



Bridging the Gap Between Theory and Practice: The Role of Expert Structural Engineers in Enhancing Decision-Making Among Graduate Engineers on Construction Sites

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ABSTRACT

BACKGROUND

Graduate structural engineers often face challenges transitioning from academic knowledge to real-world decision-making on construction sites. Despite a solid theoretical foundation, limited practical exposure hampers their ability to assess structural risks, ensure safety, and collaborate effectively. Although initiatives like BEM work placements and university internships aim to close the gap, they often fall short in nurturing the depth of expertise needed to handle complex site realities.

PURPOSE

This study explores how expert structural engineers apply epistemic practices, understood as the processes through which knowledge is acquired, validated, and applied, to support graduate engineers in cultivating professional judgment, regulatory competence, and adaptive problem-solving abilities. It aims to create a decision-making framework that enhances knowledge translation for graduates entering the workforce.

METHODOLOGY

Adopting a qualitative case study within a constructivist paradigm, the research involved semi-structured interviews, site observations, and documentation from structural engineers with over a decade of experience. Using inductive thematic analysis, key themes were identified around hierarchical learning, adaptive strategies, and collaborative problem-solving.

FINDINGS

The findings show that epistemic practices are central to effective decision-making. Expert engineers synthesize theoretical understanding with experiential insights and regulatory knowledge to respond to dynamic site challenges. They foster learning through mentorship, structured guidance, and reflective knowledge exchange, all underpinned by strong ethical practices.

CONCLUSION

This study underscores the importance of embedding epistemic practices into engineering education through hands-on learning and mentorship. Integrating these practices can better equip graduates for industry demands, bridging the persistent gap between classroom learning and on-site engineering realities.

KEYWORDS

Epistemic Practices, Decision-Making, Structural Engineering.

Introduction

This study seeks to explore the role of expert structural engineers, who possess extensive practical insight into epistemic practices, in bridging the persistent gap between academic preparation and on-site decision-making. By offering structured guidance, facilitating knowledge transfer, and supporting graduates in developing practical reasoning, these experts can help emerging engineers navigate the complexities of real-world construction challenges more effectively.

Graduate engineers, particularly in Malaysia, face significant challenges in real-world decision-making due to limited practical exposure. This deficiency impacts their ability to assess risk and safety factors comprehensively, navigate complex on-site decision-making scenarios, and collaborate and communicate effectively with stakeholders. The gap between theoretical knowledge and practical application restricts their professional competency, making it difficult for them to transition smoothly into the demands of the construction industry. As a result, many graduate engineers struggle to apply their academic learning to real-world structural challenges, which can compromise safety, efficiency, and overall project success. Addressing this issue is crucial to ensuring that young engineers are adequately prepared to handle the complexities of on-site construction and make informed, responsible decisions in their professional roles.

Several sources support the identified problem regarding the challenges faced by graduate engineers in decision-making due to limited practical exposure. Haroglu et al. (2023) discuss the global challenges of decision-making issues among graduate engineers, emphasizing the need for improved practical training. In the Malaysian context, Rahman et al. (2022) highlight how limited practical exposure further exacerbates these challenges, making it difficult for graduates to adapt to real-world scenarios. Similarly, Barner and Brown (2021) identify the lack of real-world structural design experience as a significant barrier to professional competency among graduate structural engineers. Durandet et al. (2020) point out that limited field exposure hinders graduates' ability to effectively apply theoretical knowledge to on-site issues, further reinforcing the gap between academic learning and practical application.

As a potential solution, Cosgrove and Reilly (2020) suggest that expert structural engineers with extensive industry experience can play a crucial role in bridging this gap by mentoring and guiding graduates. However, although internship and industrial training programmes are widely implemented, they often fall short in providing graduates with meaningful exposure to critical on-site decision-making scenarios. These programmes are typically short in duration and limited in scope, failing to replicate the complexities, uncertainties, and interdisciplinary coordination required in actual construction projects (Rahman et al., 2022; Durandet et al., 2020).

