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Situating engineering within the Australian pre-tertiary education system

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Abstract

A global shortage of engineers is coinciding with an increasing demand for engineering skills. Clear education pathways are needed to attract future engineers who will work across the traditional boundaries of disciplines. This paper explores the visibility of engineering-related learning in pre-tertiary education as a means to spark students' interests and skills and encourage them to enter engineering as a profession. The national Early Years Learning Framework for Australia (EYLF) and Australian Curriculum, Version 9 for Foundation to Year 10, are analysed as pre-tertiary documents that guide learning from birth to Year 10. Engineering is not explicitly named in the EYLF, but associated behaviours are woven through the document. Within the content of the Australian Curriculum F-10, whilst engineering may be named in the sub-strand title, it is predominantly located in optional elaborations rather than content descriptors. Further, despite shared characteristics of engineering learning identified in the EYLF and the Australian Curriculum, the differing structures of the documents impede the articulation of learning across education contexts. This highlights the need for vertical alignment of guiding documents so that engineering-related learning outcomes and pedagogical approaches build cumulatively through pre-tertiary learning environments. Concerns regarding equity and access are highlighted, as these have implications for workforce participation and the extent to which Australia will be equipped to meet sector demands in a world that increasingly relies on engineering skills.

Keywords Initial teacher education · Pedagogy · Australian Curriculum F-10 · Early Years Learning Framework for Australia (EYLF) · Makerspaces

Extended author information available on the last page of the article

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Introduction

The availability of engineers is critical to addressing future economic prosperity through innovative products, services and solutions, and to achieving net-zero objectives to improve the health of the planet. Yet, a shortage of engineering graduates to meet the needs of societies characterised by rapidly evolving engineering and Science, Technology, Engineering and Mathematics (STEM) demands is a key challenge for many countries. Australia faces an acute shortage of engineers (Briggs, 2023) with demand exceeding supply at a rate three times more than that of the general workforce. This is exacerbated by lower participation of women in engineering professions in Australia, although the number of women employed in STEM-qualified occupations increased by 76% from 2013 to 2023 (Australian Government, 2024). A recent survey of US engineering jobs (Kodey et al., 2023) revealed that nearly one-third of engineering job vacancies remain unfilled, highlighting that a significantly lower proportion of school leavers are entering the engineering profession despite strong growth in job opportunities. Across the United Kingdom, engineering jobs are projected to grow at 2.8% adding another net 173,000 jobs by 2030—this is faster than the national average of growth in all occupations (Dwan-O'Reilly & Magrini, 2023). Australia is heavily reliant on skilled migrants to meet the demand for engineers, in part due to the retirement of 25,000 qualified engineers from the workforce over the five years up to 2026 (Briggs, 2024). There are simply not enough engineering graduates entering the workforce (Barak et al., 2024; Briggs, 2023). Madew and MacMaster elaborate in the foreword to the 15th Engineers Australia report:

> As we consider the transformational changes required to create a sustainable, safe, energy efficient world, engineers are already and will increasingly become more critical. Why? Because the engineering profession touches almost every aspect of life. (Briggs, 2023, p. 2)

The quantity, quality and areas of specialisation of future engineers are shaped by current educational systems. Consequently, we set out to explore how engineering is positioned within Australian national curriculum documents and the extent to which engineering is visible within such documents across education sectors (early childhood, primary, secondary) as a springboard into tertiary engineering education.

Definitional challenges

Engineering is generally accepted to include five main disciplines: civil engineering, chemical engineering, electrical engineering, mechanical engineering and software (or digital) engineering. However, sectors reliant on engineering are diverse and include (as but a few examples) agriculture, infrastructure and utilities, defence, mining, transport, nuclear engineering, aerospace and healthcare. The breadth and diversity of the profession contribute to the challenge of defining what engineering is and what engineers do. The absence of consensus on concrete characteristics of engineering as a discipline, as opposed to descriptions of how engineers think and act, may further contribute to the challenges in specifying aims for learning and teaching in schools and preschools (Lucas et al., 2014).

To this end, we used Engineers Australia's (2021, p. 1) definition of an engineer to guide our document analysis:

> Engineers create technology solutions to solve problems using mathematics and science to understand the problem, design and improve the solution.

Yet, engineering may *precede* scientific understanding: Hammack and Anderson (2022) suggest that 'to work at the margins of solvable problems and step beyond current scientific knowledge, responding to societal wants and needs, is the raison d'être of engineering' (p. 5).

Engineers have been described as transforming dreams, and bridging imagination and reality (Engineers Australia, 2024). Engineers innovate, design, build and maintain materials, machines, devices, systems and processes, incorporating empirical observations and iterative experimentation. Key professional and personal attributes of an engineer include ethical conduct, effective communication skills, the ability to be creative and innovative, the ability to use and manage information, and the ability to be a member of and lead teams (Engineers Australia, 2019).

Australian priorities

A recent national review of engineering education in Australia reported seven major findings (Australian Council of Engineering Deans [ACED], 2021). These included the need to avoid over-reliance on skilled migrants to meet domestic engineering expertise requirements, the importance of attracting women and Aboriginal and Torres Strait Islander students to engineering as a profession, and the importance of leveraging potential engineering students' desire to address 'real world' problems. O'Connor et al. (2024) offer important insights: citing research undertaken by Teese (2013) in Victoria (VIC) and Roberts, Dean and colleagues in New South Wales (NSW) (Dean et al., 2023; Roberts et al., 2019), they report persistent 'social selection' patterns evident in senior secondary school students' (Years 11 and 12, in Australia) access 'to different subjects spatially structured and patterned by gender, location and student family characteristics' (p. e7). Engineering is one such example.

