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When Slides Replace Thinking: How PowerPoint Culture Undermines Conceptual Learning in Engineering Education

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When Slides Replace Thinking: Conceptual Learning and Slide-Centered Instruction in Engineering Education

Abstract

Presentation technologies are now deeply embedded in engineering classrooms and provide important advantages for organization, visualization, and communication of technical material. At the same time, foundational engineering courses such as Statics, Dynamics, and Mechanics of Materials have traditionally relied on step-by-step reasoning, paced derivation, and explicit articulation of assumptions to develop analytical thinking. In many programs, instructional delivery has gradually shifted toward slide-centered formats designed to improve efficiency and content coverage. Although these formats offer practical advantages, they also raise questions about how students cognitively engage with engineering concepts when information is presented primarily in completed form. Drawing on established research in cognitive science and engineering education together with descriptive classroom observations collected across multiple offerings of foundational mechanical and civil engineering courses, this paper examines how instructional pacing and delivery format may influence conceptual learning. Observations suggest that reasoning-centered instruction supported by live derivation is associated with improved student ability to articulate assumptions, reconstruct analytical processes, and apply knowledge in unfamiliar contexts. Rather than arguing against instructional technology, this paper advocates a balanced instructional approach in which slides support, rather than replace, active reasoning and conceptual engagement.

1. Introduction

Engineering education aims to develop graduates who can reason from first principles, evaluate assumptions critically, and apply analytical methods under unfamiliar conditions. These capabilities are cultivated most directly in foundational engineering courses shared across disciplines, including Statics, Dynamics, and Mechanics of Materials. The teaching approaches adopted in these early courses therefore play a central role in shaping how students learn to think as engineers.

Over the past two decades, instructional practices in engineering programs have increasingly emphasized efficiency, standardization, and visual presentation. Slide-based instruction has become common in undergraduate classrooms because it provides clear organization and visual clarity while enabling consistent coverage of technical content [1]. However, engineering learning depends not only on exposure to final equations or solved examples but also on understanding how analytical reasoning develops. When instruction presents information primarily in completed form, students may observe results without fully engaging in the thinking processes that produce them. This paper examines how instructional pacing and presentation format influence conceptual learning and considers whether current practices align with established knowledge of how students develop engineering reasoning.

2. Concept-Centered Teaching in Engineering

Historically, foundational engineering instruction resembled a cognitive apprenticeship. Instructors developed equations incrementally, verbalized assumptions, and modeled analytical decision making as problems unfolded. Students engaged actively by writing, questioning, and reconstructing reasoning in parallel with the instructor's thought process. Such approaches naturally regulated instructional pacing and allowed learners time to connect equations with diagrams, physical interpretation, and engineering judgment [2].

Slide-centered instruction changes this dynamic by presenting information in completed form. Although this can improve clarity and efficiency, it may reduce opportunities for students to witness reasoning as it develops. Engineering expertise emerges not only from reviewing final results but from observing and practicing analytical construction of solutions.

3. Cognitive Foundations of Engineering Learning

Engineering problem solving imposes substantial demands on working memory because students must integrate mathematics, spatial visualization, and physical intuition simultaneously. Cognitive Load Theory suggests that learning is most effective when information is introduced gradually enough for meaningful processing and integration [3].

Research in cognitive psychology further emphasizes the importance of generative learning. Activities such as note-taking, reconstructing derivations, and self explanation help students build internal mental models that support long-term retention and transfer [4-5]. Handwritten note-taking in particular has been associated with deeper conceptual processing compared to passive viewing of provided material [5].

Slide-driven instruction does not inherently prevent learning; however, challenges may arise when dense technical information is presented faster than students can process. Under such conditions, students may rely on recognition rather than conceptual understanding, reducing their ability to transfer knowledge to unfamiliar problems. The conceptual relationships among instructional format, cognitive processing mechanisms, and transfer outcomes are summarized in Figure 1.

