Engineering Educators Bringing the World Together
2025 ASEE Annual Conference & Exposition
Palais des congrès de Montréal, Montréal, QC • June 22–25, 2025
Paper ID #47371

# Transforming Statics Instruction: An Integrated OER and Algorithmic Problem-Solving Framework to Advance Student Success in Engineering

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# Transforming Statics Instruction: An Integrated OER and Algorithmic Problem-Solving Framework to Advance Student Success in Engineering


## Abstract

This paper presents the development and implementation of an interactive Open Educational Resource (OER) based instructional model for Statics, a foundational engineering mechanics course known for its high cognitive demands and attrition rates. The redesigned course integrates a modular, strategically designed and openly accessible OER textbook, a structured seven-step problem-solving framework, scaffolded active learning strategies, collaborative laboratory sessions, and thematically aligned instructional video lectures. These elements function as a unified instructional system intended to enhance cognitive efficiency, promote procedural and conceptual fluency, and increase equity in engineering education.

Quantitative analysis comparing cohorts from a traditional delivery and a newly implemented Interactive OER Statics model demonstrated statistically significant improvements in student performance. The average final grade increased from 76% to 87% ($p$ = 0.0001), and the DFW (Drop, Fail, Withdrawal) rate declined from 15% to 3%, without any changes to grading policy or course rigor. Student surveys further supported the impact of the redesign, with ratings of 4.6 for the textbook, 4.5 for the video lectures, and 4.3 for perceived motivation to persist in engineering.

These findings demonstrate that the Interactive OER Statics model, grounded in pedagogical alignment, cognitive support, and inclusive design, can substantially enhance student achievement and retention in a conceptually demanding course. By unifying structured resources, algorithmic reasoning, and multimodal instruction, the model offers a scalable and replicable framework for advancing equity and academic success in undergraduate engineering education.


## Introduction

Statics is widely recognized as a “gateway course” in undergraduate engineering education, serving as a foundational milestone that significantly influences student retention, persistence, and long-term success [1], [2]. As the first core course in Engineering Mechanics for most students, Statics marks a critical transition from procedural, equation-driven problem solving (often encountered in introductory physics) to a more abstract, principle-based framework rooted in equilibrium analysis and spatial reasoning. For many students, particularly those encountering formalized engineering thinking for the first time, this conceptual shift creates a steep cognitive learning curve. Difficulties with foundational geometry, vector decomposition, and multi-dimensional visualization frequently compound these challenges. These barriers are especially pronounced for first-generation and historically underrepresented students in STEM [3]–[5], and are often exacerbated by the high cost of textbooks, online platforms, and supplemental materials [6], [7].

In response to these pedagogical and structural challenges, Open Educational Resources (OER) have emerged as a powerful tool for democratizing access to foundational engineering education. By offering cost-free, customizable, and openly licensed materials, OER reduce financial barriers that disproportionately affect students from underserved backgrounds [8]–[10]. Traditional Statics courses often require expensive textbooks and third-party learning platforms, such as SolidProfessor, which are not always pedagogically aligned with the conceptual demands of the course. In contrast, OER environments can be designed to directly support student learning through intentionally structured content, multimedia enhancements, and inclusive pedagogical strategies. When combined with research-informed practices such as visual scaffolding, interactive exercises, and multimodal reinforcement, OER have been shown to improve both engagement and conceptual understanding, particularly in abstract, high cognitive load disciplines like Statics [11]–[15].

Structured problem-solving frameworks are critical for improving student outcomes in foundational engineering courses such as Statics, where learners often struggle to navigate abstraction and complex decomposition. Algorithmic approaches that break problems into manageable, repeatable steps have demonstrated clear benefits in supporting knowledge retention, fostering conceptual depth, and enhancing long-term transfer of learning [16]–[18]. These strategies are increasingly supported by cognitive science and neuroscience research, which emphasize reducing cognitive load, enhancing dual coding, and activating memory consolidation mechanisms as key pathways to deeper learning [19]–[21]. Despite this growing evidence base, traditional Statics instruction often fails to systematically incorporate such structured methods, leaving many students without the scaffolding needed to build confidence and competence in analytical problem-solving [22], [23].