National census data indicate that in 2021, the qualified engineer population working in engineering occupations in Australia was predominantly male (86%) with 0.3% of men being Indigenous Australian and 0.0% of the women identifying as Indigenous Australian (Engineers Australia, 2024, p. 9). Data from 2011 to 2015 indicate a growing number of students identifying as Aboriginal and Torres Strait Islander commencing and completing higher education qualifications in engineering and related technologies, yet in 2015, only 145 students commenced and 49 completed, and across the data 12–16% of the students were women (ACED, August 2017a). This low representation is despite Aboriginal and Torres Strait Islander people having 'worked with natural ecosystems for thousands of years, in contrast to post-colonial exploitation of natural resources' (ACED, August 2017a, p. 1), employing engineering systems and solutions to support this sustainable lifestyle. For example, Pascoe (2018) documents extensive examples of agricultural and aquacultural engineering across Australia such as interconnected dam walls, wells, weirs, and complex fish traps such as those still in existence at Brewarrina.

The ACED report that female engineers prefer branches of engineering that focus on people and communities, with 2015 data indicating, for example, that one-half of biomedical engineers were women compared with 25% of mining and chemical engineers, 15.4% of civil engineers and fewer than 10% of aerospace, electrical and electronic, mechanical and related branches of engineering (ACED, March, 2017b). This phenomenon is explained by the pre-tertiary engineering pipeline. In 2024, girls were still underrepresented in information technology, physics and astronomy, and engineering and related technologies—with girls' enrolments in these Year 12 subjects between 24 and 26%, although in biological sciences 65% of enrolments were girls, and slightly below 50% in chemical, earth, and mathematical sciences (Australian Government, 2024, p. 12). In 2017, girls were reported to be 'more influenced (than boys) in their study decisions by perceptions of identity and ability' (ACED, March, 2017b, p. 1). Such perceptions have persisted: female secondary school students who were not intending further STEM study reported reasons such as STEM subjects being too hard (42% compared with 40% of male students), not being interested in the subjects (72% compared with 59%), and not feeling clever enough (42% compared with 31%) (Australian Government, 2024).

The perception that enjoying mathematics and science subjects is not sufficient to consider studying engineering appears to prevent female students from enrolling in engineering courses (Engineers Australia, 2022). Female graduates enter a vertically segregated workforce with few women in senior leadership positions. This in turn impacts the number of women choosing tertiary engineering, thus gendered perceptions are cumulative and compounded by unconscious bias, stereotypes and myths that further perpetuate the low participation of women in engineering (Sharma et al., 2019). However, it is likely that pragmatic considerations also play a role. For example, in 2021, 10 years post-qualification, 53% of female STEM graduates had child care responsibilities compared with 18% of male STEM graduates—such responsibilities impact women's participation in the workforce.

Locating engineering within curriculum documents

There is growing interest in STEM as an integrated subject rather than teaching science, technology, engineering and mathematics as discrete subjects, both in prior-to-school and school education. A STEM approach has been depicted as disciplinary, multidisciplinary, interdisciplinary or transdisciplinary (Tytler et al., 2021; Vasquez, 2015). Yet, whilst connected, science, technology, engineering and mathematics are distinct disciplines and educators need to understand both the distinctions and the opportunities for integration. For example, while science investigates the natural world, engineering and technology focus on human-made aspects of our world. We rely on the definition of STEM as 'the integration of [science, technology, engineering and mathematics] either in any dyad, triad or ideally all four disciplines'

(Timms et al., 2018, p. 2), acknowledging that under this definition, STEM may not necessarily include engineering. Indeed Grubbs and Strimel (2015) attribute the traditional ('siloed') approach to teaching STEM disciplines as much to blame for students' disinterest in STEM and later, STEM careers.

In the context of early childhood education, the arts are frequently included with STEM disciplines and the acronym 'STEAM' applied (Cohrssen & Garvis, 2021). However, Clements and Sarama have argued persuasively against STEAM education and warn against attempts to force-fit science, technology, engineering and mathematics into learning experiences despite the affordances of play-based curricula (Clements & Sarama, 2021). Whilst there is growing interest in STEM education in schools (ACED, 2021) and early childhood education (Keane & Garvis, 2024), 'the "E" representing engineering in STEM, has remained relatively silent and needs to be amplified' (ACED, 2021, p. 11), more expressly conceptualised, and articulated.

The importance of promoting engineering education within the pre-tertiary education environment is increasingly recognised as it is fundamental to life in an increasingly technological world. However, Barak et al. (2024) suggest that despite the importance of engineering thinking, students may complete school having received minimal if any engineering education because few teachers have an engineering background. Minimal, if any pre- or in-service professional learning about engineering education is available to teachers. In addition, the authors say, engineering requires the application of scientific and mathematical skills—and integrating these with engineering knowledge and skills is complex. This applies to early childhood, primary and secondary teachers. However, early childhood education is largely absent from the literature addressing engineering education priorities. This gap may be a consequence of the perception that as the interface between science and technology, engineering does not apply to early childhood, yet children spontaneously demonstrate engineering thinking from a very young age.

