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MATHEMATICS, ENGINEERING & SCIENCE IN THE NATIONAL INTEREST

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FOREWORD

The Prime Minister asked that I provide her with advice on means to encourage greater participation in mathematics, statistics and science courses of study at university...

My Report is attached. I have included some consideration of engineering because it is an essential component of the future that is dependent on the mathematics and science disciplines.

I was not asked by the Prime Minister to advise her on why Science, Technology, Engineering and Mathematics (STEM) studies are important. I have, however, highlighted some of the action being taken elsewhere in the world, in part to emphasise that we are not alone in facing the issues we face, and that many countries are now taking substantial action as they attempt to reverse the trend of declining interest from students at the exact time that the demand for these skills in the workforce is increasing. It will doubtless result in a significant premium on these skills in a global market.

Work on this project commenced in earnest early in January 2012 when I was joined by Dr Claire Findlay on secondment from DIISRTE and Ms Lucy Du on secondment from DEEWR.

From mid-January to mid-February the three of us engaged in an intensive round of discussions/consultations/communications with as wide a range of representative groups and individuals as time would permit. I am grateful to all those people for their contribution, often at short notice, to this advice. I also acknowledge that there are many I could have engaged with, but time or timing precluded contact.

What follows is representative of where views converged, and where our own views developed after all the input we received.

EXECUTIVE SUMMARY

KEY MESSAGES AND RECOMMENDATIONS

There is a global perception that a workforce with a substantial proportion educated in Mathematics, Engineering and Science (MES) is essential to future prosperity.

The Rocard Report reviewing science education in Europe states *the availability of highly qualified science and technology professionals is a key factor for the establishment, import and success of high-tech industry in the European Union. Europe should be in a position to anticipate rather than follow demand as it moves towards a knowledge based economy. Furthermore the link between the local availability of a highly skilled workforce and investment decisions as regards, for example, the location of R&D facilities is very apparent in global economic terms. The Report includes the recommendation, because Europe's future is at stake decision-makers must demand action on improving science education from the bodies responsible for implementing change at local, regional, national and European Union level.* [1]

It is similar in the U.S.—it is estimated that scientific innovation has produced roughly half of all U.S. economic growth in the last 50 years. [2] The science, technology, engineering and mathematics (STEM) *fields and those who work in them are critical engines of innovation and growth: according to one recent estimate, while only about five percent of the U.S. workforce is employed in STEM fields, the STEM workforce accounts for more than fifty percent of the nation's sustained economic growth.* [3]

Australia's graduation rates in (MES) are low by international comparison (Table 1.0). Yet a high output in these disciplines is seen to be a critical underpinning for the future of innovative economies. Policies are emerging around the world that focus on STEM and seek to grow the supply of graduates with the skills and knowledge developed through a quality education in the STEM subjects. The reason is straightforward: the world's dependence on knowledge and innovation will grow and not diminish and to be ahead in the race, a community needs the skills to anticipate rather than follow.

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

Whatever we choose to do (and doing nothing is surely not an option), we should understand that success will result from a long-term investment—spanning generations.

Therefore what we do must be at the heart of our education system, indeed a central plank in our educational philosophy: high quality, contemporary, engaging and equitable

The recommendations that follow focus largely on schools—where most students clearly identify their future study options, and teachers, who have the greatest influence on the choices students make. While universities need to examine how they offer science and mathematics to their students—especially in the early years—we need to ensure that the school sector maximises interest and provides opportunities for all students to study high quality mathematics and science leading to careers in those disciplines and in engineering.

I note the *Smarter Schools National Partnerships,* in particular, the N*ational Partnership Agreement on Improving Teacher Quality* and concur with many of the objectives.

I note also that responsibility for managing the school sector rests with states and territories, and there are imaginative ways to deliver the curricula being developed around Australia. Some of these were provided as part of this process and are summarised in Appendix A.

We still fall short, however. After a lot of effort by many people, the proportion of mathematics and science students in schools still goes down; and in universities (as with engineering) it is virtually flat. Something different has to be done demanding a paradigm shift.

There is a role for the Commonwealth working with states and territories to ensure that all Australians have access to an education that meets a high threshold of quality—while the content of the curriculum is delivered to suit local circumstances.

I have identified five key areas that need to be addressed (in priority order) and present recommendations for each below. The recommendations are broadly in priority order, commencing with those of highest immediate priority, and followed by those that will have longer lead times to impact on Australia's future.

1. INSPIRATIONAL TEACHING

Inspired teaching is undoubtedly the key to the quality of our system, and to raising student interest to more acceptable levels. It is the most common thread running through the responses in every country where the issue has been assessed in any detail.

Inspiring teachers will generally be those confident that they know their subject well, and can transmit that confidence, and their passion, into the classroom.

We have many teachers like that, but we need more. We require coherent in-service support for teachers, and quality pre-service education.

Together they mean a re-think on how we prepare our teachers and how we support them: support to strengthen their content knowledge, to maintain it at contemporary levels and to instil the confidence to deliver the curriculum in interesting and novel ways.

(i) Teacher Qualifications

The quality and focus of initial teacher qualifications are critical to the capacity to teach effectively. The Australian Institute for Teaching and School Leadership (AITSL) has developed standards for both primary and secondary teacher education programs. They make clear our aspirations. They should be applied rigorously. [4]

RECOMMENDATION 1: Reinforce commitment to AITSL standards with the goal that only teachers who are qualified or accredited to teach mathematics and science subjects do so.

It is not clear that the measures of teacher qualifications are sufficiently nuanced. For example, a teacher with a major in physics may well be able to teach mathematics to some level. While new teachers need to meet the AITSL standard on the basis of their qualifications, established teachers without formal qualification should be accredited against the standard of "Professional Knowledge" in order to continue to teach MES subjects.

RECOMMENDATION 2: Education employing authorities should use AITSL Professional Knowledge Standard 2.1 to certify and/or accredit formally a teacher's knowledge and capability if they do not (yet) have a major and/or a minor in a field or fields. [5]

(2.1 - Graduate) Demonstrate knowledge and understanding of the concepts, substance and structure of the content and teaching strategies of the teaching area.

(2.1 - Proficient) Apply knowledge of the content and teaching strategies of the teaching area to develop engaging teaching activities.

This may require assessable professional development for teachers to be undertaken to demonstrate their knowledge and capabilities.

(ii) Pre-Service Programs

To sustain quality education in mathematics and science in schools in Australia, we need an adequate supply of able students graduating from the relevant programs. We should revise pre-service training for aspiring teachers of mathematics and science and draw student teachers from a wider pool. The latter could be assisted by getting undergraduates not currently in education programs to undertake appropriately structured work in schools.

RECOMMENDATION 3: Determine that mathematics and science teacher education be the first of the recently proposed Flagship Programs [6] with any additional funding contingent on specified criteria being met (Appendix B).

RECOMMENDATION 4: Introduce up-front financial incentives that will encourage high-achieving students to consider entering the tailored program (Appendix B).

RECOMMENDATION 5: As part of Compact negotiations, the Commonwealth should encourage universities to establish internships in schools for mathematics, engineering and science undergraduates not enrolled in education programs, for credit, as is done with other potential employers.

(iii) In-Service Programs

Teachers expressed appreciation for the support from their peer group and from the Australian Science Teachers Association (ASTA), although many were keen to see a more co-ordinated approach to in-service support, especially in the light of the Australian Curriculum.

There are two parts to in-service support:

A. Professional development which is largely the responsibility of the states and territories. It is a critical element underpinning a knowledgeable and confident teaching workforce that offers Australia what it needs.

Professional development has been a discussion point for years. Yet the student numbers fall, many think mathematics and science is boring and they cannot see how what they are taught relates to anything they know and see.

There are teachers who don't think that the professional development they can access is necessarily appropriate for their needs at the time.

Doing more of the same is unlikely to bring about a sea-change. There must be a clear role for the Commonwealth, obviously working with the states and territories, to ensure that there is appropriate and coherent action (and not just activity) across Australia.

B. Support for day-to-day teaching and related activities. I believe that as part of the national support structure, a National Centre for Mathematics and Science Teachers should be established. It would have multiple roles (see Appendix C) and would include two Advisory Committees to focus on the state of the mathematics, engineering and science disciplines. It would link to Education Services Australia (ESA) and ASTA, but would highlight a strong national focus on mathematics and science.

RECOMMENDATION 6: The Commonwealth Government encourage more focused and better quality professional development for MES teachers and act as appropriate to ensure equitable access to relevant opportunities for teachers anywhere in Australia.

RECOMMENDATION 7: The Commonwealth Government provide focus on its support for mathematics and science through the establishment of a National Centre for Mathematics and Science Teachers to facilitate equitable access to support systems for schools and teachers wherever they may be in Australia. (Appendix C)

RECOMMENDATION 8: The National Centre should include two Advisory Committees, one on science and engineering and one on mathematics. Their role would be to advise both the National Centre and separately the Government (through the Chief Scientist) on matters related to the disciplines.

RECOMMENDATION 9: Remove any financial barriers that may inhibit teachers from renewing their qualifications or attending professional development

RECOMMENDATION 10: Negotiate with universities to ensure that structured development programs for teachers lead to credit towards a qualification and that any credits are transportable between universities

(iv) Regional Centres

To support both primary and secondary teachers there is a need for specialist facilitators in each state and territory or region. This should be done Australia-wide with the expectation that facilitators would be trained using a national approach that would enhance the implementation of the Australian science and mathematics curricula.

RECOMMENDATION 11: Connect regionally-based mathematics, engineering and science facilitators to the National Centre.

