2026 ASEE
ANNUAL CONFERENCE June 21–24, 2026 | Charlotte Convention Center, NC
Host Sponsor UNC Charlotte
Paper ID #51386

The Fun Statics Scavenger Hunt: Connecting Engineering Theory to Real-World Systems

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Abstract

Engineering Statics is one of the first courses in which mechanical engineering students encounter the challenge of abstracting real physical systems into idealized mathematical models. While equilibrium, internal forces, and free-body diagrams (FBDs) are foundational skills, students often perceive the course as formula-driven and detached from real-world problem solving. This paper presents the design, implementation, and assessment of an innovative project, The Fun Statics Scavenger Hunt, developed to foster authentic learning, conceptual understanding, and student engagement. In this project, students identified real structures within their daily environments, captured photographs, developed corresponding FBDs, articulated simplifying assumptions, and conducted team-based analyses connecting theory to application. Data from 47 anonymized student survey responses were analyzed to evaluate engagement, conceptual learning, and self-efficacy gains. Quantitative results indicate that 85.1% of participants found the project engaging, 89.4% found it relevant to real-world engineering, and over 80% agreed that it improved their ability to visualize and model forces. Qualitative responses revealed deeper conceptual reasoning, specifically regarding modeling assumptions and the limits of static analysis. The paper argues that experiential, observation-based assignments in traditionally abstract courses not only improve learning outcomes but also cultivate engineering identity and critical thinking.

Keywords: Engineering education, statics, free-body diagrams, experiential learning, student engagement, engineering modeling.

1. Introduction

Engineering Statics introduces students to one of the most fundamental practices of engineering thinking: simplifying complex physical systems into idealized, analyzable models. This abstraction process underpins not only structural analysis but also mechanical design and systems modeling across disciplines. However, Statics is frequently perceived by students as theoretical and disconnected from hands-on application [1]. Typical instruction relies on idealized textbook problems that feature perfectly smooth pins, frictionless pulleys, or symmetrical trusses. While these problems efficiently illustrate mathematical principles, they risk obscuring the relevance of modeling assumptions and distancing learners from real artifacts encountered in professional engineering practice [2].

Educational research has repeatedly shown that students learn more effectively when they can connect new knowledge to familiar experiences [3], [4]. Constructivist theories argue that conceptual understanding develops through active interaction between learners and their environments. Activities that integrate observation and reflection establish stronger cognitive connections than those relying solely on procedural problem solving [5]. Within this context, the

Fun Statics Scavenger Hunt was developed to create a tangible bridge between theoretical analysis and the physical world. Constructivist theory serves throughout this paper not merely as a motivation for the study design, but as an interpretive lens through which student responses and learning outcomes are analyzed.

This paper presents the theoretical framing, structure, and results of implementing the scavenger hunt in a sophomore-level mechanical engineering Statics course. The paper also discusses how the assignment served as a platform for developing engineering judgments, specifically, the ability to discern what features of a real system are essential to represent in an analytical model and what can be simplified or neglected.

2. Background and Literature Review

2.1 The Conceptual Difficulty of Statics

Several studies have documented persistent conceptual challenges in Statics learning. Students often memorize algorithms for equilibrium equations without developing a deep conceptual sense of how forces interact [6]. Visualization and spatial reasoning deficits exacerbate this problem, particularly when transitioning from concrete systems to abstract diagrams. Using the Statics Concept Inventory (SCI) developed by Steif et al. [7], Brose and Kautz [8] examined persistent conceptual difficulties in statics. Their findings reveal a disconnect between procedural problem-solving ability and conceptual understanding, as many students who successfully complete numerical calculations still misunderstand core concepts such as reaction forces and internal moments [8]. It is also worth noting that students' prior preparation in introductory Physics and Mathematics plays a meaningful role in how readily they engage with modeling tasks in Statics; gaps in vector mechanics or equilibrium fundamentals from prerequisite courses can amplify the cognitive challenges documented here, suggesting potential value in cross-disciplinary coordination between Statics instructors and colleagues in Physics and Mathematics.

2.2 The Role of Modeling and Abstraction

Litzinger et al. [9] and Johri [10] emphasize engineering modeling as a defining dimension of professional expertise. Statics provides an early and accessible context for teaching this skill since all analysis begins with an FBD. However, modeling involves more than drawing lines and arrows—it requires understanding the assumptions and simplifications implicit in representing real supports, joints, and materials. Practicing this abstraction explicitly helps students internalize what engineers mean by "idealization."