Learning is a cumulative process: existing knowledge and skills become the foundations on which additional knowledge and skills are built (Duncan et al., 2007). Early engineering behaviours are evident in children's play and engagement with the environment from early in life (Bairaktarova et al., 2011): infants will pull on a blanket to bring a toy closer to their reach, or look at the spoon in a bowl of food and then use their hands to eat with—a much more efficient solution to transporting food. When using a shape sorter or stacking blocks, children observe, test and refine repeatedly and as they mature, collaborate with peers to solve more elaborate problems like transporting water from a tap through a sand pit and working out how to prevent the water from seeping away. Indeed, it has been suggested that of the four STEM disciplines, engineering best supports the integration of the other disciplines in problem-solving learning experiences (Timms et al., 2018) and to this end, 'makerspaces' have become increasingly popular in early childhood education and school settings for encouraging STEM thinking, socioemotional skills, creativity and problem-solving (Hatzigianni et al., 2021; Yang et al., 2025). Further, makerspaces give licence for older students to tinker and engage in this iterative learning process which is inherent in how engineers do their work.

Regardless of the age of the student, teachers play a crucial role in facilitating learning by iteratively responding to students' prior knowledge to extend their thinking from the everyday manipulation of objects to conceptual understanding (Mørch et al., 2023). Students are encouraged to solve problems when asked open-ended why, when, and how questions that encourage higher order thinking, but research suggests that teachers predominantly ask closed questions that require simple knowledge or recall with fewer opportunities to employ higher level thinking skills that prompt children to articulate their ideas (Birbili, 2013; Eliasson et al., 2017; Hamel et al., 2021; Navarro et al., 2024; Siraj-Blatchford & Manni, 2008). Yet, when open-ended questions are asked, students are more likely to use a wider range of vocabulary, complex sentences and higher level cognitive skills (Lee & Kinzie, 2012).

Bairaktarova et al. (2011) propose five categories of engineering-related behaviours in children's play: asking questions or stating goals, explaining how things work or are built, constructing things, solving problems and evaluating their constructions to determine whether it works as intended. Reflecting on an engineer's cognitive processes, van Meeteren (2018b) names the ability to focus, to consider multiple sources of information and move flexibly between considering both 'details within the whole, or the whole in light of the details' (p. 38). However, van Meeteren (2018a) also notes a tendency for teachers to encourage children to follow a linear approach to solve an engineering design problem which side-steps the complexity and iterative problem-solving nature of engineering.

Engineers Australia describe the elements of the engineering process as follows (n.d., p. 2):

- Ask: Understand the problem, identify constraints, and technologies available to solve the problem
- Imagine: Identify possible solutions, estimate solution effectiveness
- Plan: Identify how the solution will be implemented, identify technologies and processes to be used
- Create: Build the solution and test it
- Improve: Evaluate test results, identify areas for improvement, implement improvements

Within the context of engineering education, activities need to provide opportunities for students to apply the engineering process in practice (Cunningham & Sneider, 2023) to facilitate learning about 'making 'things' that work and making 'things' work better' (Lucas et al., 2014, p. 29), support the argument that engineering provides an effective vehicle for STEM-related problem-solving (Timms et al., 2018), and align closely with twenty-first century skills (Battelle for Kids, 2019). In addition, Albion et al. (2018) point out that these characteristics also align closely with the 'technology process' (investigate, design, produce, evaluate) and further, that while engineering is not generally a discipline area in school but is in university, technology education is a discipline area in school but may not be an entry-level subject for a university degree in engineering in Australia.

Visibility of engineering in national, pre-tertiary curriculum documents

Whilst 35% of women employed in science careers had considered science careers before senior secondary school, only 21% of women in engineering had done so (Engineers Australia, 2022). The same report argues the need for a focus on engineering in primary school. In this paper, we propose the need to be explicit about engineering learning in early childhood education and care (ECEC) to support both purposeful planning for children's playbased learning experiences *and* educators' professional learning (Ho & Pang, 2024; Isabelle et al., 2021) and so we set out to investigate the visibility of engineering in documents that guide learning from ECEC through the primary and secondary education phases in Australia. We briefly describe the documents included in this study before diving deeper to uncover engineering-specific foci within each.

The Early Years Learning Framework for Australia Version 2.0 (EYLF; Australian Government Department of Education, 2022) is an accredited national framework that sets out the vision for learning for children from birth to age five in ECEC settings. 'Belonging, being and becoming' is central to the world view of this document, which enshrines children's rights (United Nations, 1989; Australian Human Rights Commission, 2018) and is underpinned by the Alice Springs (Mparntwe) Education Declaration (Education Council, 2019). Designed to guide early childhood teachers and educators in their practice, the EYLF sets out principles, practices and five learning outcomes to support curriculum decision-making that focus on children's (i) identity, (ii) sense of connectedness and contribution to their world, (iii) sense of wellbeing, (iv) learning, and (v) communication skills. It also informs pre-service training for teachers and educators, and consequently, contributes to curriculum quality at ECEC setting level (Cohrssen et al., 2023) . Early childhood education environments provide rich opportunities for children to spontaneously integrate mathematical and scientific thinking to solve engineering problems using technology in their play, such as to transport water from one area of the sandpit to another, or to build ramps that help their cars travel farther. Yet, in the planning of learning experiences, educators are more likely to plan for discrete disciplines than provocations for children to find technology solutions to problems that draw on integrated STEM discipline knowledge (Campbell et al., 2018). This may be due to little elaboration of science, engineering and technology concepts in the EYLF (AGDE, 2022) and consequently, differing attention to discipline areas in initial teacher education programs.