(v) University Prerequisites

Physics and chemistry (and some mathematics) are seen as difficult subjects. Students will be more inclined to choose them if there is sufficient reward for effort. In recent years, many universities have relaxed the requirement for students to have completed these subjects, thus reducing their strategic value. The perceived relative difficulty of these subjects needs to be matched by appropriate rewards.

RECOMMENDATION 12: Urge universities to send accurate signals about the value of mathematics, engineering and science to schools, students, teachers and careers advisors.

(vi) Research Degrees

RECOMMENDATION 13: Offer research scholarships to students as part of the new Joint Research Engagement Engineering Cadetship scheme to attract students and demonstrate employment pathways for mathematics, engineering and science graduates

2. INSPIRED SCHOOL LEADERSHIP

Teachers and schools exert a substantial influence on their students and the choices they make. Leadership in schools is a key. Inspiring leaders will encourage innovation and support teachers as they develop particular ways to deliver the curriculum.

RECOMMENDATION 14: Continued support for school leadership and the further development of their skills should remain a priority.

3. TEACHING TECHNIQUES

Students generally commented that the teaching of science was too didactic, even boring. They thought that the scientific facts were not related to what students saw about them, and practical classes were largely about recipes or watching teachers following recipes, with little time for reflection. Teachers themselves acknowledged the issues and thought that health and safety guidelines restricted their ability to offer 'interesting' practicals, and the lack of technical support meant that too much of the preparation was left to teachers with too little time. The importance of technical support for science teachers was emphasised time and again.

The issue is that science is not taught as it is actually practised: hypothesis, experimentation, observation, interpretation and debate. And interesting ways of getting the facts into context are not used often enough.

There are novel ways of enhancing the classroom experience of students while supporting teachers and bringing practitioners into the classroom. The best of these draw on the expertise and enthusiasm of the mathematics, engineering and science community - the active practitioners.

RECOMMENDATION 15: Fund the proposed science collaboration programs detailed in Appendix D at levels that maximise their reach into Australian schools. Ensure coordination using the National Centre.

RECOMMENDATION 16: Fund the proposed pilot program from the Australian Council of Deans of Science (Appendix E) so that innovative practical programs can be offered to secondary school students.

4. GENDER ISSUES

The discrepancies in enrolments between men and women in some programs are substantial. We are not making best use of our talent. This is particularly true in Engineering and related areas.

RECOMMENDATION 17: Expand effective programs for encouraging more women into mathematics, engineering and science. Use the National Centre to ensure appropriate career advice and support is offered to women contemplating mathematics, engineering and science studies at university.

5. SCIENTIFIC LITERACY

Science plays an increasing part in our lives. The world we face requires citizens to make important decisions—about their health, about the environment, etc—many of which will have some scientific basis as solutions to issues emerge. A higher level of scientific literacy within the broader community is essential for a modern, well-informed society.

It is also important to profile our achievements—especially of our young people—to the community.

We should also be prepared to highlight the performance of our high achievers – our present and future role models. In particular, the achievements of the young people who represent Australia in the Science Olympiads should be broadcast widely. Getting selected in the first place and then succeeding against some of the world's very best should be known by as many in the community as possible—it is no less an achievement than that of any other Olympian.

BACKGROUND

MATHEMATICS, ENGINEERING AND SCIENCE IN THE NATIONAL INTEREST

Mathematics, Engineering and Science (MES) are fundamental to shaping the future of Australia, and the future of the world. They provide enabling skills and knowledge that increasingly underpin many professions and trades and the skills of a technologically based workforce.

They are the disciplines that help us to understand the natural world, and enable us to build a constructed world in which we apply what we know to improve the lot of human-kind. They are seen as part of the essential path to a future that is broadly socially, culturally and economically prosperous.

Australia's future is not one of vastly lower wage rates seeking to compete in low-end manufacturing. Our future lies in creating a high technology, high productivity economy; to innovate and to compete at the high-end of provision. To do so, the technical skills and scientific awareness of the entire workforce must be raised. The number of MES graduates needs to increase to allow industry to expand in these areas. Yet our current performance is wanting, and we compare poorly to our leading Asian neighbours.

Around the world, there are concerns that the supply of the relevant skills is inadequate, in part due to an observed decline in the interest of students in studying MES (or STEM: Science, Technology, Education and Mathematics)—it is a particular concern in the developed countries.

In making a case for a European Coordinating body for Mathematics, Science and Technology education, the European Round Table (ERT) of Industrialists emphasise that the more developed the country, the less the inclination of students to pursue careers in these disciplines. [7]

Figures 1.0 and 1.1 are drawn from the ERT report. Citing Sjoberg and Schriener (2008), the Report shows the responses from students aged 15, with countries listed in order of the United Nations Human Development Index:

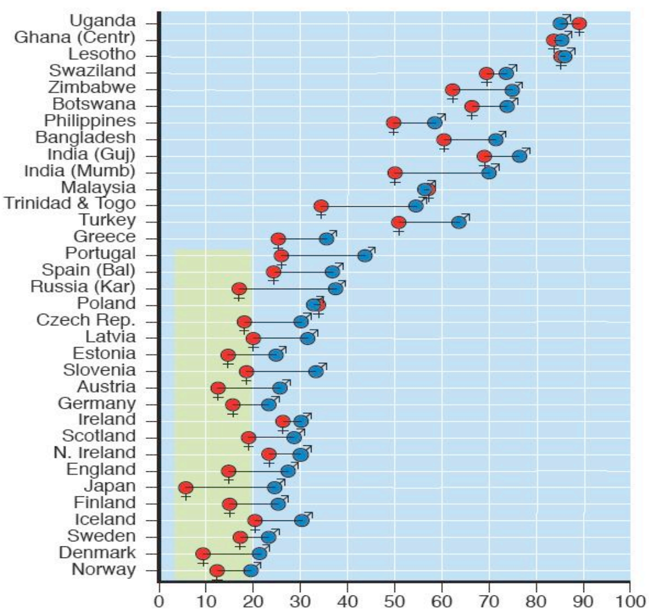

Figure 1.0
Statement: I would like to become a scientist

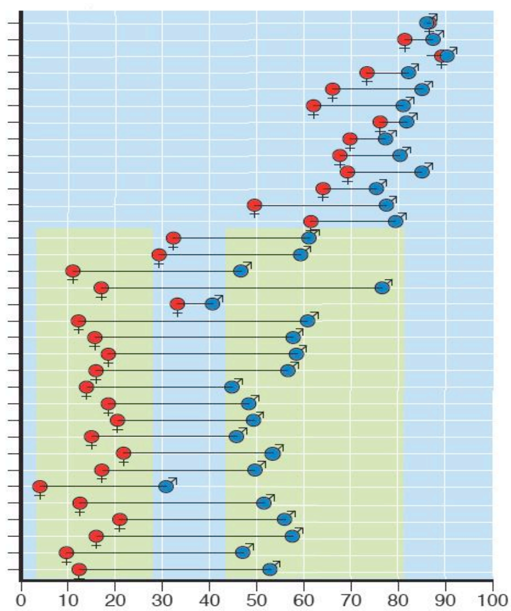

Figure 1.1
Statement: I would like to get a job in technology

There are numerous reviews, urgings, speeches and declarations of intent: all aimed squarely at reversing the trend. And many use what has been achieved in South Korea, Singapore, Hong Kong, China and elsewhere to illustrate what has to be done. Already these countries more than double our performance on numbers of MES graduates (Table 1.0). In some cases, such as South Korea, action began decades ago—and demonstrates what can be achieved.

A FEW EXAMPLES:

- In 1994, *it is hard to remember, given South Korea's present level of development, that, in 1948, (when) a modern education system began to be built there, the very vocabulary to talk about modern science and mathematics hardly existed in the Korean language and had to be invented before textbooks could even be written… Serious and sustained special attention to scientific and technical education came only in 1973 with the establishment of vocational schools associated with the 'movement to scientificize the whole people.'* , [8, 9]
- In 2001, Education Ministers in Europe set the objective of increasing enrolments in STEM in order to contribute to the process of …*fostering a dynamic and innovative knowledge-based economy…and progress in 16 countries was recently reviewed.* [10]
- In 2005, the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine of the U.S. commented on the need to *increase America's talent pool by vastly improving K-12 mathematics and science education. In April 2009, they revisited their earlier study: Rising Above the Gathering Storm Two Years Later: Accelerating Progress toward a Brighter Economic Future.* [11]
- In 2007, the British Government released a review of its science and innovation policies. Amongst the recommendations were measures to *improve further the teaching of Science, Technology, Engineering and Mathematics (STEM) subjects, by boosting investments in the training of specialist science teachers, improving STEM careers advice.* [12]
- In 2009, President Obama declared that *American students will move from the middle to the top of the pack in science and math over the next decade. For we know that the nation that out-educates us today—will out-compete us tomorrow.* [13]
- In 2011, UK *employers and businesses welcome support for STEM subjects: the Confederation of British Industry (CBI) recently conducted a survey of its members and found that 43% of respondents listed 'raising the numbers and quality of STEM graduates' as one of the top three priorities for the Government in this area. This figure increased to 63% for manufacturing respondents and 83% for science, engineering and IT firms.* [14]
- Other countries have fostered a similar commitment to STEM subjects. China and India each produce approximately half a milliton engineering graduates annually and both, along with other developed and developing Asian countries, are firm in emphasising the benefits that STEM graduates bring to the economy. [15]
- President Obama has committed the U.S. to training 100,000 new STEM teachers over the next decade ($80m). [16]
- In 2011, the UK increased teacher training places in physics and chemistry by a total of 2000—the first time the government has set subject-specific training recruitment targets for science. [17]
- Some approaches in the U.S. are summarised in U.S. News. In essence, disinterest amongst students is growing while the demand is rising sharply. About one-third of the nation's fastest growing jobs are in STEM-related fields.
- The competencies of a STEM education are transferable: We conclude that our education system is not producing enough STEM-capable students to keep up with demand both in traditional STEM occupations and other sectors across the economy that demand similar competencies. The demand for STEM competencies outside STEM occupations is strong and growing. [18]

Then, there is a report released in February 2012 by The President's Council of Advisors on Science and Technology (PCAST). [19]

The report, *Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics,* highlights the need, the urgency and the benefits. To be clear: the report argues that the U.S. should add one million **additional** graduates in STEM over the next **decade** if the U.S. is to *retain its historical pre-eminence in science and technology.*

The report also emphasises the need to change; doing more of the same, or fiddling at the margins and hoping, will not generate the numbers they believe they need.

