Engineering Education Review

OPINION

Beyond experience: Reshaping the academic essence of teaching reform in engineering education

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In recent decades, engineering education has witnessed a proliferation of reforms. From curriculum restructuring and pedagogical innovation to systemic initiatives like conceive-design-implement-operate (CDIO), outcome-based education (OBE), and new engineering education transformation (NEET), the array of measures has been overwhelming. Yet, despite these extensive efforts, many institutions remain trapped in a cycle of "pilot fatigue": Promising innovations are launched with great fanfare, only to fizzle out after a few semesters without leaving a lasting impact (Borrego & Bernhard, 2011).

What lies at the root of this issue? Much of it stems from blurring the lines between "implementation" and "understanding", focusing heavily on "improving teaching behaviors" rather than "researching learning processes". The core reason why most teaching reforms fail to produce sustainable results is not a lack of excellent concepts, but a lack of deep, academic exploration into teaching itself (Henderson *et al.*, 2011). In the engineering domain, educational "reform" is often reduced to a standard engineering problem: Identify the issue (*e.g.*, low student engagement), design a solution (*e.g.*, the flipped classroom), and roll it out. This instrumentalist rationality assumes that applying the correct technical method will automatically result in improved student learning. However, teaching is not a mechanical system; it is a complex, context-dependent human practice influenced by cognitive laws, cultural backgrounds, and epistemological factors (Singer & Smith, 2013). To achieve sustainable improvement, we must view teaching as a field worthy of academic inquiry, not merely a subject for operational adjustment.

This is where the scholarship of teaching and learning (SoTL)—a concept introduced by Ernest L. Boyer in 1990—offers a critical correction. Boyer challenged the narrow definition of "scholarship equals scientific research", advocating for a pluralistic perspective that integrates "systematic, evidence-based research on student learning" into the realm of scholarship (Boyer, 1990). However, in the engineering sector, SoTL remains marginalized. Teaching is frequently viewed as "service work", while scholarship is considered the exclusive domain of the laboratory.

The core attributes of engineering—rooted in problem-solving, empirical verification, and iterative design—actually make the discipline naturally suited to embrace SoTL. Imagine approaching a new teaching method with the same rigor applied to prototype R&D: Defining key variables, collecting performance data, analyzing failure modes, and iterating based on evidence. This goes beyond simply "teaching better"; it represents the "engineered construction" of the learning process. It requires moving past anecdotal success stories to establish testable hypotheses, maintain methodological transparency, and provide theoretical underpinnings.

Take, for example, a common reform scenario: Integrating artificial intelligence (AI) into an engineering practice course. A typical reform project might stop at deploying the tool, surveying student satisfaction, and reporting an increase in pass rates. A SoTL approach,

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Received: 30 December 2025; Revised: 29 January 2026; Accepted: 29 January 2026
https://doi.org/10.54844/eer.2025.1133

however, guides practitioners to ask deeper questions: Under what conditions does AI promote conceptual understanding and transfer? Does guided inquiry foster deeper understanding than open-ended exploration? This is followed by designing control experiments, analyzing platform log data, coding the reasoning processes of students using AI assistance, and interpreting the results within relevant theoretical frameworks.

Such research does more than validate the effectiveness of a single intervention; it generates generalizable knowledge regarding the learning patterns of engineering students. Crucially, it reshapes the narrative: Teaching is no longer a burden to be minimized, but an intellectual exploration worthy of peer review, publication, and professional recognition.

Although recent policy shifts—such as the "breaking the five-only" initiative in China—have significantly reduced the excessive emphasis on research metrics and redirected some attention to teaching, the existing faculty performance systems offer limited support for this transition (Li & Dai, 2025). Promotion committees still favor papers in Institute of Electrical and Electronics Engineers (IEEE) or American Society of Mechanical Engineers (ASME) journals over findings in educational journals like Advances in Engineering Education. Accreditation bodies tend to focus on whether programs meet preset outcomes rather than evaluating whether institutions have studied the pathways to achieving those outcomes (Froyd *et al.*, 2012). Furthermore, funding streams prioritize scientific research projects and laboratory hardware over "teaching R&D". While these systems are quietly evolving, SoTL currently remains a niche pursuit for those with intrinsic motivation.

