The Conversation Toward Single-Case Study Research for Engineering Workforce Development

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Abstract

Background: This theory/methods paper is intended to start the conversation that single-case-study research is a rigorous approach to investigating complex, context-dependent phenomena. In engineering education, particularly in work-based learning and workforce development programs, learning is embedded in localized partnerships, authentic tasks, and sociotechnical systems that resist experimental or comparative abstraction. Despite this alignment, single case-study designs remain under-theorized and under-discussed in engineering education methodological literature.

Purpose: The purpose of this theory/methods paper is to make a methodological case for the use of single case-study research in engineering education research, with particular attention to its suitability for studying work-based learning and workforce development interventions.

Method: We conducted a narrative review of case-study publications from 2020 to 2025 from the *Journal of Engineering Education (JEE)*, *Studies in Engineering Education (SEE)*, and *American Society of Engineering Education (ASEE)* conference proceedings. The review articles were coded by venue of publication, type of case study, case context, unit of analysis, data sources, analytical approaches, and alignment with professional engineering practice. Selected single-case examples demonstrate applications across capstone design, fabrication-centered learning, specialized laboratories, makerspaces, and ethics instruction, contexts that function as workplace analogues.

Conclusion: Findings indicate that while single-case study research is used to examine work-based learning and workforce development in engineering education, its methodological contributions are rarely made explicit. When research questions focus on how learning unfolds within reliable professional contexts, single case-study designs offer depth, process sensitivity, and natural validity well-suited to work-based learning and workforce-oriented interventions in engineering education.

Keywords: *Case-study; work-based learning; workforce development; engineering education research; methodology*

Introduction

Engineering Education Research (EER) is a maturing, interdisciplinary field that leverages social science methods to improve teaching, learning, and workforce development. While quantitative and qualitative paradigms are well-established [1], [2] research methods in EER, there is a growing recognition that no single method is inherently superior [3]. This paper highlights the relevance of single case study methodology for investigating engineering workforce development (EWD) interventions.

As the engineering sector evolves, EWD programs, specifically work-based learning (WBL) such as training, pre-apprenticeships, apprenticeships , and internships, have become vital pathways for post-traditional learners [4], [5]. Despite their significance, WBL programs remain underexplored in EER [6], [7]. Their inherent complexity and contextual variability often challenge conventional research methods, necessitating flexible, context-sensitive approaches [8].

Single case studies offer the depth required to examine EWD interventions within their real-world social and institutional contexts [9]. This paper is organized into two sections: first, a foundational distinction between single and multiple case studies is presented; and second, a narrative review of EER literature published between 2020 and 2025 from the *Journal of Engineering Education (JEE), Studies in Engineering Education (SEE), and the American Society of Engineering Education (ASEE) conference proceedings*. By analysing how case studies are currently utilized in EER, this work motivates the conversations on the use of single-case designs to investigate complex, context-specific workforce interventions in the engineering research community.

Background

What is case study research?

Case study research is a qualitative methodology used to investigate complex phenomena within real-life contexts, particularly when the boundaries between the phenomenon and its context are ambiguous[10]. While widely used in education, its specific application in EER varies depending on the researcher's epistemological stance. As showed in table 1, four case study scholars have different foundational perspectives that have shaped case study inquiry.

Table 1. Foundational Perspectives on Case Study Research

Scholar	**Orientation**	**Key Focus & Contribution**
Stake [11]	Naturalistic & Interpretive	Focuses on the "particularity and complexity" of a case. Distinguishes between *intrinsic* (case-focused), *instrumental* (issue-focused), and *collective* studies.
Stenhouse [12]	Practitioner-Led	frame case study as a tool for curriculum inquiry. It is a "democratic and moral act" enabling

		educators to reflect on and improve teaching practice.
Yin [13]	Post-Positivist & Structured	Views case study as empirical inquiry. Outlines *exploratory, descriptive,* and *explanatory* types, emphasizing design logic, triangulation, and validity.
White & Cooper [14]	Narrative & Arts-Based	Emphasizes storytelling and lived experience. Uses hermeneutic interpretation to surface marginalized voices and challenge dominant narratives.

