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Emerging Themes in Engineering Education Research: Insights from the AAEE Winter School

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ABSTRACT

CONTEXT

Despite limited funding opportunities, reduced visibility, legitimacy issues, and significant underappreciation, the field of engineering education research (EER) has seen gradual growth in Australia. The Australasian Association of Engineering Education (AAEE) Winter School on EER brings together engineering educators and researchers to support their transition into EER. Winter School's participants are anticipated to drive the direction of EER in Australia, thus insights into their research interests can provide useful information on the state-of-the-art of EER.

PURPOSE OR GOAL

This paper aims to investigate two research questions: (i) "*What are the future directions of EER in Australia as informed by the participants of the 2024 AAEE Winter School?*"; and (ii) "*What theories, methodologies and methods are most commonly proposed in these EER studies?*".

APPROACH OR METHODOLOGY/METHODS

This study recruited 18 of the 20 participants who attended the Winter School. During the event, all participants created a poster outlining their current or future EER interests. These responses were screened and coded inductively using an open-ended qualitative approach. Thematic analysis was performed to identify the patterns and trends in the proposed research topics in EER. We also employed content analysis to determine the most common theories, methodologies and methods reported by the participants.

ACTUAL OR ANTICIPATED OUTCOMES

Four key research interests emerged: (i) professional (skills and identity) development, (ii) student support and engagement, (iii) AI in education, and (iv) curriculum design. The diversity of theories (13), methodologies (11), and methods (13) proposed by the participants underscores rich and varied approaches to EER.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY

There is a strong alignment between the research interests of the Winter School's participants and recent trends in EER. The codes and themes identified in this study highlight the field's responsiveness to evolving educational needs and technological changes. As participants progress in their careers, their work will likely shape the future of engineering education, emphasizing holistic and inclusive approaches. Sustaining momentum and increasing support for EER will be crucial for the continued evolution of EER. In future work, we aim to investigate the influence of identity and trajectory in the selection of EER interests.

KEYWORDS

Engineering education research; research methodologies; research methods; thematic analysis.

Introduction

The year 2020 was significant for Engineering Education in Australia and New Zealand for being officially recognised as a distinct field of research (code 401002) for the first time (CAULLT, 2020). This recognition, along with the *Australasian Journal of Engineering Education* achieving Q1 status in 2022 (AAEE, 2022), signified the emergence of engineering education research (EER) as a distinct and valued research field. However, the sustainability of a research field depends on adequate funding, relevance to the discipline and society, and support for emerging researchers. It is with these later two aspects that this paper is focused.

Since the early 1990s, EER has evolved to distinguish itself from technical engineering research (TER) and higher education research, with the aim of reforming engineering education based on scholarly evidence (Felder et al., 2005; Froyd et al., 2012). Streveler et al. (2007) introduced a four-level model of inquiry in engineering education: (1) good teaching, (2) scholarly teaching, (3) scholarship of teaching and learning, and (4) EER. Advancing through these levels involves moving from local to more general findings, with greater emphasis on theory, formal methodologies, public dissemination, and peer review. Gardner and Willey (2013) critiqued this hierarchy, arguing that even research adhering to the norms of EER (level 4) does not guarantee high quality. Buckley et al. (2023) noted that, while EER benefits from the problem-solving values and evidence-based approach inherent to engineering, it can suffer from limited engagement with broader educational research literature and communities.

Given the ongoing debate over the nature of EER and broader changes in engineering education, it is unsurprising that the focus of EER has evolved over the last thirty years. Felder (1993) set an agenda for reforming and potentially revolutionising engineering education through increasingly rigorous research methodologies. Over the next decade, Wankat (2004) observed that the papers published in the *Journal of Engineering Education* had keywords related to teaching and learning, with additional focus on information technology, design, assessment, collaborative learning, accreditation, and curriculum. Emerging areas of research included professional competencies (such as communication, ethics and entrepreneurship), and the contexts or culture of engineering education (including gender, international and retention). Twenty years later, Kondrashev et al. (2024) analysed 6,338 papers on engineering education from various sources and found that the ranking of keywords was somewhat inverted compared to Wankat (2004).