In the Australian school sector, the Australian Curriculum, Version 9.0 (Australian Curriculum and Assessment Reporting Authority [ACARA], n.d) for Foundation to Year 10 (henceforth referred to as the Australian Curriculum F-10) has been set as a model curriculum. However, states and territories have scope to adapt and modify the curriculum to meet the needs of local contexts and communities, and while some aspects of state curricula may be similar to the model Australian Curriculum F-10, others differ. For example, in the NSW Kindergarten to Year 6 (K-6) curriculum, Science and Technologies are merged into one single syllabus but are separate in the Australian and VIC curricula. Further, in the NSW curriculum for Years 7 to 10, a range of elective subjects within the Technologies and Applied Studies learning area is available *in addition* to the core (mandatory) Technology 7–8 syllabus. The degree of choice within the NSW syllabus content thus varies across subjects and since the curriculum is in the process of being updated, depends upon the year of publication.

The Australian Curriculum F-10 comprises three dimensions: learning areas, general capabilities and cross-curriculum priorities. The learning areas are the foundation of the curriculum, outlining the essential content for teaching and learning. The general capabilities and cross-curriculum priorities are not separate subjects. Rather, they are a set of identified knowledge, skills and behaviours that enrich curricula *within* the learning areas.

Turning briefly to the final two years of school, the content and achievement standards for senior secondary subjects (Years 11 and 12) are presented in the Australian Senior Secondary Curriculum. The Australian Senior Secondary Curriculum specifies the rationale and aims, learning outcomes, content descriptors and achievement standards for each subject. The rationale for each subject includes a statement to explain the place and purpose of the subject, how learning in the subject is valuable and how it contributes to meeting the national goals of schooling. It is intended to be used as a common base for state/territory curriculum authorities to develop local curricula, and it is not directly delivered in schools. Rather, state curriculum and assessment authorities determine how to integrate the Senior Secondary Curriculum content and achievement standards into their courses and are responsible for all assessment (ACARA, n.d.-b).

Method

Working on the premise that teaching practice in early childhood, primary and secondary learning environments is shaped by the guiding framework/curriculum, we set out to identify where engineering is located in pre-tertiary framework/curricula documents in 2024. This process was guided by Greatorex et al. (2019) six key stages of curriculum mapping.

1. *Define study aims*

We set out to reveal and compare the presence or absence of engineering as a specific discipline, and/or components of engineering, in documents that guide teaching and learning in pre-tertiary learning environments. This was intended to investigate the visibility of engineering content in the various guiding documents.

2. *Decide which curricula will be considered*

The EYLF (AGDE, 2022), the national early childhood framework mandated for use across Australia, and the Australian Curriculum F-10 (ACARA, n.d.-a) were included in the analysis. Since the Australian Senior Secondary Curriculum is not taught directly in schools, it was not included.

3. *Determine the curriculum features that will be the basis of comparison*

Due to the widely differing structures of the two documents, we focused on different document features. However, in analysing both documents, search terms were based on Engineers Australia's definition of an engineer (Engineers Australia, 2021):

- Engineering, engineer(s)
- Technology, technologies
- Mathematics, mathematical thinking
- Science, scientific thinking, science process skills
- Design
- Problem solving, overcome/ing problem(s)
- Innovate, innovation, innovativeness, invent

4. *Collect relevant documentation and sources of data*

Both documents are publicly available online.

5. *Extract data and input it into the standard mapping instrument*

The EYLF (AGDE, 2022) was searched first for the search terms 'engineering' and 'engineer(s)'. Thereafter, we searched for the terms associated with Engineers Australia's (2021) definition of an engineer used in contexts related to curriculum content or learning outcomes and this information was recorded in a mapping instrument (an Excel file). Instances in which search terms were used in the context of principles of practice and teaching strategies (as opposed to curriculum content) were excluded from the dataset, as were key terms used in the glossary. The focus was thus primarily on learning outcome evidence markers.

All learning areas and year levels of the Australian Curriculum F-10 (ACARA, n.d.), were searched using the online curriculum search function.[1] We identified 97 results for the search terms 'engineer'/'engineering'. Next, each result was screened against our inclusion and exclusion criteria: instances of the word 'engineer' in learning area strands, sub-strands, content descriptors[2] or elaborations[3] were included, whereas curriculum connections, cross-cutting concepts and general capabilities were excluded. Nine duplicates, along with a further 10 results that referred

[1] See Appendix for the structure of the Australian Curriculum F-10.

[2] Content descriptors describe what is to be taught and what students are expected to learn, for example (AC9TDE8K03). Content descriptions are organised into strands and, in some learning areas, are further organised into sub-strands and include knowledge, understanding and skills, described at a year level or band of years, for example (AC9TDE10K03).

[3] Content elaborations are optional and are provided to give teachers ideas about how they might teach the content.

