



Transforming STEM teaching in Australian primary schools: everybody's business

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A strong economy in the twenty-first century prospers through science, technology, engineering and mathematics (STEM). Across the world, nations are competing for the high-growth firms and highly capable workers of the future; and securing the pipelines in their education systems today. They know that children entering the education system in 2016 will be joining a very different workforce in 2030. They see the rising premium on skills in STEM. In these nations, STEM education counts.¹

We can learn from high performers. We must, because the evidence indicates that we are falling behind² (Figure 1).

We know what it takes to do better. STEM education begins in primary school,ⁱ and here teachers make a serious difference. It is great teaching, more than any other attribute, which accounts for the success of the world's best performing school systems.³

Great teachers are intellectually capable, passionate and knowledgeable about their subjects, rigorously prepared and well supported and resourced. They inspire students to learn and to immerse themselves in a topic. Great education systems develop and retain these teachers, by making teaching the attractive and prestigious profession it ought to be.⁴

We can make it so in Australia, if we choose. After numerous Commonwealth and state reviews into teacher education over the last 20 years,⁵ we ought to know how. And we must do it – in the interests of an Australia that is positioning itself in a changing world.

The Australian Government has signalled its determination to act, restoring the focus on science and mathematics in the curriculum and teacher education, and committing to a national strategy for STEM in schools.

'For too long the issues about STEM in education have been neglected... We cannot be an innovative, agile and creative nation unless we have a quality education system that is interlocked and produces the skills needed in the future.'

- Senator the Hon Simon Birmingham, 29 October 2015

The **vision** for Australia must include an education system that expects and achieves a high level of student achievement, mastery, enjoyment and innovation in science,

technology and mathematics, year after year – through well-resourced, knowledgeable, inspiring and passionate teams of teachers.

The **issues** that need to be addressed are both immediate and inter-generational, requiring a response that is both urgent and sustained.

The **magnitude** of the challenge demands collaboration, at scale, through a new and genuinely national approach that embraces public and private investment.

These are the steps we can take today to make great teaching of science, technology and mathematics the norm in Australian schools, and teaching a profession of choice for our high achievers.

1. Raise the prestige and preparedness of teachers, by
 - (i) Attracting high achievers in STEM to primary school teaching.
 - (ii) Boosting the science, technology and mathematics in pre-service teaching and increasing the rigour of pre-service courses.
2. Transform STEM education in primary schools, by
 - (iii) Ensuring teachers in every school are supported by specialist teachers in STEM disciplines.
 - (iv) Creating a national professional development program in science, technology and mathematics.
 - (v) Educating principals to be leaders in STEM.
3. Think bold, collaborate and lead change.

i. In this paper the acronym STEM is used to describe the STEM subjects taught in Australian primary schools: science, mathematics and technology (which can include engineering).