2.3 Learning Through Experience and Exploration

Experiential learning frameworks suggest that knowledge is constructed through cycles of action, reflection, conceptualization, and application [11]. Active and inquiry-based learning strategies, when integrated into engineering science courses, improve student motivation, retention, and transfer of understanding [12], [13]. Activities that promote physical observation, such as designbuild projects, laboratory modeling, or field-based tasks, are particularly effective in making invisible forces conceptually visible [14]. The scavenger hunt draws from these pedagogical traditions. By asking students to locate equilibrium conditions "in the wild," the assignment positions learners as investigators of everyday engineering, transforming passive classroom content into lived experience.

3. Project Description

The Fun Statics Scavenger Hunt was introduced midway through the semester after students had learned equilibrium in two and three dimensions and had practiced conventional FBD exercises. Teams of two to three students were tasked with selecting two real-world systems that exemplify principles of static equilibrium. The team-based structure was chosen deliberately: peer discussion encourages students to verbalize and negotiate their modeling assumptions, which is particularly valuable when encountering the ambiguity of real structures, an approach grounded in social constructivist theory [15]. This collaborative discourse also helps calibrate initial idealizations and reduces cognitive overload when students first confront open-ended problems. Examples included door hinges, bicycle frames, weight machines, lamp arms, construction tools, playground equipment, and truss bridges.

Teams submitted a photo essay containing the following elements:

- Photographic documentation of each system from multiple views.
- Annotated identification of supports and members (e.g., pins, rollers, fixed connections, beams).
- Free-body diagrams, complete with labeled forces and coordinate systems.
- A written analysis of equilibrium equations or qualitative reasoning (moment and force balances).
- A reflection discussing assumptions, simplifications, and modeling insights.

Projects were graded on completeness (30%), accuracy of FBDs (40%), analysis and discussion (20%), and clarity of reflection (10%). A detailed rubric was shared ahead of time to guide student expectations.

The activity spanned four weeks and culminated in a class gallery discussion. Students displayed their submissions and informally shared observations, allowing peer feedback and comparison of different systems. This collaborative phase was intended to normalize discussion of modeling challenges, lower anxiety about "real-world complexity," and encourage meta-reflection.

4. Methods

4.1 Participants

The study involved 47 students enrolled across 3 sections of a Statics course during the Fall 2025 semester. Respondents voluntarily completed the post-project "Student Learning Impact Survey."

The survey was administered under IRB-exempt status, as responses were fully anonymized and collected solely for educational improvement and curriculum research purposes. Responses were used only for instructional improvement and curriculum research. It should be noted that voluntary participation may introduce a degree of selection bias, students with particularly strong reactions to the project (positive or negative) may be more likely to respond. Future implementations should consider in-class administration to maximize response rates and reduce this potential bias.

4.2 Survey Instrument Design

The survey consisted of 18 questions divided into five sections:

- Project Experience (engagement, relevance, workload, AI use).
- FBD Learning Outcomes (force identification, reaction awareness, system isolation).
- Connections to Real-World Problems.
- General Learning Outcomes and Confidence.
- Open-Ended Questions (qualitative reflections).

Fifteen questions (shown in Appendix) applied a five-point Likert scale (1 = Strongly Disagree; 5 = Strongly Agree). Three open-ended prompts provided qualitative elaboration on learning experiences, AI involvement, and improvement suggestions.

4.3 Analytical Approach

Descriptive statistical analysis was performed to determine response distributions and mean scores for each item. Open-ended responses were coded for recurring concepts such as "visualization," "connection to reality," "team collaboration," and "feedback need." These themes were identified using inductive content analysis [16]. Patterns were triangulated by cross-referencing quantitative responses with narrative comments. Constructivist theory served as the interpretive framework for analyzing student responses: themes were examined not only for frequency but for evidence of knowledge construction, negotiation of modeling assumptions, and shifts in engineering identity.

