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Research article

STEM outreach redefined: Insights from a civil engineering case study

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Abstract: Outreach programs play a crucial role in addressing the declining interest in science, technology, engineering, and mathematics (STEM) fields, particularly in civil engineering, where workforce shortages continue to grow. Traditional outreach activities, such as bridge building challenges, have long been a staple of engagement programs, but concerns over sustainability, material consumption, and repetitive engagement necessitate a re-evaluation of current practices. This study examines the effectiveness of alternative outreach strategies through a pilot study that utilizes a framework aligning activities with developmental stages and diverse student motivations. The study evaluates the pilot study of hands-on activities using commercially available sustainable materials, incorporating real-world engineering simulations, and leveraging digital outreach methods to extend engagement beyond physical events. Findings suggest that the effectiveness of an activity is highly dependent on age-appropriate complexity, group dynamics, and the integration of theoretical and practical components. The results highlight the need for outreach initiatives to move beyond one-size-fits-all approaches and towards tailored, scalable, and sustainable models that foster long-term STEM engagement. This research offers an outreach framework that could enhance inclusivity, maximize resource efficiency, and align with evolving educational and workforce needs in civil engineering.

Keywords: STEM outreach, civil engineering, workforce engagement, sustainability, inclusive education, hands-on learning

1. Introduction

Universities hold a critical role in shaping future professionals by providing education and training that enable students to meet the demands of evolving industries. However, in the context of rapid advancements in artificial intelligence (AI), robotics, and automation, there is growing concern over the declining interest in traditional science, technology, engineering, and mathematics (STEM) careers. Research shows that students' decisions to pursue STEM fields are influenced by a complex array of factors, including age, socioeconomic status, gender, environmental conditions, and familial support [1–3]. Dawes et al. [4] found that career decision making is a gradual process, beginning as early as year 8, when students often select a broad area of interest, and becoming more specific by year 12, when 73% of students report having finalized their university and degree choices. All educators play a central role in shaping these decisions, with classroom educators identified as the most influential figures, followed by parents and relatives, who account for 23.32% of reported influence [4]. These findings underscore the importance of early and sustained interventions to foster interest in STEM fields, particularly among underrepresented groups such as women and students from low socioeconomic backgrounds.

Despite these insights, several systemic barriers hinder efforts to attract and retain students iyearn STEM in Australia. One of the most pressing challenges is the prevalence of underqualified teachers delivering STEM curricula, which can negatively impact student engagement and interest in these subjects. Bentley et al. [5] highlight the importance of equipping graduate teachers with both deep subject matter knowledge and innovative pedagogical techniques to make STEM subjects more engaging and relevant to students. Furthermore, while tertiary education outreach and transition programs are widely recognized as critical tools for fostering interest in STEM, their effectiveness varies significantly depending on how they are managed. Top-down outreach initiatives, managed centrally by universities, benefit from institutional legitimacy and funding but often rely heavily on external partnerships for sustainability [6,7]. In contrast, bottom-up approaches, driven by individual academics, can be more innovative but frequently lack the resources and stability needed for long-term success [8]. Striking a balance between these two models is essential to ensure that outreach programs are impactful and enduring. Research consistently shows that early and sustained engagement with students has a positive impact on their decisions to pursue STEM fields [9].

The challenges facing STEM education are particularly acute in civil engineering, where workforce shortages have become a pressing issue. This decline is particularly alarming for civil engineering, which faces increasing demand due to global population growth, urbanization, and the need for sustainable infrastructure. In Australia, civil engineering vacancies rose by 31% in 2022, leaving approximately 2,500 positions unfilled [10]. Despite this demand, the supply of qualified graduates remains insufficient, with only 1,117 civil engineering graduates entering the workforce in 2018, a marked decline from previous years [11]. Addressing this gap requires an understanding of the factors that influence students' career choices and a strategic approach to engaging prospective engineers at critical stages in their education.

To engage prospective civil engineers, educational strategies must evolve to incorporate modern tools and technologies alongside practical experiences such as site visits, internships, and opportunities to work on real-world projects [12]. Additionally, outreach and recruitment efforts must address the diverse motivations of students. Research by [13] highlights that while men are often drawn to civil engineering for its technical challenges and management opportunities, women are more likely to prioritize work-life balance and job stability. Recognizing and addressing these differences can help create inclusive and effective initiatives that appeal to a broader range of students.

