Abstract

This paper addresses the barriers and issues to the supply of engineers within Australia's education supply line.

It provides context, background, opinion, and the consequences if these barriers are not addressed. Examples of useful domestic support programmes aimed at lowering them are also discussed.

Contents

Overview

There are serious systemic barriers in the primary to secondary education pipeline to the eventual supply of domestically educated engineers.

Teacher shortage

A 2019 survey of over 3000 Technologies teachers by the Design and Technologies Teachers Association (DATTA) revealed that 96% of schools were experiencing difficulties recruiting Technologies teachers; and that 84% of schools were using teachers from a variety of other learning areas to teach Technologies.

There is also evidence that schools have stopped offering a range of Stage 5 and 6 Technology subjects as they have not been able to staff them effectively. Anecdotally, the situation in 2023 is worse than predicted in the 2019 survey.

No matter how much money and effort is expended on teacher support programmes, they will not succeed if there are no teachers to support!

Invisibility of Engineering

A recent survey by Engineers Australia revealed that girls were not contemplating a career in engineering because they did not know what engineering is, or what engineers do.

The relative invisibility of engineering in early curricula years is not confined to Australia. Survey data gathered by the UK's Institute of Mechanical Engineers as part of their the STEM Ambassador training revealed that 79% of 11–14-year-olds; 69% of parents ; and 42% of teachers don't know what an Engineer does.

If a student is not formally introduced to engineering concepts by the end of mandated subject learning in Year 8 then, unless they choose engineering-based electives in the remainder of their secondary education, they may never know what engineering is or what engineers do.

Additional barriers and issues

- Many Technologies curriculum outcomes in the middle school (Years 5-8) can (and should) be identified and named as Engineering outcomes – but they are not. You can't be what you can't see!
- Opportunities for pre-service teachers (i.e., those studying at university for a degree in education) to study Technology or Engineering specialisation are few and diminishing.
- For elective engineering courses in later years, including the prerequisites for university engineering entrance, if schools cannot find a suitably qualified teacher, they are simply not offering them. Once these subjects are lost from the curriculum, they are difficult to reinstate.
- By being slow to embrace change, and a tendency to focus mainly on the implementation of the vocational aspects of the learning area in most schools, Technologies is no longer highly valued in education. This is, of course, the opposite of how it is viewed by business and industry.
- The standard of technology and engineering education that is offered in many schools has not kept up with the rapid pace of technological change, the curriculum, or with learning theory.

Addressing all the above is important, but the most pressing need is to increase the number of Technologies teachers in our secondary schools.

The school education pipeline

In Australia, approximately 300,000 students each year are progressively moving through the education pipeline from kindergarten through primary school to secondary school. In 2022, there were approximately 6,500 primary schools (years K-6), 1,500 secondary schools (years 7-12), and 1,500 combined schools (years K-12).

Australian schools are either Public (70%), Catholic (15%), or Independent (15%). NSW, as the most populous State, educates around 1.1M students per year (660k primary and 500k secondary).

Individual States are responsible for their own education systems which should be guided by the educational outcomes of the agreed Australian Curriculum.

The Technologies learning area in the Australian Curriculum is divided into two streams, Digital Technologies (DT) and Design and Technologies (D&T). Their learning outcomes should be included in the curriculum in all States from Kindergarten/Foundation to Year 10.

In NSW, learning outcomes from both these streams are combined in the Science and Technology learning area in Primary schools, and in the Technology (Mandatory) Syllabus for years 7 and 8. Elective technologies and engineering courses are offered in years 9-12.

Why don't students know about engineering?

Engineering as a separate learning area does not exist in the Australian Curriculum. It is subsumed within the Technologies learning area. "Engineering principles and systems" are taught from Foundation to Year 10 as a context within the D&T strand of the Technologies learning area.

Apart from the title of the context, the outcome descriptions and the language used in the elaborations included for the guidance of teachers, rarely reference "engineering". Teachers therefore cannot be criticised for conflating Technologies with Engineering.