Types of Case Studies
Methodologically, case study research generally employs one of two primary designs, each suited to specific research objectives. For instance, single case study focuses on one bounded system to provide deep, contextualized insights [15]. This design is ideal when a case is unique, critical, or revelatory, allowing researchers to capture the intricacies of implementation and outcome [10, 13]. And multiple case study examines several cases to enable cross-case comparison and pattern identification. While this enhances theoretical replication and generalizability, it often prioritizes breadth over the depth found in single-case designs [16]. By prioritizing depth, single case study offer a framework to capture the 'useful realities' of WBL programs, where unique contextual factors, such as specific industry partnerships and local learner demographics, significantly shape program success

Purpose

The primary purpose of this paper is to critically examine the application of case study methodologies within EER, with a specific focus on their utility for EWD. While EWD programs (e.g., internships and apprenticeships) are increasing in prominence, the methodological approaches used to study them often prioritize breadth over depth. Consequently, this paper aims to:

1. Characterize how case study research is currently employed in leading EER journals (2020–2025).
2. Highlight the underuse of single-case designs in workforce development contexts.
3. Demonstrate why single-case studies are uniquely suited to capturing the useful realities of complex, context-dependent WBL interventions.

Method

To build the conversations for the use of single-case study methodology in EWD research, we first conducted a targeted narrative review [17] of the literature related to case study research in the field of engineering education using leading disciplinary outlets. Specifically, *JEE, SEE, and* the *ASEE Conference Proceedings* were used to conduct the review. Search results from 2020 to 2025 were narratively analyzed to identify relevant methodological applications, with the five-year window chosen to capture the most current methodological developments while avoiding outdated practices that no longer reflect contemporary trends. We descriptively analyzed the trends in the general application of case study designs, distinguishing between single-case and multiple-case approaches to establish the status of the methodology in the field. Next, we analyzed specific examples of single-case applications to understand and describe the benefits of this approach for capturing the context-dependent realities of workforce development programs more broadly.

Results

To understand the current state of case study methodologies, we conducted a narrative review [17] of 48 peer-reviewed articles from three major venues: *JEE*, *SEE*, and *ASEE Annual Conference Proceedings* (2020–2025), focusing on identifying the existence of single versus multiple case study designs, their methodological orientations (i.e., descriptive, exploratory, or explanatory), units of focus programs (e.g., course, program, institution, students, faculty, etc.), and alignment with professional engineering practice (i.e., EWD and WBL).

Description of case study research in engineering education

As shown in Figure 1, the frequency of case study designs in engineering education has been shown to be consistent with general trends in social sciences research, with multiple-case study designs dominating the engineering education literature. Of the 48 articles reviewed, (n=31) utilized a multiple-case design, compared to (n=17) that employed a single-case design. This trend is observable across all three major venues. The *ASEE Annual Conference* and *SEE* show a higher absolute number of single-case studies compared to *JEE*, suggesting that conference proceedings and specialized journals may be more open to the depth and particularity offered by single-case research. *JEE* favored multiple-case designs (8 multiple vs. 4 single), while *SEE* almost exhibited a more balanced distribution (11 multiple vs. 9 single), consistent with its openness to both comparative and depth-oriented qualitative inquiry.