This paper explores the factors influencing students' decisions to pursue STEM fields, with a particular focus on civil engineering. By analyzing current outreach practices, educational strategies, and workforce trends, it seeks to identify effective solutions for bridging the gap between the demand for civil engineers and the supply of qualified graduates through outreach activities.

Research Questions:

1. What specific activities and tools are most effective in engaging students at different educational stages in STEM outreach programs focused on civil engineering?
2. How can STEM outreach programs incorporate sustainable practices, including reusable materials and scalable designs, while maintaining educational value?

2. Background

2.1. Outreach and engagement programs in Australia

Outreach programs in Australia offer a diverse range of activities designed to inspire students and encourage their interest in STEM fields, particularly civil engineering. A common component of these programs is hands-on engagement, with bridge-building activities standing out as a staple of initiatives such as "Discovery Day," "Engineering the World," and the Queensland University of Technology (QUT) Bridge Building Challenge. These activities cater to a broad age range, from primary to secondary school students. While bridge-building activities are popular, they also come with limitations. For instance, balsa wood bridge construction, a common format, requires quick-set glue, which poses safety concerns for younger participants and prolongs the activity due to drying times. Despite these challenges, variations such as spaghetti bridges and paddle pop designs remain central to civil engineering outreach due to their accessibility. The sustainability of such activities is increasingly under scrutiny, with materials like balsa wood being both costly and disposable. Larger outreach events often involve over 100 participants in a single day, consuming significant resources. This raises questions about the environmental and financial feasibility of these activities as long-term outreach solutions. With the widespread adoption of these activities, most institutions include a balsa bridge-building activity within their civil engineering outreach programs, which causes repetition and a lack of engagement for students.

In addition to bridge building, other civil engineering outreach activities have emerged to address these challenges while maintaining engagement. Programs like "Engineering the World" have diversified their offerings to reduce reliance on resource intensive materials while preserving hands on interaction. Similarly, broader STEM outreach efforts in Australia have leveraged innovative methods, including digital media. Short videos hosted on university websites, YouTube, and social media platforms have gained traction as effective tools for reaching young audiences. Research indicates that YouTube generates over 20.4% of all global mobile internet traffic [14]. This underscores the potential for digital outreach to complement traditional hands-on activities by extending reach and accessibility. With the prevalence of generative AI (GenAI) reaching mainstream education, the adoption of these tools will need to be considered to begin the ethical and

AI-literacy of students [15,16].

Several Australian universities have pioneered notable STEM outreach programs that integrate civil engineering elements. The Science and Engineering Challenge (SEC), founded by the University of Newcastle, is a nationwide initiative aimed at inspiring students to “make a difference in the world by choosing a career in science and engineering” [9]. Targeting Year 9 and 10 students in its challenge segment and Year 5 and 6 students in its “Discovery Day” events, the SEC features activities that promote teamwork, problem-solving, and creativity—critical professional engineering skills that are lacking within the current engineering curriculum. With approximately 15,000 participants annually, the program has demonstrated significant success in motivating students to pursue STEM education [6].

The University of Melbourne’s Endeavour program offers another example of a large-scale outreach initiative. Hosted by the School of Engineering, Endeavour features an annual expo where final-year engineering students showcase their design projects to school students, industry members, and academics. Running for over a decade, the expo serves as a hub for STEM engagement, complemented by interactive classroom presentations for primary and secondary students across Victoria. This program has established strong relationships between the university and local schools, creating pathways for future enrollments and fostering sustained interest in engineering careers [17].

La Trobe University has adopted a creative approach to STEM outreach with its LaserTag Activity, developed by the Department of Engineering. Designed to engage high school students, this program allows participants to assemble LaserTag devices and apply engineering concepts through gameplay scenarios. By combining fun with practical application, the activity has successfully increased student interest in engineering careers, particularly among those previously uncertain about their career paths [18]. Building on this success, the program has expanded to include escape room activities, using similar design frameworks to foster problem-solving and collaboration [19].

Collectively, these programs demonstrate the diversity and innovation in Australian STEM outreach, with civil engineering playing a central role. From resource intensive hands-on activities to scalable digital initiatives, these efforts highlight the potential for outreach to inspire future engineers while addressing sustainability and accessibility challenges. Continued refinement and evaluation of these programs will be crucial in ensuring they meet the evolving needs of students and the engineering profession. The outreach and engagement activities themselves cannot alone solve the systemic issues with students’ decision-making being a crucial pathway.

