Untangling Active Learning: A Framework of Dimensions, Strategies, and Outcomes

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Active learning has become a widely cited cornerstone of undergraduate education reform; yet the construct remains conceptually ambiguous, leading to challenges in research synthesis, instructional implementation, and policy alignment. This paper synthesizes literature across mathematics and STEM education to trace this ambiguity to the conflation of three distinct but interconnected facets: dimensions of engagement, strategies for implementation, and outcomes of learning. To address this gap, I propose a theoretical framework that disentangles and defines these facets, providing analytic clarity for both researchers and practitioners. By situating this framework within ontological, epistemological, and axiological perspectives, the paper illuminates how differing research traditions conceptualize, investigate, and value active learning. This reframing enables systemic inquiry into how strategies activate specific engagement dimensions to produce desired outcomes in diverse contexts, informing instructional design. The framework thus offers researchers, practitioners, and policymakers a roadmap for advancing both scholarship and meaningful reform in undergraduate mathematics education.

Keywords: active learning, undergraduate mathematics education, student engagement, instructional strategies, learning outcomes

Calls for widespread adoption of active learning in undergraduate STEM education are ubiquitous (e.g., Conference Board of the Mathematical Sciences [CBMS], 2016; President's Council of Advisors on Science and Technology [PCAST], 2012). Meta-analyses and large-scale studies consistently report a positive impact of this pedagogical approach on student achievement and persistence (e.g., Freeman et al., 2014; Graham et al., 2013). Active learning has been credited with cementing the shift in focus to learner-centered environments, deepening learning "beyond surface-level knowledge acquisition", reducing achievement gaps for underrepresented students, and building student resilience (Duran et al., 2022; Kerrigan & Kwaig, 2024; PCAST, 2012; Theobald et al., 2020).

However, despite the theoretical arguments and mounting empirical evidence in favor of the construct, the adoption of active learning practices in undergraduate STEM has not kept pace (Børte et al., 2020; Nguyen et al., 2021). A significant barrier lies in the conceptual ambiguity surrounding the term itself: researchers and practitioners invoke "active learning" in divergent, sometimes conflicting ways—referencing engagement, strategies, outcomes, or a combination of them interchangeably. This definitional drift complicates efforts to synthesize the research and hinders its translation into effective, context-sensitive teaching practices. This ambiguity also weakens the influence of research on educational policy and large-scale reform initiatives.

The purpose of this paper is to bring conceptual clarity to the active learning construct by proposing and explicating a theoretical framework that distinguishes among three interrelated facets: dimensions of engagement, instructional strategies, and learning outcomes. This reframing of the construct seeks to clarify what characterizes active learning, how it can be effectively implemented, and what outcomes it produces. The framework paves a way for researchers, practitioners, and policymakers to interpret the active learning literature and make intentional decisions aligned with their goals.

Conceptual Ambiguity in Active Learning

Although "active learning" has become one of the most frequently invoked terms in undergraduate mathematics education reform, its meaning remains elusive.

Examining the Ambiguity

Often, active learning is thought of as the "antithesis of lecture" (Driessen et al., 2020). This broad conceptualization has created significant challenges in practice:

Multiple, sometimes conflicting interpretations. Bonwell and Eison's (1991) early definition of active learning as "activities involving students in doing things and thinking about what they are doing" highlights student engagement and reflective participation. Expanding on the idea of shifting students away from passively listening, Freeman et al. (2014) emphasize higher-order thinking and group work in their widely cited consensus definition of the construct. Laursen and Rasmussen (2019) stress the "inherently social nature" of active learning and emphasize equity in instructional design, "a characteristic that is notably absent in many scholarly definitions" (Williams et al., 2022). The use of broad descriptors—like "involving" and "doing"—leads to multiple, conflicting interpretations (Braun et al., 2017): Does active learning require group work? Are both conceptual and procedural tasks considered active learning? At what point does a traditional lecture, interspersed with some activities, qualify as active learning?

Variation in operationalization. Even when studies share a definition of active learning, they often operationalize it in very different ways. Some focus on a single technique (e.g., think-pair-share) while others examine whole-course transformations. Freeman et al.'s (2014) seminal meta-analysis on active learning included a wide range of courses, from lectures with "only 10-15% of the time devoted to clicker questions" to entirely "lecture-free 'studio' environments". These significant variations in intensity of practice limit comparability of research and risk rendering the construct too broad to be analytically useful (Lombardi et al., 2021).

Overlapping constructs. Active learning's porous boundaries with related approaches—such as inquiry-based, cooperative, and problem-based learning—have diluted the precision of the construct (Prince, 2004; Lombardi et al., 2021). Many studies treat these overlapping categories as interchangeable, making it difficult to isolate their individual impact. As a result, stakeholders often speak past one another while implicitly drawing on different conceptions of what *counts* as active learning.