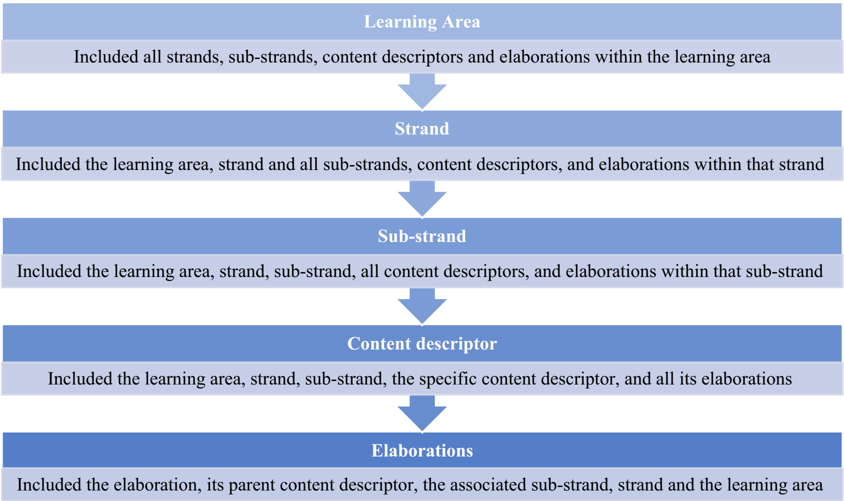

Fig. 1 *Data extraction flowchart*

to the word 'engine' rather than 'engineer'/'engineering' were excluded. A total of 44 instances of the word 'engineer' met our inclusion criteria.

Next, the dataset was created by extracting content based on where the terms 'engineer/engineering' were found using the flowchart depicted in Fig. 1. This ensured the comprehensive capture of engineering-related content across the curriculum, allowing for detailed analysis of the subject's presence within the Australian Curriculum F-10.

Finally, each content descriptor and its associated elaborations were reviewed and examined to find the search terms identified in Stage 3 above. A search term frequency count table was developed to summarise the data.

Research findings are presented, analysed and discussed below.

Results

Findings are presented by phase of education, starting with the national early years framework and followed by the school curriculum.

Early Years Learning Framework for Australia

While the terms 'engineering' and 'engineer(s)' are not used in the EYLF (AGDE, 2022), engineering skills are woven through the framework and particularly prominent in Learning Outcomes 4 and 5 which focus respectively on learning and communication. Indicative examples of statements from the framework are provided in Table 1. Multiple engineering behaviours are woven through the EYLF (AGDE, 2022). Ranked according to frequency of use, problem-solving and technology

Table 1 Indicative examples of children's engineering-related behaviours, by EYLF Learning Outcome (AGDE, 2022)

Search term	Frequency count	Indicative framework descriptor by learning outcome
Engineering/engineer(s)	0	–
Technology/ies	8	*Learning Outcome 5: Children are effective communicators* ● incorporate real or imaginary technologies as features of their play ● use digital technologies to access images and information, explore diverse perspectives and make sense of their world
Mathematics; mathematical thinking	6	*Learning Outcome 4: Children are confident and involved learners* ● contribute to mathematical discussions and arguments ● use a range of strategies and digital tools to organise and represent mathematical and scientific thinking *Learning Outcome 5: Children are effective communicators* ● use language to communicate thinking about quantities to describe attributes of objects and collections, and to explain mathematical ideas
Science; scientific thinking; science process skills	1	*Learning Outcome 4: Children are confident and involved learners* ● use a range of strategies and digital tools to organise and represent mathematical and scientific thinking
Design	1	*Learning Outcome 5: Children are effective communicators* ● use digital technologies and media for creative expression (e.g., designing, drawing, composing)
Problem solving; overcome/ing problems	8	*Learning Outcome 2: Children are connected with and contribute to their world* ● participate with others to identify and address environmental challenges and problems, and contribute to group ideas and plans ● express their views about important topics and work together to problem solve and enact solutions within their communities *Learning Outcome 4: Children are confident and involved learners* ● apply a wide variety of thinking strategies to engage with situations and solve problems, and adapt these strategies to new situations ● develop and test theories to solve problems
Innovate; Innovation; Innovativeness; Invent	1	*Learning Outcome 4: Children are confident and involved learners* ● manipulate natural and manufactured materials and resources to investigate, take apart, assemble, invent and construct

appear eight times and mathematics six times. Science, design and innovation are each referred to once. ‘Science’ is used in association with mathematics: ‘children use a range of strategies and digital tools to organise and represent mathematical and scientific thinking’ (p. 53).

Australian Curriculum Foundation to Year 10

The terms ‘engineer’ or ‘engineering’ were identified 44 times across the sub-strands, content descriptors and elaborations in the Australian Curriculum F-10 (Fig. 2). This includes the sub-strand *Engineering principles and systems* which is repeated across five bands (i.e., Years 1 & 2, Years 3 & 4, Years 5 & 6, Years 7 & 8, and Years 9 & 10). In the analysis that follows, we have removed this duplication, resulting in a total of 40 instances of the search terms ‘engineer’ or ‘engineering’. Just over half of the elaborations (54%) and 14% of the content descriptors in our data set included the terms ‘engineer’ or ‘engineering’.

Within our dataset, the word ‘engineers’ appears for the first time in the Foundation Science elaboration (but not the content descriptor): ‘…noticing how people including scientists, ***engineers,*** naturalists or citizen scientists ask questions…’ (AC9SFH01). When reviewing the learning area *Design & Technologies,* the term ‘engineering’ appears for the first time in the sub-strand title *Technologies context: Engineering principles and systems: Materials and technologies specialisations* at Years 1 & 2, however it does not appear in the related content descriptors or elaborations for this sub-strand.

