STEM: Country Comparisons

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REPORT SUMMARY

Why is STEM education important?

The STEM skills policy agenda worldwide is driven by the:

- need to lift quality and supply of human capital,
- need to increase workforce capability to compete globally in technological innovation,
- skill shortages, and
- desire to lift overall levels of numeracy, science and digital literacy.

Countries performing high in PISA[1] Science and Maths – Singapore, Taiwan, Korea, Finland, Switzerland, and Shanghai and Hong Kong in China – have the lowest proportion of underperformers, are strong in research and development, and have experienced two decades of exceptional economic performance. OECD modelling demonstrates that differences in cognitive skills (e.g. as measured by PISA) explain historic differences in economic growth rates.

Countries that are strong in STEM have the following attributes:

- Highly esteemed teachers who are well paid working in meritocratic career structures.
- Compulsory focus on disciplinary content (unlike Australia).
- Active reform of curriculum and pedagogy with more engaging, problem/inquiry-based learning, critical and creative thinking.
- Prestige attached to careers in science.
- Strategic (bipartisan) national STEM policy frameworks which provide targets, objectives, metrics, approaches, coordination and collaboration across institutions and initiatives.
- Targets to motivate collaborative action – e.g. the USA's target of one million additional college graduates with STEM degrees in the next ten years to address labour market shortages.

Australia is lagging despite the plethora of reviews and policies

Australia has a long tail of underperforming students in STEM, with 30 per cent scoring below levels of minimal competency[2]. In addition there has been a steep decline in student commitment to science and maths between Years 4 and 8, and a declining percentage of Year 12 students participating in STEM.

There are capacity gaps in STEM teaching with a high proportion of Australian secondary school teachers teaching out of their field of expertise. The problem is not only with the number of teachers, but also their qualifications and confidence. There is also fragmentation within the education system, with most STEM students concentrated in high socio-economic status schools.

At the tertiary level, participation in mathematics and engineering is weak with enrolments at only about 50 per cent of the OECD average. Decreasing numbers of domestic students are commencing PhDs compared to rapid growth in STEM doctorates in other countries. There are also low completion rates across STEM in higher education.

Growing the STEM Pool

Expanding the talent pool from which STEM high achievers may be drawn requires:

- reducing subject choice in Year 12,
- making mathematics compulsory to Year 11 or 12,
- a focus on effort rather than innate talents – expecting high standards from all students,
- growing the proportion of women and low SES students, and
- encouraging talented law and business students to do STEM at tertiary level.

Attitudes to STEM

There is considerable evidence that student experiences and intentions in primary and lower secondary years are strongly indicative of eventual choices. Positive student attitudes to STEM are linked to performance. By Year 8 the proportions of Australian students who like mathematics and science are well below the international average.

There is a marked gender difference in attitude towards STEM careers. A survey of 15 year old Australians found 46 per cent of males plan careers in IT or engineering compared to eight per cent of females, while 26 per cent of males expect careers in health science or nursing, compared to 71 per cent of females.

Positive public attitudes to STEM may not translate into high national participation and performance in STEM education as a result, for example, of perceptions of low prestige and pay rates compared to medicine.

The role of families in mathematics and science education is vital and needs further development.

Labour market and industry a "black box"

Current policy focuses on the supply side (education system) and expects employers (demand) to make use of graduate skills. Further research is needed on the manner in which, and extent to which, STEM graduates' human capital is used at work.

STEM related skills - independent thought, quantitative reasoning, problem solving skills, ability to ask critical questions, forming and testing hypotheses - are increasingly adaptive in the modern world.

STEM graduates often work in non-STEM careers so inquiry-based learning providing knowledge of scientific processes and analytical skills give more flexibility than rote learning and repetitive tests (e.g. Singapore initiatives: Teach Less, Learn More; Thinking Schools, Learning Nations, p105)

Women are underrepresented in STEM education and careers

Australia is well below OECD and EU21 averages of per cent of qualifications awarded to women in STEM tertiary programs in engineering, manufacturing and construction, sciences, life sciences and mathematics. In IT, women account for 15 per cent of enrolments; in Engineering, 14 per cent.

Female participation in STEM careers is comparatively low, with a high attrition rate. This is important because poor gender balance is equated with less productive and relevant research, lower quality STEM research, poor social justice, and underutilised/wasted resources.

Approaches include targets, scholarships, mentoring, curricula, workplace change, and career advice.

Data shortages

There is a lack of standardised international data on upper secondary level participation in STEM. There is a need for the following:

- A comprehensive survey of secondary maths and science teachers to identify the number and full qualification profiles of teachers of all STEM subjects at all year levels.
- Data concerning the destinations of STEM graduates in the first 5-10 years after graduation, identifying the roles of STEM education and training.

References:

[1] OECD Programme for International Student Assessment (PISA)

[2] Trends in International Mathematics and Science Study (TIMMS)

Australian Government

OFFICE OF THE CHIEF SCIENTIST

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Recommendations

BACKGROUND

Developing Science, Technology, Engineering and Mathematics (STEM) skills is a subject of policy consideration worldwide.