Erasure of Context. Outcomes of active learning are not uniform and are moderated by context—class size, student identities, instructor beliefs and preparation, instructional choices, and institutional culture. However, active learning is often promoted as a "one-size-fits-all" solution for enhancing student learning and success. Ignoring the contexts in which it operates leads to a disconnect between conceptual understanding and practical application of the construct, widening the research-practice gap in mathematics education.

Consequences of Ambiguity

This conceptual murkiness has significant consequences. For researchers, the conflation of the characteristics, enactment, and outcomes of active learning complicates cumulative knowledge-building. Results are often aggregated over a wide range of interventions, which fails to provide a clear understanding of which strategies produce the desired outcomes under what conditions and why. For practitioners, this lack of clarity fosters misconceptions about active learning and hesitancy to adopt it. Thus, addressing this conceptual ambiguity and definitional drift is essential for advancing empirical research, supporting evidence-based teaching reforms, and enabling clearer dialogue within the mathematics education community.

A Framework for Active Learning

To address this ambiguity, this paper proposes a conceptual framework that unravels active learning into three interconnected but distinct facets: (1) dimensions of engagement, (2) strategies for implementation, and (3) outcomes of learning. These elements frequently overlap in the literature and are often used interchangeably, yet each plays a unique role in shaping how active learning is conceptualized, studied, and practiced.

Dimensions of Engagement

The first facet concerns the dimensions of engagement that characterize *how* students participate in active learning environments. Rather than treating engagement as a single construct, this framework recognizes multiple pathways through which learners can be actively involved in mathematical meaning-making. Synthesizing across scholarship (Edwards, 2015; Laursen & Rasmussen, 2019; Lombardi et al., 2021; Vale & Barbosa, 2023), five dimensions are identified. Table 1 outlines these dimensions with descriptions and illustrative examples.

Table 1. Dimensions of Engagement in Active Learning

Engagement	Description	Examples
Cognitive	Students' deep thinking about mathematical ideas	Higher-order thinking, purposeful meaning-making, self-regulation (planning, goal setting, adjusting approaches), metacognition
Social	Students' interaction with peers and instructors	Collaborative problem solving, co-construction of knowledge, mathematical communication
Behavioral	Students' observable participation and efforts	Use of movement and tools, task-focused persistence, resilience despite challenges
Emotional	Students' affective connection to learning	Curiosity, excitement, enjoyment, interest, sense of belonging
Agentic	Students' contributions to shaping the learning process	Initiating discussions, forming study groups, offering feedback to shape course design

Dimensions of engagement remain a relatively hidden paradigm of active learning research. This framework helps bring them to the forefront since they are essential to defining and understanding active learning. This multidimensional engagement model acknowledges that not every active learning technique will activate all dimensions uniformly, enabling researchers and practitioners to examine which aspects of engagement are activated by instructional choices.

Strategies for Implementation

The second facet centers on instructional strategies, the concrete practices and pedagogical approaches that operationalize active learning in classrooms. These strategies are the most visible aspect of the construct and range in complexity from brief, targeted activities (e.g., think-pair-share) to more comprehensive reforms (flipped classroom, using inquiry-based learning curriculum). Synthesizing the literature (Bonwell & Eison, 1991; Driessen et al., 2020; Freeman et al., 2014; Lombardi et al., 2021; Nguyen et al., 2021; Nardo et al., 2022; Martella & Schneider, 2024; Prince, 2004), the documented strategies can be condensed into three categories. Table 2 outlines these categories with descriptions and illustrative examples.

Table 2. Strategies for Implementation of Active Learning

Strategies	Description	Examples
Class Activities	Structured opportunities for student interaction, collaboration, and reflection	Think-pair-share, gallery walks, jigsaw, clicker questions
Assignments	Opportunities for scaffolding learning and extending engagement outside class	Pre-class work, formative checks for understanding, projects
Course Planning	Alignment of goals, materials, activities, and feedback processes for sustained participation	Backward course design, surveys, incorporating student input into curriculum and course design

By emphasizing the spectrum of strategies, this facet resists the tendency to flatten "active learning" as a single technique. For one, these strategies vary significantly in terms of intensity and design—for instance, a course that inserts occasional activities into the lecture bears little resemblance to a flipped classroom where all class time is dedicated to collaborative work—yet they are all labeled as active learning. Moreover, different strategies activate different forms of engagement. For example, clicker questions may primarily elicit cognitive and behavioral engagement, while group work may additionally support social, emotional, and agentic engagement. Thus, strategies need to be understood as means or *mechanisms* for activating specific dimensions of engagement, which in turn shape the learning results.