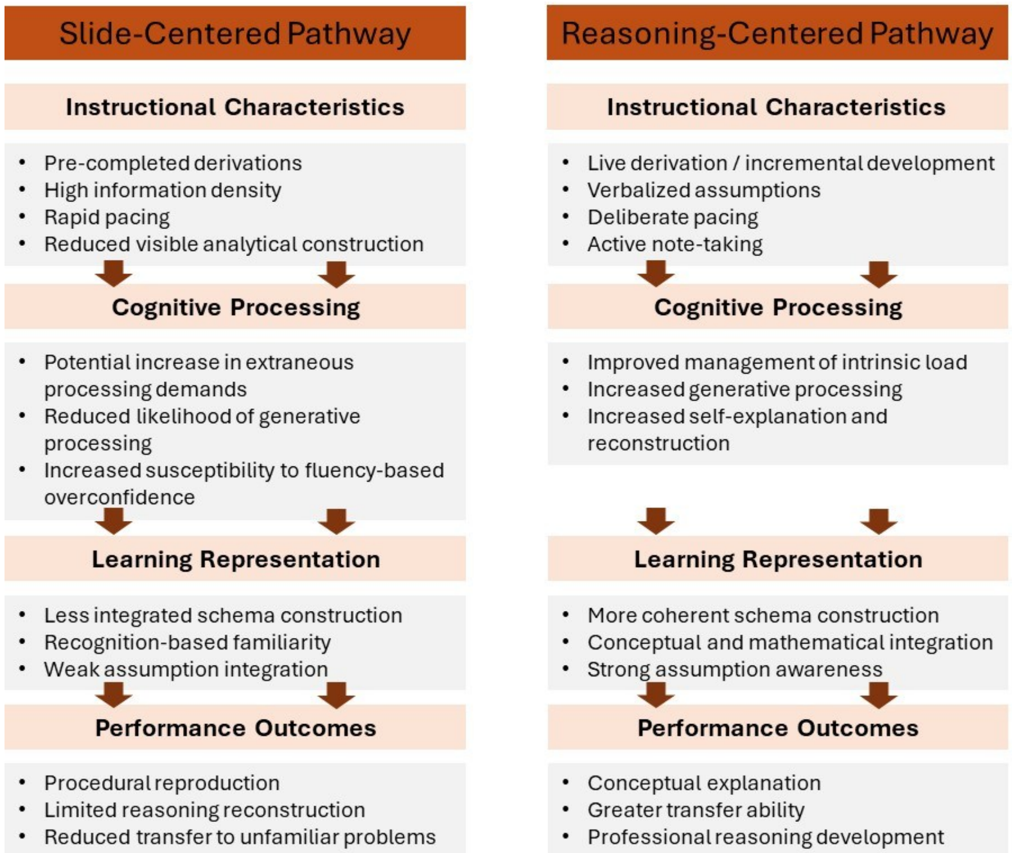

Figure 1. Conceptual framework linking instructional format, cognitive processing mechanisms, and conceptual transfer in foundational engineering courses.

4. Presentation Fluency and Perceived Understanding

Cognitive psychology describes the phenomenon of presentation fluency, in which well organized information creates a sense of understanding that may exceed actual mastery [6]. In engineering classrooms, polished slides can make analytical procedures appear straightforward even when students have not internalized the underlying reasoning.

This distinction becomes visible when students attempt to reconstruct derivations independently, explain the physical meaning of terms, or adapt methods to new contexts.

Difficulties in these tasks suggest that clarity of presentation does not always correspond to depth of understanding. Research on learning approaches indicates that passive exposure often produces familiarity rather than durable conceptual integration [7-8].

5. Instructional Context and Institutional Influences

The increasing reliance on slide-based instruction reflects broader institutional realities rather than individual teaching preferences alone. Large enrollments, standardized curricula, and limited preparation time encourage adoption of publisher-prepared materials that promote efficiency and consistency across course sections [9-10]. These materials provide valuable support, particularly in high-demand foundational courses.

At the same time, strong dependence on prepared slides may reduce opportunities for spontaneous conceptual exploration or pacing adjustments based on student feedback. Institutional reward structures that prioritize research productivity over instructional innovation may further reinforce efficiency-focused teaching practices [9]. Viewing the issue through this systemic lens helps frame the discussion as a pedagogical challenge rather than a critique of individual instructors.

6. Classroom Observations and Descriptive Evidence

The observations presented in this study are based on instructional experiences across multiple universities and several offerings of foundational engineering courses, including Statics and Dynamics. While similar trends have been observed in larger classes such as 180 or more students, the results reported here focus on sections with class sizes ranging from approximately 25 to 35 students to maintain consistency in comparison.

Two instructional formats were implemented across different semesters: (1) predominantly slide-centered instruction and (2) board-based instruction emphasizing live derivation, in which equations and problem solutions were developed step-by-step in real time without reliance on pre-prepared slides. Note that each course offering was delivered using a single instructional format for the entire class; no within-class splitting or parallel sections were used to isolate instructional effects. As a result, comparisons are made across different semesters rather than within the same cohort.