The STEM skills policy agenda is driven by the:

- need to lift quality and supply of human capital,
- need to increase workforce capability to compete globally through technological innovation,
- skill shortages, and
- desire to lift overall levels of numeracy, science and digital literacy.

Australia's future competitiveness rests on innovation and enterprise. Virtually all sectors rely on STEM graduates.

New technology-based enterprises and high value-added sectors particularly depend on those with high level STEM skills.

The leaders, managers and workers of the future have to be numerate. Employment in STEM occupations, eg in ICT and engineering, is projected to grow at almost twice the pace of other occupations.

However, according to a recent Australian Industry Group (AIG) report[1], employers from across the economy report that STEM skill shortages are already limiting their business and ability to innovate.

The shortage of STEM skills will grow as the world becomes more technologically complex.

Addressing the shortage is a national challenge which will require the focus and effort of every sector to meet it.

If we are to address this STEM skills shortage, we need to fix the science and mathematics supply line and build better bridges between educators and employers.

Australia is lagging behind other countries on a range of STEM performance indicators from primary education through to employment.

While various initiatives exist across Australia that target the improvement of STEM education and match education with industry needs - to have the required impact and put the right people in the right places at the right time, Australia needs a large scale and coordinated approach.

The objectives of the following recommendations are to:

- 1. Make sure that students in primary school spend sufficient time on science and mathematics.
- 2. Lift the quality of STEM teaching at all levels of schooling to ensure students understand and are inspired by science and mathematics.
- 3. Ensure useful, meaningful and high-quality resources are easily accessible to support STEM teaching and learning at all levels of schooling.
- 4. Increase the number of students studying STEM disciplines to the end of Year 12 and in tertiary education.
- 5. Understand the demand for STEM skills in the workforce so that we can develop strategies to get the right skills in the right place at the right time.

Implementation of these objectives and the following recommendations will require consultation across multiple jurisdictional boundaries.

Recommendation ONE

Analyse and evaluate cross-portfolio and cross government STEM education initiatives

The Australian Government needs to:

- 1.1 Implement a stocktake and evaluation of innovative domestic STEM education initiatives, highlighting duplication, opportunities for coordination and gaps at all three levels of education (15.1, page 27)[2].
- 1.2 Compare and contrast Australian pre- and in-service education and resources for STEM teachers with countries that perform highly in STEM (9.1, page 22).
- 1.3 Coordinate and communicate findings to the STEM Reference Panel (15.1 and 15.2, page 27).

Recommendation TWO

I. Grow the pool of STEM informed people in the Australian community
II. Increase the quantity and improve the quality of the STEM cohort in higher education

Understanding of the underlying principles of STEM should be universal. We need to ensure that there is not only a STEM educated, flexible and resilient workforce, but also a community-at-large that is able to understand the rapidly growing demands of global technological change and innovation.

Successful economies are driven by rapid innovation and knowledge based industries. Evidence exists that Australian employers cannot find the STEM skills that they need (AIG, 2013). Yet the proportion of Australian students in both high school and tertiary institutions participating in STEM education is in decline. In 2002, Australia had 22% of graduating first degree students in STEM subjects compared to 64% in Japan, and 52% in China. In 2010, the proportion in Australia dropped to 18%. The US has recently set a target for one million additional STEM graduates by 2020. Australia would need around an additional 13,500 additional STEM graduates in order to keep pace with the US[3].

National, State and Territory Governments should ensure that:

- 2.1 Subject choices are reduced in Year 12, and STEM subjects made compulsory (5.1, pages, 19, 70, 71, 79 and 81).
- 2.2 Science teaching time in primary school should be increased from an average of less than three per cent to closer to the European average (9.5, page 24).
- 2.3 High standards are expected from all students by building resilience and confidence in solving maths problems through effective primary school curricula and remedial programs in mathematics, (5.1, page 19).
- 2.4 New and innovative strategies are established to grow the proportion of women, indigenous and low SES and disadvantaged students in STEM education and occupations (12.1-12.5 and 13.1-13.3, pp 24-26).
- 2.5 Performance in numeracy and science is measured via the National Assessment Program (including reporting of assessments against minimum, proficient and advanced standards) as well as international assessments such as PISA[4] and TIMSS[5] to identify areas for improvement and track progress toward the goal of being in the top five countries internationally in mathematics and science by 2025 (8.2, page 22).
- 2.6 An agreed target is established (across the industry, education and government sectors) and associated incentives introduced for an increased percentage of students in both secondary and tertiary STEM education in Australia (7.1, pages 21 and 98)
- 2.7 Significant prestigious STEM-focused schools and VET Centres of Excellence are established and formal linkages between schools, VET and Higher Education developed to encourage STEM (5.2, page 19).
- 2.8 STEM prerequisite requirements are re-introduced for relevant university programs (5.4, page 20).