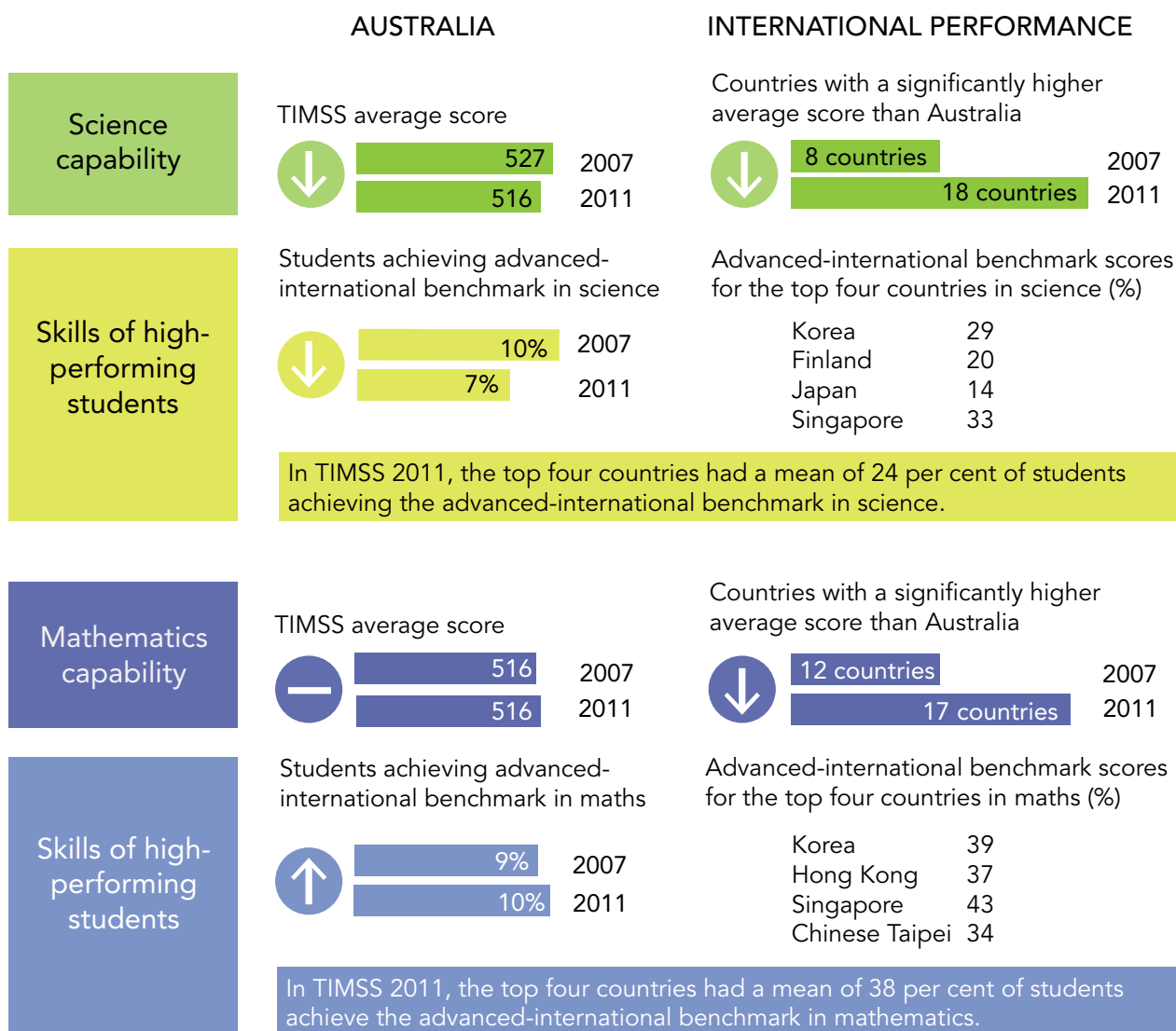


FIGURE 1: In the Trends in International Mathematics and Science Study (TIMSS), the performance of Australian Year 4 students in science declined between 2007 and 2011. The number of countries outperforming Australian students in both science and mathematics increased.

Source: S. Thomson, et al., "Monitoring Australian Year 4 student achievement internationally: TIMSS and PIRLS 2011".

1. RAISE THE PRESTIGE AND PREPAREDNESS OF TEACHERS

(i) Attracting high achievers in STEM to primary school teaching

'Once teaching became a high-status profession, more talented people became teachers, lifting the status of the profession even higher... Where the profession has a low status, it attracts less talented applicants, pushing the status of the profession down further and, with it, the calibre of people it is able to attract.'⁶

In the world's highest-performing school systems, entry to teaching is as competitive as entry to medicine, law and engineering. The ratio of applicants

to places in Finland, for example, is 10 to 1.⁷

In these systems, selection occurs **before the start** of teacher training. In systems where the selection process occurs after teacher training, too many students are trained – leading to a glut of teachers, a drop in the quality of both the trainees and the courses and a diminution of the prestige of teacher training.⁸

In Australia, there is a significant gap between ATAR entry levels for teaching in comparison to other courses. In 2015, only 21 per cent of Year 12 offers for places in teacher education courses went to students with ATAR scores above 80, compared with 65 per cent for science and 69 per cent for engineering. Of the 46 per cent of students who entered teaching courses using an ATAR, twice as many entered with a score under 50 as did with a score over 90.⁹

Seventy nine per cent of respondents to a 2014 survey of mathematics teacher educators reported that students entering their courses had either a poor mathematical background, or significant gaps in their mathematical knowledge.¹⁰ Many aspiring teachers displayed significant levels of ‘mathematics anxiety’.