2.2. Decision making

Studies on students in the Year 5 and 6 age group reveal that their decision-making processes are often emotionally driven when faced with difficult choices [20,21]. Key factors impacting these decisions include fears about career prospects, investment in the decision-making process, and knowledge of the professional world [22]. Addressing these areas of concern can significantly enhance students’ confidence in their future workforce prospects. Recognition for completing tasks also provides a positive experience and fosters personal growth [23]. As students mature, their career decisions evolve based on a growing understanding of their abilities and achievements. A study of Year 3 to 9 students found that while interest in science and engineering exhibited minimal variance (±1% per year group), students’ understanding of specific careers deepened with age, influencing their preferences. This highlights the importance of engaging students at a younger age to nurture their career interests and provide opportunities for informed decision-making [24].

External influences also play a significant role in shaping students' career choices. Career advisors, parental support, and exposure to professional role models are among the most impactful factors. Students who engaged in face-to-face discussions with career advisors reported more positive experiences compared to those who did not have access to such interactions. Parental careers significantly influenced students, particularly in STEM fields, with students more likely to follow these paths when they received support from parents in STEM-related professions. Among these influences, parental support was identified as the strongest, surpassing the impact of career advisors [25].

A sense of belonging is another critical factor influencing career choices, particularly in engineering [26]. This is shaped by various elements, including gender, sociocultural background, peer acceptance, and disabilities. Engineering remains a male-dominated field, with women representing only 16% of engineering graduates and 16% of the workforce in Australia [27]. Surveys reveal that the most significant barriers deterring women from pursuing engineering careers include concerns about the difficulty of coursework (29%), lack of awareness about the profession, and fears about entering a male dominated industry (29%) [27]. Cultural perceptions within the profession also contribute, as 13% of women expressed concerns about not fitting in [27]. These findings suggest that while progress has been made, the engineering profession still has significant cultural barriers to overcome [28].

This issue is not confined to civil engineering or Australia. Studies in Germany also reveal that the term "engineering" itself can discourage women from pursuing related careers due to stereotypes and concerns about workplace discrimination [13]. Many women entering engineering careers report encountering gender-based challenges that can hinder their long-term participation in the field. Addressing these issues requires fostering inclusivity through outreach programs, mentorship, and representation in media campaigns to challenge stereotypes and create a welcoming environment for all genders [29,30].

Socioeconomic status (SES) also significantly impacts career aspirations and educational pathways. While students from low-SES and high-SES backgrounds often share similar career goals, financial limitations and difficulty navigating university systems are significant barriers for low-SES students [3]. Outreach programs can play a vital role in bridging these gaps by providing targeted support, resources, and guidance tailored to the unique challenges faced by low-SES students. Programs that nurture career aspirations while offering practical pathways to higher education are essential for promoting equitable access to STEM careers.

Effective outreach programs should address these diverse factors by fostering confidence, providing information, and creating inclusive opportunities for all students. Tailored interventions that consider gender, sociocultural background, SES, and disabilities are necessary to ensure that students from all walks of life feel supported in their career journeys.

3. STEM outreach framework

The application of a recently developed framework [31] for conceptual designs offers a promising pathway to reimagine outreach activities. By replacing balsa bridges with alternative, sustainable, and inclusive activities, this framework aligns outreach programs with contemporary educational needs, fostering greater accessibility, environmental responsibility, and lasting interest in engineering careers. Described in Table 1 is the STEM Outreach Methods of Interactions and Descriptions Framework. The framework was validated for this purpose by the above literature review and contextual design for the Australian outreach community.

Table 1. Framework of STEM outreach methods of interactions and descriptions.