The literature has also reported on trends in the methodologies, methods and theories used in EER. Wankat (2004) found that a significant majority of studies relied on quantitative methods without theoretical foundations (84%). Borrego et al. (2013) similarly noted a strong preference for quantitative methods among engineering education researchers. When theories were used, they often focused on learning styles, the Myers–Briggs type indicator, and Kolb's experiential learning theory. More recent analyses provide insights into current practices. Wankat et al. (2014) and Buckely et al. (2023) noted increasing citations of non-engineering education sources drawing on knowledge, theory, and methodology from disciplines such as education, psychology, and sociology. This shift is supported by Klassen and Case (2021) who found that EER is evolving into a porous area that integrates insights from social sciences and practitioners' experiences.

In transitioning from TER to EER, an epistemological paradigm shift is needed to accommodate qualitative research methodologies, education-based theories, and an interpretivist research approach (Borrego, 2007; Dart, Trad & Blackmore, 2021). Key motivations for this transition include personal interest in teaching and learning and the desire to improve learning outcomes and the student experience, i.e., 'right pedagogical wrongs' (Gardner & Willey, 2018; Borrego & Bernhard, 2011). Enabling factors for this transition include formal and informal networks (e.g., collaborations, mentors, role models and invitations to the EER community), formal instruction in qualitative research methods, and the recognition and success of other EER academics (Willey et al., 2022; Goldsmith et al., 2023). In contrast, inhibitors include the significant differences in methodologies and theories between TER and EER, a limited number of academics interested in engineering education at many institutions, restricted funding opportunities, heavy teaching workloads, and the lower status often ascribed to EER compared to TER, i.e., EER not seen as ‘proper’ research or being perceived as ‘career suicide’ (Dart, Trad, and Blackmore 2021; Willey et al., 2022; Goldsmith et al., 2023).

To support academics transitioning into EER, the Australasian Association of Engineering Education (AAEE) has offered Winter and Summer School intensive workshops on education since 2011 (Willey et al., 2022; Matemba, Parker and Jolly, 2018), covering a variety of topics:

- Designing and undertaking effective EER projects, including relevant research methodologies, methods, theories, and data analysis (with a focus on qualitative research).
- Evaluating teaching and curriculum and positioning evaluation and research activities considering current trends.
- Publications and ethical considerations.
- Career development, EER grants, and networking opportunities across Australasia for new and emerging engineering education researchers.

While previous works outlined the landscape of EER and explored various aspects of the transition from TER to EER, we argue that academics who are beginning their journey into EER are well-positioned to shape or at least provide insights into its future directions. Therefore, this paper aims to address the following research questions: (i) “*What are the future directions of EER in Australia as informed by the participants of the 2024 AAEE Winter School?*”; and (ii) “*What theories, methodologies and methods are most commonly proposed in these EER studies?*”.

Methodology and Methods

This work uses an open-ended qualitative approach to analyse themes emerging from the data collected during the AAEE Winter School 2024. 18 out of 20 participants agreed to join this research project. 8 participants contributed to the research design, analysis and discussion, and the writing of this paper (the first eight authors listed). The remaining 10 participants agreed to be listed as authors, consented to the use of their information, and were offered the opportunity to provide feedback on the initial drafts and subsequent revisions of the paper.

Throughout the Winter School, all participants were asked to create a poster outlining their current or future research interests in engineering education. Each poster addressed the following points:

1. *Phenomenon*: Describe the thing in the world (phenomenon) you want to know more about.
2. *Current knowledge*: What do you know about this phenomenon?
3. *Literature*: What have others said about this phenomenon?
4. *Research objectives*: What do you want to find out/confirm/investigate?
5. *Hypothesis*: What do you think is happening?
6. *Evidence*: What would be evidence of this occurring?
7. *Methodology*: What methodology are you considering? Why?
8. *Theoretical framework*: What theories are you considering? Why?
9. *Research methods*: What research instrument/method(s) are you considering? Why?
10. *Ethical considerations*: What are the ethical considerations and how will you address them?

From the activity above, a total of 19 posters were produced, of which 17 were included in this work. We note that one of the eight authors of this study did not participate in this activity and, therefore, did not contribute a poster. After the Winter School, the author team collaborated online to share files, discuss the findings, and provide feedback at various stages throughout the study. To gain insights into the participants’ backgrounds, the authors co-developed a brief survey, which was distributed via e-mail to all 18 participants (Table 1).

An open-ended thematic analysis approach was used to analyse the posters and categorise the participants’ research interests outlined in the posters mostly through item (1) listed above, but also supported through items (2)-(6). Following the thematic analysis guidelines by Braun and Clarke (2006) and inspired by Dart, Trad and Blackmore (2021), an inductive approach was used to capture unanticipated patterns. Three authors independently analysed the data to identify initial codes. After this initial coding stage, the authors discussed their findings to reach consensus on the final set of codes and emerging themes in EER.