An individual’s knowledge and academic background in STEM is strongly linked to their capacity to teach it.¹¹ Teaching is an intellectual activity that requires academic capacity.¹² The evidence suggests that increasing academic standards at entry also helps to attract strong candidates and raises the prestige of the profession in the community.¹³

More of the high-performing school cohort could be encouraged to consider a career in teaching by following the lead of New South Wales. From 2016, to study to be a teacher in NSW, a student will require:

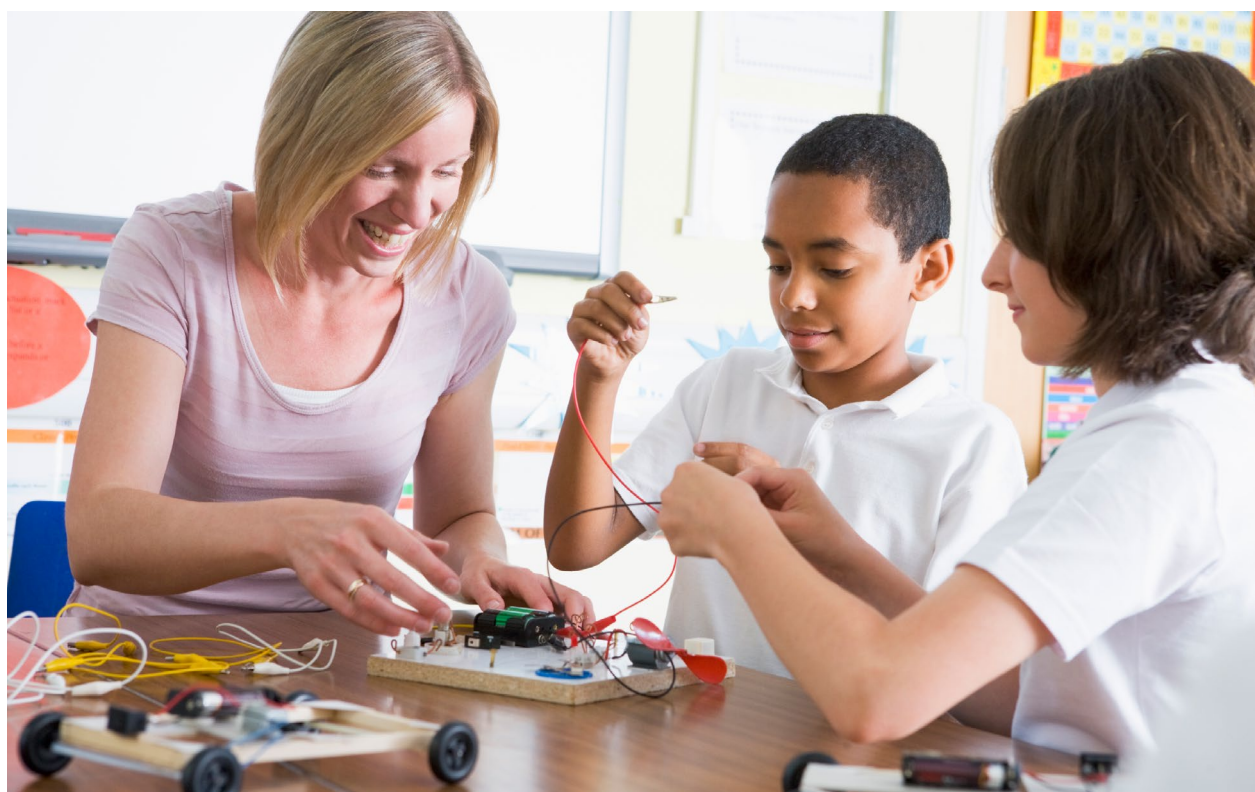
1. At least three Band 5 HSC results, including one in English¹⁴ or
2. A pass in bridging units benchmarked to a Band 5 HSC result or
3. Enrolment in an accredited degree and pass a full year of academic studies in required subjects or
4. Completion of a BOSTES approved alternative entry pathway as advised by the prospective university.¹⁵