For Statics (186 students), slide-centered instruction was used in Fall 2012, while board-based (live derivation) was implemented in Spring 2013 (Figure 2). For Dynamics (142 students), slide-centered instruction was also used in Fall 2012, followed by board-based (live derivation) in Spring 2013 (Figure 3). In Heat Transfer (45 students), both instructional formats were implemented within Fall 2013 (Figure 4). For Fluid Mechanics (32 students), slide-centered instruction was used in Fall 2018, followed by board-based (live derivation) in Spring 2019 (Figure 5).

Student performance was evaluated using common course assessments, including midterm and final examinations, which included both procedural problems and conceptual questions. As shown in Figures 2–5, across all courses and assessment categories (midterm, final, and total scores), sections incorporating live derivation consistently demonstrate higher average performance compared to slide-centered sections. The observed improvement in overall and conceptual performance typically ranges from approximately 8% to 12%.

The trends shown in all figures are consistent across Statics, Dynamics, Heat Transfer, and Fluid Mechanics. This indicates that the observed effects are not limited to a single course context. In Statics, improvements were particularly evident in students' ability to correctly construct free-body diagrams and articulate equilibrium assumptions. In Dynamics, students exposed to live derivation demonstrated stronger performance in interpreting kinematic relationships and applying governing principles to new problem configurations. Similar improvements were observed in Heat Transfer and Fluid Mechanics, particularly in students' ability to apply governing equations and interpret the underlying physical meaning during problem solving.

Variability in student performance, as indicated by standard deviation, remained comparable between instructional formats. This suggests that the observed differences in mean performance are not attributable to increased dispersion or outlier effects. Instead, the results indicate a systematic shift in performance associated with instructional approach.

In addition to quantitative performance measures, consistent differences in classroom engagement were observed between instructional formats. Sessions incorporating live derivation showed increased note-taking activity, more frequent student questions related to assumptions, and greater peer discussion during problem-solving activities. In contrast, slide-centered sessions more often exhibited reduced note-taking and greater reliance on posted materials. Informal student feedback across course offerings indicated that observing derivations in real time improved understanding of how formulas are developed and increased confidence in independent problem solving. These observations align with active-learning research demonstrating improved conceptual outcomes when students participate in constructing knowledge [11–13].

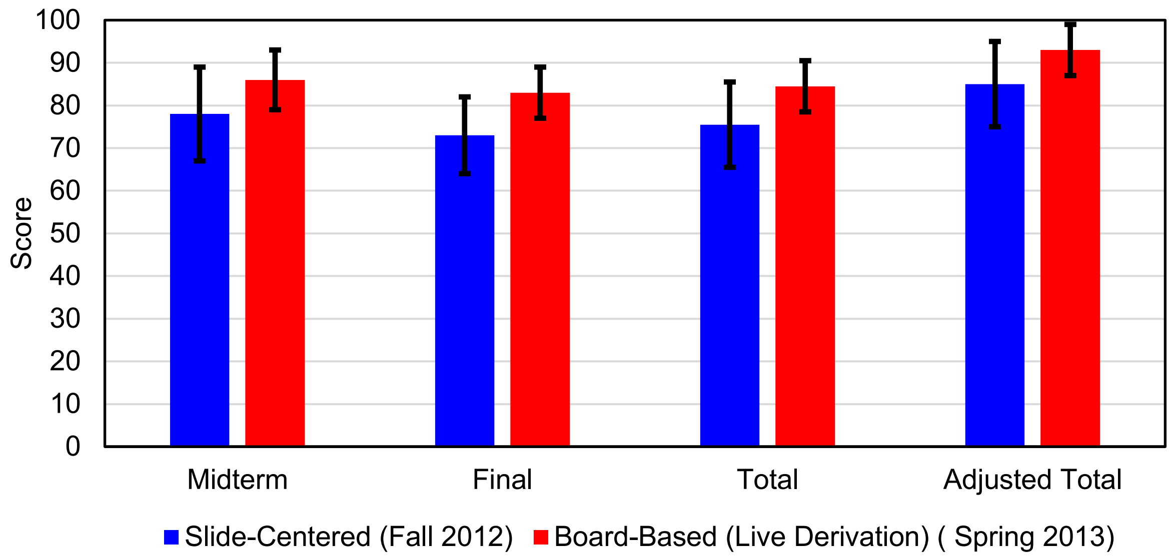

Figure 2. Average Statics scores (mean ± SD) for slide-centered (Fall 2012) and board-based with live derivation (Spring 2013), 186 students.