Historically, "Technology" was introduced into the classrooms of the western world in the early 20th Century to teach the skills required by the workers needed for the assembly lines of the factories and mills of the industrial revolution. These were trade skills and taught as such.

Engineering principles and systems were gradually introduced to Technologies curricula in the early, mandatory, subject school years (K-8), but Engineering as a distinct discipline only emerges from the current Technologies curriculum in the later elective subject years (9-12).

It is difficult to identify with something that is not named!

The late primary and early secondary mandatory subject years 5-8 (sometimes referred to as middle school) are where students firm up in their own minds the most appropriate education pathways to achieve their goals in life, and where they work out what they would like to do.

Organisations such as the excellent CSIRO's federally funded STEM Professionals in Schools programme confirm that one of their greatest difficulties in engaging with teachers is that they just don't recognise and identify the parts of the curriculum that are actually engineering rather than technology.

If students are not made aware of engineering in these Middle School years, they are less likely to choose the STEM subjects in years 9-12 that lead to an engineering career.

Shortage of Design & Technologies Teachers

In addition to the 96% of schools experiencing difficulties (in 2019) recruiting Technologies teachers; and the 84% of schools using teachers from a variety of other learning areas to teach Technologies;

- 39% of schools had reduced the amount of Technologies education they offered;
- 68% of these schools indicated that the quality of the remaining programs had been affected by the shortage of qualified teachers; and
- 71% of Technologies faculties in the schools surveyed indicated that they had received no direct STEM funding, resources, or support.

The problem has worsened since 2019 and is now so severe that the mandatory Technologies learning area in many secondary schools is being delivered in as simple a manner as possible by whatever out-of-field teacher is asked to deliver it.

For elective engineering courses in later years, including the prerequisites for university engineering entrance, if schools cannot find a teacher, they are simply not offering them.

The shortage and quality of Technologies teachers in our secondary schools identified by DATTA in their 2019 report is the most critical barrier not only to the supply of future engineers, but also to the future supply of skilled technologists, and technicians.

Teacher accreditation

In NSW, teachers are accredited by the NSW Education Standards Authority (NESA) to teach in NSW schools in accordance with appropriate qualifications gained through either a four-year Bachelor of Education degree, or a specialist degree (eg, Maths, Science), followed by a two-year Master of Education degree covering philosophy, pedagogy and curriculum etc.

NESA accreditation guidelines for teaching the Stage 6 Engineering Studies elective require the study of a minimum number of units in an Engineering degree. However, it is not NESA's job to either ensure, or check, that schools employ a suitably accredited teacher for the subject or elective being taught.

A barrier to the recruitment of teachers with prior experience (ie as an IT consultant) or practical skills (ie CAD or 3D printing), is that these skills and experience are not taken into account in the current accreditation process.

NESA is developing a recognised prior learning (RPL) framework to assist in the assessment of the prior training, skills, and experience of applicants for teacher accreditation and for already qualified teachers seeking recognition in additional subjects/teaching areas.

This is also a component in the proposed National Teacher Workforce Action Plan (NTWAP) with this work to be led by jurisdictions and the Australian Council of Deans of Education.

Schools in Victoria with a workforce shortage can apply for Permission to Teach (PTT) accreditation of individuals with appropriate subject experience but who are not yet qualified and accredited as teachers.

This is an attractive "Earn as you Learn" option for postgraduate students undertaking a Master of Education degree.

Teacher Professional Development (PD)

There is an abundance of professional development courses to up-skill teachers in response to the rapid pace of technology change. This is particularly the case for the development of Digital Technologies (DT) skills, where just a PC/Mac, smartphone or tablet and good online courses such as Adelaide University's CSER STEM Professional Learning can do the heavy lifting at minimal expense.

Off-screen DT resources have tended to concentrate on the programming of educational tools such as Bee-Bot, Sphero, and Lego Mindstorms robots.

Developing a teacher's Design & Technologies (D&T) skills on the other hand, can require more expensive hands-on experiential learning content and equipment, and time-consuming face-to-face support and mentoring by the programme suppliers.