Alternative entry pathways should also be benchmarked to Band 5, and all four pathways should include at least one science or mathematics subject. Given the mutual recognition of teacher registration between jurisdictions, this standard (or the nearest local equivalent) could be adopted nationally.

A prestigious national public-private scholarship could also be established to encourage students to become STEM specialist teachers through the completion of a degree in a STEM discipline followed by appropriate pedagogical training and employment. These scholarships could be provided as loans, and written off according to the number of years spent in primary teaching, with a view to attracting high performers and subject specialists to schools in need.

(ii) Boosting the science, technology and mathematics in pre-service teaching and increasing the rigour of pre-service courses

Many students entering teacher training courses have not thrived in science, technology or mathematics in their own schooling, nor have they been encouraged to continue these subjects to Year 12.¹⁶ For these students, teacher training needs to play a critical remedial role. For all students, it needs to provide the best possible knowledge of content and pedagogy.





There are more than 150 accredited primary school teacher training courses in Australia.¹⁷ Graduates report a lack of preparedness to teach STEM. Primary school teachers surveyed in 2014 rated science content low in their pre-service training, at an average 5.2 points out of 10, while science pedagogy was rated 5.1 points.¹⁸ Digital technology was a particular source of anxiety, with many respondents unaware of the need to teach it, or how to teach it well.¹⁹

We know that primary school principals are also concerned with the preparedness of graduates to teach mathematics, with 51 per cent reporting in 2015 that their graduate teachers ‘could not teach mathematics to a reasonable level’.²⁰ These concerns were echoed by mathematics teacher educators who reported that insufficient time is allocated to mathematics in pre-service education.²¹

Mathematics is central. Student success in STEM is dependent upon an understanding of mathematics and the ability to apply it.

Technology encourages creativity, innovation and enterprise – skills integral to the future economy – and its importance is recognised in the form of the new Technologies curriculum.²² Yet it is only included in pre-service education in a small number of universities.

To lift our game, we must collaborate to develop an agreed national minimum curriculum and standards in science, technology and mathematics for primary school pre-service teachers. We must make collaboration between education and STEM faculties routine and address the incentive structures in universities which often prevent it.²³ Discipline content should be taught well by discipline experts, and pedagogy by pedagogical experts.

The *Enhancing the Training of Mathematics and Science Teachers* programme,²⁴ involving 25 universities and funded by the Australian Government, provides innovative approaches and supplies the evidence base we need for action.



2. TRANSFORM STEM EDUCATION IN PRIMARY SCHOOLS

(iii) Teachers in every school supported by specialist teachers in STEM disciplines

Confidence in teaching science is highest amongst primary school teachers with a science qualification. These teachers tend to devote more classroom time to science, rely less on textbooks and kits and are more likely to pursue science-focused professional development.²⁵

The appointment of specialist teachers has been consistently shown to improve student outcomes.²⁶

Currently only a minority of Australia's primary school teachers have an educational background in a STEM discipline. In 2011, only 16 per cent of Year 4 students were taught science by a teacher who specialised or majored in science and only 20 per cent had a teacher who specialised in mathematics.²⁷ Fewer than one in three primary teachers has completed any tertiary study in computing or information technology.²⁸

The Australian Government has announced that all future primary pre-service teachers will be equipped with at least one subject specialisation, including a priority on science and mathematics.²⁹ Over time, we can expect to have access to far greater STEM

expertise in schools. In the short term, all primary teachers should have access to specialist STEM teachers as co-teachers, coordinators, mentors, and providers of sustained professional development.