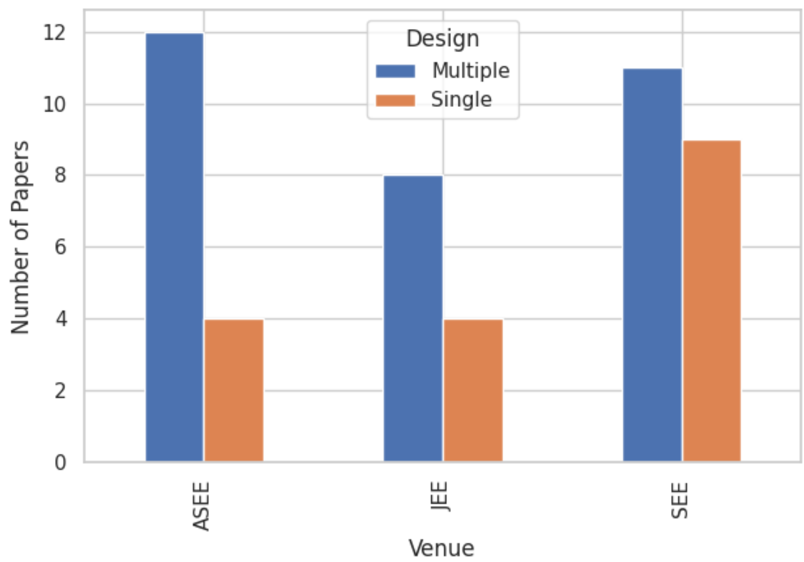

Figure 1. Distribution of Case Study Designs by Venue

Multiple-case studies were commonly employed to compare experiences across courses, teams, institutions, or participant groups[18], [19], [20], whereas single-case studies were used to generate in-depth, contextualized understandings of bounded or unique cases, such as individual learners [21], specific programs [22], or localized interventions[23].

Case study research in engineering education trends over time

While multiple-case studies remain more frequent, there is a notable persistence of single-case research. As illustrated in Figure 2, the gap between the two designs narrowed significantly in 2022 and 2023, with single-case studies reaching near parity in 2022. This suggests a sustained, albeit smaller, community of researchers finding value in the deep examination of bounded systems.

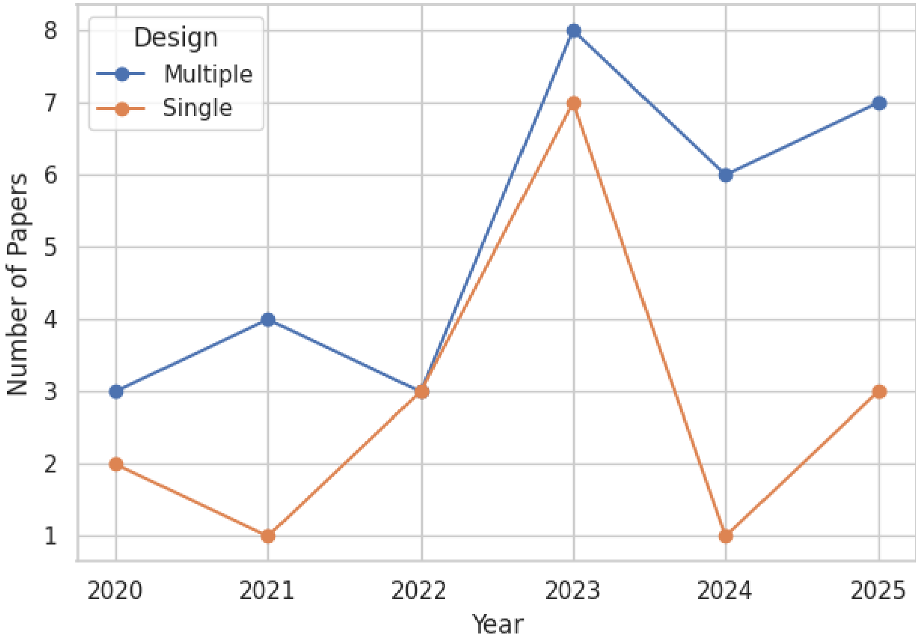

Figure 2. Trends in Case Study Designs (2020-2025)

Methodological Orientation

The "Descriptive" Niche in Engineering Education Research

A critical finding emerged when categorizing studies by their methodological purpose (i.e., descriptive, exploratory, or explanatory). We notice that the exploratory studies were heavily skewed toward multiple-case designs (17 multiple vs. 4 single). The researchers used multiple cases to explore a phenomenon across different contexts to broaden generalizability [19], [20], [38], [44], [45], [46], [47], [48], [49], [50], [51], [52], [53], [54], [55], [56], [57]. The findings also showed that the descriptive studies demonstrate a slightly balanced distribution (9 multiple vs. 8 single). This finding highlights a distinct opportunity for the fact that descriptive single-case studies are an established but underutilized method. Descriptive single case studies are particularly effective when the goal is to provide a "thick description" of a unique programmatic intervention, such as a specific WBL, rather than to compare surface-level features across disparate sites [24], [25], [26], [27], [28], [29], [30], [31].