The main issue, however, apart from the shortage of teachers more generally, is that teachers are finding it increasingly difficult to find the time to attend PD courses.

Technologies deficit in pre-service teacher education

Very few Universities offer a technologies specialisation and, where they do, there is low enrolment. There is therefore a spiral of lack of demand leading to lack of university support for such a specialisation.

Reasons may include an inadequate understanding of the learning area, lack of confidence by pre-service teachers, lack of qualified tutors, expense of workshop facilities, the small proportion of classroom time (5-6%) recommended for teaching Technologies in the classroom; and the need to rely on other faculties (ie Engineering) for support.

A greater focus on the Technologies component of pre-service teacher education is essential to the understanding of engineering as a discipline; the role of the engineer in society; and the implementation of effective Technologies learning content.

Teacher Gender

There is an issue in that the proportion of male teachers in all school sectors (public, catholic, independent) is predominantly female, with 18-20% male teachers in primary and 40% in secondary years.

Boys are influenced in their career choices by role models and, because technologies and engineering are still regarded as predominantly male domains, they are more likely to associate these subjects with male rather than female teachers.

This is a particular problem in the formative last two years in primary school (Years 5/6) where female teachers are likely to comprise over 75% of the teaching staff.

Adding to this problem is the understandable lack of confidence in teaching Technologies due to the deficit in pre-service teacher education, and the predominantly Humanities nature of our school curriculum.

As recommended by ACARA (the body responsible for the Australian Curriculum), Humanities subjects and unallocated time (21%) occupy more than 60% of classroom teaching time in primary school. Of the remaining 30% allocated to Science, Technologies and Mathematics subjects, only 6% is allocated to Technologies. **This equates to around 1.5 hours of classroom time per week.**

The male teacher issue has been recognised and is being addressed as part of the National Teacher Workforce Action Plan.

Low enrolment in Master of Education Courses

Enrolments in Master of Education Courses in Design and Technologies are low nationally. Master's courses have closed due to lack of demand, and there are fewer and fewer capable people of training teachers to teach existing content in Technology and Engineering education. The last course in Victoria at La Trobe University is now in teach-out mode due to a lack of enrolments.

Reasons for this situation could be similar to those offered for the low availability and enrolment in pre-service degree Technologies specialisations.

The low number of enrolments in a Master's degree not only reduces the pool of available Technologies teachers in schools, but also the number available to teach both pre-service and masters university courses.

Vocational technologies education in schools

Traditionally Years 11-12 were only for those students who wanted to continue to university and so focussed on academic studies. Between 1984 (NSW) and 2010 (WA) senior secondary education was made compulsory. One way of retaining students, and keeping them interested, was to make Year 11-12 studies more general, and a diverse range of industry-accredited vocational studies were introduced into these years of schooling.

Emphasis was placed upon the provision of a range of pathways, not just leading to university but to further technical education and employment entry. Course design has been such that the pathways are flexible, to delay the determination of specific career paths for as long as possible. As a result, vocational education in schools is growing in importance as an educational route for an increasing number of students.

Decades of this vocational-style implementation of Technologies education has led to strong and persistent perceptions that this is not an innovative, academic learning area that is of value to a broad range of students. Consequently, there is a limited desire for highly qualified teachers to teach in this area even though the State and Australian curricula for Technologies are very progressive and embrace 21st-century practices and considerations, such as design thinking and ethical and sustainable impacts of Technologies on society.

By being slow to embrace change, and a tendency to focus mainly on the implementation of the vocational aspects of the learning area in most schools, Technologies education is no longer highly valued in society, schools or by potential new teachers.

Keeping up with technological change

The standard of technology education that is offered in many schools has not been able to keep up with either the rapid pace of technological change or with learning theory. Keeping up is both expensive in terms of equipment and in the professional development of teachers – assuming that they are available.

The response to this challenge differs between States, but the increasing emphasis on vocational studies may be crowding out efforts to teach the more conceptual and higher order thinking aspects of both technologies and engineering.