Learning Outcomes

The third facet addresses the learning outcomes associated with active learning. Outcomes are the most measurable aspect of this construct and encompass not only disciplinary knowledge but also developmental gains. This framework distills the outcomes reported in the literature (Bonwell & Eison, 1991; Freeman et al., 2014; Lugosi & Uribe, 2020; Theobald et al., 2020) into seven categories. Table 3 presents an overview of these, along with examples of impacts.

Table 3. Learning Outcomes of Active Learning

Outcomes	Examples of Impact
Cognitive	Increasing conceptual understanding, retention, problem-solving, metacognition
Academic	Improving exam performance, advancing toward credentials/ standards.
Relational	Enhancing collaboration, communication skills, interpersonal connections
Behavioral	Demonstrating greater task-focused effort, resilience, persistence
Affective	Experiencing greater motivation, confidence, sense of belonging
Agentic	Increasing ownership of and autonomy in learning, knowledge co-construction
Equity	Narrowing achievement gaps, providing equitable student support, fostering empathy and justice in learning spaces

This framework intentionally distinguishes academic from cognitive outcomes, recognizing that they may exist independently of each other (see Table 3). It also uses the term *relational* to emphasize the intimate, interpersonal connections often discussed in the literature under *social* outcomes. Importantly, outcomes mirror but are not identical to the engagement dimensions. For example, social engagement in class may foster collaboration (relational outcomes) while simultaneously influencing understanding (cognitive), belonging (affective), and co-construction of knowledge (agentic) outcomes. By separating *process* (dimensions) and *results* (outcomes), this framework enables clearer theorizing about how strategies produce learning gains by activating specific dimensions of engagement.

Interrelations among the Facets

The dimensions of engagement characterize active learning (what it is), the instructional strategies highlight how active learning is enacted (how we come to know and observe it), and the outcomes capture why active learning matters (what values and purposes it advances). While conceptually distinguishable, these facets are dynamically interconnected: strategies are designed to activate specific dimensions of engagement, which in turn, produce context-situated learning outcomes. By making these relationships explicit, this multilateral model helps researchers and practitioners to navigate the complex landscape of active learning, enabling targeted research inquiry and better alignment of instructional choices with goals.

Note the connections of these facets, as described, to the ontology (what it is), epistemology (how we come to understand it), and axiology (what values shape its use) of active learning. In the next section, we will examine the philosophical underpinnings of the construct, both to strengthen the framework and to situate active learning within the broader traditions of mathematics education research.

Philosophical Grounding of the Framework

The ambiguity surrounding active learning is not merely a pedagogical challenge—it is deeply philosophical. Researchers (and practitioners) enter the conversation with different assumptions about what active learning is (ontology), how we can know it (epistemology), and why it matters (axiology). Making these philosophical perspectives explicit deepens theoretical rigor and enhances practical relevance.

Ontology: What Counts as Active Learning?

Ontology concerns the nature of the phenomenon. The lack of clarity surrounding the term "active learning", as described earlier, is fundamentally an ontological problem: Is active learning a set of instructional strategies, a mode of engagement, or a class of outcomes? Current literature often collapses these categories, producing competing ontologies. The framework addresses this tension by delineating three ontological layers—dimensions (process), strategies (practice), and outcomes (consequence)—and invites scholars to specify which aspect(s) their work investigates, thereby reducing ambiguity and supporting cumulative knowledge-building.

Epistemology: How Do We Know Active Learning?

Epistemology, here, examines the nature and origin of knowledge about active learning. Some studies on active learning employ positivist lenses, emphasizing empirical evidence and generalizability. These often examine outcomes of active learning (e.g., measuring exam achievement). On the other hand, studies focusing on dimensions and strategies (e.g., examining instructor beliefs, sense of belonging) often reflect interpretivist or social-constructivist paradigms. Distinguishing between dimensions, strategies, and outcomes helps researchers to align methodological choices with research questions.

Axiology: Why Does Active Learning Matter?

Axiology foregrounds the values and priorities that shape research and practice. Advocacy for active learning often rests on tacit or explicit value commitments: promoting equity, fostering inclusion, nurturing belonging and agency, or advancing deeper understanding. By ensuring that values are centrally situated in how active learning is understood and discussed, this framework helps researchers and practitioners to align their values with their practice, inviting the field to more systematically investigate not just *what works* but also *what matters and for whom*.

Interplay of Ontology, Epistemology, and Axiology

Recognizing diverse ontological, epistemological, and axiological orientations clarifies why even a seemingly intuitive term like active learning can foster confusion. The proposed framework clarifies these orientations by making these philosophical underpinnings explicit: the dimensions of engagement that characterize active learning address the question, "What is active learning made of?" (ontology). Strategies enact active learning and shape the ways researchers and practitioners study it, answering the question, "How do we know active learning?" (epistemology). Finally, outcomes of learning reflect the values and intended purpose, answering the question, "Why does active learning matter?" (axiology). Rather than erasing differences among researchers, the framework offers a structure for explicitly naming them, enabling more transparent and productive inquiry and dialogue.