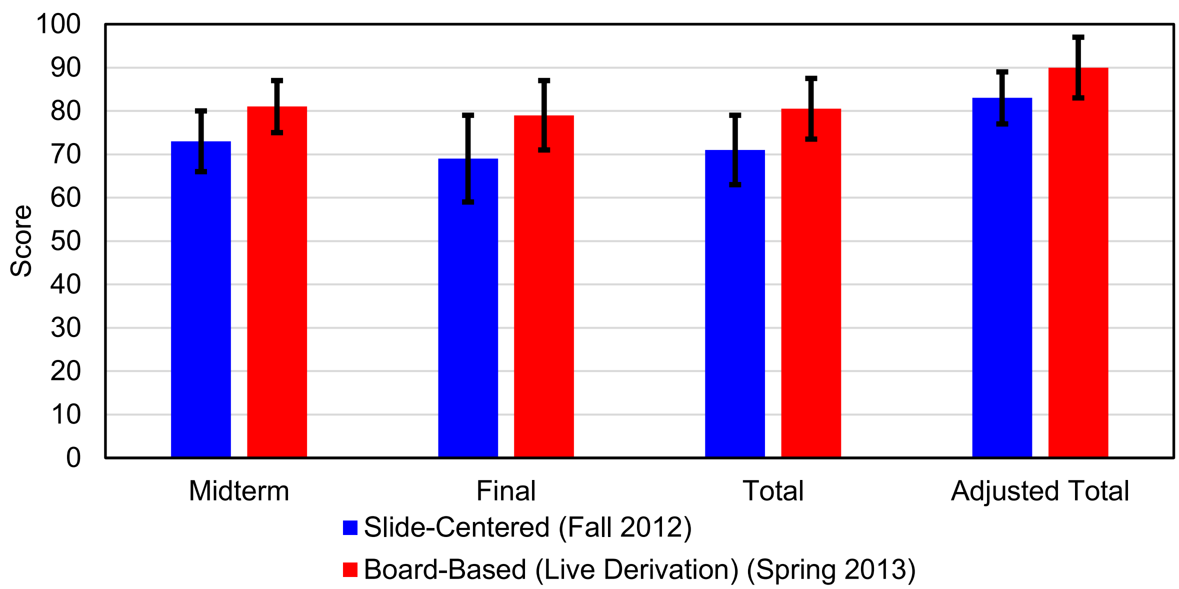

Figure 3. Average Dynamics scores (mean ± SD) for slide-centered (Fall 2012) and board-based with live derivation (Spring 2013), 142 students.

It is important to note that the data presented here are descriptive and does not represent a controlled experimental design. Variations in cohort, semester, and instructional context may influence absolute performance values. However, the consistency of the observed trends across multiple offerings and course types suggests a meaningful relationship between instructional format and conceptual learning outcomes.

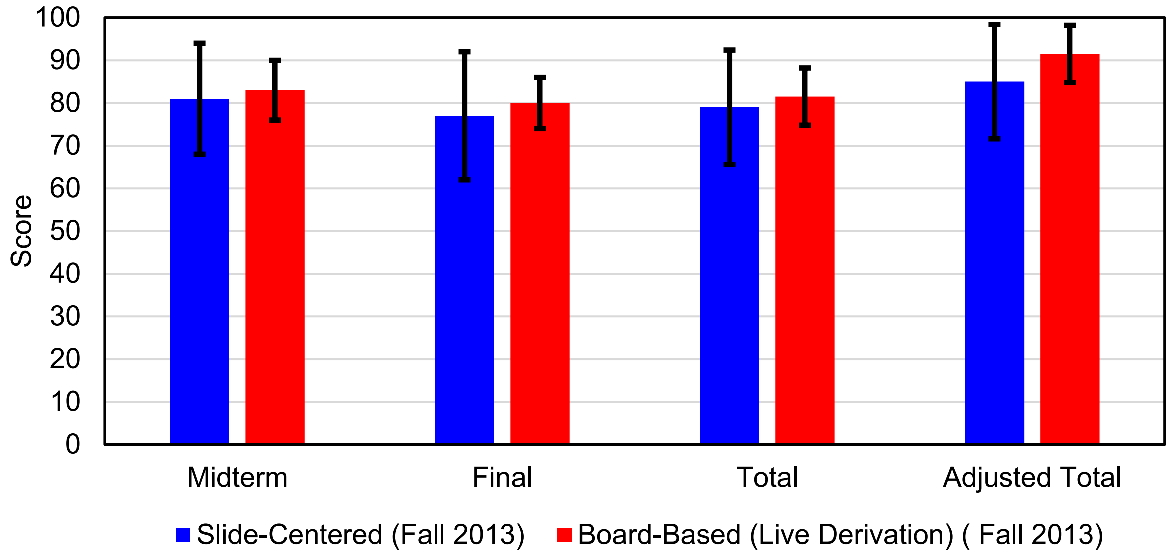

Figure 4. Average Heat Transfer scores (mean ± SD) for slide-centered (Fall 2013) and board-based with live derivation (Fall 2013), 45 students.