INTERNATIONAL COMPARISONS

As the world moves, we in Australia cannot afford to be left behind—reduced to being an importer of the knowledge and skills we need—if we can find somewhere to buy them in a world where the premium will be high and the competition for them vigorous. We, too, must produce adequate numbers skilled in the MES disciplines and in their uses.

HOW DO WE COMPARE INTERNATIONALLY?

Comparative data show that Australia is lagging. The National Science Foundation has compiled data for many countries on the share of *first university* degrees awarded in STEM fields.

The international average for the ratio of STEM to non-STEM degrees was 26.4 per cent in 2002. [20, 21]

The Australian ratio in 2002 was 22.2 per cent; by 2010 it was 18.8 per cent—the fall reflecting the halving of graduations in Information Technology over that period.

The data show that the United States has one of the lowest rates of STEM to non-STEM graduates—at 16.8 per cent of all first university degrees awarded.

The US has subsequently taken action to: increase the supply of new STEM teachers, improve the skills of current STEM teachers, enlarge the pre-collegiate pipeline, increase postsecondary degree attainment, and enhance support for graduate and early-career research in response to Recommendations in the National Academy of Science Report Rising Above the Gathering Storm. [22]

Table 1.0 Field of Study by selected region and country, 2002 [23]

Region/Country	All Fields	STEM Fields	Percent STEM
All Regions	9057193	2395238	26.4
Asia	3224593	1073369	33.3
China	929598	484704	52.1
India	750000	176036	23.5
Japan	548897	351299	64.0
South Korea	239793	97307	40.6
Middle East	445488	104974	23.6
Europe	2682448	713274	26.6
France	309009	83984	27.2
Spain	211979	55418	26.1
United Kingdom	282380	72810	25.8
Central/Eastern Europe	1176898	319188	27.1
Russia	554814	183729	33.1
North/Central America	1827226	341526	18.7
Mexico	321799	80315	25.0
United States	1305730	219175	16.8
South America	543805	96724	17.8
Brazil	395988	61281	15.5

SHOULD WE SET A TARGET?

There is little evidence that targets for outcomes are regularly set anywhere. Targets for improving quality of education often are.

This is likely to be for the same reason that we face in Australia: students can choose what they want to study. In general terms, the prevailing attitude is to prepare students the right way (and offer incentives as appropriate) so that they will be eager to study MES at university. Hence the investment in STEM teachers that we see as a common thread running through the educational approaches in many countries—particularly in the developed countries where current interest is generally low.

One of the few countries to set a target recently is the U.S. And we can illustrate what will happen if we do nothing and the U.S. achieves the one million additional (STEM) graduates over the decade.

	STEM Graduates per decade	Estimated workforce in 2020 (million)	Per 1000 in workforce
Australia	200,000	13.4 [24]	15
U.S.	4,000,000	164 [25]	25

The U.S. needs a 33 per cent change to reach its target; Australia would need around 13,500 additional STEM graduates per annum for a decade just to keep pace.

Shortly after the release of the PCAST Report, Science Insider reported that: *education leaders caution that those recommendations, by the President's Council of Advisors on Science and Technology (PCAST), are deceptively challenging and will require overcoming steep obstacles at the thousands of U.S. colleges and universities that educate the next generation of workers. 'Changing the academic culture is hard, and I'm not going to pretend that we're assured of success. We're not' says Hunter Rawlings, former president of Cornell University and now head of the Association of American Universities.* [26]

Our differences from the U.S. are largely (not only) ones of scale: we have a similar academic culture, similar aspirations for prosperity, similar aspirations to develop a high-skill, innovative workforce, similar community expectations about the future and similar responsibilities as global citizens.

While we cannot argue, as the U.S. does, that we must invest to retain (our) historical pre-eminence in science and technology, [27] we are proud and substantial contributors: we generate about three per cent of the world's stock of knowledge with about 0.3 per cent of the world's population. Much of our work is excellent. Arguably, more of it should be applied.

Our achievements are also important for Australia's positioning in the world. The three per cent provides us with a seat at the table where the important decisions are made, and gives us influence beyond our population share. In times past we were not significant contributors—and waited for the rest of the world to tell us what we needed to know. It was not a comfortable or useful place for Australia to be. Just cheap.

Our three per cent leaves 97 per cent. We must be able to interpret (adapt to Australian conditions when necessary) and use the other 97 per cent. And it will be more than 97 per cent of a much larger volume if the world's objectives are met. That means we must invest appropriately and wisely in MES in Australia, not waste our talent, and ensure a highly skilled cohort of Australians well able to contribute to the world's stock of knowledge, and able to use the knowledge and apply it to the benefit of our own community and humanity more widely.

There is no case for letting others make the investment and do the work, while we take (or buy) what we need. Along with the rest of the world, we are in one of two races: one to rise, one to fall.

PROGRAM FOR INTERNATIONAL STUDENT ASSESSMENT (PISA)

Australia is still, at present, reasonably placed in PISA—above average—though not at the top. But we are slipping. It is noteworthy that one of the galvanising forces regularly referenced in the U.S. is their relatively poor performance in these assessments (labelled a 'disaster in the making' by CNN).

In a comparison of PISA performance from 2000 to 2009 an increasing number of countries outperform Australia.

Table 1.1 Countries that outperform Australia in PISA testing

2000	2003	2006	2009
Korea Japan	Finland Japan Korea	Finland HK Canada	Shanghai- China Finland Hong Kong- China Singapore Japan Korea
Australia	Australia	Australia	Australia

It is no coincidence that the countries that now out perform us in PISA are those that have taken steps to increase the proportion of MES graduates.

THE AUSTRALIAN PICTURE (very) BRIEFLY

Mathematics, Engineering and Science are pervasive. They are with us and used by us every day. The food we eat, the clothes we wear, our banknotes, mobile telephones, computers, televisions, cars and medicines are all examples of where MES has an impact.

Yet attitudes to science in Australia vary widely. In a survey of 1,200 Australians aged 18 years and over in 2010 [28 29], there was strong support for science and scientists. Over 85 per cent thought that science had made life easier for most people; and close to 85 per cent thought that science and technology would enable more opportunities for future generations.

Scientists were rated the third highest contributors to the well-being of society—after doctors and teachers. Roughly one-half the sample felt they were not well informed about science.

A survey of year 11-12 students indicated less support—or understanding. Of those studying science, 33 per cent thought science was 'almost always' relevant to their future (although) 47 per cent thought it 'almost always' relevant to Australia's future!) and 19 per cent thought it 'almost always' useful in everyday life. Of the students not studying science (roughly one-third the cohort), 1 per cent thought it relevant to their future 'almost always' (42 per cent thought never) and 4 per cent thought it 'almost always' useful in everyday life, 42 per cent thought sometimes and 18 per cent thought never.

AT SCHOOL

The proportion of enrolments in mathematics and science in Year 12 has decreased over the years. It continues to fall slowly.

Year 12 enrolments vary between the states and territories but nationally, 51 per cent of students take a science subject or subjects—including psychology; this amounted to 110,328 students in 2010. [31]

Between 1992 (after which school retention rates were fairly stable) and 2009, the proportion of Year 12 students taking physics, chemistry and biology fell by 31 per cent, 23 per cent and 32 per cent respectively. [32]

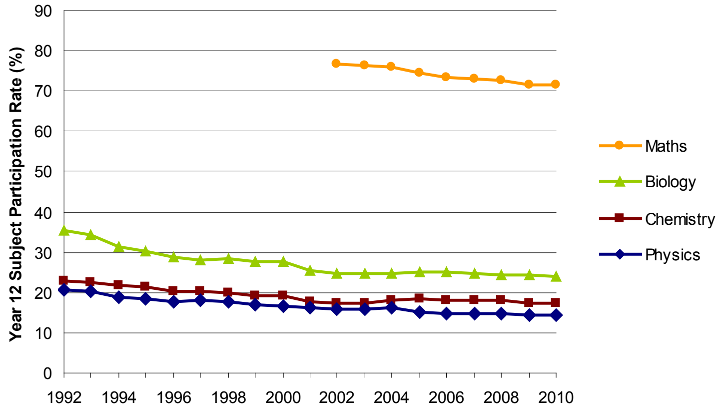

Figure 1.2 Year 12 maths and science participation, 1992-2010

Notes:

1. *1992-2010 Science Participation Series* [33]
2. *2002-10 Maths Series* [34]

Since 2004, the proportion of Year 12 students taking one or more science subjects has declined. [35]

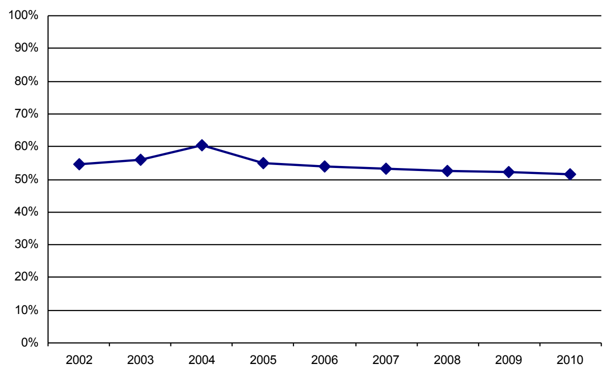

Figure 1.3 Student participation in science, 2002-10

There were 153,512 students studying mathematics in Year 12 in 2010, or 72 per cent of the cohort [36] although the raw numbers tell just part of the story. There has been a shift from 'advanced' and 'intermediate' to the 'elementary'.

