of science is to investigate and understand the universe, while engineering’s is to solve the problems we experience living in the world (such as harnessing and using energy in clean and efficient ways). Mathematics is also part of understanding the universe, and it provides ways to represent and model that are applied in the other disciplines. Technology is also involved in understanding, but is focused on manipulation of the matter and energy around us in order to solve problems. Although in this representation each discipline touches only two others, it is accepted that all disciplines are connected.

SHIFT TO AN EMPHASIS ON PRACTICE

Adopting the model shown in Figure 4 gives a way of arriving at a cohesive, integrated STEM curriculum, but to do so, the educational emphasis needs to be on learning and applying the practices and ways of thinking in a discipline. That is not to say that disciplinary knowledge is not important but it should not be the main focus in an integrated STEM curriculum. Internationally, there are examples of curricula that have made this shift.

In science, the United States of America has created the Next Generation Science Standards (NGSS) (2013) to set out what young people should know and be able to do in science. It does not specify what should be taught or how it should be taught, only the standards that should be achieved. The NGSS are based on an earlier Framework for K–12 Science Education (National Research Council, 2012) that emphasised the practices, cross-cutting concepts and core ideas for the discipline rather than the subject areas within science.

An example from mathematics in which the curriculum focus was shifted away from the knowledge components of the discipline and placed on the skills needed to apply mathematics can be seen in the KOM curriculum approach taken in Denmark (Højgaard, 2009). The Danes have organised their curriculum around a set of mathematical competencies rather than content area divisions. In the KOM approach – an acronym in Danish that stands for Competencies and the Learning of Mathematics – mathematical competence is defined as ‘the ability to understand, judge, do, and use mathematics in a variety of intra- and extra-mathematical contexts and situations in which mathematics plays or could play a role.’ This approach provides a more skills- and application-focused view of mathematics that makes it easier to integrate with other STEM disciplines.
Including the technology and the engineering from STEM in the already crowded school curriculum is a challenge because, unlike science and the mathematics, they have not been a traditional part of the curriculum. There has been a recent push to include technology in Australia via the introduction of the Australian Curriculum: Technologies that focuses on systems thinking as a unifying approach so that students can develop the technologies knowledge, understanding and skills that are needed in modern society and the workplace of tomorrow (ACARA, 2017c).

Not many countries have developed a comprehensive school curriculum for engineering. In Australia, engineering is typically featured as a choice for students in Years 11 and 12. The UK offers engineering as a subject choice for its General Certificate of Secondary Education (GCSE) assessment program that students usually take at age 16 but there is no curriculum for primary years. In the United States, the National Assessment Governing Body that operates the National Assessment of Educational Progress developed a new Technology and Engineering Literacy (TEL) Framework and assessment. The framework focuses on the level of knowledge and competencies about technology and engineering needed by all students and citizens to function in a technological society (National Assessment Governing Board (NAGB), 2014).
An integrated STEM curriculum has been defined as ‘an effort to combine some or all of the four disciplines of science, technology, engineering, and mathematics into one class, unit, or lesson that is based on connections between the subjects and real-world problems’ (Moore & Smith, 2014).

An integrated STEM curriculum needs to be carefully designed. At present, we teach the content and skills of each discipline and hope that students will see the connections to real-life applications. An integrated approach needs to locate the connections between STEM subjects and create a relevant context in which essential skills from each discipline can be developed, and content can be learned. Of the four subjects, engineering seems to offer the best scope to create problem-based curriculum units that allow integration of the subject areas, but the other subjects also offer opportunities.

In summary, contemporary approaches to integrated STEM curriculum include:

- a definition of what is meant by an integrated STEM curriculum
- an integrated approach that combines at least two of the STEM strands
- a focus on the practices, skills and capabilities of the disciplines rather than on particular components of disciplinary knowledge
- a consideration of the long-term currency of the curriculum in the face of expansion and progression of the disciplines by focusing on core ideas
- a design for the acquisition and development of skills across the years of schooling by focusing on cross-cutting and recurring themes in the disciplines.
CONCLUSION

Australian STEM education seems caught in a whirlpool of problems that are contributing to one another. Student engagement and performance in STEM are declining, but we do not have the supply of qualified teachers we need to improve learning. The STEM curriculum is unbalanced and fragmented, leading to less interest among students. It is not possible to break out of the downward cycle from within the current system and it requires policy changes that address the issues raised in this report. This means developing well-considered, systemic and joined-up policies that address the following challenges.

CHALLENGE 1: STRATEGIES FOR IMPROVING STUDENT OUTCOMES

- Monitor STEM learning skills more broadly over time rather than just testing knowledge in summative assessments.
- Develop universal and early intervention programs to close the gaps that will otherwise persist over time.
- Encourage broader participation through specialised STEM schools and career academies.
- Stimulate interest in STEM through accessible, affordable out-of-school activities.

CHALLENGE 2: STRATEGIES FOR BUILDING THE STEM TEACHER WORKFORCE

- Deliver better data on the teacher workforce to power better policy.
- Offer tangible incentives to qualify and work as a STEM teacher.

CHALLENGE 3: STRATEGIES FOR RETHINKING THE STEM CURRICULUM

- Work from an agreed definition of STEM curriculum.
- Shift to an emphasis on STEM practices.
- Move towards an integrated STEM curriculum.
REFERENCES


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