Method	Description	Age Group
Hands-on, Interactive Demonstrations	Activities that encourage physical interaction with engineering concepts, such as building simple machines or conducting basic experiments. This stage emphasizes exploration through play to stimulate curiosity about STEM.	Primary and Middle School Students
Narrative-Driven Engagement	Using stories and real-life scenarios to make engineering concepts relatable and engaging, fostering a personal connection to the subject.	Primary and Middle School Students
Simple Engineering Challenges	Basic challenges designed to develop problem-solving skills and teamwork. Collaborative tasks are particularly effective for fostering communication and cooperation.	Primary and Middle School Students
Constructivist Learning Approach	Emphasize learning through doing, where students construct knowledge via direct engagement and social interaction.	Primary and Middle School Students
Guided Inquiry and Exploration	Encouraging students to ask questions and explore answers through experimentation within a structured framework. Includes project-based learning to foster curiosity and understanding.	Middle and High School Students
Team Projects	Group projects where students collaboratively design and build solutions to real-world problems, reinforcing learning outcomes through peer interaction.	Middle and High School Students
Engineering Design Processes	Teaching students the engineering design process, including conceptualization, prototyping, and testing. These principles help students understand how engineers solve problems systematically.	Middle and High School Students
Advanced Tools and Technologies	Introducing students to industry-standard tools like CAD software and 3D printing, allowing them to visualize and refine designs. Exposure to the latest technological innovations through industry or academic professionals.	High School Students (Years 9–12)
Real-World Simulations	Contextual learning activities that mimic	High School Students (Years

	real-world engineering challenges, connecting theoretical concepts to practical applications and fostering deeper comprehension.	9–12)
Critical Thinking and Analysis	Activities requiring students to analyze data, evaluate engineering design choices, and test solutions, developing higher-order thinking skills.	High School Students (Years 9–12)
Industry Collaboration and Mentorship	Partnering with professionals for mentorship, guest lectures, or collaborative projects. This exposes students to real-world engineering practices and helps bridge academic and professional experiences.	High School Students (Years 11–12)
Complex Design Challenges	Advanced tasks requiring in-depth planning, teamwork, and execution, such as prototyping innovative products or addressing societal issues through engineering solutions.	High School Students (Years 11–12)

4. Conceptual design

The conceptual designs of the four outreach activities were governed by the framework and the contextual requirements of Australian students. To achieve the project's aims, an off-the-shelf material (PASCO) was purchased for sustainability and scaling purposes. The purchased material consisted of truss members designed from a flexible plastic material, available in set lengths, and connected via bolts. The technology-driven component of these resources is the accelerometers and computer interface, which enable the collection of real-time force and acceleration values.

4.1. Primary school (Years 5 & 6): Forces in equilibrium

For younger students in Years 5 and 6, the activity focused on introducing the concept of forces in equilibrium through a hands-on, interactive approach. Using a simple beam structure constructed entirely from the PASCO resources, students explored how forces shift as weights are applied at different points along the beam. The activity allowed students to observe how reaction forces at the supports change dynamically in response to load placement. Once the experiment was completed, students compared their observations with theoretical calculations, fostering an early understanding of fundamental physics concepts.

Alignment with Framework:

- Hands-on, Interactive Demonstrations: The activity uses physical interaction to teach foundational engineering principles, aligning with the framework’s focus for primary school students.
- Constructivist Learning Approach: Students construct knowledge by engaging with the beam model and observing how forces respond to different conditions.
- Age-Appropriate Complexity: The simplicity of the beam structure and the focus on equilibrium suits the developmental stage of Year 5 and 6 students, emphasising exploration and play.

4.2. High school (Years 7 & 8): Internal forces in truss structures

For students in Years 7 and 8, the activity progressed to studying internal forces using a simple truss structure. Leveraging PASCO resources, students constructed and tested a truss to understand how internal forces are distributed when loads are applied to different joints. The experiment demonstrated how reaction forces are shared among supports and beams, emphasizing teamwork and problem-solving as students worked collaboratively to analyze their structures.

Alignment with Framework:

- Simple Engineering Challenges: The truss activity represents a basic engineering challenge that promotes teamwork and problem-solving, key goals for middle school students in the framework.
- Guided Inquiry and Exploration: Students are encouraged to explore how loads interact with the truss structure through testing and observation, supporting inquiry-based learning.
- Constructivist Learning Approach: By constructing and testing trusses, students actively engage in building knowledge about internal forces.
- Age-Appropriate Complexity: The activity introduces a more complex structure (truss) than the beam used in Years 5 and 6, reflecting the increasing cognitive capabilities of students in Years 7 and 8.

4.3. High school (Years 9 & 10): Truss analysis and asymmetry

In Years 9 and 10, students delved deeper into truss analysis, focusing on asymmetrical truss bridge structures. Again, using PASCO resources, students constructed their designs and tested them under varying load conditions. This activity allowed students to observe and compare the differences in load distribution and stability between symmetrical and asymmetrical designs. By analyzing how reaction forces shift with changes in geometry and load application, students gained an intermediate understanding of truss analysis concepts.