The search term ‘technology’ co-occurred most frequently with ‘engineer’ and/or ‘engineering’ ($n=20$), followed by ‘design’ ($n=19$) and ‘science’ ($n=13$),

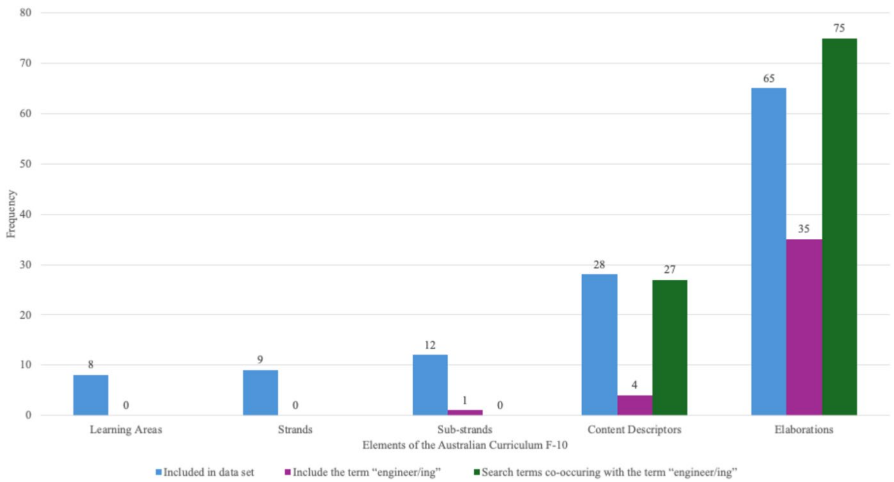

Fig. 2 *Total frequency count of the curriculum elements included in the dataset, curriculum elements including the term ‘engineer’/’engineering’ and search terms co-occurring with the term ‘engineer’/ ‘engineering’*

highlighting the emphasis of the Australian Curriculum F-10 on these disciplines in the context of engineering (Table 2).

Defining 'Design and Technologies', the Australian Curriculum F-10 states that 'students use design thinking and technologies to generate and produce designed solutions for authentic needs and opportunities'. Further, the rationale for the Design and Technologies curriculum states that: 'Learning in Technologies is also important for a diverse and capable science, technology, engineering and mathematics (STEM) workforce'. Yet, in the very next sentence, engineering is omitted, rendering engineering within STEM invisible:

> STEM learning involves explicit teaching of knowledge and skills in each learning area: Science, Technologies and Mathematics. A transdisciplinary approach can enhance the application of students' scientific and mathematical literacy, design and computational thinking, problem-solving and collaboration skills. (ACARA, 2022, p. 4)

The Design and Technologies learning area comprises two strands and ten sub-strands. Four of the sub-strands within the Knowledge and Understanding strand are described as 'technology contexts' and this section of the curriculum is structured to provide students with multiple opportunities to produce designed solutions within different technologies contexts. Schools decide on the combination of technologies contexts and designed solutions. As a result, student experience in relation to the *Engineering principles and systems* sub-strand is highly varied. Indeed, our analysis demonstrated that in Years 1, 2, 5 and 6 whilst the word 'engineering' is included in the sub-strand title, it is neither mentioned in the associated content descriptors nor in elaborations. The curriculum thus provides teachers with no guidance on how to operationalise the engineering content reflected in the sub-strand title, and any engineering focus is likely to be incidental rather than planned.

Table 2 Frequency of search terms co-occurring with the term 'engineer'/'engineering' in the Australian Curriculum F-10

Search terms	Australian Curriculum F-10		
	Within content descriptors	Within elaborations	Frequency
Technology, technologies	7	13	20
Mathematics, mathematical thinking	0	2	2
Science, scientific thinking, science process skills	8	5	13
Design	6	13	19
Problem solving, overcome/ing problem(s)	1	2	3
Innovate, innovation, innovativeness, invent	1	5	6

Discussion

In both ECEC settings and schools, educators turn to curriculum documents to guide their teaching. Differences in the structures of the documents included in the analysis were immediately evident, highlighting challenges in facilitating the iterative and accumulating nature of learning across education sectors. We worked from the premise that the more frequently the words 'engineer' or 'engineering' are used in the content of such documents, the more explicit the focus on engineering content in teaching and learning would be. This is an important first step towards supporting the continuum of learning from early childhood through school, and encouraging students to enrol in engineering subjects (if available) in secondary school which in turn equip students with foundational knowledge and dispositions to proceed into tertiary engineering qualifications.

Engineering within the Early Years Learning Framework

The EYLF (AGDE, 2022) is a framework rather than a curriculum document. The distinction is salient: ECEC standards documents have been categorised as 'skills progression documents' or 'framework documents' which can be further categorised as 'curriculum frameworks', 'inclusive frameworks' (the EYLF is in this category), and 'general learning goals' (Kagan et al., 2013). Consequently, one could assume that given the framework's focus on play-based learning, engineering-related child behaviours would nonetheless be included—as they are.

Consequently, our position differs somewhat from that of Keane and Garvis (2024) who report no mention of engineering in the EYLF (AGDE, 2022) and suggest that early childhood teachers are consequently not expected to engage with engineering within early years settings. Indeed, the specific words 'engineer' and 'engineering' are not used. Yet, we found an abundance of references to key terms that derive from the definition of an engineer we employ in this paper.