Table 2. Methodological orientation of case study (2020-2025)

Authors	Methodological orientation	Type of case study	Number of papers

[24], [25], [26], [27], [28], [29], [30], [31]	Descriptive	Single case	8
[32], [33], [34], [35], [36], [37], [38], [39], [40]		Multiple case	9
[22], [41], [42], [43]	Exploratory	Single case	4
[19], [20], [38], [44], [45], [46], [47], [48], [49], [50], [51], [52], [53], [54], [55], [56], [57]		Multiple case	17
[58]	Explanatory	Single case	1
[59]		Multiple case	1

Application of case study with engineering workforce development

To understand how case study methodologies are currently applied to EWD, we categorized the identified studies based on their design (multiple vs. single), level of analysis, and primary research utility. Table 3 summarizes the results of this comparison, revealing distinct functional differences between the two approaches. The results indicate that multiple-case designs are the dominant methodological choice that researchers have used to investigate workforce-related topics. Of the 31 multiple-case studies reviewed, (n=20) addressed WBL programs. Single-case designs, on the other hand, showed moderate use by researchers, with (n=6) of the 17 identified studies addressing similar workforce themes.

Table 3. The case study focuses on engineering workforce development

Feature	**Multiple-Case Studies**	**Single-Case Studies**
Prevalence of EWD Focus	20 out of 31 studies [18], [19], [20], [38], [39], [40], [46], [47], [48], [49], [50], [51], [52], [53], [54], [55], [57], [59], [60], [61]	6 out of 17 studies [21], [25], [30], [31], [58], [62]
Primary Level of Analysis	Focuses on comparing programs, curriculum implementation across sites, or K-12 pipeline partnerships.	Focus on the "lived experience" of professional formation, identity development, and specific skill acquisition.
Dominant Research Goal	**Generalizability & Scalability:** Seeks to understand if an intervention (e.g., a new curriculum or faculty development program) works across different contexts.	**Depth & Complexity:** Seeks to understand how a specific environment (e.g., a makerspace, a capstone team, or an apprenticeship) fosters the transition from student to professional.

Example Contexts	*Inter-organizational partnerships [19] * Curriculum implementation across districts [61] * Faculty development programs [59]	* Identity work in makerspaces [21] * Complex problem-solving in capstones [31] * Skill acquisition in nanofabrication labs

The "Breadth" of Multiple-Case Designs in Engineering Education Research

The use of multiple case studies by the researchers was utilized to examine curriculum implementation, partnership structures, or faculty beliefs across disparate sites (e.g., [47], [48]). For instance, the study conducted by Ali and Abhyankar [47] looked at engineering faculty development via pedagogical transformation that focused on improving teaching practices and impacting student readiness through engineers workplace. Also, Gillen and colleagues [48] studied interorganizational collaboration between middle school teachers, industry, and the university to integrate engineering into the middle school science curriculum in rural schools. The resulting utility of the multiple case study approach is for scalability and transferability, allowing for the identification of common patterns and "best practices" answering the question of what works across different contexts.

The "Depth" of Single-Case Designs in Engineering Education Research

Conversely, the single-case studies reviewed focused on experiential and situated analysis. These studies (e.g., [21], [31]) examined the lived experience of specific bounded systems, such as individual makerspaces or capstone teams. The primary utility of this approach is depth and complexity, enabling researchers to open the black box of how specific environments facilitate professional formation and identity negotiation.