Alignment with Framework:

- Engineering Design Processes: Students engage with key aspects of the engineering design process, including building, testing, and analyzing truss structures.
- Critical Thinking and Analysis: By comparing symmetrical and asymmetrical designs, students develop higher-order thinking skills and the ability to evaluate engineering solutions.
- Project-Based Learning: The activity incorporates elements of long-term project-based learning, where students work through design and testing phases.
- Age-Appropriate Complexity: The focus on asymmetrical structures introduces nuanced concepts that are suitable for students at this stage of their education.

4.4. High school (Years 11 & 12): Advanced truss analysis

For senior students in Years 11 and 12, the activity expanded on the foundational truss analysis explored in Years 9 and 10. Students revisited the asymmetrical truss bridge design but engaged with the activity at a higher level of complexity, focusing on detailed calculations, theoretical modelling, and advanced problem-solving. This approach tested the depth of their understanding, bridging theoretical knowledge with practical applications. The activity encouraged the use of analytical and teamwork skills, preparing students for transitions to tertiary education or careers in engineering.

Alignment with Framework:

- Complex Design Challenges: The activity's emphasis on detailed calculations and advanced modelling aligns with the framework's focus on developing sophisticated problem-solving abilities in senior students.
- Real-World Simulations: The testing of asymmetrical trusses mirrors real-world engineering challenges, connecting theoretical learning to practical applications.
- Industry Collaboration and Mentorship: While not explicitly involving industry professionals, the activity encourages students to approach challenges in a professional manner, fostering career readiness.
- Age-Appropriate Complexity: The activity's depth and focus on theoretical modelling reflect the advanced cognitive abilities and educational needs of senior high school students.

5. Pilot evolution

The evaluation of the activities was undertaken as part of an invitation to local primary and high schools. Due to privacy concerns at the school, no student perspectives could be captured, and the following represents an evaluation perspective review from the design team. While this approach limited direct student input, it provided valuable pilot data on engagement, group dynamics, and instructional clarity.

The field testing of instruction sheets revealed encouraging interaction rates, ranging from 75% to 95%, but also highlighted several challenges. Younger students in Years 5 and 6 were enthusiastic yet often struggled with focus and task completion. Distractions were common while waiting for instructions, and some students expressed curiosity through questions that went beyond the scope of the activity, such as those about real-world structures. Retention of activity sheets was moderate, with approximately 75% of students keeping them. These results suggest that activities for this age group should focus on hands-on tasks that nurture curiosity, reduce theoretical complexity, and align with the framework's emphasis on exploration and play.

For middle school students in Years 7 and 8, distractions persisted, and gender dynamics became more noticeable. Female students often took observational rather than hands-on roles, and larger group sizes (around 10 students) reduced equitable participation. Engagement remained at about 80%, but activity completion rates were inconsistent, and retention of materials fell to 50%. These findings indicate the need for smaller groups, guided inquiry techniques, and collaborative problem-solving approaches to sustain engagement and align with the framework's focus on constructivist learning and teamwork.

As students progressed into Years 9 and 10, a more stable activity structure produced improved outcomes. Engagement averaged 75%, and most groups successfully completed their tasks with results aligning well with theoretical predictions. However, large group sizes again limited full participation, and retention of activity sheets dropped to only 25%, suggesting weaker post-activity engagement. For this age group, a balance of theoretical and hands-on components, smaller groups, and structured follow-up tasks would better align with the framework's emphasis on critical thinking and the engineering design process.

Senior students in Years 11 and 12 demonstrated the highest levels of engagement, with interaction rates reaching 95%. Competitive teamwork proved to be a strong motivator, and small groups of around four students allowed equitable involvement and deeper understanding of theoretical concepts. The activities were successfully completed, with results that closely matched theoretical predictions. Retention of instructional materials, however, remained low at 25%. For this group, maintaining small group sizes, using competition strategically, and introducing advanced tools such as computer-aided drawing (CAD) software would enhance authenticity and align with the framework's emphasis on real-world simulations, industry collaboration, and project-based learning.

Overall, the pilot field testing confirmed the feasibility of the activities and provided important lessons for refinement. Younger students benefit from simplified, hands-on activities that prioritize creativity and exploration. Middle school students require structured guidance, gender-balanced participation, and inquiry-based approaches. Older students respond well to advanced, collaborative, and competitive tasks that mirror authentic engineering challenges. Although the absence of student feedback is a limitation, future iterations should incorporate teacher reflections, student surveys, and follow-up studies to capture a richer evidence base. By addressing these refinements within the conceptual framework, outreach programs can be further developed to support diverse learners and ensure equitable, meaningful engagement in STEM.