- 2.9 Strategies are developed and implemented for reducing attrition rates across higher education STEM courses such as Engineering, ICT, Mathematics and Sciences - especially where they are higher than average (pages 60 and 138).

Recommendation THREE

Improve STEM education and awareness through development, streamlining and implementation of better teacher training and resources

Teachers throughout the education system need to meet the Australian Professional Standards for Teachers and must be resourced to provide meaningful, stimulating and challenging education that will broaden (increase quantity) and deepen (increase quality) both STEM engagement and achievement.

National, State and Territory Governments should ensure that:

- 3.1 Requirements and incentives are implemented for STEM teachers at both junior and senior secondary levels to support implementation of both the Australian Professional Standards for Teachers and the Accreditation of Initial Teacher Education Programs: Standards and Procedures in Australia (9.1, page 22).
- 3.2 The quality of, and access to, professional development and performance feedback, is improved through supporting the adoption of the Australian Teacher Performance and Development Framework and the Charter for Professional Learning of Teachers and School Leaders in Australia (9.3, page 23).
- 3.3 Career progression requirements and incentives for continuous (discipline and pedagogy) professional development for teachers is implemented in school and tertiary educational institutions (9.1-9.2, pp22-23).
- 3.4 A national program is developed to train specialist mathematics and science teachers to teach in all primary schools (9.5, page 24).

Recommendation FOUR

Facilitate a national approach to STEM teaching and learning that meet the needs of Aboriginal and Torres Strait Islander students

The engagement of Aboriginal and Torres Strait Islander students in STEM requires culturally responsive teaching, curriculum and pedagogy. This will ensure that indigenous students feel empowered to become involved in STEM subjects at school, through higher education and into professional pathways.

Australian Governments should ensure that:

- 4.1 Successful and new STEM activities are identified and implemented through a national coalition approach involving school, VET, higher education, and business (13.1, page 25).
- 4.2 Culturally responsive resources and teacher professional learning support are developed (13.1 - 13.3, page 26).

Recommendation FIVE

Identify the skill base that employers require from STEM graduates in the workforce now and in the future

Policy has traditionally focused on the supply side (ie the education system) and expected demand to make use of graduate skills. Conversely, employers have generally outsourced the training of young people to schools and universities, expecting tailor-made graduates.

While it is recognised that both specialist and generic STEM related skills (eg independent thought, quantitative reasoning, problem solving skills, ability to ask critical questions, form hypotheses and test them) are required in the workplace, we have a poor understanding of the manner and extent to which STEM graduates' human capital is used at work.

If we can determine what STEM skills are required by employers then we can target strategies and programs to get the right skills in the right place at the right time.

The Australian Government should:

- 5.1 Introduce a process by which the skills required of STEM graduates (from VET and higher education) in the labour force is identified through consultation and surveys (11.1, page 24).
- 5.2 In partnership with industry, compare and contrast the current and projected future requirements of STEM skills in the workforce with current workforce arrangements and forecast STEM skills through the education pipeline (11.1, page 24).
- 5.3 In partnership with industry, develop and implement a comprehensive Work Integrated Learning Policy. It will ensure that students complete work-related projects or placements throughout higher education. At least 50 per cent of STEM undergraduate students should complete a work-related placement or project during their course (page 51).

Recommendation SIX

Develop a STEM Reference Panel reporting to the relevant Federal portfolio ministers, through the Chief Scientist, to report on STEM provision and participation in Australia

National coordination will make a significant contribution to the enhancement of STEM education, participation, relevance and performance in Australia - as it has been shown to do in many other countries.

All stakeholders (education, industry and government, including States and Territories) in the STEM pipeline need to be engaged and develop a consistent and shared strategy and action plan to fix the supply chain of STEM skills from education to the workplace and community.
The STEM Reference Panel will undertake the following activities:

- Identify and compile data and potential gaps concerning participation and performance in STEM education (e.g. teacher workforce data) and report annually where appropriate (page 27).
- Prioritise factors contributing to the lack of STEM Skills in Australia, their dependencies and their interrelationships (page 27).
- Develop targets, an action plan, an evaluation framework, and communications strategy to address these priorities.
- Coordinate and network policies and programs designed to enhance approaches to STEM teaching and participation (page 27).
- Enhance students' knowledge about STEM jobs and professions (p. 21; p. 108).
- Develop an interdepartmental and intergovernmental STEM education committee across DEEWR, DIISRTE, and State Education Departments (Finding 15.2, p. 27, p.97).

References

[1] Australian Industry Group (2013) Lifting our Science, Technology, Engineering and Maths (STEM) Skills

[2] Numbers in brackets refer to paragraphs and page numbers in the ACOLA Report.

[3] Mathematics, Engineering & Science in the National Interest, 2012

[4] OECD Programme for International Student Assessment (PISA)

[5] Trends in International Mathematics and Science Study (TIMMS)