Play is the primary vehicle for learning in Australian early childhood education settings and is described in the EYLF as 'both a context (a place or space where children play) and a process (a way of learning and teaching) where children can ask questions, solve problems and engage in critical thinking' (AGDE, 2022, p. 21). Indeed, the EYLF further states that when children are confident and involved learners (Learning Outcome 4), they 'use active mental processes such as exploration, experimentation, questioning, collaboration and problem solving across all aspects of curriculum' (AGDE, 2022, p. 50)—all of which align with engineering processes (Engineers Australia, n.d.). However, in the absence of the words 'engineer' or 'engineering' it is unlikely that educators would associate such behaviours as characteristics of engineering skills or practices during the first five years of a child's learning. This highlights the need for research to investigate both educators' pedagogical content knowledge (Shulman, 1986) and the efficacy of their pedagogy within the context of the increasingly popular makerspaces in ECEC as opportunities to support STEM exploration.

While we argue that the framework provides opportunities for educators to synthesise demonstrations of component behaviours and recognise them as engineering thinking, we draw attention to an imbalance in the relative attention paid to them in the framework. Mathematics is referred to six times in the EYLF (AGDE, 2022), and to support early childhood educators' ability to identify and respond to children's mathematical thinking, the Australian Education Research Organisation has developed learning trajectories that elaborate on mathematics (AERO, 2023). The only mention of science in the previous version of the EYLF was one reference to educators modelling 'mathematical and scientific language and language associated with the arts) (DEEWR, 2009, p. 38) causing Guarrella and colleagues (2022) to hope that science would be 'placed on an equal footing with literacy and mathematics' in the revised EYLF (AGDE, 2022). Little changed in the revised framework.

In this paper, we rely on a definition of engineering that incorporates *mathematics and science* thinking. However, the sole reference to children applying scientific thinking is not elaborated by suggestions about how to do so beyond being guided to 'model mathematical and scientific language, e.g., count out loud and point out patterns' (p. 53) and 'use cooking experiences, as well as sand and water play, to support mathematical and scientific skills such as observation, reasoning and measurement' (p. 54). Further, science learning trajectories were not included in the AERO Early Childhood Learning Trajectories, and are not included in the Preschool Outcomes Measure (Australian Government Department of Education, n.d.) currently in development for use in Australia, or the Early Years Assessment and Learning Tool (The University of Melbourne & Victorian Department of Education, n.d.).

Several early childhood education researchers have raised concerns regarding the absence of an explicit focus on science in the EYLF (AGDE, 2022) and the extent to which teachers guide children's science learning in the early years (Guarrella, 2021; Guarrella et al., 2021, 2022; Keane & Garvis, 2024; Klofutar et al., 2020; Sliogeris & Almeida, 2019). However, Harrison et al. (2019) examined the practices of 21 educators employed at five ECEC sites, all of which at least met the Australian National Quality Standard. Here, 13.81% of the participants' total time was spent focusing on intentional teaching as they negotiated the diverse demands on their time. Problem-solving and numeracy learning experiences were reported to receive little attention (0.6 and 0.4% respectively), science/nature (0.7%) and media/technology, no attention (0.0%) (p. 530). Whilst the authors do not imply their study to be representative of the field, one can nonetheless infer that children enrolled in such programs would have few opportunities for educator-facilitated mathematics and science learning, or their application to solve engineering problems.

In summary, engineering behaviours are *woven through* the framework and mostly evident in Learning Outcomes 4 and 5. However, engineering learning is incidental (Ramanathan et al., 2023) and dependent upon EC educators' individual abilities to recognise them and at the time of writing, no discrete engineering subjects were found in accredited Australian early childhood initial teacher education courses. When included in STEM or STEAM subjects, the focus on engineering specifically is inevitably diffused by the need to address all discipline areas and their integration.

Engineering within the Australian Curriculum, Foundation to Year 10

Within the content of the Australian Curriculum F-10, engineering is predominantly located in the optional elaborations. Within our dataset, 'engineer'/'engineering' is not explicit in the titles of learning areas or strands, and appeared only once in a sub-strand. It is explicit in four content descriptors, but 35 elaborations (see Fig. 2), which teachers may or may not access since elaborations are defined as 'suggestions of ways to teach the content description and connect it to general capabilities and cross-curriculum priorities. Content elaborations are optional.' (ACARA, n.d.).

In Australia, students' opportunities to access pre-tertiary engineering education differ widely. For example, in NSW, explicit engineering education is located mostly in elective subjects outside the mandated curriculum and students have agency to choose Technology and Applied Studies options. This brings into focus the importance of students' prior learning experience—from ECEC through primary school—and in particular, their perspectives on science and technology as these will be instrumental in guiding students' subject choices in junior secondary school and beyond (Palmer, 2020). The Australian Curriculum F-10 places the most emphasis on the design characteristics of engineering. This suggests an opportunity to explicitly link the engineering and design, and technology curricula. Grubbs and Strimel (2015) suggest the teaching of STEM disciplines as discrete learning areas has contributed to student disinterest in STEM subjects.

However, research also indicates the importance of teacher expertise in both discrete discipline-specific knowledge and pedagogical strategies when facilitating STEM learning through bottom-up (student led) and top-down (curriculum led) approaches to differentiating teaching through problem-solving learning opportunities. This equips teachers to meet students at their point of entry to the learning (that is, the prior knowledge they bring to the problem) as well as to ensure that curriculum goals are met. Here, Mørch et al. (2023) describe teachers' recognition that at times, students may not have mastered prerequisite concepts and highlight the need for integration of traditional school subjects with opportunities for hands-on, problem-solving, makerspace type pedagogies. Students select Year 11 and 12 subjects in Year 10, therefore students who have not selected mathematics, physics and chemistry at this point are unlikely to enrol in tertiary engineering courses.