Compounding the cognitive and pedagogical barriers in Statics are persistent financial and structural inequities that disproportionately impact students from underserved backgrounds. High textbook costs, paywalled digital platforms, and disconnected supplemental tools place additional burdens on learners already navigating academic and social hurdles [24]. These systemic barriers are not merely logistical; they influence who succeeds, who persists, and who ultimately graduates in engineering. Addressing them requires more than incremental change; it demands a holistic instructional redesign that integrates cost-effective resources, inclusive teaching strategies, and research-based learning frameworks. Foundational courses like Statics, which serve as academic gatekeepers, must be reimagined as equitable on-ramps that intentionally support all students, regardless of their prior preparation or socioeconomic background.

This paper presents the development and implementation of a strategically designed, interactive OER textbook and a complementary series of instructional video lectures, hosted on YouTube, aimed at transforming the teaching and learning of Statics. At the core of this initiative is a unified, algorithmic problem-solving framework that is systematically integrated across lectures, labs, and assignments to provide students with a repeatable, structured approach to complex engineering problems. The OER textbook is not only freely accessible but is also intentionally written and organized to support cognitive efficiency through visual scaffolding, targeted repetition, and a concept-layered structure. While this paper focuses on the textbook and digital materials, the broader instructional framework also incorporates in-class active learning strategies such as guided note-taking with embedded blanks, animated concept visualizations for high-spatial-load content, and supplementary video tutorials to support flexible reinforcement outside class. These components are integrated to form a cohesive, student-centered learning environment grounded in research-based pedagogical principles. By addressing financial, cognitive, and structural barriers, this work aims to enhance student comprehension, retention, and confidence in Statics while also equipping them with the foundational skills necessary for success in advanced engineering coursework. This approach contributes to systemic efforts to close equity gaps and strengthen diversity across the engineering education pipeline.

## Course Redesign and Implementation

### *Curricular and Structural Challenges*

Many engineering programs face structural and curricular constraints that hinder effective instruction in foundational courses like Statics. In some implementations, Statics is offered with reduced lecture contact hours, such as two hours per week rather than the more common three, and is paired with extended lab sessions. While this format may align with institutional norms, it compresses conceptual instruction time and limits opportunities for scaffolded problem-solving during lecture. Additionally, in an effort to streamline curricula, some programs incorporate content typically reserved for other engineering courses, such as engineering graphics, into Statics, thereby expanding its scope well beyond the course's intended learning outcomes. This curricular overloading imposes additional cognitive and logistical strain on a course already recognized for its abstract reasoning demands. In some formats, lab sessions are split between Statics content and unrelated technical tasks, further diluting time for applied problem-solving. The instructional misalignment becomes more pronounced when students are required to purchase access to third-party platforms originally developed for other domains, which offer limited pedagogical value in the context of Statics. These issues contribute to persistently high failure and withdrawal rates; in many implementations, the DFW rate for Statics hovers around 15%, consistent with national trends. When layered onto longstanding challenges, such as high textbook costs and gaps in prerequisite knowledge, these structural misalignments can significantly exacerbate barriers to persistence and equity. The course redesign presented here was developed to directly address these obstacles through a unified instructional framework that emphasizes cognitive alignment, accessibility, and active engagement.

### *Instructional Design Strategy*

The instructional model described in this study, referred to throughout as Interactive OER Statics, represents a comprehensive redesign of the Statics course to address structural, cognitive, and equity-related barriers to student success. For comparison, the Traditional Statics approach relied on a conventional textbook-based format without structured problem-solving support framework or integrated multimedia support.