In 2010 there were only 62,000 taking advanced and intermediate mathematics—the mathematics requirements for some courses in universities. [37]

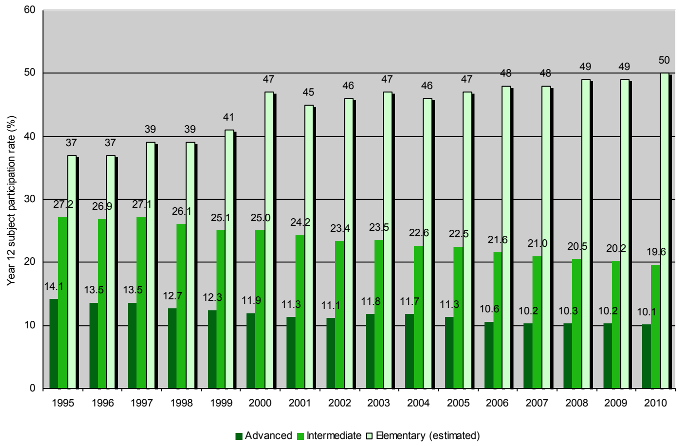

Figure 1.4 Student participation in mathematics, 1995-2010

The decline in mathematics and science students is not unique to Australia; the global consensus is that enrolment in STEM studies and/or careers has been in decline for more than a decade. [38] A summary can be found in Lyons and Quinn. [39]

THE TEACHING

Inspirational teaching was time and time again identified as the key to future study choices of students. This is true for most, nearly all, countries. It was raised in our consultations every time—teachers and students alike highlighted the issue of teachers who lacked confidence and/or knowledge and therefore taught more often from the textbook. Students were unimpressed.

These views are generally supported by surveys of Australian students: some love mathematics and science, some don't; some do it because they have to, some avoid it at all costs. The reasons are many; but it is almost universal that mathematics and science is seen as boring and not related to real life.

It is, of course possible to make mathematics and science interesting without making it simplistic. That is our challenge.

A review of almost three hundred reports and refereed publications from several countries identified a number of the barriers or key issues to address. The review identifies the complexity of the matter—and identifies good teaching as the most frequently cited reason for inspiring young people to enjoy science. Other barriers include: the perceived difficulty of STEM subjects; the disillusionment with the transition from primary to secondary school; the negative views about success in STEM and negative stereotypes; and career opportunities. [40]

The review commented that teaching needs to be high quality and inspirational while content is generally seen as *… irrelevant to life after school. The teaching is seen as boring because so much is seen as knowledge transmission of correct answers with neither time nor room for creativity, reflection or offering opinions.* [41]

The development of effective and attractive (STEM) curricula and teaching methods, and improved teacher education and professional development are at the heart of the drive to make (STEM) studies and careers a more popular option for young learners. The most comprehensive approach is taken by countries that have implemented national strategies and/or set up dedicated national or regional centres. [42]

Inspiring students to engage with mathematics and science can be best achieved by teachers who are passionate about the subject and have the knowledge and confidence to present the curriculum imaginatively.

This is not about dumbing down. It is not in Australia's interests to produce a raft of people with second rate skills and knowledge.

Teaching students concepts and processes and delivering curricula interestingly is not 'dumbing down'. It is about imaginative approaches to teaching not about teaching as we were taught—an approach with its own literature. Scientific facts can be imparted as concepts and processes of science and can be illustrated at school and university.

The issue before us is to prepare teachers well, give them the confidence and support them as they progress through their careers.

Mathematicians, Engineers and Scientists in Schools

Part of that support can come from programs that have been piloted and that draw on experts and their enthusiasm from the Australian Academy of Science, the Australian Academy of Technological Sciences and Engineering and CSIRO.

These programs have now led to a revised suite that is poised for expansion into many more schools.

School principals and teachers made it abundantly clear that each program had offered a great deal to them and their students. These new programs form a continuum from primary to senior secondary; all are in curriculum; they offer opportunities otherwise not available and they bring the Academies and CSIRO into the schools.

The Australian Council of Deans of Science also seeks to overcome barriers to laboratory and fieldwork. This program is detailed in Appendix E.

They are significant programs. Each facilitates the development of broader pedagogical skills, especially inquiry-based teaching skills as outlined in the Australian science curriculum, use quality resources and support teachers to work with the broader community including scientists and industry.

Details of the programs in their new form are at Appendix D.

TEACHER QUALIFICATIONS

The qualifications of Australia's secondary teachers have been frequently studied—and much is made of the 'out of field', 'unqualified' and 'qualified' teachers.

To arrive at these assessments, some count teachers with a major in a field as 'qualified' while others measure in terms of when the subject was studied: one completed semester in first year means Year 1. Or one semester in second year means Year 2 although given the structure of university courses, it is not clear that this would always mean a second year level subject.

In order to determine accurately whether a teacher is 'out of field', 'unqualified' or 'qualified', we may need a more nuanced assessment. A teacher with a major in, say, physics may well be able to teach certain mathematics and to label them as out of field or unqualified is unhelpful.

New Teachers

The quality and focus of initial teacher qualifications are critical elements in future supply. The AITSL standards for both primary and secondary teacher education programs make clear our aspirations. [43]

It is important that the AITSL National Professional Standards for Teachers be implemented and that they are used so that only appropriately qualified and certified teachers take classes in MES subjects. For secondary teachers, these include at least a major study in one teaching area and preferably second teaching area comprising at least a minor study. This direction is the right one.

The standards make explicit the professional expectations of those graduating from initial teacher education programs, but issues remain. To prepare teachers at secondary level, for example, it is expected that the accredited programs must provide a sound depth and breadth of knowledge appropriate for teaching area/s the graduate intends to teach. [44] It would be interesting to know how many new teachers get to teach what they thought they would when they were choosing their subjects as students.

In the meantime, we have few students enrolled in education after mathematics and science in a first degree.

Table 1.2 Students enrolled in a Graduate Diploma in Education who had undertaken previous undergraduate science study, 2005-10

	2005	2006	2007	2008	2009	2010
DipEd students with previous under graduate science study	244	371	427	341	534	550
All students currently undertaking initial teacher training	63,194	64,973	68,699	68,033	69,516	72,808

There is a substantial difference in the ATAR distribution of offers made to students entering the natural and physical sciences and education. An important part of our approach must be to get more of the students interested in science to become teachers.

Table 1.3 Number of offers to Year 12 Tertiary Admissions Centre applicant by ATAR, 2011

	10.00 or less	10.05-20.00	20.05-30.00	30.05-40.00	40.05-50.00	50.05-60.00	60.05-70.00	70.05-80.00	80.05-90.00	90.05 or more
Natural and Physical Sciences	<10	<10	<10	14	153	791	1,511	2,726	3,758	5,779
Education	<10	<10	17	74	252	1,166	2,374	2,202	1,462	457
Total Offers	cc.	cc.	cc.	cc.	1,942	9,521	18,501	23,258	27,485	32,393

Note: Some cells are suppressed due to small number of observations (<10), or they are being consequently confidentialised (cc).

Established Teachers

With an estimated 57,000 secondary teachers teaching mathematics and science already in the workforce where a good number will stay for 30+ years, together with a need to begin the process of change sooner than a commencing pipeline of student teachers would allow, something coherent needs to be done about in-service support for teachers. The matter becomes more urgent given the age and qualification profile of the workforce.

The Staff in Australia's Schools (SiAS) 2010 Survey, shows the median age of science teachers (N=2468) is 43 years (year 7-12) and mathematics teachers (N=2747) is 45 years. Senior teachers (years 11-12) are a little older, 45 and 48 years respectively.

There appears to be a generation gap. In South Australia, teachers surveyed in 2009 who were currently teaching senior physics classes in South Australia, 39 per cent under 40 hold a major in physics compared to 63 per cent of teachers over 40 years. [45]

Qualifications also vary between regions.

Table 1.4 Teachers with either none or Year 3 and higher level of tertiary education teaching in field, 2010

	Highest Year Level of Tertiary Education in Field								
	None			Year 3 and higher			Total		
	Metro.	Prov.	Remote	Metro.	Prov.	Remote	Metro.	Prov.	Remote
Year 7-10 Maths	359 -24%	223 -31%	31 -26%	669 -45%	266 -37%	48 -40%	1484	724	119
Year 11-12 Maths	112 -12%	62 -16%	7 -14%	600 -64%	226 -57%	22 -43%	943	397	51
Year 11-12 Physics	21 -8%	11 -9%	2 -18%	139 -56%	66 -55%	4 -36%	248	120	11
Year 11-12 Chemistry	12 -4%	7 -5%	0	220 -74%	103 -71%	1 -17%	299	145	6
Year 11-12 Biology	18 -5%	17 -9%	2 -11%	342 -88%	147 -82%	14 -78%	389	180	18

Note: A more detailed breakdown of qualifications can be found at Appendix F.