Table 1: Summary of all 18 participants' information.

		Attribute	Participants
Gender		Male	8
		Female	10
Institution	NSW	UNSW Sydney	8
		University of Sydney	3
		University of Technology Sydney	2
	VIC	University of Melbourne	2
	QLD	Queensland University of Technology	1
	SA	University of South Australia	1
	Malaysia	Monash University Malaysia	1
Experience in Engineering Education		Less than 2 years	10
		2–6 years	4
		6–10 years	0
		More than 10 years	4
Role Type		Teaching	12
		Research	9
		Professional	6
Background		Engineering qualification	9
		Education qualification	9
		No engineering background	2

To encourage collaboration and peer review, the initial poster development during the Winter School was followed by an activity where each participant could add comments to each poster using sticky notes. In the second phase of the analysis, we categorised the number and content of these sticky notes to gain further insight into the dominant topics and themes in EER as identified by the participants. Finally, the third phase involved content analysis to systematically assess the presence and frequency of the methodologies, theories, and methods reported by the participants, corresponding to items (7), (8) and (9), respectively.

Results and Discussion

Future Directions of EER in Australia

The results from the open-ended thematic analysis of research topics are summarised in Table 2 for all 17 posters. The themes and codes reveal a focus on four main EER areas: (i) developing professional skills and identity, (ii) supporting student engagement and well-being, (iii) integrating artificial intelligence (AI) into education, and (iv) improving curriculum design (particularly assessment practices and teaching methods). There is increasing demand to train student engineers that are well-equipped with both technical and professional skills. There is also a sustained interest in creating flexible and innovative curricula and learning environments that embed both AI tools and the perceptions, experiences and expectations from students, academics, industry and society to advance the future of engineering education.

These results are encouraging and align with the recent literature, as demonstrated by Kondrashev et al.'s (2024) study, whereby a bibliometric analysis of 6,338 articles published between 2014 and 2023 identified six clusters summarising research trends in EER. Some of the main keyworks for each cluster were as follows: (i) assessing students' professional aspects, views of engineering design, self-efficacy beliefs, and experiences and perceptions; (ii) e-learning, learning systems, and computer-aided instruction; (iii) education computing, project-based learning, problem-based learning, and problem-solving; (iv) design, decision-making, sustainable development, and innovation; (v) STEM education, personnel training, technology education, professional development, and technology integration; and (vi) active learning, artificial intelligence, technical presentations. Therefore, the future directions of EER in Australia, as proposed by the Winter School participants, are well-aligned with recent global trends in engineering education, particularly considering the emphasis of the participants on professional skills development, innovative teaching practices, and AI in education.

Table 2: Frequency of main codes and themes for the proposed EER projects.

Themes	Codes	Code Count	Theme Count
Professional Development	Professional skills assessment	3	7
	Teamwork and collaboration	3	
	Communication skills	2	
	Feedback and reflection	2	
	Professional skills from academic and industry perspectives	1	
	Engineering educator development	1	
	Professional identity development	2	
Student Support and Engagement	Mathematics support	2	5
	Equity and inclusivity	2	
	Student motivation	2	
	Support for low SES and equity cohorts	1	
	Women in engineering	1	
AI in Education	AI integration in assessments	3	4
	AI tools evaluation	2	
	AI impact on learning outcomes	2	
	Creativity and dependency on GenAI	1	
Curriculum Design	Project-based learning	2	5
	Group work assessment	2	
	Authentic assessment	1	
	Graduate attributes alignment	1	
	Learning outcomes evaluation	1	

To further assess the interest and impact of the themes identified in Table 2, Table 3 summarises the frequency of poster comments for each theme. The dominant research interest is professional development, which may be attributed to participants' intrinsic motivations, the need for skills development as outlined by Australia's engineering accreditation body (Engineers Australia, 2019) or the high number of participants with professional roles at the Winter School. Interestingly, the theme of AI in education, despite being featured in only four posters, received the second highest number of comments. This indicates that, although many participants are not currently researching in this area, AI in education is viewed as a compelling topic for future research and which may influence the other proposed research directions.

Table 3: Total number of comments, as measured by sticky notes added to each poster.