Moreover, the application of mentorship practices across the industry remains inconsistent. While some firms offer structured guidance through experienced professionals, many lack formal systems to ensure mentorship quality and continuity, resulting in varied levels of practical learning and preparedness among graduates (Cosgrove & Reilly, 2020). To address these persistent challenges, the Board of Engineers Malaysia (BEM) has established the Registration of Engineers Regulations 1990, Revised 2015, mandating a minimum of three years of practical experience before graduates can sit for the Professional Engineer (PE) examination. Despite these efforts, the need for more structured, guided, and experience-rich practical exposure remains critical in ensuring that graduate engineers are well-equipped to handle real-world challenges effectively. Figure 1 illustrates the progression of graduate engineers from academic preparation to professional competency, highlighting key barriers encountered at each stage and the structural gaps that limit decision-making effectiveness.

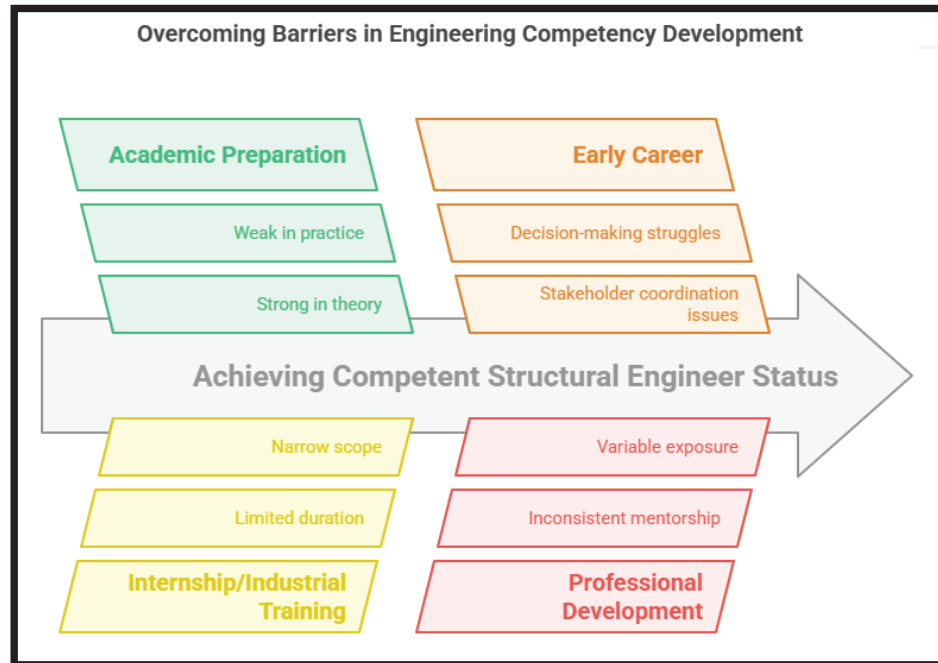


Figure 1: Overcoming Barriers in Engineering Competency Development

This diagram highlights the key stages in an engineer's development, including academic preparation, internship, early career, and professional growth, alongside the corresponding barriers that restrict their ability to achieve competent decision-making in real-world construction scenarios.

Literature Review

Epistemic Practices of Expert Structural Engineers

Epistemic practices, defined as how knowledge is acquired, validated, and applied, are critical in shaping engineering decision-making (Vincenti, 1990; Cech et al., 2017). Expert structural engineers often possess refined epistemic skills that enable them to make informed decisions under pressure, transfer knowledge through mentorship, and navigate interdisciplinary site demands. These practices extend beyond textbook learning and involve reflective judgment, adaptive reasoning, and experience-based problem-solving (Schön, 1983; Cosgrove & Reilly, 2020).

Mentorship by epistemic practice experts offers graduate engineers structured guidance and real-time exposure to complex structural challenges. However, such mentorship is inconsistently applied across the industry, leading to disparities in training quality (Cosgrove & Reilly, 2020).