Even though single case study design showed moderate use in EER, the review showed that it is uniquely suited for EWD studies, where the context (e.g., WBL), such as a specific internship, pre-apprenticeship, and apprenticeship culture or an intense capstone project, is inseparable from the learning outcomes. For instance, Xu and Gravel [24] found that an undergraduate engineering “making to learn” course supported students’ identity work by helping them recognize their prior making experiences as legitimate resources for engineering learning. Also, Fernando [60] explored how engineering students tackle complex engineering problems (CEP) in their capstone design projects, and they found that the capstone program prepares engineering students to solve CEPs and incorporate real-world CEPs.

Work-Based Learning in Engineering Education

WBL is an educational strategy that provides students with real-life work experiences where they can apply academic and technical skills to develop employability. In engineering education, WBL extends beyond traditional internships and apprenticeships to include authentic, situated learning environments, such as capstone projects, industry-sponsored clinics, and high-fidelity simulations, that replicate the social and technical complexities of professional practice.

Single-Case Studies as WBL Contexts in Engineering Education Research

Single-case study methodology is uniquely suited for WBL research because it treats the workplace (or simulated workplace) as a bounded system. This allows researchers to examine not just *what* skills are learned, but *how* students negotiate the transition from student to practitioner within a specific professional culture.

As shown in Table 4, single-case studies in EER reveal that WBL is frequently operationalized through bounded educational contexts that closely approximate professional engineering practice, even when such programs are not formally designated as internships or apprenticeships. Table 4 summarizes five representative single-case studies that illustrate how diverse educational settings, capstone projects, fabrication-centered courses, specialized laboratories, makerspaces, and ethics instruction function as authentic WBL environments.

Table 4. Single Case Contexts and Alignment with Work-Based Learning

Authors	The Case Context	WBL Alignment
[31]	Capstone Design Project A senior design team addressing a "Complex Engineering Problem" (CEP) as defined by the International Engineering Alliance.	***Simulated Professional Practice*** The study maps the nonlinear stages of solving a complex problem, mirroring the ambiguity and stakeholder requirements found in industry rather than the clean "textbook" problems of the classroom.
[21]	"Making to Learn" Course An undergraduate mechanical engineering course centered on open-ended fabrication and design tasks.	***Identity Negotiation*** The case explores the process of "becoming" an engineer. It fits WBL by highlighting how students adopt professional identities and agency through the physical act of creating functional artifacts, like R&D environments.
[62]	Nanofabrication Laboratory A specialized training module using the "NanoFrazor" for undergraduate students.	***Technical Skill Acquisition*** The context is a high-tech facility where students learn specific, high-demand industry skills (semiconductor fabrication). It lowers barriers to entry for the specialized workforce, functioning as a pre-apprenticeship skill builder.
[25]	Academic Makerspaces An informal, communal design space used by engineering students outside of formal class time.	***Communities of Practice*** The makerspace acts as a proxy for an engineering shop floor. The study examines the "lived experience" of women in this space, highlighting how professional norms, tool usage, and peer mentorship occur informally, much like in a workplace setting.
[30]	Inter-Institutional Ethics Course	***Professional Acculturation*** By integrating industry speakers and real-world ethical dilemmas, the

	A collaborative course between an MSI and a PWI involving industry speakers and environmental decision-making.	course exposes students to the non-technical dimensions of the workforce, specifically the power dynamics and ethical responsibilities required of licensed professionals.

Across these cases, single-case designs enabled researchers to document how learning unfolds within specific sociotechnical systems, capturing interactions among participants, tools, norms, and organizational structures. Importantly, the learning outcomes emphasized in these studies, professional identity development, ethical reasoning, adaptive problem solving, and participation in communities of practice, are process-oriented and embedded within local contexts.

These recognized patterns identified in this study, indicate that while multiple-case studies dominate EER, single-case designs have unique methodological value in EWD research, particularly for exploring identity work, contextualized learning, and authentic sociotechnical participation."