6. Limitations and future work

This study was constrained by the absence of direct student feedback due to privacy restrictions, limiting the ability to quantitatively measure learning gains. The pilot evaluation was also conducted within a single national context, meaning that cultural and curriculum differences in other countries could influence outcomes. As discussed by Neher-Asylbekov and Wagner [32] and Xu and Ouyang [33], variations in prior knowledge, cultural background, and local educational contexts significantly influence student interest and learning outcomes. Therefore, implementing the proposed framework internationally should be undertaken with clear contextual adaptation and purpose. Future work should include cross-cultural comparative studies and longitudinal data collection to better measure the sustained impact and transferability of the outreach model across STEM disciplines and educational systems.

In addition to contextual adaptations across countries, future outreach research should also consider the growing influence of emerging technologies. Emerging GenAI tools could further strengthen this outreach model by enabling adaptive learning experiences and real-time analytics. GenAI tools could assist educators in creating contextualized simulations and problem scenarios [34]. Integrating GenAI into outreach programs could also enable more data collection, allowing for the evaluation of engagement and learning outcomes with greater ease. Ethical considerations, including data privacy and GenAI literacy, must be embedded within future research to ensure responsible implementation [35].

7. Conclusions

This study highlights the importance of tailored outreach programs in fostering interest and engagement in STEM fields, particularly civil engineering. By considering factors such as age, gender, socioeconomic background, and parental influence, the research demonstrates the value of designing activities that align with students' developmental stages while addressing systemic barriers. The use of a conceptual framework ensured that activities were age-appropriate, engaging, and effective in building foundational skills. Although the field trial was limited to qualitative and observational data, the results provided indicative evidence of the framework's effectiveness in aligning outreach activities to student developmental stages. Engagement rates between 75–95% across age groups support the framework's central claim that tailoring complexity and context enhances learning outcomes. While the evaluation remains preliminary, the principles of developmental alignment, sustainability, and inclusivity are not discipline-specific and could be extended to other STEM fields.

Pilot field tests confirmed the feasibility of the activities and revealed promising interaction rates across year groups. Younger students responded best to hands-on exploration, middle school students benefited from structured inquiry and balanced group dynamics, and senior students engaged strongly with advanced, authentic engineering challenges. These findings reinforce the importance of scaffolding outreach activities to developmental needs.

The pilot also identified areas for refinement, including group management, instructional clarity, and limited retention of materials. While the absence of direct student feedback is a limitation, future research should incorporate teacher input, student surveys, and longitudinal tracking to strengthen evidence of impact. By embedding inclusivity, sustainability, and engagement, refined outreach programs can create meaningful pathways into engineering and inspire diverse student populations to pursue STEM careers.

Author contributions

Zachery Quince – Conceptualization, Methodology, Writing – original draft, Writing – review & editing, Supervision; Ben Coultas - Conceptualization, Methodology, Investigation, Writing – original draft, Writing – review & editing.

Use of Generative-AI tools declaration

The authors declare they have used Artificial Intelligence (AI) tools in the creation of this article.

AI tools used: Perplexity & ChatGPT

How were the AI tools used? The tools were used to refine the structure and development of the manuscript

Where in the article is the information located? Throughout the article

Conflict of interest

The authors declare that they have no conflicts of interest.

Ethics declaration

This study did not require ethics committee approval.

References

1. Regan, E. and DeWitt, J., Attitudes, interest and factors influencing STEM enrolment behaviour: An overview of relevant literature. *Understanding Student Participation and Choice in Science and Technology Education*, 2014, 63–88. https://doi.org/10.1007/978-94-007-7793-4_5
2. Wang, M.-T., Ye, F. and Degol, J.L., Who chooses STEM careers? Using a relative cognitive strength and interest model to predict careers in science, technology, engineering, and mathematics. *Journal of Youth and Adolescence*, 2017, 46(8): 1805–1820. https://doi.org/10.1007/s10964-016-0618-8