Teaching along vocational lines neither excites nor encourages students to consider Engineering as a career.

STEM Education

Engineering and Technology are both important components of STEM (Science, Technology, Engineering, and Mathematics) education, but the distinct differences between them are poorly understood.

Judith A. Ramaley, the former director of the National Science Foundation's Education and Human Resources division in the USA coined the term STEM and described Science and Mathematics as the 'Bookends' to Technology and Engineering.

The primary difference is that Engineering is focused on the design, development, and application of systems and structures, whilst Technology is focused on the use of tools, techniques, and equipment to solve problems and improve processes.

It is the process and practices learnt through Engineering that enable the results of Scientific inquiry; Mathematical logic; and the tools of Technology, to be combined and focussed on the delivery of sustainable and ethical solutions to real world issues and problems. STEM in practice.

However, because of the relative invisibility of engineering as a separate discipline in the early mandatory curriculum years, both teachers and students struggle to understand and explain the differences.

"STEM Education" is now an accepted phrase in public discussion of education yet, for many, the "E" is just there to provide the vowel that makes STEM pronounceable!

It is comforting for engineers to hear educators and public intellectuals call for more "STEM Education". Whilst some clearly understand the role of Engineering; for others it is a plea for greater focus on their own STEM speciality.

Engineering electives in schools

Dedicated in-curriculum engineering electives are available for years 11/12 in all States. However, as the 2019 DATTA report reveals, finding teachers for these courses is becoming increasingly difficult.

Engineering courses for Years 9 and 10 are less common, but an innovative iSTEM elective in NSW is proving very popular and is worthy of national attention. Again, finding teachers to teach this subject is problematic.

NSW also offers an elective subject, Industrial Technology – Engineering, for Years 9 and 10. Both iSTEM and other Year 9/10 engineering and technologies electives are viewed as crucial for maintaining student enrolment in the Engineering Studies elective for Years 11 and 12.

The curriculum for Stage 6 (Years 11/12) engineering studies electives should be continuously reviewed to both keep up with both technology change and with advances in pedagogical theory. Seamless hand-off from similar courses in earlier years, should improve enrolment and ultimately an increase in the number of Engineering undergraduates.

University outreach

Many University Engineering Faculties have outreach programmes to both inform and to persuade mainly) secondary school students to consider engineering as a career. In NSW these have reduced significantly over the last few years.

However, such programmes are generally aimed at students who have already elected to study a STEM subject (i.e., students in Year 9 and above) and are therefore largely an exercise to recruit engineering undergraduates in a contested marketplace.

If we are to grow the cohort of students electing to study STEM subjects in later secondary years, outreach and other similar programmes must be extended to middle school students (Years 5-8).

Industry outreach

Companies and businesses can support many school STEM based outreach programmes – either by donating to charities and not-for-profits like the Smith Family's STEM Learning Clubs, or by providing engineer mentors to both students and teachers through programmes such as the federally funded CSIRO STEM Professionals in Schools or the Australian Business and Community Network's Innovate programmes.

Scholarships/bursaries and mentoring used to be available to secondary students in NSW engaged in Stage 6 engineering studies. If they then continued to university, these would continue. They were a valuable incentive for Technologies teachers and careers advisors to encourage students to choose engineering electives. **They no longer appear to be offered.**

Programmes such as these rely on either grants or donations and must engage individually with both companies and schools. Companies find it difficult to dedicate staff to administering and engaging with such outreach programmes.

We could make it easier for both companies, and those providing mentoring and workshops, by coordinating their administration and funding at the governance level of representative organisations such as EA, ATSE, and AiG, rather than at the individual school and individual business level.

Engineering support programmes

Overview

There are numerous programmes designed to excite students and support teachers in delivering Science, Technologies, Engineering, Mathematics (STEM) education across the whole K-12 education spectrum. Many can be found on Engineering Australia's Star Portal platform.

Whilst many STEM activities and projects use fundamental engineering design and management principles, teachers will probably continue to identify and teach them as Technology because their learning outcomes are mapped to the "Technologies" curriculum.