Table 1.5 Highest level of tertiary education of General Science (Year 7-10) teachers, 2010

Highest year level of tertiary education of General Science teachers (Year 7-10)		
School location	Year 2 or higher	Total
Metropolitan	965 (81%)	1189
Provincial	455 (75%)	610
Remote	65 (71%)	92
Total	1485 (79%)	1891

Note: Teachers with tertiary education in Physics, Chemistry and Biology are also considered to have the relevant qualifications to teach Year 7-10 General Science.

Discussions with teachers, principals and others highlighted their need for a coordinated and systematic approach to professional development and support.

It is therefore proposed that there be a national approach to the support of teachers across Australia. With respect to professional development of teachers, it is clearly a state and territory responsibility, but with a definite role for the Commonwealth.

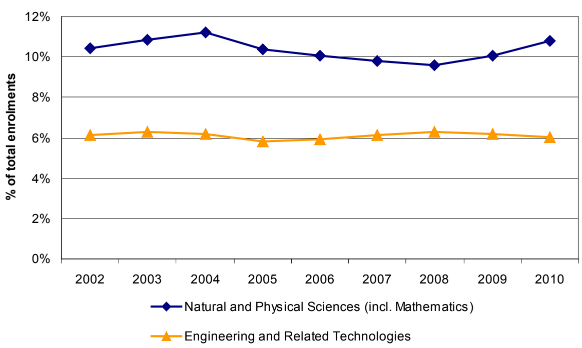

Figure 1.5 Domestic undergraduate student enrolments as a percentage of total enrolments, 2002-10

AT UNIVERSITY

Enrolments in MES as a percentage of all enrolments in university generally fell in the 1990s and were flat between 2002 and 2008. There was a small increase in both 2009 and 2010.

The graduation rate is likely to be between 50-55 per cent (we don't have a cohort study). Notably, in the U.S. the PCAST Report laments the graduation rate of 40 per cent. If the U.S. were able to get that rate to 50 per cent, they would add 750,000 of the one million graduates by that means alone. There are differences between men and women—both in enrolments and in graduations.

Doubtless there are multiple reasons for these differences and attempts to change the pattern have been many though clearly with limited impact.

One possible reason, with all its complexity, is employment. Admittedly this is chicken and eggish—if the women are not graduating they can't be employed, but if employment numbers are low, why would they enrol in the first place? The OECD figures place Australia at number nine—above average but not at the top [46]—in terms of employment of science and technology professionals. However, we are one of the **bottom three** in terms of the proportion of those employed who are female.

SCIENTIFIC LITERACY

If we are to achieve what we need to achieve we need cultural change. The investment in MES has to be encouraged by the community. That will require an 'education program'—why science is important, how it is done, what it offers, what goes wrong, the differences between an expectation of certainty and the reality of probability.

In our discussions, there was a general view that the level of scientific literacy in the community is low.

There are two definitions that offer insight:

1. Scientific literacy is the knowledge and understanding of scientific concepts and processes required for personal decision-making, participation in civic and cultural affairs, and economic productivity. [47]

2. Daily we read and hear stories about global warming, cloning, genetically modified foods, space exploration, the collection and use of DNA evidence and new drugs that will improve the quality of life and make us look years younger. As a consumer, and as a citizen, we need to

critically evaluate the claims made in the name of science and make informed decisions and choices about these and other science based issues. In short, we need to be scientifically literate and more importantly we need to develop scientifically literate students. [48]

It is important to note that scientific literacy requires a broad understanding of the concepts and processes of science—not only a burning desire to wear a laboratory coat. These skills should be taught explicitly to all students in junior and probably middle secondary school.

A recent comment in the Scientific American notes that: teachers at the high school and undergraduate university level aren't giving students a broad enough understanding of how scientists go about their research. While scientific literacy in the United States is increasing, thanks to the requirement that college students take at least one year of science, the general public is relatively ignorant about the process of scientific inquiry and the nature of science. The importance of clearly defining the field and explaining the methodology behind it are paramount at a time when debates among policy-makers about addressing climate change and among educators about teaching evolution are blurring the public's understanding of the difference between science and ideology. [49]

We should also be prepared to highlight the performance of our high achievers – our present and future role models. In particular, the achievements of the young people who represent Australia in the Science Olympiads should be broadcast widely. Getting selected in the first place and then succeeding against some of the world's very best should be publicly celebrated—it is no less an achievement than that of any other Olympian.

Table 1.6 Commencing Domestic Undergraduate Student Enrolment numbers, 2002-10

	2002	2003	2004	2005	2006	2007	2008	2009	2010
Natural and Physical Sciences	17,451	17,362	17,995	17,646	17,509	17,556	17,328	19,577	22,461
Engineering and Related Technologies	10,247	10,089	9,885	9,924	10,298	11,008	11,314	12,010	12,511
Total Enrolments	167,183	160,192	160,372	170,467	174,213	179,020	180,393	195,031	208,054

Note: Statistics refer to students in Bachelor's Graduate Entry, Bachelor's Honours and Bachelor's Pass degrees.

Table 1.7 Domestic Undergraduate Student Graduations, 2002-10

	2002	2003	2004	2005	2006	2007	2008	2009	2010
Natural and Physical Sciences	10,683	10,863	11,235	11,634	11,786	11,661	11,558	11,296	11,942
Engineering and Related Technologies	5,737	5,814	5,994	5,677	5,963	5,761	6,055	6,054	6,252
Total Graduations	101,625	104,852	106,670	107,645	107,627	106,836	107,231	110,451	112,162

Note: Statistics refer to students in Bachelor's Graduate Entry, Bachelor's Honours and Bachelor's Pass degrees.

THE NATIONAL INTEREST

THE NATIONAL INTEREST

Our investment in science and technology serves the nation's interests. It establishes a cohort of experts; it makes a contribution to global knowledge and understanding; it builds a capacity to adapt solutions to Australian problems while contributing to solutions to global problems; it is a contribution to Australia's standing in the world; and properly used it will increase the level of science literacy in the community—citizens able to make better choices when faced with options.

Investing in mathematics, engineering and science is the key to productivity growth and higher living standards for our community. An adequate supply of people highly skilled in mathematics and science is critical for our future success. [50]

We must get off the escalator and get into the elevator—exchanging incremental shifts for a step change. To do less would mean that the gap between Australia and those countries investing seriously in the future through MES will increase. It might never be closed.

The 'national interest' is a major reason to drive reforms—changes should benefit all Australians wherever they may live and whatever their circumstances. The objective here is to position the Australian economy as a whole for the future. This is not about cosmetic changes or ad-hoc measures.

The national government should overtly take direct responsibility for signalling the importance of MES to the community, and for taking steps that will provide the support teachers, students and Australia needs over a long enough period to make the difference.

At the macro level, there is the essential need for Australia to be competitive. We need to build an economy that has within it a deep knowledge-base which can be used to innovate and develop new industries, new forms of employment and to ensure a level of prosperity for all citizens. The current mining boom has created a two-speed economy, showing the dangers of localised activities that cannot be shared equally across the economy.

Closer to home, and in order to develop our nation's potential, all Australians should be able develop theirs—through access to a quality education. Australians have choices in education, government or non-government. Whatever their choice, there should be a threshold level of quality which is always met—testing, challenging, fitting a need but accessible to all.

Ensuring the quality of education, across Australia, is a role for the Commonwealth Government.

CONCLUSIONS

CONCLUSIONS

The preceding analysis of the state of MES learning in Australia suggests a range of interconnected and reinforcing strategies.

The problem is national, the objective is national, and many of the solutions need to be national.

The aim is to increase the level of MES graduates substantially over the next generation of learners, and to increase the level of scientific literacy in the community.

Clearly, ensuring inspirational teaching by well trained teachers is central to reaching both these goals. Through this, students will be more engaged, learn more, and be more inclined to pursue careers in MES areas.

- Teachers must be trained well and be knowledgeable in their subjects.
- They need to teach the areas of their specialisation, wherever possible.
- They need access to good school leadership, and good curriculum material.
- They need to meet professional standards, and undertake professional development.
- They need to be supported in their classrooms.

Students, both male and female, need to be aware of and see value in MES career pathways, including as mathematics and science teachers themselves.

- Students should be encouraged to pursue these pathways.
- University courses should be innovative and of the highest quality.
- The pool from which mathematics and science teachers are drawn needs to be broadened.

And, the understanding of the pervasiveness in and importance of MES to Australia's future needs to be promoted and nurtured across the community.

To achieve these goals, a number of initiatives can be implemented - some funded through the Commonwealth budget, some through charging Education Ministers with responsibility to develop strategies directed at particular issues.

And if we fail to act? A decline in our productivity growth relative to our region's leading economies would put us at a growing disadvantage in maintaining our national wealth and security.

The impact of declining MES capability will be felt by individuals in the community. Those without adequate scientific literacy, those with lower levels of technical skills or those employed in industries that cannot innovate and adapt to a higher knowledge-base will be disadvantaged. As the current two-speed economy shows, the price of adjustment is difficult to bear for those disadvantaged, and calls out for other forms of government intervention.