School systems and universities could define the expectations for these specialists and the best ways for them to be deployed in schools. Their role will be to ensure that all students demonstrate appropriate skills in STEM subjects at the end of primary school.

(iv) A national professional development programme in science, mathematics and technology

STEM knowledge is dynamic. Content, teaching practices, resources, and approaches to assessment constantly evolve. In particular, ICT education has moved from preparing students to use technology, to equipping them to understand its concepts and workings.³⁰ Teachers must be supported to keep pace with change, and to keep their knowledge up to date amidst the day-to-day pressures of the classroom.

High performing education systems provide the time for teachers to be mentored, master new teaching resources, have their classes observed, and integrate constructive feedback. In Singapore, teachers receive 100 hours of professional development every year, in a carefully structured programme.³¹ These education systems recognise teachers as valued professionals; teaching as a critical and complex task; and continual improvement as the universal goal.³²

BOX 1: Making professional development work in Australia

In science, **Primary Connections**³³ is a leading programme with a long track record of success. Teachers have gained the confidence to increase the classroom time devoted to science, and achieved strong improvement in student performance.

The **Australian Mathematics and Science Partnership Programme** is making professional learning resources for mathematics easily accessible via the Australian Association of Mathematics Teachers (AAMT) DIMENSIONS web portal.³⁴

The Australian Government's **Mathematics by Inquiry** and **Coding Through the Curriculum** initiatives will generate new teaching resources for these subjects, linked to the Australian Curriculum.³⁵ In the first, the Australian Academy of Science is working with the AAMT to improve the tools and guidance provided to teachers to target problem solving and reasoning.

The University of Adelaide's **Digital Technologies MOOC**³⁶, supported by Google, provides a starting point for teachers approaching the new digital technologies curriculum.

CSIRO's **CREativity in Science and Technology (CREST) awards**,³⁷ and the **Young ICT Explorers competition**³⁸ support students to design and carry out their own open-ended science investigation or technology project. CSIRO's **Scientists, Mathematicians and ICT Professionals in Schools**³⁹ can support and mentor teachers to implement these initiatives.

Questacon's National Outreach programmes, the **Ian Potter Foundation Technology Learning Centre**, and the **National Mentoring for Science and Mathematics Teachers Project** provide important professional development opportunities for teachers.

Australia's education systems are committed to professional development in principle, but often struggle to reflect it in practice. Just 30 per cent of Year 4 students are taught science by a teacher who has undertaken professional development in the subject during the preceding two years.⁴⁰



Universities are well-placed to collaborate together, with the teaching profession and with school systems to deliver nationally consistent professional development. The most successful Australian STEM education initiatives have been based on evidence, had a large reach, and combined professional learning with mentoring and curriculum resources (see Box 1).

Any professional development programme must address existing barriers including the cost of relief teachers, the need to balance online professional development with face-to-face, and servicing the needs of regional and remote schools. A national

professional development programme in STEM, built by universities, the teaching profession, agencies, and education authorities in close collaboration, will learn from and share what works in every jurisdiction and system and achieve consistent success.

(v) Educating principals to be leaders in STEM

We know that principals create the environments in which teachers succeed or fail in improving STEM education.⁴¹ They signal to teachers where the school's priorities lie and what standards are expected, as well as controlling access to the available resources and support.

Some schools, under some principals, have achieved significant progress in mathematics in a relatively short window of time, as NAPLAN data confirms. The Office of the Chief Scientist has commissioned new research to identify these schools and learn from their approaches to form a national picture of best practice.⁴²

Change begins at the top, requiring an understanding from principals that STEM is vital; that teachers require time to master it, and to collaborate; and that progress can be achieved and ought to be expected through a whole-of-school approach.

BOX 2: Industry provides and sponsors a wide variety of valuable resources and competitions, including:

The **Young ICT Explorers**⁴³ competition, created by SAP and sponsored by Intel and Deloitte and supported by Digital Careers.