The redesigned Statics course was structured around a prewritten, interactive OER textbook that served as both a content resource and a core instructional tool. To maximize the effectiveness of limited lecture time, the textbook included embedded fill-in-the-blank prompts for key terms and procedural steps, allowing students to engage actively through listening, observing, and writing in real time. This approach was designed to optimize multisensory processing and reinforce long-term retention. The textbook also incorporated "Extra Sheets" to review prerequisite knowledge and "Recall Boxes" to reinforce conceptual continuity within and across topics. In-class instruction was further supported by a "three-neighbor rule," which encouraged students to discuss questions with nearby peers before responding, fostering collaborative participation in a low-pressure environment. To support students' spatial reasoning, animated visualizations were embedded into lectures to sequentially demonstrate abstract topics such as three-dimensional force systems and moment analysis. Collectively, these strategies were intended to reduce cognitive load, promote engagement, and improve comprehension of fundamental Statics concept in a traditionally high-attrition learning environment.

A core element of the course redesign involved the systematic integration of a structured, algorithmic problem-solving framework. This approach was first introduced to students in a typical first-year engineering course (e.g., Introduction to Engineering) as a logical method for constructing and communicating well-organized engineering solutions. It was then reinforced throughout Statics to provide students with a consistent, repeatable process for analyzing and solving complex problems. The seven-step framework guided students through the full problem-solving process: (1) define a coordinate system and establish sign conventions; (2) identify knowns and unknowns; (3) record assumptions; (4) construct a free-body diagram; (5) formulate governing equations; (6) solve the system; and (7) conduct a final reasonableness check on the solution. This framework was explicitly modeled and applied across all course topics. To maximize class-time efficiency and reinforce professional communication standards, practice problems were worked through collaboratively during lecture using prestructured solution templates. Each template followed a consistent sequence—Given, Find, Solution, and Answer—and was partially prefilled, requiring students to complete key components such as coordinate definitions, free body diagrams, and equation formulation. This scaffolded format not only supported procedural fluency but also provided repeated exposure to well-organized, industry-aligned engineering documentation practices.

*Laboratory Design and Multimedia Integration*

Although laboratory sessions are not typically included in standard Statics curricula, they are a required component of this program's engineering course structure. To align the lab experience with the course's cognitive and pedagogical goals, the laboratory component was strategically reimagined as an extension of the structured problem-solving framework introduced in lecture. Each session was designed as a collaborative, applied exercise that reinforced the specific Statics topic introduced during the corresponding lecture. To promote equitable participation and simulate authentic engineering team dynamics, lab groups were intentionally composed to represent a range of academic preparation, communication styles, and lived experiences. This structure enabled students to experience the value of diverse perspectives in problem-solving, an essential competency in professional engineering practice, and emphasized the importance of collaborative thinking from the earliest stages of their education. The labs provided a low-stakes environment for students to deepen procedural fluency, articulate reasoning aloud, and construct well-organized solutions using the structured templates modeled in class. This approach positioned the lab as a space for reinforcing engineering problem-solving practices through hands-on collaboration, aligned with the broader goals of the course redesign.

To bridge the gap between abstract theory and physical interpretation, students were also introduced to real, fabricated examples of support types commonly encountered in Statics, such as pins, rollers, hinges, journal bearings, thrust bearings, and rockers. Through hands-on interaction with these components, students could observe the actual mechanical constraints and degrees of freedom associated with each support, deepening their understanding of how these elements resist forces and moments in applied contexts.

To further extend instructional reach beyond the classroom, a series of video lectures was developed and hosted on YouTube as an open-access supplement to the OER textbook. These videos were carefully aligned with each chapter of the course and assigned as pre-lab preparation, ensuring that students entered lab sessions with a working grasp of key concepts and problem-solving methods. Each video walked through complex Statics problems using the same structured framework modeled in class, reinforcing both conceptual understanding and procedural fluency. The asynchronous format allowed students to engage with the material at their own pace, revisit challenging topics as needed, and prepare more effectively for both labs and assignments. By maintaining a consistent instructional voice across modalities—textbook, lecture, lab, and video—the course promoted continuity in problem-solving while supporting diverse learning preferences and flexible pacing.