3. Xie, Y., Fang, M. and Shauman, K., STEM education. *Annual Review of Sociology*, 2015, 41: 331–357. https://doi.org/10.1146/annurev-soc-071312-145659
4. Dawes, L., Long, S., Whiteford, C. and Richardson, K., Why are students choosing STEM and when do they make their choice? *Proceedings of the 26th Annual Conference of the Australasian Association for Engineering Education (AAEE2015)*, 2015. School of Engineering, Deakin University.
5. Bentley, B., Sieben, R. and Unsworth, P., STEM education in Australia: Impediments and solutions in achieving a STEM-ready workforce. *Education Sciences*, 2022, 12(10): 730. https://doi.org/10.3390/educsci12100730
6. Eilam, E., Bigger, S.W., Sadler, K., Barry, F. and Bielik, T., Universities conducting STEM outreach: A conceptual framework. *Higher Education Quarterly*, 2016, 70(4): 419–448. https://doi.org/10.1111/hequ.12105
7. Figgis, J., Butorac, A., Clayton, B., Meyers, D., Dickie, M., Malley, J., et al., Advancing Equity: Merging "Bottom Up" Initiatives with "Top Down" Strategies. *A National Vocational Education and Training Research and Evaluation Program Report*, 2007. ERIC.
8. Brinkhurst, M., Rose, P., Maurice, G. and Ackerman, J.D., Achieving campus sustainability: top-down, bottom-up, or neither? *International Journal of Sustainability in Higher Education*, 2011, 12(4): 338–354. https://doi.org/10.1108/14676371111168269
9. Reed, S., King, D., Whiteford, C., Coleman, B. and Pfeiffer, L., STEM Outreach: Are we making a difference? A case study evaluating the Science and Engineering Challenge Program. *Journal of Higher Education Outreach and Engagement*, 2021, 25(2): 59–77.
10. Egnieers Australia. *The engineering profession: a statistical overview, 15th edition*, 2023. Available from: https://www.engineersaustralia.org.au/publications/engineering-profession-statistical-overview-15th-edition.
11. Kaspura, A., *Engineering Construction on Infrastructure: Ten Years of Trends*. 2018. Engineers Australia.
12. Sneider, C.I. and Ravel, M.K., Insights from two decades of P-12 engineering education research. *Journal of Pre-College Engineering Education Research (J-PEER)*, 2021, 11(2): 5. https://doi.org/10.7771/2157-9288.1277
13. Becker, F.S., Why don't young people want to become engineers? Rational reasons for disappointing decisions. *European Journal of Engineering Education*, 2010, 35(4): 349–366. https://doi.org/10.1080/03043797.2010.489941
14. Loh, F., Wamser, F., Poignée, F., Geißler, S. and Hoßfeld, T., YouTube dataset on mobile streaming for internet traffic modeling and streaming analysis. *Scientific Data*, 2022, 9(1): 293. https://doi.org/10.1038/s41597-022-01418-y
15. Nikolic, S., Quince, Z., Lindqvist, A.L., Neal, P., Grundy, S., Lim, M., et al., Project-work Artificial Intelligence Integration Framework (PAIIF): Developing a CDIO-based framework for educational integration. *STEM Education*, 2025, 5(2): 310–332. https://doi.org/10.3934/steme.2025016
16. Quince, Z., Petkoff, K., Michael, R.N., Daniel, S. and Nikolic, S., The current ethical considerations of using GenAI in engineering education and practice: A systematic literature review. *Proceedings of the 35th Annual Conference of the Australasian Association for*

Engineering Education (AAEE 2024), 2024. Engineers Australia. https://search.informit.org/doi/10.3316/informit.T2025032000018100288643600