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Figure 1.0. Statement: I would like to become a scientist

Source: European Round Table of Industrialists, Mathematics, Science and Technology Education Report: The Case for a European Coordinating Body, 2009. http://ert.eu/ERT/Docs/01717.pdf

Figure 1.1. Statement: I would like to get a job in technology

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Figure 1.2. Year 12 maths and science participation, 1992-2010

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Figure 1.3. Student participation in science, 2002-2010

Source: Goodrum et al. (2011)

Figure 1.4. Student participation in mathematics, 1995-2010

Source: Barrington, F (2011) as cited in the AMSI report

Figure 1.5. Domestic undergraduate student enrolments as a percentage of total enrolments, 2002-2010

Source: DEEWR Higher Education Statistics Data Cube

Figure 1.6. Proportion of domestic undergraduate student graduations of total student graduations, 2002-2010

Source: DEEWR Higher Education Statistics Data Cube

Table 1.0. Field of Study by selected region and country, 2002

Source: National Science Foundation, Science and Engineering Indicators, 2006, Volume 1, Arlington, VA, NSB 06-01, January 2006, Table 2-37, cited in CRS Report for Congress, Science, Technology, Engineering, and Mathematics (STEM) Education: Background, Federal Policy, and Legislative Action, 2008, http://www.fas.org/sgp/crs/misc/RL33434.pdf

Table 1.1. Countries that outperform Australia in PISA testing

Source: Goodrum et al. (2011)

Table 1.2. Students enrolled in a Graduate Diploma in Education who had undertaken previous undergraduate science study, 2005-10

Source: DEEWR Higher Education Statistical Collection

Table 1.3. Number of offers to Year 12 Tertiary Admissions Centre applicant by ATAR, 2011

Source: DEEWR Higher Education Statistical Collection

Table 1.4. Teachers with either none or Year 3 and higher level of tertiary education teaching in field, 2010

Source: Staff in Australia's Schools 2010 National Data Files.

Table 1.5 Highest level of tertiary education of General Science (Year 7-10) teachers, 2010

Source: Staff in Australia's Schools 2010 National Data Files.

Table 1.6. Commencing Domestic Undergraduate Student Enrolment numbers, 2002-2010

Source: DEEWR Higher Education Statistics Data Cube

Table 1.7. Domestic Undergraduate Student Graduations, 2002-10

Source: DEEWR Higher Education Statistics Data Cube

APPENDIX

SUMMARY OF STATE AND TERRITORY GOVERNMENT INITIATIVES

Ministers for Education and the Heads of Departments of Education in each state and territory were invited to provide input on the teaching of maths and science in their jurisdictions. The following provides a summary of the responses received from state and territory governments. For further information on policy and programs delivered by the relevant state and territory government refer to their websites (noted below).

NEW SOUTH WALES GOVERNMENT

www.det.nsw.edu.au

- NSW Quality Teaching Framework
- Revisions of maths and science syllabuses underway
- Extracurricular programs for students including
  - Murder under the Microscope (Yrs 5-10)
  - Rediscovering Science and Science Talk – online, videoconferences and DVD recourses
- Teaching and Learning Exchange – resource for teachers
- Strategies to attract, retrain and retain teachers in science and maths: teaching scholarships; graduate recruitment and retention programs.
- Rural and distance education support including:
  - Country Areas Program, supporting 240 geographically isolated government and non-government schools through the provision of grants, professional learning and consultancy support
  - Scholarships for boarders attending agricultural high schools

VICTORIAN GOVERNMENT

www.education.vic.gov.au

The first wave, 1990: policy to devolve educational, financial and management responsibilities to schools.

The second wave, 2000s. Capacity building through

- Developmental Learning Framework for School Leaders
- Effective Schools Model
- Bastow Institute of Educational Leadership

Third wave, currently underway:

- $24m funded 100 Primary Mathematics and Science Specialists
- Re-introduce pupil free days to schools
- Compacts between Department and Schools – collaborative partnerships
- Specialist government schools (e.g. John Monash Science school)
- Four selective entry secondary schools
- $2.5m grants program for schools to develop a specialisation in a field of their choice
- Establish the Bio21 science school in Parkville
- Support schools in offering international baccalaureate
- Develop the Victorian Baccalaureate:
  - new initiative at the senior secondary level - Victorian Curriculum and Assessment Authority (VCAA) to develop for public consultation and further consideration
  - designed to recognise high achievement across a breadth of study areas, including languages, mathematics and science/technology
  - students may be expected to: include subjects from the learning areas of English, Mathematics, Science/Technology, Languages and Humanities/The Arts; complete the new Extended Investigation study; and, demonstrate a benchmark level of achievement to be awarded the VB
  - proposed introduction in 2014

– VCAA preparing for consultation, a parallel series of certificates that would recognise high achievement in specialist areas rather than broad fields of study to encourage and recognise excellence in specialised fields of study including Mathematics, Science/Technology, The Arts, Sport and Physical Education, the Humanities and Languages

– to be awarded a Specialist Certificate, students would be required to include in their senior secondary course of study English and at least two subjects drawn from their specialist area

– the level of recognition associated with these awards will provide a new incentive for students to include subjects drawn from the learning areas of Mathematics and Science/Technology in their senior secondary programs

– VCAA will consult with ACARA in the design of both the proposed Victorian Baccalaureate and the senior Specialist Certificates

- Work closely with industry to develop new industry pathways for students
- Establish Business Working with Education Foundation - to connect business with Victorian State schools
- New on-line assessment platform for teachers to assess students
- NETschool in Bendigo works with 15-20yr old who are experiencing difficulties with mainstream school and who want to get back into learning
- Youth Partnerships – delivery of youth service and pathways provision for young people who have disengaged
- Develop school partnerships: community colleges and early childhood facilities; government and non-government schools; etc.

QUEENSLAND GOVERNMENT

www.deta.qld.gov.au

- Science Spark - $37.7m Queensland Government funding for 2010-2012 to
  - Promote teaching of science
  - Fund 15 regional managers and 100 full time primary science facilitation
  - Professional development for every teacher of Yrs 4-7 in Queensland State Schools
  - Increase teachers scientific knowledge
  - Develop teachers skills in teaching science
  - Enhance teachers confidence in teaching science
- Smart State Strategy (total funding $120m) 2008-2012 includes $23m to attract and retain some of the brightest minds in science and industry
- Scholarships to support high-calibre STEM graduates to become teachers
- Various student and teacher scholarships, e.g.:
  - Peter Doherty Awards for Excellence in Science and Science Education (five categories)
  - Scholarships to support Yr 12 students in rural and remote areas and indigenous students who have chosen teach as their career
- Remote Area Teaching Education Program
- Five Teacher Education Centres of Excellence focusing on
  - early, middle and senior phases of learning
  - Indigenous students and community engagement
  - preparing aspiring teachers for students with special needs
  - Literacy and Numeracy in schools in low socioeconomic communities
  - teaching of Science, Technology, Engineering and Mathematics
- Vacation Professional Development for Teachers program

APPENDIX A

WESTERN AUSTRALIAN GOVERNMENT

www.det.wa.edu.au

- First Steps in Mathematics; Getting it Right – programs to develop primary teachers' mathematical pedagogic content knowledge
- Primary Science – similar model for primary school teachers'
- Scitech programs in regional Australia – outreach programs to regional areas
- Early Child hood Toddlerfest – allows parents and preschoolers access to exhibits
- Mathematical Association of Western Australia – Have Sum Fun; Mathematics Activity Day – opportunity for student to purse interest in maths
- University of Western Australia – Mathematics Olympiad program
- Seven Teacher Development Schools for maths and 14 for science – provide support for teachers and professional learning opportunities
- SPICE program through The University of Western Australia – access to professional learning for secondary teachers
- Department of Education collaborates with industry and employ groups
- Schools Pathways Program – Defence Industries – 22 schools participating through four clusters of schools, one lead school per cluster, linked to Trade Training Centres- program focusing on applied science, technology, engineering and maths
- 2006 pilot – in secondary schools to identify the nature and cause of students difficulties with maths and to develop strategies to address this

SOUTH AUSTRALIAN GOVERNMENT

www.decd.sa.gov.au www.training.sa.gov.au

- Outreach Education programs
- Guaranteed Instruction Time in Primary Schools
- Yr 3 a minimum of 1.5 hours a week on science and 5 hours on maths
- Yrs 4-7 minimum of 2 hours on Science and 5 on maths

o Yrs 2 minimum of 1.5 on science and 5 on maths from 2013

- Primary Mathematics and Science Strategy (2009-2013)
- Teaching for Effective Learning Framework
- Oliphant Science Awards
- Teach SA
- Industry Pathways program
- Le Fevere maritime High School

TASMANIAN GOVERNMENT

www.education.tas.gov.au/dept

- Tasmanian Science Talent Search
- State program associated with National Science Week
- State, national and international mathematics and science competitions and challenges
- Tasmania Sustainability Centre as part of the Australian Sustainable Schools Initiative
- Hands on programs, e.g. CSIROSEC (Tasmania); Molesworth Primary School and Environment Centre; Woodbridge School marine Discovery Centre

AUSTRALIAN CAPITAL TERRITORY GOVERNMENT

www.det.act.gov.au

- Flipping the Classroom – enabling secondary maths and science students access outside the classroom allowing self-paced learning and time for teachers to provide greater personalised learning of maths and science
- Engaged with ANU secondary college
- Proposed partnership between ACT Education and Training Directorate and ANU to develop an ACT space science education centre at Mt Stromlo to engage in science, using facilities and expertise of ANU astronomers and space engineers

NORTHERN TERRITORY GOVERNMENT

www.det.nt.gov.au

- Centres for Excellence – high achieving Yr 10-12 students participate in specialised science and maths programs delivered at Charles Darwin University in conjunction with a number of partners (e.g. ConocoPhillips, NT Department for Health, Menzies School of Health) and includes visits to institutes in Singapore (Institute of Molecular and Cell Biology; Singapore Science Centre; NeWater Plant; Sands sky Park – architecture; Marina Barrage – tidal barrier).