## Results and Discussions

### *Quantitative Course Performance*

To evaluate the impact of the instructional redesign, final course grade distributions were compared between students enrolled in the traditional Statics format and those taught using the Interactive OER Statics model implemented in this study. The Traditional Statics course, delivered between 2011 and 2023, relied on conventional textbook instruction with no integrated algorithmic problem-solving framework or multimedia supports. In contrast, the redesigned Interactive OER Statics model introduced a strategically structured OER textbook, multimodal engagement through instructional video lectures, and active learning strategies designed to reduce cognitive load and enhance student retention.

Figure 1 presents the probability distributions of final grades for both cohorts, normalized by total enrollment to facilitate direct comparison. Under the traditional model, the average final grade was approximately 76%, with a considerable proportion of students earning below the 70% threshold typically required to pass. Following implementation of the redesigned approach, the average grade increased to approximately 87%, and the distribution shifted markedly to the right, indicating improved performance across the cohort. This shift was accompanied by a pronounced reduction in low-performing outliers. A two-sample $t$-test yielded a $p$-value of 0.0001, demonstrating that the improvement was statistically significant at the 95% confidence level.

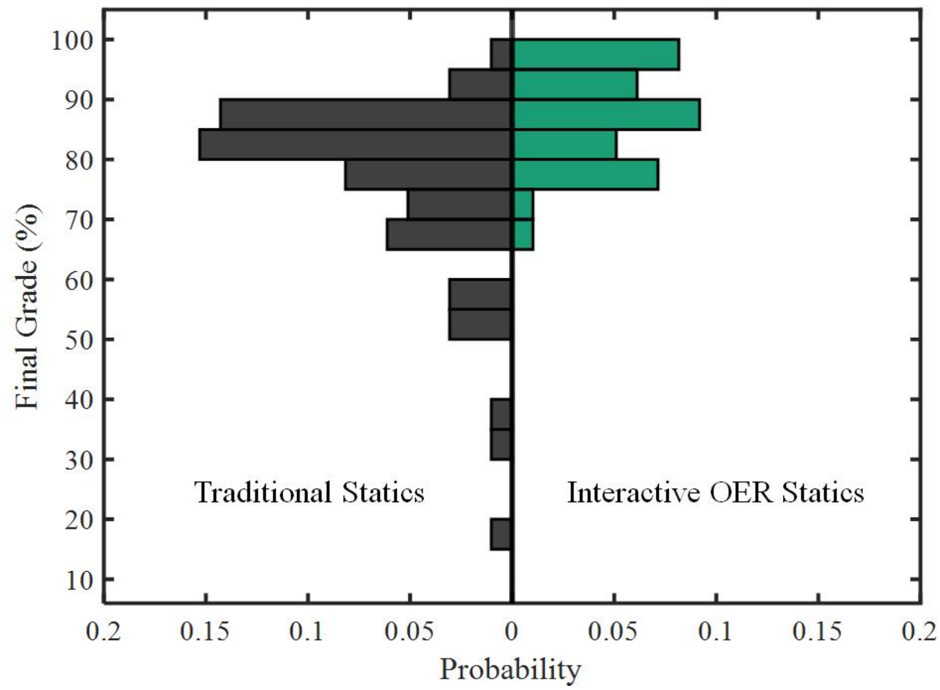


**Figure 1. Probability distribution of final course grades for students enrolled in Traditional Statics and Interactive OER Statics. Binned histograms reflect normalized student counts using a bin width of 5%. The Traditional cohort shows a wider spread and higher concentration of low-performing grades (below 70%), while the Interactive OER cohort demonstrates a rightward shift with more students achieving higher performance bands (80–95%). Grade distributions were normalized by total enrollment across cohorts to enable direct comparison.**

This improvement in student outcomes is further illustrated in the box-and-whisker plot shown in Figure 2. The Traditional Statics cohort exhibited a broader interquartile range, a lower median, and a more pronounced lower tail, indicating greater performance variability and a left-skewed distribution. In contrast, the Interactive OER Statics cohort showed a narrower interquartile range and a higher median, reflecting tighter clustering of scores around the mean and reduced incidence of low-performing outliers.