Theme	Posters	Comments
Professional Development	7	32
Student Support and Engagement	5	24
Artificial Intelligence in Education	4	25
Curriculum Design	5	21

Emerging Theories, Methodologies and Methods

Following the analysis of EER interests, Table 4 summarises the most common theories, methodologies, and methods in the posters. A diverse array of theoretical frameworks was considered, with 13 theories reported in total. The high frequency of constructivism amongst the suggested theories reflects a strong interest in active and experiential learning, where learners are encouraged to build their own understanding and knowledge through hands-on experiences and reflection. Self-determination theory is frequently mentioned for its focus on motivation and autonomy. Theories of collaborative and transformative learning highlight the importance of social interactions and critical reflection in the learning process. Cognitive load theory is valued for its insights into cognitive processing and instructional design. Additionally, the consideration of creativity and identity theories underscores the recognition of creativity and identity development in engineering education. Other theories, such as Bourdieu's theory of practice and goal theory, provide additional lenses on the sociocultural and motivational aspects of learning.

Table 4: Frequency of theories, methodologies, and methods most reported amongst participants.

		Posters (Out of 17)
Theories	Constructivism	7
	Self-determination theory	7
	Cognitive load theory	2
	Constructive alignment	2
	Zone of proximal development	2
Methodologies	Case study	7
	Mixed methods	4
Methods	Surveys	5
	Interviews	5
	Thematic analysis	2
	Performance analysis	2

The EER literature also provides previous studies on the theories, methodologies and methods used in various journals. Malmi et al. (2018) evaluated the articles published by the *European Journal of Engineering Education* (EJEE) in 2009, 2010 and 2013, while Williams and Neto (2018) analysed publications from *IEEE Transactions on Education* (IEEE ToE) and *Advances in Engineering Education* (AEE) in 2021. Although using different taxonomy categories, Malmi et al. (2018) reported that 72% of EJEE papers included theories. In comparison, Williams and Neto (2012) reported 62% of IEEE ToE papers and 73% of AEE papers included theories. Within the theories highlighted by Malmi et al. (2018), the five most frequently used were constructivism, formative assessment, problem-based learning, threshold concepts, and variation theory of learning. In the Winter School posters, 88% included theories, with constructivism and self-determination theory being the most prominently featured.

Table 4 shows that case studies and mixed methods are the most prevalent methodologies among the Winter School posters. The frequent use of case studies underscores their value for in-depth, contextualised investigations, while the popularity of mixed methods reflects the complexity of educational phenomena and the need for comprehensive analysis. Overall, participants considered a diverse range of 11 methodological approaches, and 71% of posters included methodologies. In comparison to the EER literature, 85% of EJEE papers (Malmi et al., 2018), 95% of IEEE ToE papers, and 55% of AEE papers outlined methodologies (Williams & Neto, 2012). Both Malmi et al. (2018) and Williams and Neto (2012) identified case studies as the most common methodology. We note that the considerable number of qualitative methodologies outlined by the participants, such as phenomenography, phenomenology, and narrative analysis, indicates a strong interest in understanding personal experiences and perceptions. In addition, action research and evaluation frameworks demonstrate a commitment to practical application and continuous improvement.

The analysis also reveals that participants considered a wide range of 13 research methods and data sources. The most frequently used methods in this study were surveys (29%) and interviews (29%). This aligns with the most common data sources reported for EJEE papers: questionnaires (39%), interviews (15%) and literature (12%) (Malmi et al., 2018). Participants also reported evaluating academic performance (e.g., grades), which is consistent with the American tradition of allocating "considerable emphasis on evaluating the impact of educational innovations on learning outcomes" (Malmi et al., 2018, p. 181). Nevertheless, the prevalence of interviews and surveys (with a focus on pre- and post-interventions) among the participants reflects a strong emphasis on understanding students' experiences, conceptions, attitudes, and motivations, aligning more closely with the European research tradition (Malmi et al., 2018). Additionally, the use of methods such as focus groups and comprehensive, reflective and creative assessments (e.g., journey maps, portfolio analysis, collective recordings, and creativity assessments) underscores the importance of measuring depth in student evaluations and gathering diverse perspectives.

The research topics proposed by the AAEE Winter School participants can also be linked to the recommendations in the 'Engineering Futures 2035' report developed by the Australian Council of

Engineering Deans (ACED), which highlights 7 key recommendations to better prepare future Australian engineering graduates for the evolving workplace (Crosthwaite, 2021).

Table 5: List of recommendations highlighted by the 'Engineering Futures 2035' report.