APPENDIX B

HIGHER EDUCATION INITIATIVES TO INCREASE MES TEACHER GRADUATES

1. Flagship Program in Mathematics and Science Education

The mathematics and science component of these programs should be taught by experts in the relevant field and the education component should be likewise. This means drawing from the scientists in the university and those in education schools or faculties.

A Flagship program for these purposes can be described as integrated programs that have been purposefully negotiated between the science schools and the education schools.

For the Commonwealth to consider these as Flagship programs, eligible for additional funding, the criteria should include:

- A negotiated combined program where the aim of producing teachers with deep knowledge in their chosen area and first rate pedagogical training.
- The science or mathematics component must be taught by staff whose discipline in the university received at least a rating of 4 in the Evaluation of Research Australia;

Programs negotiated could be between as well as within institutions. Quality science and quality education are not always coincident.

These should be targeted programs—and used to encourage interest from high-achieving students.

2. Up-front financial support.

Possibilities include:

A. Cadetships: Students studied and were paid by the employer and repaid the debt either literally or in kind by working as a teacher for a period;

B. Bursaries: Students undertaking initial teacher training will be eligible for an additional loan (bursary) on top of their FEE-HELP. Upon completion of their degree, the additional debt would be waived if they work as teachers (within specified criteria i.e. rural, low-SES, maths/ science).

These options could be offered to students with an ATAR of, say, 85+ who entered the combined program.

APPENDIX C

NATIONAL CENTRE FOR MATHEMATICS AND SCIENCE TEACHERS

The National Centre should have the following main tasks:

- Have two Advisory Committees, one on science and one on mathematics. Their role would be to advise both the National Centre and separately the Government (through the Chief Scientist) on matters related to the disciplines;
- Make available science and mathematics education experts through an online support centre which provides advice on high quality curriculum support materials, pedagogy and lessons, and forms of support (including the Scientists/Mathematicians in Schools program) accessible to teachers beyond school hours;
- Broker collaborative national undertakings, among key stakeholders, including ESA, AITSL, state and territory education authorities, the Australian Science Teachers Association, the Australian Association of Mathematics Teachers, CSIRO, the Australian Academy of Science, the Academy of Technological Sciences and Engineering to coordinate activity and manage national connectivity between initiatives;
- A national awareness campaign for mathematics and statistics targeting both the school and higher education sector and the general public as proposed by AMSI after its national forum in 2012.
- Deliver national initiatives or programs in science and mathematics education;
- Work as a clearinghouse for science and mathematics educators;
- Maintain a web portal access for teachers with links to the Australian Curriculum for science and mathematics and develop networks for online national collaboration;
- Develop web activities for teachers to participle in online activities such as 'talk to a scientist';
- Provide an online advisory service for school laboratory technicians to ensure safety standards in practical science lessons; and
- Provide careers advice.

APPENDIX D

SCIENCE COLLABORATIONS IN SCHOOLS: THE AUSTRALIAN CURRICULUM

There is strong evidence that the quality and status of science and mathematics teaching in Australian schools needs to be elevated.

As part of achieving this, there is a clear need to continue the delivery of support programs and resources to teachers and students in primary and secondary schools to enhance the uptake of mathematics and science. There are a number of excellent programs which will come together to underpin the Australian Curriculum and in particular the science and mathematics components of the Curriculum, providing a key enabling tool to deliver the teaching of science and mathematics to world best practice.

The umbrella program of Science Collaborations in Schools is one that utilises five proven successful inter-curricular programs for enhancing teacher capabilities, student learning and highlighting the relevance of science and mathematics as exciting career options to students. It will co-ordinate with ESA as appropriate.

The Science Collaborations in Schools program would encapsulate four components:

- Science Partnerships – Mathematicians, Engineers and Scientists in Schools (CSIRO) in primary and secondary schools (years F to 12) with particular focus on rural and remote schools;
- Science Innovation – expanded Science and Technology Education Leveraging Relevance (STELR - years 7 to 10) (ATSE) with a new on-line, interactive component to be delivered utilizing the NBN;
- Science Connections – an enhanced Primary Connections (Foundation to year 6) and Science by Doing (years 7 to 12) (AAS); and
- Science Practice – expanded Advancing Science Education by Learning in the Laboratory (ASELL) initiative which will deliver educationally sound and safety-compliant laboratory activities to secondary science teachers (years 7-10) (ACDS).

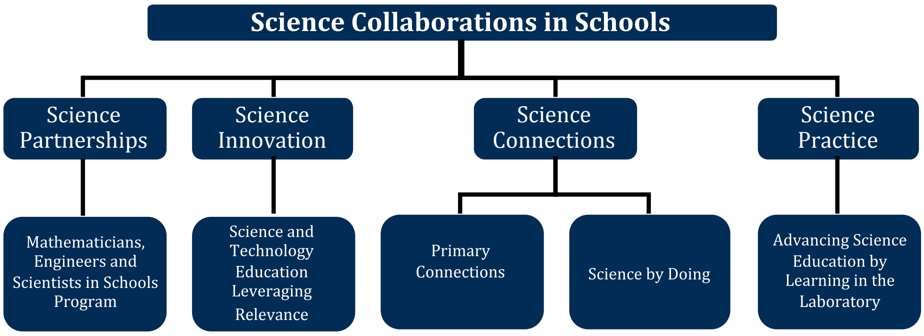
All elements have a focus on delivering the Australian Curriculum, enhancing ongoing teacher professional learning, using an inquiry based learning with real life relevance and career showcases. Further the program targets all students including remote and rural, indigenous and disadvantaged.

An important component of this initiative will be to provide professional learning workshops for teachers, mentoring programs and exposure to career mathematicians, engineers and scientists working in areas of national importance for Australia including emerging technologies, sustainability, nanotechnology, climate change, energy and biosecurity.

In addition, the Science Collaborations in Schools program will:

- implement a national, integrated approach to the Australian curriculum in science and mathematics;
- focus on teacher professional learning;
- use an inquiry-based approach to student learning;
- link teachers and students with real-life, relevant role models and contexts;
- be inclusive of gender, geographic location, Indigenous and low socio-economic groups;
- deliver a national program via a network of regional centres; and
- deliver educationally sound and safety-compliant laboratory activities to secondary science teachers.

Figure 1: Science Collaborations in Schools



APPENDIX E

SCIENCE PRACTICE THROUGH ADVANCING SCIENCE EDUCATION BY LEARNING IN THE LABORATORY (ASELL)

Laboratory and field work are the paradigms by which science gathers evidence and tests ideas. Exposure to laboratory and field activity is an essential element in the education of a scientifically literate citizenry, for the insight that it provides into nature of scientific enquiry, into what scientific ideas really mean, and into the issues involved in validating and interpreting scientific data.

It should be noted that laboratory activities are often favoured by students over 'dry theory', since well constructed activities make science ideas real, and can allow students the freedom to explore them in their own terms.

Regrettably exposure to laboratory activities in secondary education has decreased substantially in recent years. Among the reasons, two are notable.

- Much more stringent occupational health and safety (OHS) requirement have been enacted, which many teachers lack the expertise and resources to meet.
- Many teachers lack laboratory experience themselves, and so find it hard to produce educationally sound activities in this environment, and to adapt creatively to limited resources.

ASELL is a national community of practice built around programs of laboratory workshops for tertiary science teachers.

The Australian Council of Deans of Science (ACDS) believes that substantial progress can be made towards addressing these issues by extending ASELL to year 7 -10 science teachers.

At the workshops staff and students test and evaluate experiments that staff have submitted. In the context of this peer environment staff are challenged and provided with resources to:

- Expand their understanding of issues surrounding learning in the laboratory,
- Place educational ideas into appropriate theoretical frameworks;
- Improve their experiments in the light of educational analysis and feedback from students and staff.

One of the outcomes is a database of experiments which are educationally sound,

have been evaluated by students and staff, and have everything needed in order to run them, including materials and OHS requirements.

ASELL directors and the ACDS have recently begun to explore the adaptation of the program into secondary schools. The objectives of the program are to:

- Provide a peer environment in which university and school science teachers and education experts together develop educationally sound and tested laboratory activities appropriate to teachers' resources and environment.
- Provide a web portal through which teachers and university staff can interact, and which provides a curated and supported database of inquiry projects and laboratory activities.
- Develop a rural and remote outreach by partnering with existing initiatives and drawing on the National Broadband Network.
- Draw on the expertise of university staff to build capacity for science teachers to address OHS problems currently inhibiting the provision of laboratory activities
- Identify reforms to overly risk adverse OHS protocols that can be negotiated with the relevant education authorities by bodies such as the ACDS.
- Build capacity of university staff to engage with the issues of science teaching and learning in high schools
- Build the capacity of high school teachers to implement the intent of the Science Inquiry Skills strand of the National Curriculum in programs of laboratory activity.
- Build capacity of high school teachers to design and negotiate open-ended inquiry projects that are scientifically valid and educationally sound.

Such a program will forge better links between schools, science faculties and education faculties, facilitating greater co-operation and re-invigorating interest in science for both teachers and students.

Curtin University science faculty has successful experience in developing such

interactions with its ALTC project Science for early childhood teacher education students, and it has one of the founders of ASELL on its staff. The University of

Sydney, with another of the founders of ASELL on its staff, recently held an exploratory workshop with 15 science teachers to canvass the idea of an ASELL workshop in June.

The participants expressed unanimous enthusiasm for the ideas expressed above, offered school laboratories for the June workshop and agreed to recruit colleagues and students to it.

The ACDS proposes that the Government fund a pilot scheme for ASELL in schools aimed at teachers of years 7-10.