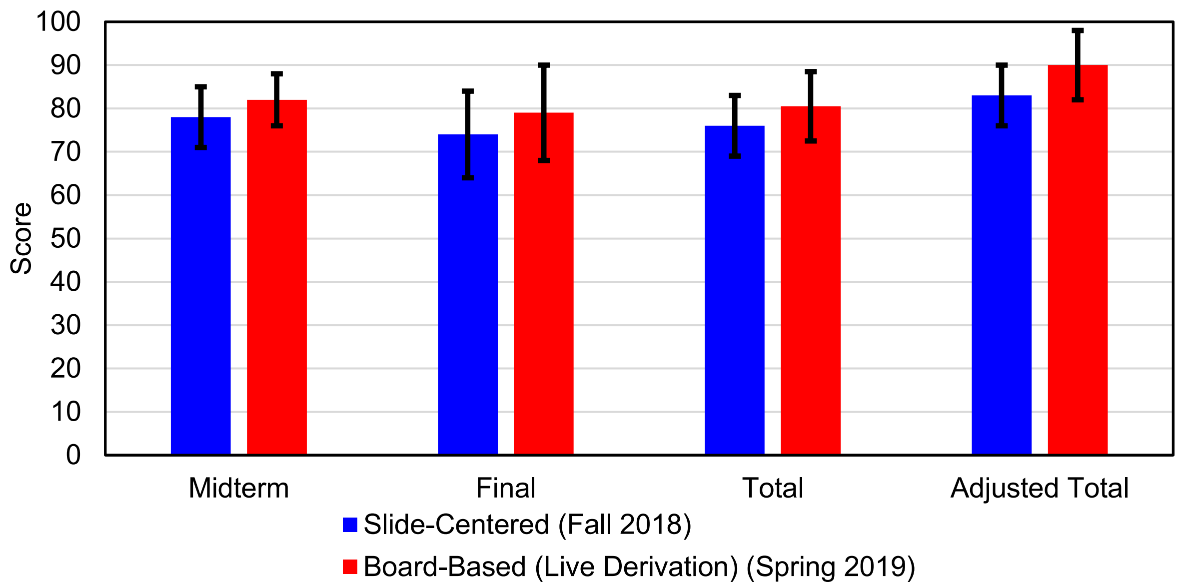

Figure 5. Average Fluid Mechanics scores (mean ± SD) for slide-centered (Fall 2018) and board-based with live derivation (Spring 2019), 32 students.

7. Implications for Engineering Practice

Conceptual gaps originating in foundational courses often become visible in upper-level coursework and project-based learning. Students may struggle to justify assumptions, construct accurate free-body diagrams, or approach open-ended engineering problems with confidence. Such challenges suggest that professional engineering competence depends not only on procedural familiarity but also on reasoning habits cultivated through sustained conceptual engagement [14].

8. Recommendations for Balanced Instruction

A balanced instructional model appears most consistent with both classroom experience and learning research. Slides remain valuable for visualization, organization, and presentation of complex diagrams. However, integrating slides with live derivation or digital writing preserves pacing and allows students to observe reasoning as it develops.

Recommendations include emphasizing conceptual depth in foundational courses, supporting faculty development in reasoning-centered pedagogy, and encouraging instructional approaches that combine visual tools with active analytical engagement. The goal is not to eliminate slides but to ensure that they support rather than replace the thinking processes central to engineering education.

9. Scope and Contribution

This paper offers a scholarly perspective synthesizing cognitive science and engineering education research with descriptive classroom observations. It does not present controlled experimental results but instead aims to contribute to ongoing discussion regarding how instructional tools influence the development of engineering reasoning and professional judgment.

10. Conclusion

Presentation technologies provide significant organizational and visual benefits in modern engineering education. At the same time, both classroom experience and learning research suggest that conceptual understanding develops most effectively when students can observe and participate in reasoning as it unfolds. When slide-centered delivery dominates instruction, opportunities for this engagement may diminish. A balanced approach that integrates visual tools with paced reasoning and active participation may better support conceptual learning and the development of engineering judgment in foundational engineering courses.

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