Discussion

The results in this method/theory paper highlight a critical methodological strain in EER. While the field increasingly prioritizes broad, generalizable findings through multiple-case designs, the context-dependent nature of workforce development often demands the depth provided by single-case inquiry [63].

The Trade-off Between "What Works" and "How it Works"
The dominance of multiple case studies (31/48) across JEE, SEE, and ASEE proceedings suggests a disciplinary preference for variance theory, seeking to identify factors that hold across differing contexts [13], [16]. While valuable for scaling curriculum, this approach often obscures the local sociotechnical dynamics that define WBL [64], [65]. As noted in the results, multiple case studies were effective at mapping structural implementations (e.g., *Gillen et al.* [48]), but they rarely penetrated the experiences of student identity formation within those structures. In contrast, the single-case studies reviewed (e.g., *Xu & Gravel* [24]; *Fernando* [60]) demonstrated that workforce readiness is not merely a competency to be acquired but a professional identity to be negotiated. By treating specific environments, such as a makerspace or a capstone team's bounded systems, these researchers successfully documented the *process* of professionalization. This aligns with Stake's [11] assertion that the value of the single case lies in its particularity. For EWD, the particularity is the point; the specific cultural norms of a coop placement or the unique constraints of a community-based design project are precisely what shapes the student's transition from novice to practitioner.

Reclaiming the "Descriptive Niche" for Workforce Development
The results also revealed that descriptive single-case studies are an established but underutilized "niche" in the current engineering education literature. There is a prevailing misconception that rigor requires comparison. However, this review argues that for WBL or engineering workforce intervention research, *thick description* is a form of rigor. For instance, when researchers provide a deep, descriptive account of a unique pre-apprenticeship/apprenticeship model or a novel industry partnership, they

offer practitioners an indirect experience [11] that is often more transferable to their own teaching practice than statistical generalizations. The findings suggest that the EER community should start the conversation around descriptive single case studies, recognizing it not as a trial for a larger study, but as a method for capturing the complex nature validity of workforce interventions.

Methodological Alignment with Professional Practice

Finally, the review demonstrates that single-case designs mirror the reality of engineering practice itself. Just as engineers often solve unique, site-specific problems under constraints (e.g., complex engineering problems), EWD research often struggles with non-replicable educational settings. The successful application of single-case study designs in contexts like ethics instruction [23], professional development programs [22], instructional innovation [41] and nanofabrication labs [59] confirm that these methodologies are uniquely capable of capturing the messiness of real-world engineering environments, a complexity that is frequently leveled in comparative multiple-case designs research.

Conclusion

This paper introduces the conversation that single-case study research is a rigorous and essential methodology for investigating the complex, context-dependent nature of EWD/workforce intervention programs. Through a narrative review of 48 articles published between 2020 and 2025, we established that while multiple-case designs dominate the landscape of EER, they often prioritize breadth and generalizability over the contextual depth required to understand WBL. The findings indicate that single-case studies are uniquely suited to the useful realities of WBL. Whether examining a capstone design team, a makerspace community, or an industry mentorship, the single-case design allows researchers to trace the longitudinal development of professional identity and technical agency in ways that comparative designs cannot.

Future Directions

For the EER community to fully understand how students become the workforce of the future, scholars must broaden their methodological acceptance of single-case research. Therefore, the authors of the study recommend that future researchers should

1. Not shy away from purely single-case studies when investigating novel WBL programs; the field needs detailed maps of these emerging educational terrains.
2. Explicitly define the "case" (the bounded system) in workforce studies, clarifying whether the unit of analysis is the student, the partnership, or the activity system.
3. Use single-case designs specifically to answer "how" and "why" questions regarding professional formation, moving beyond simple outcome measurement.

Finally, if engineering scholars aim to prepare students for a diverse and complex workforce, engineering research methods must be capable of capturing the complexity of the workforce interventions. Single-case study research shouldn’t be merely a preliminary step toward generalization of research findings; it should be considered a powerful lens for seeing the complicated mechanisms of professional growth.

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