Price

Having to charge for activities, challenges, and support programmes is a significant barrier to implementation at scale. Most schools, particularly regional ones, have very small STEM education budgets. Providing programmes for free is very difficult when promoted by small operators who lack the funds or size to attract significant sponsorship.

An excellent example of significant industry/business sponsorship of a national programme – albeit in the DT space - is the *Schools Cyber Security Challenges (Cyber Challenges),* a $1.35 million national program which will see cyber security taught to Years 7-10 students for the first time in Australia. Taught to students in years 7-10 through the Australian Computing Academy (ACA), a University of Sydney centre, it is funded through an initial joint contribution from ANZ, the Commonwealth Bank, NAB, Westpac and BT, which was then matched by AustCyber.

Ideally, good support programmes must have adequate sponsorship for them to be provided free over the long term.

Teacher availability

Even if support programmes were free, there would still be the barriers of teacher availability and the tyranny of distance.

With a shortage of teachers across the board, release for professional development (PD) is becoming increasingly difficult for all schools. Where teachers can be made available there is cost for a replacement casual teacher which has to be covered from the funds allocated to a school for PD.

With classroom time for Technologies being such a small percentage (around 6%) of classroom, there is unlikely to be much funding available for Technologies PD.

Even if there were an adequate PD budget, casual Technologies teachers, particularly in the Regions are almost impossible to find due to the distances they often have to travel and its associated expense.

Until teachers, and their casual replacements become more plentiful, PD providers will find it difficult – particularly in the Regions – to fill their programmes.

Online delivery has become more acceptable due to COVID lockdown experience, but D&T PD in particular still requires significant face-to-face support and mentoring.

Current support programmes

Examples of excellent engineering programmes and challenges include:

- The Boston Museum's "Engineering is Elementary" national, in-curriculum, programme for primary schools which has been adapted for the Australian Curriculum by Questacon.
- STELR (**S**cience and **T**echnology **E**ducation **L**everaging **R**elevance) is a national, in-curriculum, initiative of the Australian Academy of Technology and Engineering (ATSE)
- The four national programmes developed by the Re-Engineering Australia Foundation - "F1 in Schools", "Subs in Schools", "4x4 in Schools", and "Space in Schools".
- The University of Newcastle's national Science and Engineering Challenge run with support of Rotary.
- STEM Professionals in Schools is run by the CSIRO and places STEM professionals alongside teachers to assist schools to implement STEM related projects
- Young ICT Explorers is a national challenge created by SAP and supported by CSIRO and the Smith Family. Although primarily directed to digital technology projects it inspires students in years 3-12 to solve real-world problems and projects which often exhibit a good knowledge and application of engineering skills – even if they don't realise it!
- Promoting STEM in Newcastle schools is a very active programme run by the Newcastle division of Engineers Australia
- Various robotics challenges including RoboCup Junior; First Lego League; and Australian National VEX Robotics Championship.
- The establishment of the Australian Space Agency has sparked a renewed fascination with space, leading to increased interest in various programs. These include the Australian Virtual Astronaut (AVA) challenge, Young Space Explorers, and the Powerhouse Museum's Future Space Programme, all of which have gained popularity. Many of these programs have been tied to the NSW curriculum and can be incorporated directly into the curriculum, as opposed to being offered as extracurricular activities.

Most of the above – and similar - programmes rely on sponsors outside of the formal education system for their development; and skilled and dedicated teachers and often volunteers for their

implementation. However, only one of the above (EiE), is currently focused entirely on the primary school years.

They all face severe implementation challenges because their sponsors must negotiate with schools on an individual basis. However, schools have their own challenges of classroom time; budget constraints; teacher skills; and teacher availability. They also rely on a "champion" teacher for their introduction and implementation, and programmes can cease abruptly if the champion leaves the school.

These, and other, experiential programmes offer exciting learning opportunities and are invaluable to the identification of engineering as an exciting career prospect.

Their ongoing long-term funding by Government, Foundations, Institutions, businesses, industry and individuals is essential to their ongoing existence and viability.