Whether the SoTL can gain broader recognition in higher engineering education depends on addressing several key issues: (1) Institutional recognition. Universities must recognize SoTL outputs—including peer-reviewed teaching research papers, validated instructional designs, and open educational resources (OERs)—as achievements equivalent to traditional academic contributions in tenure and promotion reviews. (2) Accreditation frameworks. Engineering accreditation bodies should encourage (or even require) evidence of systematic inquiry into teaching effectiveness, thereby fostering a culture of reflective practice. (3) Funding mechanisms. Funding agencies should establish specific grants for "Educational Innovation Research" in the engineering sector to support cross-disciplinary collaboration between faculty, learning scientists, and industry partners.

While domestic education reform has produced numerous results, and some are of exceptionally high quality, the research paradigms of others require further optimization. The SoTL framework is well-positioned to enhance the academic rigor of these reforms. In summary, a practical framework for integrating SoTL in engineering can be distilled into five steps: (1) Problem reframing. Transform vague themes and pain points into testable hypotheses regarding cognitive or emotional mechanisms. For instance, reframe "How can I make students like this course?" to "What type of instructional materials reduce cognitive load when learning this specific content?" (2) Methodological fusion. Combine tools applicable to engineering (such as learning analytics) with social science research methods (interviews, grounded theory). This mixed-method approach ensures findings are both technically rigorous and pedagogically relevant. (3) Evidence triangulation. Establish validity through multi-source data. For example, a study on cultivating practical skills could combine course platform submission histories, student reflection logs, and instructor observation records to verify conclusions about team dynamics. (4) Theoretical interpretation. Move beyond simple summary reports. Connect research findings to learning theories (*e.g.*, cognitive load theory [Sweller, 1988], situated cognition [Lave & Wenger, 1991]) to explain not just "that" something was effective, but "why"; (5) Knowledge community building. Publish results in relevant engineering education journals and share peer-reviewed teaching materials and findings globally to drive collective progress in the field.

Although promoting a SoTL culture in the engineering field faces certain disciplinary barriers, they are not insurmountable. Many domestic reform projects are already high-quality inquiries into teaching problems and have produced substantial academic outcomes. Ultimately, reshaping the academic essence of teaching does not mean simply turning engineering teachers into education researchers. Rather, it is about enabling engineering faculty to realize that understanding the learning laws of future engineers is, in itself, a form of intellectual leadership (Huber & Morreale, 2002). This is as vital to the future of the engineering profession as any technical breakthrough. An engineering professor's academic contribution should not be limited to patents and papers but should also include evidence-based insights on how novices evolve into professional problem solvers and inheritors of the discipline.

The era of superficial reform has ended. Engineering education now requires depth—not more pilots, but more probing questions; not just new tools, but new ways of cognition. Let us transcend the limitations of "improving teaching" and truly commit to the exploration of "researching learning". This is the academic pursuit that engineering disciplines and faculty ought to embrace.

DECLARATION

Acknowledgement
There is no acknowledgement for this article.

Author contributions
Juan Y developed the concept for the manuscript, reviewed the literature, formulated research questions, collected the data, conducted analyses and interpreted the data. The author read and approved the final manuscript.

Source of funding
This work was supported by Educational and Teaching Research Project of the China Association of Agricultural Science Societies: "Cultivating Interdisciplinary Talents for the New Agricultural Sciences in the Context of New Quality Productive Forces: International Experiences and Local Practices" (No. PCE2411).

Ethical approval
Not applicable.

Informed consent
Not applicable.

Conflict of interest
The authors declare no competing interest.

Use of large language models, AI and machine learning tools
The authors declare that no large language models, artificial intelligence, or machine learning tools were used in the preparation or writing of this manuscript.

Data availability statement
No additional data.

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