Regulatory Standards

The Board of Engineers Malaysia (BEM) requires graduate engineers to complete at least three years of practical work experience before qualifying for the Professional Engineer (PE) exam (Registration of Engineers Regulations 1990, Revised 2015). This regulation is intended to ensure sufficient exposure to real-world engineering practices. However, practical experience alone does not guarantee structured learning or decision-making competence (Rahman et al., 2022; Durandet et al., 2020). The variation in workplace training and the absence of formalized mentorship programs limit the effectiveness of this mandate.

Context-Specific Conditions (Site Realities & Project Constraints)

The construction environment is dynamic, often marked by unpredictability, time pressures, interdisciplinary coordination, and evolving constraints. These real-world complexities differ markedly from controlled academic settings. Site-based experiential learning enhances situational awareness, reflexive thinking and communication skills, which are qualities not easily developed through traditional classroom instruction (Durandet et al., 2020; Braun & Clarke, 2006). The following Table 1 highlights the key differences between formal university training and site-based experiential learning. It compares both approaches across several educational dimensions, illustrating how real-world construction environments provide distinct learning opportunities that complement academic instruction.

Table 1: Contrast Between Formal University Training and Site-Based Experiential Learning

Aspect	Formal University Training	Site-Based Experiential Learning
Knowledge Type	Theoretical and codified (textbooks, formulas, simulations)	Tacit and experiential (judgment, reflexes, problem anticipation)
Decision-Making Context	Controlled scenarios, typically idealised or simplified	Dynamic, uncertain, and often constrained by time, resources, and site realities
Collaboration Experience	Primarily individual or team-based within academic settings	Multidisciplinary coordination with clients, contractors, consultants, and regulators
Problem Nature	Hypothetical, often structured for clarity and evaluation	Ill-defined, emergent, and evolving in real time
Learning Outcome	Conceptual understanding and exam performance	Situational awareness, practical judgment, and professional confidence
Assessment Method	Exams, assignments, and capstone projects	Performance on-site, responsiveness to issues, and adaptability to change
Guidance Structure	Lecturer-led, standardised curriculum	Mentor-led, fluid learning shaped by project-specific experiences

Graduate Engineers' Decision-Making Ability

Graduate engineers often face difficulty translating theoretical knowledge into practice, especially in high-stakes construction environments. Poor decision-making can lead to structural failures, inefficiencies, and safety risks, impacting both project success and public safety (Barner & Brown, 2021; Chahine et al., 2021). Without consistent on-site exposure and structured mentoring, graduates lack confidence and professional adaptability in handling interdisciplinary collaboration and stakeholder negotiation.

Despite internships and industry training programs, many graduates are not meaningfully involved in critical decisions. These programs are frequently short in duration and limited in scope, falling short of replicating real-world site conditions (Rahman et al., 2022). Moreover, university curricula, while integrating case studies and simulations, cannot fully capture the unpredictability of actual construction challenges (Durandet et al., 2020).

Improved Industry Readiness and Professional Competency

To effectively prepare graduates for professional practice, a more structured and comprehensive approach to field training is needed. Enhancing mentorship programs and integrating epistemic practices into practical training can ensure more consistent, high-quality exposure to real-world engineering tasks. As discussed by Cosgrove and Reilly (2020), experienced engineers who actively mentor graduates help bridge the gap between theory and practice, fostering confidence, decision-making competence, and professional growth.

Despite various regulatory and educational initiatives, the current system does not consistently deliver the depth of training necessary for graduates to meet industry expectations. A structured framework involving expert guidance, real project exposure, and decision-making autonomy is essential for closing the gap and building a more competent engineering workforce.