17. Schmid, R., Meaker, N. and Thomas, D., Engaging engineering students with the wider community: The Endeavour program at the University of Melbourne. *23rd Annual Conference of the Australasian Association for Engineering Education 2012: Profession of Engineering Education: Advancing Teaching, Research and Careers*, 2012. Engineers Australia.
18. Ross, R., Whittington, J. and Huynh, P., Lasertag for STEM engagement and education. *IEEE Access*, 2017, 5: 19305–19310. https://doi.org/10.1109/ACCESS.2017.2753218
19. Ross, R. and Bell, C., Turning the classroom into an escape room with decoder hardware to increase student engagement. *2019 IEEE Conference on Games (CoG)*, 2019. IEEE. https://doi.org/10.1109/CoG.2019.8848020
20. Defoe, I.N., Dubas, J.S., Figner, B. and van Aken, M.A.G., A meta-analysis on age differences in risky decision making: Adolescents versus children and adults. *Psychological Bulletin*, 2015, 141(1): 48–84. https://doi.org/10.1037/a0038088
21. Li, D., Wu, M., Zhang, X., Wang, M. and Shi, J., The roles of fluid intelligence and emotional intelligence in affective decision-making during the transition to early adolescence. *Frontiers in Psychology*, 2020, 11: 574903. https://doi.org/10.3389/fpsyg.2020.574903
22. Krieshok, T.S., Black, M.D. and McKay, R.A., Career decision making: The limits of rationality and the abundance of non-conscious processes. *Journal of Vocational Behavior*, 2009, 75(3): 275–290. https://doi.org/10.1016/j.jvb.2009.04.006
23. Sidiropoulou-Dimakakou, D., Mylonas, K., Argyropoulou, K. and Drosos, N., Career decision-making characteristics of primary education students in Greece. *International Education Studies*, 2013, 6(5): 22–32. https://doi.org/10.5539/ies.v6n5p22
24. Gore, J., Holmes, K., Smith, M., Fray, L., McElduff, P., Weaver, N., et al., Unpacking the career aspirations of Australian school students: Towards an evidence base for university equity initiatives in schools. *Higher Education Research & Development*, 2017, 36(7): 1383–1400. https://doi.org/10.1080/07294360.2017.1325847
25. Murcia, K., Pepper, C. and Williams, J., Youth STEM career choices: What’s influencing secondary students’ decision making. *Issues in Educational Research*, 2020, 30(2): 593–611.
26. Hills, C., McAlister, C., Kist, A., Baillie, J., Quince, Z. and Seligmann, H., Orientation for credit, transition for success. *34th Australasian Association for Engineering Education Conference (AAEE2023)*, 2023, 621–629.
27. Romanis, J., Women in Engineering: Identifying avenues for increasing female participation in engineering, by understanding the motivators and barriers around entry and progression. Technical report, 2022. Engineers Australia. Retrieved from https://www.engineersaustralia.org.au/sites/default/files/women-in-engineering-report-june-2022.pdf
28. Cheryan, S., Lombard, E.J., Hailu, F., Pham, L.N.H. and Weltzien, K., Global patterns of gender disparities in STEM and explanations for their persistence. *Nature Reviews Psychology*, 2025, 4: 6–19. https://doi.org/10.1038/s44159-024-00380-3
29. Quigley, N.R., Broussard, K.A., Boyer, T.M., Fishman, S.M., Comolli, N.K., Grannas, A.M., et al., Differentiated career ecosystems: Toward understanding underrepresentation and ameliorating disparities in STEM. *Human Resource Management Review*, 2024, 34(1): 101002.

https://doi.org/10.1016/j.hrmr.2023.101002

30. Tang, D., Meltzoff, A.N., Cheryan, S., Fan, W. and Master, A., Longitudinal stability and change across a year in children's gender stereotypes about four different STEM fields. *Developmental Psychology*, 2024, 60(6): 1109. https://doi.org/10.1037/dev0001733
31. Shields, N. and Quince, Z., Designing interactive engagement activities for entry to mechanical engineering programs. *International Journal of Mechanical Engineering Education*, 2025, 0(0): 03064190251366790. https://doi.org/10.1177/03064190251366790
32. Neher-Asylbekov, S. and Wagner, I., Modelling of interest in out-of-school science learning environments: A systematic literature review. *International Journal of Science Education*, 2023, 45(13): 1074-1096. https://doi.org/10.1080/09500693.2023.2185830
33. Xu, W. and Ouyang, F., The application of AI technologies in STEM education: A systematic review from 2011 to 2021. *International Journal of STEM Education*, 2022, 9(1): 59. https://doi.org/10.1186/s40594-022-00377-5
34. Quince, Z. and Nikolic, S., Student identification of the social, economic and environmental implications of using Generative Artificial Intelligence (GenAI): identifying student ethical awareness of ChatGPT from a scaffolded multi-stage assessment. *European Journal of Engineering Education*, 2025, 1–20. https://doi.org/10.1080/03043797.2025.2482830
35. Quince, Z., Petkoff, K., Lidfors Lindqvist, A., Faulconer, E., Chow, W. and Nikolic, S., Exploring GenAI image generation in engineering: A thematic analysis of ethical and representational biases. *International Journal of Engineering Education*, 2025, 41(6): 1462–1472.

Author's biography

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