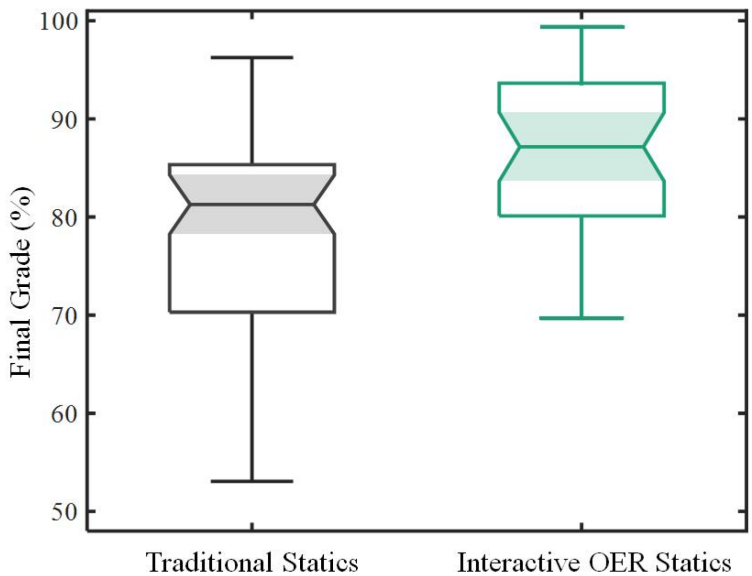


**Figure 2. Box-and-whisker plot comparing final grade distributions in Traditional Statics and Interactive OER Statics. The Interactive OER cohort shows a higher median, smaller interquartile range, and fewer low-end outliers, reflecting more consistent and improved student outcomes.**

In addition to overall grade distributions, DFW (Drop, Fail, Withdrawal) rates were analyzed as a key indicator of student retention. As shown in Table 1, the Traditional Statics model yielded a consistent DFW rate of 15% across cohorts from 2011 to 2023.

**Table 1. Comparison of DFW Rates Between Traditional Statics and Interactive OER Statics.**

| Years | DFW Rate (%) |
|---|---|
| 2011–2023 | 15 |
| 2024 | 3 |

Following implementation of the Interactive OER Statics model, the DFW rate declined to 3%, representing an 80% decrease. This reduction occurred without changes to assessment methods, grading criteria, or course rigor, strongly indicating that the improvement in student outcomes resulted directly from the instructional redesign. These results reflect not only a significant enhancement in student achievement but also reduced attrition and improved grade consistency. These are indicators of deeper conceptual understanding, sustained engagement, and greater instructional equity. The statistically significant improvement in final grades, coupled with the sharp decline in DFW rates, offers compelling evidence for the effectiveness of the redesigned course and reinforces its potential for broader adoption in other high-attrition, conceptually intensive STEM gateway courses.

*Student Perceptions of Learning and Retention*

To complement the quantitative outcome data, students enrolled in the redesigned Interactive OER Statics course were surveyed to assess their perceptions of instructional effectiveness and its influence on academic motivation. The survey included three items, each rated on a five-point Likert scale (1 = Not Effective / No Impact; 5 = Extremely Effective / Significant Impact):

Q1. The effectiveness of the OER textbook in supporting their understanding of Statics concepts and problem-solving skills;
Q2. The effectiveness of the instructional video lectures in enhancing comprehension of course content and solution strategies; and
Q3. The extent to which the redesigned course—comprising the OER textbook, video lectures, and algorithmic framework—influenced their decision to persist in engineering.