Research Methods

This study utilizes purposive sampling to select three expert structural engineers who meet specific criteria to ensure the relevance and depth of the findings. The selected participants must have a minimum of 10 years of professional experience in structural or civil engineering, demonstrating their expertise in the field. They must also hold at least a degree in Civil Engineering or Structural Engineering from an accredited institution, ensuring a solid academic foundation. Additionally, participants are required to be actively involved in construction site decision-making, as their real-world problem-solving experiences are crucial for understanding epistemic practices. Finally, they must be willing to participate in semi-structured interviews and share insights into their decision-making processes, allowing for a rich exploration of their knowledge application and mentorship approaches (Palinkas et al., 2015).

To explore how expert structural engineers enhanced graduate engineers' decision-making skills, a qualitative case study approach was employed using multiple data collection methods (Yin, 2018). Semi-structured, one-on-one interviews were conducted with expert structural engineers to capture their decision-making processes, problem-solving strategies, and mentorship experiences (Creswell & Poth, 2018).

Additionally, graphic elicitation techniques will be used to visually map how expert engineers conceptualize and apply knowledge in real-world construction scenarios (Crilly et al., 2006). On-site observations will be carried out to examine decision-making in action, providing insights into how engineers navigate challenges in construction environments (Patton, 2015). To deepen the contextual richness of the qualitative data, this study integrates two visual data collection techniques, namely graphic elicitation and field visuals. These tools are particularly effective in uncovering how engineers internalise and adapt knowledge on-site. Graphic elicitation involves co-constructing diagrams during interviews to reveal decision pathways, constraints, and problem-solving logic. Field visuals, such as annotated site photographs or sketches, document real-time construction challenges and material conditions. These methods support the constructivist framework by aligning visual and experiential data with epistemic practices. Table 2 outlines the definition and purpose of each technique within the study.

Table 2: Visual Data Collection Techniques Used in the study

Method	Definition	Purpose
Graphic Elicitation	A visual mapping technique conducted during interviews, where participants draw or annotate diagrams to explain how they make structural decisions in real time.	✓ Enhances articulation of complex and implicit reasoning. ✓ Facilitates reflection-in-action (Schön, 1983). ✓ Reveals problem-solving strategies in layered decision contexts.

Field Visuals	Photographic or sketched documentation captured on-site to illustrate the physical and contextual conditions influencing engineering decisions.	✓ Provides visual context and environmental specificity. ✓ Supports validity by linking verbal data with observable site phenomena. ✓ Highlights how site realities shape epistemic responses.
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Complementing these methods, field notes and visual documentation (photography/video recordings) will be used to capture contextual details of knowledge application, collaboration, and problem-solving practices on-site. This multi-method approach ensures a comprehensive understanding of how epistemic practices shape decision-making in structural engineering.

Data Analysis

The qualitative data obtained in this study were analysed using thematic analysis, following the six-phase approach proposed by Braun and Clarke (2006). This analytical method was selected for its flexibility and capacity to uncover both explicit and latent patterns in experiential data, particularly within complex, real-world construction settings. An inductive coding strategy was employed to allow themes to emerge organically from the data, without the constraints of pre-existing theoretical categories. This approach facilitated a nuanced understanding of how expert structural engineers operationalise epistemic practices and exercise professional judgment during on-site decision-making (Vincenti, 1990; Schön, 1983).

The analysis process commenced with data familiarisation and initial open coding, through which recurring concepts were identified, such as adaptive redesign, real-time structural judgment, and collaborative negotiation. These codes were systematically grouped into broader thematic categories through an iterative process of comparison and refinement (Braun & Clarke, 2006; Nowell et al., 2017).

To maintain analytical rigour and reflexivity throughout the process, analytic memos were systematically written to capture evolving insights, trace epistemic reasoning, and link emerging patterns across participant narratives (Saldaña, 2021). These memos served as an interpretive bridge between raw data and conceptual themes, facilitating the identification of relational dynamics between theory, experience, and site-based practice.

Thematic development was further supported by the construction of thematic networks and conceptual diagrams, which visually mapped the interconnections between tacit and explicit knowledge, regulatory constraints, and situational improvisation. These tools clarified how epistemic hierarchies and collaborative reasoning strategies shaped engineering judgments in highly variable on-site contexts (Nowell et al., 2017).