First LEGO League⁴⁴ is sponsored by Macquarie University, AndyMark, Autodesk, Ford, Rockwell Automation, AARNet, National Instruments, BAE Systems, Google and LEGO Education.

Code Club Australia⁴⁵ is sponsored by Telstra, Google and the Australian Government.

Intel provides a range of teaching resources for primary and secondary schools.⁴⁶

The **BHP Billiton Science and Engineering Awards**⁴⁷ for primary and secondary students and teachers, are managed by CSIRO. BHP Billiton also sponsors the Australian Mathematical Sciences Institute's **Choose Maths**⁴⁸ programme to change public perception of mathematics and statistics as a career choice for girls/young women.

Orica is the principal sponsor of the Australian Academy of Technology and Engineering's **STELR**⁴⁹ (Science and Technology Education Leveraging Relevance) programme.

PwC sponsors the Australian Council for Education Research's **STEM Video Game Challenge**⁵⁰; and has launched the **21st Century Minds Accelerator Program**⁵¹ to identify and grow innovative STEM education initiatives.

Digital Careers⁵² is a joint Australian government-industry-universities initiative to raise awareness and interest in ICT careers.

A national programme, Principals as Leaders in STEM — developed with the Australian Primary Principals Association, teachers' associations, universities and industry — would provide principals with the right education, encouragement and resources for a more active and constructive role in STEM education and professional development within their schools.



3. THINK BOLD, COLLABORATE AND LEAD CHANGE

Australia's primary schools are facing considerable challenges in teaching science, mathematics and technology. Deliberate action is needed to enhance the capability of our teachers and schools to develop, access and apply world-class STEM education. Action must be co-ordinated, systematic, monitored and sustained.

Education authorities, industry (see Box 2), universities and others are developing their own approaches and resources for STEM education, in a vast array of disconnected, duplicating and competing programmes. If managed strategically, these could be evaluated and incorporated to enrich education in all primary schools, in line with the Australian curriculum. Australia's federal system offers a testing ground for new ideas, but is only valuable if we evaluate, share outcomes and scale up the lessons of success.

We must implement change, for every school, through a national approach that targets everybody's investment in primary STEM education in line with the evidence of student need and program impact.

System-wide leadership is required to provide focus. A STEM Education Leadership Taskforce reporting to the COAG Education Council can be the focal point for national engagement in STEM education — coordinating industry and education providers in the delivery of STEM education initiatives, evaluating these, and ensuring that every school participates.

Members would include representatives of the Commonwealth, state and territory education departments and other authorities (independent and Catholic); universities; a wide cross-section from industry; CSIRO; the Australian Academy of Science; the Australian Academy of Technology and Engineering; the Office of the Chief Scientist; the Australian Institute for Teaching and School Leadership; the Australian Curriculum, Assessment and Reporting Authority; and principals' and teachers' associations.

The Taskforce would:

- ▶ Set a national minimum curriculum and standards in STEM for primary school pre-service teachers
- ▶ Identify, evaluate, develop and coordinate teaching practices and resources
- ▶ Nationally coordinate and provide professional development for teachers
- ▶ Develop and implement a comprehensive programme for principals and STEM leaders
- ▶ Ensure that teachers in every school have access to STEM specialist teachers.

Getting primary school teaching right is vital to securing Australia's STEM pipeline, equipping students with the creative problem solving, critical thinking, active learning and quantitative skills they need for a future dependent on STEM.

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CONSULTATION

In 2014 the Office of the Chief Scientist (OCS) commissioned the Australian Science Teachers Association (ASTA), supported by the Australian Primary Principals Association (APPA), to survey more than 800 primary school teachers and principals, and the Australian Association of Mathematics Teachers (AAMT) and the Mathematics Education Research Group of Australasia (MERGA) to conduct a survey of, and roundtable consultation with, mathematics teachers and teacher educators.

In conducting our research the OCS consulted with: AAMT; Australian Industry Group; ASTA; APPA; MERGA; the Australian Government Department of Education and Training; and state and territory departments of education.

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