Implications

The framework presented here is not intended as an end to the ambiguities surrounding active learning but as an invitation—an invitation for researchers, practitioners, and policymakers to engage intentionally with the complexity of the construct. It provides a blueprint for engaging with existing literature and highlights where further research is urgently needed. The implications that follow articulate how this shift in perspective can strengthen both the research and practice of active learning, helping to realize its full promise.

Implications for Research

The framework calls for greater transparency in scholarship and highlights several areas where active learning research could be strengthened.

Attending to context. Research needs to move beyond dichotomous comparisons (e.g., "lecture vs. active learning") and investigate which strategies, activating which dimensions, in which context, produce which outcomes.

Clarifying ontologies. Researchers need to specify the aspect(s) of active learning they are studying. Is the focus on dimensions of engagement (what characterizes active learning), instructional strategies (how active learning is enacted), learning outcomes (why active learning matters), or a combination of them? This facilitates more productive synthesis and meta-analysis.

Aligning epistemologies with research goals. Selecting methodological approaches explicitly suited to the facet of active learning under study (e.g., dimensions may be better studied using qualitative approaches) and clarifying epistemological underpinnings will help researchers strengthen the validity of their work.

Integrating axiological commitments. By making explicit the values that motivate a study—such as equity, agency, performance, belonging—the framework encourages researchers to articulate their axiological commitments and critically examine whether the selected strategies and evaluated outcomes align with those commitments.

Methodological opportunities. This framework invites research that maps how strategies activate specific dimensions of engagement, how those dimensions shape outcomes, and the role of context in the process. Addressing this complex task invites methodological innovations that can generate roadmaps for both practitioners and researchers.

Implications for Practice

The framework also offers guidance for faculty, administrators, and institutions to implement active learning.

Context-sensitive implementation. Too often, research treats context as external to the learning model. This framework cautions against "one-size-fits-all" recommendations and highlights the need to adapt strategies to local conditions. For example, collaborative group work may foster social and agentic engagement in small classes. However, it requires adaptation in large lectures, such as the addition of teaching and learning assistants.

Roadmap for backward design. Practitioners often face the question, "How can I bring active learning practices into my classroom?" By distinguishing between strategies, dimensions, and outcomes, the framework provides a roadmap to backward design their choice. Instructors first identify the desired outcomes, then consider which dimensions of engagement are most likely to support those outcomes, and finally, select strategies that intentionally activate those dimensions given their specific context. For example, an instructor teaching a first-year calculus course at a public university may want to foster persistence and collaboration among students who often feel isolated in large lecture settings. To support these outcomes, the instructor would focus on social and behavioral engagement and might adopt strategies such as group problem-solving tasks facilitated by teaching assistants. By contrast, an instructor in a small seminar-style differential equations course might pursue the same outcomes through student-led discussions or peer-instruction activities. In both cases, reflecting on which engagement dimensions a strategy activates helps instructors design more balanced active learning experiences.

Fostering equity and belonging. By centering dimensions such as emotional and agentic engagement, as well as equity-based, relational outcomes, instructors can intentionally design learning experiences that not only boost achievement but also reduce opportunity gaps and support all students in the classroom, especially those historically marginalized.

Increased support for active learning. Clearer evidence-based research claims can strengthen institutional support (Børte et al., 2020), leading to better resource allocation and more targeted professional development opportunities.

Conclusion

Active learning has become both a rallying cry for reform in undergraduate mathematics education and a construct clouded by definitional ambiguity. As this paper has demonstrated, the conflation of engagement, strategies, and outcomes undermines research synthesis, yields generic policy recommendations, and leaves instructors uncertain about what active learning entails in their specific classrooms. By disentangling dimensions of engagement, instructional strategies, and learning outcomes, the proposed framework cuts through this persistent ambiguity by providing a robust lens for analyzing, comparing, and intentionally designing active learning experiences. For researchers, it provides sharper tools to frame and critique studies without flattening diverse practices to a single "active learning" variable. For practitioners, it serves as a reflective roadmap to design, select, and adapt strategies that align with their intended outcomes, context, and values—instead of reaching for one-size-fits-all solutions.

Most importantly, this clarity paves the way for real, equity-driven impact. When the links between strategies, engagement, and outcomes are made explicit, mathematics educators can design interventions that not only raise achievement but also build belonging, agency, and justice. Adopting this framework is therefore more than a conceptual exercise—it is a call to move beyond slogans and toward deliberate, value-based transformation in undergraduate mathematics education.

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