Table 2 summarizes the results. The OER textbook received an average rating of 4.6, and the video lecture series was rated 4.5, reflecting a strong endorsement of the multimodal instructional supports. The overall influence of the redesigned model on students' motivation to remain in engineering was rated 4.3, indicating that the course redesign not only enhanced students' learning experience but also contributed positively to their long-term academic commitment.

**Table 2. Average student ratings for instructional components in the redesigned Statics course. Q1: Effectiveness of OER textbook. Q2: Effectiveness of video lectures. Q3: Influence on engineering persistence.**

| | Q1 | Q2 | Q3 |
|---|---|---|---|
| Interactive OER Statics | 4.6 | 4.5 | 4.3 |

These results reinforce the patterns observed in grade distributions and DFW rate reductions, and provide evidence that the course redesign supported both cognitive and affective aspects of student success. The high ratings across all categories suggest that the integration of accessible, multimodal instructional materials, along with aligned algorithmic frameworks, improved students' understanding, confidence, and engagement in a course widely known for its conceptual difficulty.

In particular, the strong response to Q3 underscores the motivational impact of the redesigned course, as students perceived it not only as pedagogically effective but also as reinforcing their commitment to continue pursuing engineering. These findings suggest that the full instructional framework developed in this study, including the structured algorithmic problem-solving approach, multimodal engagement strategies, and cognitively aligned OER resources, has strong potential to inform course design in other high cognitive load, high attrition gateway engineering subjects, especially those that prepare students for advanced analytical coursework.

## Summary and Conclusions

The Interactive OER Statics model developed in this study represents a comprehensive instructional redesign aimed at addressing persistent challenges in one of the most cognitively demanding foundational courses in engineering education. Grounded in research-informed pedagogy, the approach integrates a modular, openly accessible OER textbook, a structured seven-step problem-solving framework, active learning strategies, collaborative laboratory sessions, and thematically aligned instructional video lectures. Each component operates as a tightly coupled element within a unified system, functioning like interlocking gears in a well-engineered mechanism where instructional alignment and pedagogical coherence amplify their collective impact. This integrated design supports a multimodal learning environment that enhances cognitive efficiency, reinforces procedural and conceptual fluency, and promotes equitable engagement, especially within structurally constrained or resource-limited contexts.

Following implementation, the redesigned course demonstrated significant improvements in student outcomes, engagement, and retention. The average final grade increased from 76% to 87 %, with a two-sample t-test confirming the difference as statistically significant ($p = 0.0001$). Concurrently, the DFW rate declined from a longstanding average of 15% to just 3 %, representing an 80 % reduction achieved without changes to grading policies or assessment structures. These quantitative gains provide strong evidence that the redesign effectively addressed both cognitive and structural barriers to success in Statics.

The unified course framework combined the algorithmic problem-solving method, the interactive OER textbook, and aligned video lectures to promote deeper conceptual understanding, reduce performance variability, and create a more inclusive and supportive learning environment. Survey feedback further supported these results: students rated the textbook and video lectures highly (4.6 and 4.5 out of 5, respectively), and reported increased motivation to continue pursuing engineering, with an average rating of 4.3 for the redesigned model's influence on retention.

In this proposed model, the course is fully cost-free for students, as all instructional materials, including the textbook, video lectures, and supplementary resources, are openly licensed and freely accessible. This structure, combined with adaptable teaching strategies, enables broad scalability across diverse institutional contexts. The model is especially effective for high-attrition gateway courses in STEM, where equitable access, structured cognitive support, and instructional coherence are essential for improving student performance and long-term academic persistence.

Future efforts will focus on further enhancing the interactive textbook, expanding the multimedia resource library, and facilitating adoption through faculty development and cross-institutional collaboration. The demonstrated effectiveness of this instructional model provides a replicable and scalable framework for reimagining undergraduate engineering education, improving not only academic performance but also long-term persistence in the engineering pipeline.

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