Ultimately, this analytical process yielded a structured and context-sensitive account of decision-making in structural engineering. The findings reveal how expert engineers dynamically integrate formal codes, practical experience, and contextual awareness to bridge the gap between academic theory and field-based application. This methodological approach ensured that epistemic practices were interpreted not only as abstract cognitive constructs but as socially and materially embedded activities situated within Malaysia's contemporary construction environments.

Findings and Discussion

The findings presented effectively illuminate how epistemic practices shape real-time decision-making among expert structural engineers on construction sites. Thematic analysis, following Braun and Clarke (2021), "saya dah jumpa 3–4 jenis keadaan ok" (Azlan, Int., L1278) revealed several interrelated patterns grounded in contextual adaptability, tacit knowledge, collaborative reasoning, and situational responsiveness. These themes demonstrate how expert engineers

apply, validate, and modify knowledge dynamically in response to unpredictable construction site conditions.

Influence of Site Conditions

Epistemic practices are shown to be closely tied to on-site environmental realities. Engineers frequently override initial design assumptions based on real-time assessments of soil profiles, groundwater levels, and structural feasibility. As highlighted in the Pulau Aur and Pahang case studies, decisions were modified based on empirical judgement rather than strictly adhering to design reports. This aligns with Schön's (1983) concept of *reflection-in-action*, where professionals engage in continuous knowledge refinement under uncertain conditions (Vincenti, 1990).

Project Constraints and Strategic Trade-Offs

Engineers operate under the dual pressures of budgetary, temporal, and safety constraints, requiring structured yet flexible epistemic judgement. Techniques such as value engineering are routinely employed to reconcile design intent with site limitations, while still ensuring safety and compliance. Respondents demonstrated how systematic data collection, visual inspection, and interdisciplinary input inform decisions that are contextually viable and strategically sound (Dell'Isola, 2017; Tynjälä et al., 1997).

Administrative and Regulatory Influences

Decision-making is not confined to technical realms but extends into regulatory documentation and bureaucratic navigation. Examples such as the permit delay at the Type 3 Health Clinic site and EOT (extension of time) submission for the TNB (National Electricity Company of Malaysia) Substation illustrate how epistemic validation also operates through formal documentation that legitimises site decisions within institutional frameworks (Weller & Morgan, 2020; Aggrawal & Dittman, 2023). In this context, epistemic practices include the ability to justify engineering choices through procedural compliance and stakeholder engagement.

Interdisciplinary Collaboration

A recurring epistemic pattern involves collaborative problem-solving between structural engineers, architects, and contractors. Knowledge exchange across disciplines enhances design optimisation, prevents service clashes, and fosters shared accountability for structural integrity. This distributed epistemic engagement reflects the profession's reliance on collective expertise and consensus-driven decision-making, as seen in coordinated high-rise projects (Cech et al., 2017; Fernández-Sánchez et al., 2024).

Balancing Innovation and Practical Implementation

Epistemic practices also involve balancing innovation with practical feasibility. Engineers often adapt standard designs, such as converting prefabricated elements into cast in situ ones, to suit specific site needs while still complying with safety regulations. These decisions highlight the importance of clear documentation, regulatory understanding, and interdisciplinary collaboration in ensuring that creative solutions are sound (Zhou & Zhu, 2024).

Conclusion

As a conclusion, epistemic practices shape decision-making through a dynamic interplay of real-time problem-solving, reflective judgement, regulatory awareness, and interdisciplinary collaboration. Expert structural engineers are not passive implementers of pre-defined designs; rather, they are active epistemic agents who synthesise explicit knowledge with situational awareness to ensure the integrity, efficiency, and sustainability of construction outcomes. The findings affirm the centrality of epistemic adaptability and validate the

conceptual relevance of Vincenti's (1990) and Schön's (1983) frameworks within modern structural engineering contexts.

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