- The pilot would be conducted in two or three capital cities where there are universities that can contribute appropriate ASELL expertise.
- We envisage engaging 150 teachers in three workshops per year, each of which would require a day at the workshop and two days of preparation and follow up activities. At $300 per day relief teaching this is about $1,000 per teacher per workshop and so around $0.5m pa for this component.
- Administration, portal operation, academic staff time and laboratory costs could be covered by another $0.5m pa

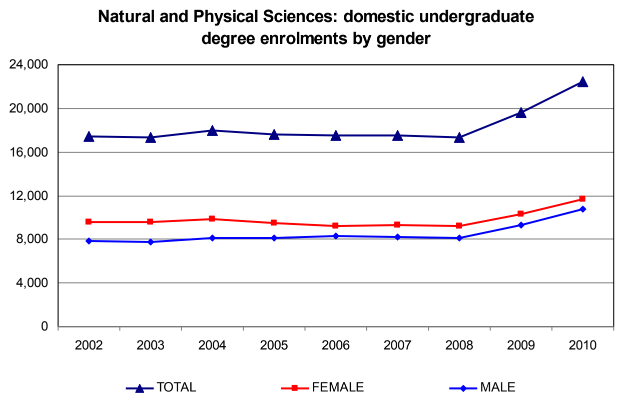
It would be preferable for such a program to be funded for three years at an overall cost of $3m, so that data can be produced to demonstrate its efficacy and to justify the implementation of a comprehensive scheme.

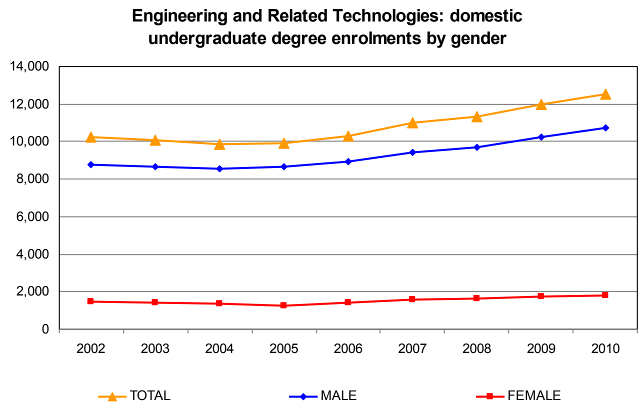
APPENDIX F

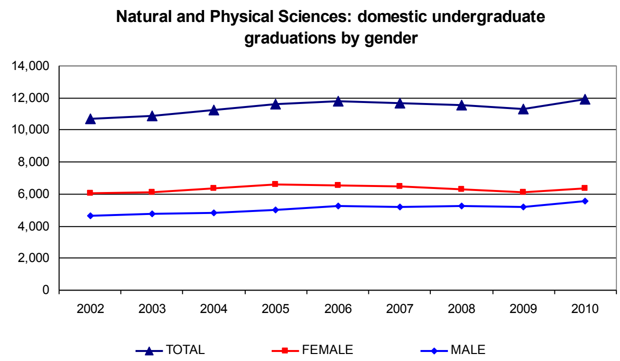
HIGHEST YEAR LEVEL OF TERTIARY EDUCATION IN FIELD BY GEOLOCATION: 2010

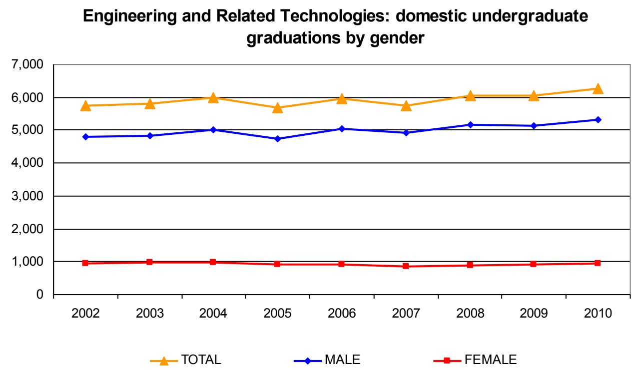
	Highest Year Level of Tertiary Education in Field														
	None			Year 1			Year 2			Year 3 and higher			**Total**		
	Metro	Prov.	Remote	Metro	Prov.	Remote	Metro	Prov.	Remote	Metro	Prov.	Remote	Metro	Prov.	Remote
Year 7-10 Maths	359 24%	223 31%	31 26%	242 16%	119 6%	20 17%	214 14%	116 16%	20 17%	669 45%	266 37%	48 40%	1484	724	119
Year 11-12 Maths	112 12%	62 16%	7 14%	92 10%	47 12%	9 18%	139 15%	62 16%	13 25%	600 64%	226 57%	22 43%	943	397	51
Year 11-12 Physics	21 8%	11 9%	2 18%	38 15%	24 20%	4 36%	50 20%	19 16%	1 9%	139 56%	66 55%	4 36%	248	120	11
Year 11-12 Chemistry	12 4%	7 5%	0	27 9%	13 9%	2 33%	40 13%	22 15%	3 50%	220 74%	103 71%	1 17%	299	145	6
Year 11-12 Biology	18 5%	17 9%	2 11%	11 3%	9 5%	0	18 5%	7 4%	2 11%	342 88%	147 82%	14 78%	389	180	18

BREAKDOWN OF ENROLMENTS AND GRADUATIONS BY FIELD OF EDUCATION AND GENDER: 2002-2010









APPENDIX H

STAKEHOLDER CONSULTATION JANUARY– FEBRUARY 2012

The following groups and individuals were consulted either face-to-face, by letter, email or telephone

ACT Minister for Education and Training

Association of Professional Engineers, Scientists and Managers, Australia

Australian Academy of Science

Australian Academy of Technological Sciences and Engineering

Australian Association of Mathematics Teachers

Australian Chambers of Commerce and Industry

Australian Council for Educational Research

Australian Council of Deans of Education

Australian Council of Deans of Science

Australian Council of Engineering Deans

Australian Curriculum, Assessment and Reporting Authority

Australian Education Union

Australian Geoscience Council

Australian Industry Group

Australian Institute for Teaching and School Leadership

Australian Mathematical Sciences Institute

Australian Mathematics Trust

Australian Research Council

Australian Science Innovations

Australian Science Teachers Association

Business Council of Australia

Chief Scientist of Western Australia

Commonwealth State and Territory Advisory Council on Innovation

Department for Education and Child Development – SA Government

Department of Education – Tasmanian Government

Department of Education and Communities – NSW Government

Department of Education and Early Childhood Development – Victorian Government

Department of Education and Training – ACT Government

Department of Education and Training – Northern Territory Government

Department of Education and Training – Queensland Government

Department of Education, Employment and Workplace Relations

Department of Further Education, Employment, Science and Technology – SA Government

Department of Industry, Innovation, Science, Research and Tertiary Education

Education Services Australia

Engineers Australia

Federal Minister for Climate Change and Energy Efficiency

Federal Minister for Education, Early Childhood and Youth

Federal Minister for Tertiary Education, Skills, Science and Research

Forum for European-Australian Science and Technology cooperation

Graduate Careers Australia

Mathematicians in Schools

National Science Teachers Summer School (45 science teachers from across Australia)

National Science Youth Forum (144 senior secondary science students)

Northern Territory Minister for Education and Training

NSW Chief Scientist and Engineer

NSW Minister for Education

Prime Minister's Science Prize Recipients

Principals Australia Institute

Queensland College of Teachers

Queensland Minister for Education and Industrial Relations

Questacon

Regional Universities Network Australia

SA Minister for Employment, Higher Education and Skills, Minister for Science and Information Economy and Minister for Education and Child Development

School of Education, University of New England

School Principals (17 from across Australia)

Science & Technology Australia

Science and Technology Education Leveraging Relevance

Scientists in Schools

Skills Australia

Tasmanian Minister for Education and Skills

The Australian Institute for Teaching and School Leadership

The Commonwealth Scientific and Industrial Research Organisation

The Department of Education – WA Government

The Group of Eight

UK Institute of Education, University of London

UK National Centre for Excellence in the Teaching of Mathematics

UNESCO (Science and Technology Education; Education for Sustainable Development; Asia-Pacific Program of Educational Innovation for Development)

Universities Australia

Victorian Chief Scientist for the Departments of Primary Industries and Sustainability and Environment

Victorian Curriculum and Assessment Authority

Victorian Minister for Education, Minister for Higher Education and Skills and Minister responsible for the Teaching Profession

WA Minister for Education

ACRONYMS

ABS – Australian Bureau of Statistics

ACDS – Australian Council of Deans of Science

AITSL – Australian Institute for Teaching and School Leadership

ALTC – Australian Learning and Teaching Council

ASELL – Advancing Science Education by Learning in the Laboratory

ASTA – Australian Science Teacher Associations

ATAR – Australian Tertiary Admission Rank

CBI – Confederation of British Industry

CNN – Cable News Network

CSIRO – The Commonwealth Scientific and Industrial Research Organisation

DEEWR – The Department of Education, Employment and Workplace Relations

DIISRTE – The Department of Innovation, Industry, Science and Research and Tertiary Education

ESA – Education Services Australia

MES – Mathematics, Engineering and Science

NBN – National Broadband Network

OECD – The Organisation for Economic Co-operation and Development

OHS – Occupational Health and Safety

PCAST – President's Council of Advisors on Science and Technology

PISA – The Programme for International Student Assessment

PMSEIC – The Prime Minister's Science, Engineering and Innovation Council

SiAS – Staff in Australia's Schools

STELR – Science and Technology Education Leveraging Relevance

STEM – Science, Technology, Engineering, and Mathematics

UK – United Kingdom

UNE – University of New England

US – The United States of America