Recommendation	Description	Winter School Codes
R1: Context	Adjusting engineering education degrees to increase engagement with contemporary engineering contexts	Mathematics support Equity and inclusivity Student motivation Support for low SES and equity cohorts Women in engineering AI integration in assessments AI tools evaluation Creativity and dependency on GenAI Group work assessment Authentic assessment
R2: Industry	Incorporates and explores diverse pathways of engaging with industry and professional practice	Professional skills assessment Teamwork and collaboration Communication skills Feedback and reflection Professional skills from academic and industry perspectives Professional identity development
R3: Program	Increasing/adjusting engineering programs with broader learning outcomes	AI impact on learning outcomes Project-based learning Graduate attributes alignment Learning outcomes evaluation
R4: Staff	Upskilling and increasing the number of teaching staff for change in engineering education	Engineering educator development
R5: Funding	Establishing new partnerships with industry and government to provide resources	
R6: Networking	Developing engineering educator networks amongst providers	
R7: Timing	Enacting on the recommendations promptly	

Based on Table 5, the Winter School EER topics seem to focus on (i) context, (ii) industry, (iii) program, and (iv) staff, showing that the participants' EER interests align with some of the directions proposed in the ACED report. We also note that, while using the ACED report recommendations is one approach to evaluating the trend of themes presented at the Winter School, the ACED report focuses on the direction of engineering education, not EER specifically.

Limitations

We acknowledge that this thematic analysis is based solely on the information provided in the posters and may not capture all aspects of the participants' EER interests. Furthermore, variability in the detail and depth of the posters could have influenced the frequency of certain codes and themes. It is also important to note that many authors reported varying levels of familiarity with qualitative research, and the results presented here may include some potential bias toward the theories, methods and methodologies covered in the Winter School. Moreover, some posters contained misclassifications by participants, e.g., methods being labelled as methodologies or theories. Finally, most participants provided data from the initial stages of their research planning and/or at the early stage of their transition into EER, hence their research focus may evolve as they gain further expertise in the field.

Conclusions

The analysis of the Winter School participants' research interests reveals a multifaceted landscape of EER directions, which reflects a field that is both responsive to and proactive about the evolving needs of engineering education including the perspectives of students, academics, industry, and society. The focus on professional skills and identity highlights a critical area where engineering education must evolve to meet the demands of the modern workplace, particularly through real-world problems, authentic assessments, work-integrated learning, and increased partnerships with industry. Additionally, the interest in AI tools suggests that future research and practice in EER will need to address the rapid technological changes that are reshaping how engineering education is delivered and assessed. AI advances are becoming increasingly central to understanding student learning behaviours, personalising education (e.g., adaptive learning platforms), and enhancing teaching effectiveness (e.g., automated feedback and grading). Finally, the attention to student well-being and engagement underscores a broader shift in education towards more holistic and inclusive approaches to teaching and learning which can support diverse learning needs, and foster more inclusive learning environments, particularly for underrepresented groups in engineering such as LGBTIQA+, disabled, Indigenous or mature age engineering students.

These emerging directions not only respond to the current needs but also shape the trajectory of EER. As the participants progress in their careers, their work will likely influence how engineering education is conceptualised, delivered, and evaluated, ultimately contributing to the ongoing evolution of the discipline. Moving forward, the challenge will be to uphold this momentum, ensuring that EER continues to receive increased recognition.

To strengthen the presence of EER, increased funding, recognition and support are needed, which should be reflected in job offers, promotion schemes and grants at least comparable to TER. Strategies to support the growth of the field include: (i) promoting EER earlier to the student cohort (e.g., informing undergraduate students of research opportunities in EER and informing postgraduate students of education-focused career pathways); (ii) establishing EER research centres to centralise research efforts, foster collaboration, and provide a home for EER projects; (iii) increasing the visibility of EER resources and role models (including mentoring opportunities); (iv) promoting EER in mainstream engineering journals and conferences, which would expand its reach and encourage interdisciplinary discussions; (v) enhancing collaboration with students, industry, and academics in non-engineering fields (e.g., social sciences, psychology and arts); and (vi) promoting participation in events such as the Winter School to upskill academics interested in EER and provide networking opportunities. Overall, these approaches can make EER more accessible, and help the field develop with greater rigour and impact.

In this first study, we identified current research directions in EER (i.e., the "what") and examined the theories, methodologies, and methods proposed by the participants. Future research will explore how identity and career trajectory influence the selection of these topics (i.e., the "who" and the "why"). While the brief survey in this work provided some initial information about the participants, we plan to develop a more detailed survey to analyse career and identity trajectories in EER. This survey will be complemented by semi-structured interviews to collect rich and descriptive data on the emerging themes in EER.

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