Limitations

We acknowledge two limitations to this work. First, the search methodology was adjusted to align with the differing characteristics of guiding documents since curricula are qualitatively different from framework documents. School curricula include syllabi, scope and sequences, units of work, standards materials and work samples, whereas the EYLF (AGDE, 2022) guides curriculum decision-making and emphasises the importance of play as a vehicle for learning. However, whilst the need to adapt our data collection method to fit the documents is one limitation of this research, it also highlights the obstacles posed to continuity of learning when frameworks and curricula are inconsistent in structure, presentation and search functions. Second, as the Australian Senior Secondary Curriculum is not taught directly in schools, it was not included in this study. Investigating continuity of learning from Year 10 through Years 11 and 12 is an important focus for future curriculum analysis.

Conclusions and implications

Advanced manufacturing, frontier technologies, healthcare and digital services, including finance, are likely to feature dominantly across the global economic landscape and, compounded by the rapid uptake of artificial intelligence, will lead to significant changes to economies across the world. Across these sectors, future engineers will be needed to work across the traditional boundaries of disciplines. Stronger and more visible pathways that encourage more students to careers in engineering are essential to address workforce challenges. In this paper, we argue the need for an integrated continuum of teaching and learning that situates engineering more visibly within guiding documents to support teaching practice and thus provide opportunities for learners at all stages of pre-tertiary education. The concept of an engineering education pipeline draws attention to the need to nurture students' engineering interest and capability from early childhood through to tertiary education and training. To ensure continuity and sustained engagement, a coherent and cumulative curriculum—aligned with national guiding frameworks such as the Australian Curriculum and the Early Years Learning Framework—would ensure that engineering learning remains engaging and relevant across all phases of education. To attract more women to engineering careers in particular, research indicates the need to shift the discourse from engineering as being difficult, to being an opportunity to make a difference to society and the environment in ways that are impactful, exciting and fulfilling (Engineers Australia, 2022).

We started from the premise that more explicit references to engineering in pre-tertiary curriculum documents may be a first step towards making careers in engineering more visible, familiar and engaging for learners. We investigated two core documents that guide teaching and learning in Australia from birth to Year 10 and found that while engineering is not explicitly named in the EYLF (AGDE, 2022), associated behaviours *are* prominent—albeit inconsistently so—in the framework document. Opportunities to access engineering education at school differ since states and territories adjust the Australian Curriculum F-10 to align with place-based learning. Thus, while some aspects of state curricula may be similar to the model curriculum, others differ. The extent to which they differ, and the implications of differing integration of the Senior Secondary Curriculum (ACARA, n.d.-b) into Year 11 and 12 subjects across states and territories, both warrant further investigation.

Engineering responds to societal priorities (Hammack & Anderson, 2022) and may *precede* scientific understanding. This highlights the need for pre-tertiary teachers—from early childhood to Year 10 and beyond—to possess both the discrete and integrated STEM discipline knowledge and skills, and appropriate pedagogies, to teach engineering (Grubbs & Strimel, 2015) breaking down silos whilst simultaneously ensuring students' learning progresses towards curriculum goals, constructing pre-requisite discipline-specific concepts along the way (Mørch et al., 2023). If achieved, the differences between girls' and boys' self-perceptions of identity and ability that influence their completion of advanced mathematics and physics subjects may be addressed (ACED, March 2017b) in turn supporting smooth transitions for school leavers into higher education, regardless of gender or identification as Aboriginal and Torres Strait Islander. Achieving this demands collaboration among stakeholders within the education sector from early childhood education and through the school years to harmonise the focus on learning progressions that incrementally increase students' skills, dispositions and engagement with engineering concepts and practice to encourage them along pathways into tertiary education.

Our findings may prompt other countries experiencing similarly low enrolment in tertiary engineering courses to examine the extent to which such subjects are visible in curricula and accessible to students as they progress through education systems.

Appendix: Structure of the Australian Curriculum Foundation—Year 10

Curriculum components	
Learning area	The Arts—comprising the subjects of Dance, Drama, Media Arts, Music and Visual Arts English Health and Physical Education Humanities and Social Sciences (HASS)—comprising the subjects of Civics and Citizenship, Economics and Business, Geography and History Languages—comprising the subjects of Arabic, Auslan, Chinese, French, German, Hindi, Indonesian, Italian, Japanese, Korean, Modern Greek, Spanish, Turkish and Vietnamese, as well as the Framework for Aboriginal and Torres Strait Islander Languages, and Framework for Classical Languages including Classical Greek and Latin Mathematics Science Technologies—comprising the subjects of Design and Technologies, and Digital Technologies
Learning area specifications	Achievement Standard Content descriptions Elaborations
General capabilities	Critical and Creative Thinking Digital Literacy Ethical Understanding Intercultural Understanding Literacy Numeracy Personal and Social capability

Curriculum components	
Cross-curriculum priorities	Aboriginal and Torres Strait Islander Histories and Cultures Asia and Australia's Engagement with Asia Sustainability
Other	

Data sourced from ACARA (n.d.)

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Declarations

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