5. Results

5.1 Engagement and Relevance

The Scavenger Hunt project demonstrated a high degree of efficacy in fostering student interest and perceived value. Overall engagement levels were remarkably high: (Question 1) 85.1% of participants (40 out of 47) rated the project as either "Engaging" or "Very Engaging." This positive reception is further supported by the students' perception of the project's professional utility; (Question 2) 89.4% of respondents agreed that the assignment connected "extremely well" or "somewhat well" to real-world engineering applications. Notably, the critical feedback was minimal, with only a single respondent (2.1%) categorizing the project as "not engaging." This high baseline of interest suggests that the autonomy to choose personal, real-world objects, ranging from bicycles to local bridge trusses, serves as a strong motivator for sophomore-level students who are often fatigued by the repetitive nature of textbook problem sets. Perceptions of workload also aligned with student success. (Question 3) 80.9% of students reported that the time required for the project was "just right." Qualitative comments revealed that while some students felt initial anxiety about "finding" a structure in their environment, the eventual process of taking the photograph and simplifying it for analysis provided a sense of accomplishment that made the time investment feel justified. As one student noted, "I start looking for trusses in real life a lot now," indicating that the project's impact extended beyond the hours logged on the assignment and into their daily observation of the built world. This aligns with prior research suggesting that applied examples significantly enhance motivation in conceptual courses [16], [17].

5.2 Conceptual Mastery of FBDs

The transition from idealized textbook sketches to real-world objects provided a significant platform for conceptual growth. Data from the 47 respondents showed strong positive outcomes across all FBD-specific metrics. Specifically, (Question 5) 80.8% of students reported an improved ability to identify all forces acting on a body (38 out of 47), while (Question 6) 83.0% (39 out of 47) indicated a better recognition of reaction forces and diverse support types, such as pins, rollers, and fixed connections. A sample of student work analyzing a dorm door is presented in Figure 1.

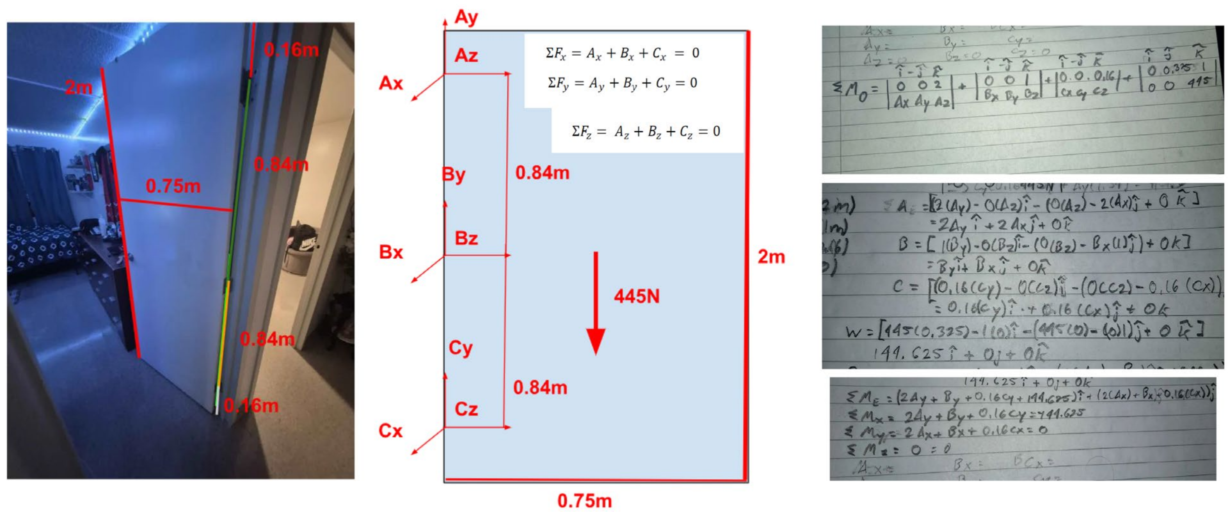

Figure 1: Side-by-side comparison showing a photograph of a door hinge and a corresponding student-drawn FBD with reaction forces labeled along with equilibrium equations

The qualitative data suggests that the "messiness" of real-world objects forced a level of critical thinking that textbook problems often bypass. One student highlighted this complexity, noting: "It helped me identify all the forces that go into something that seems simple." Another student elaborated on the cognitive challenge of simplification, stating they struggled initially to generate a simplified model because the real system "exposed the underlying assumptions which engineers make... it helped me understand the limits of statics." While the majority saw gains, a notable segment remained Neutral (38.3%) on their confidence in creating complete diagrams (Question 7). The responses are shown in Figure 2.

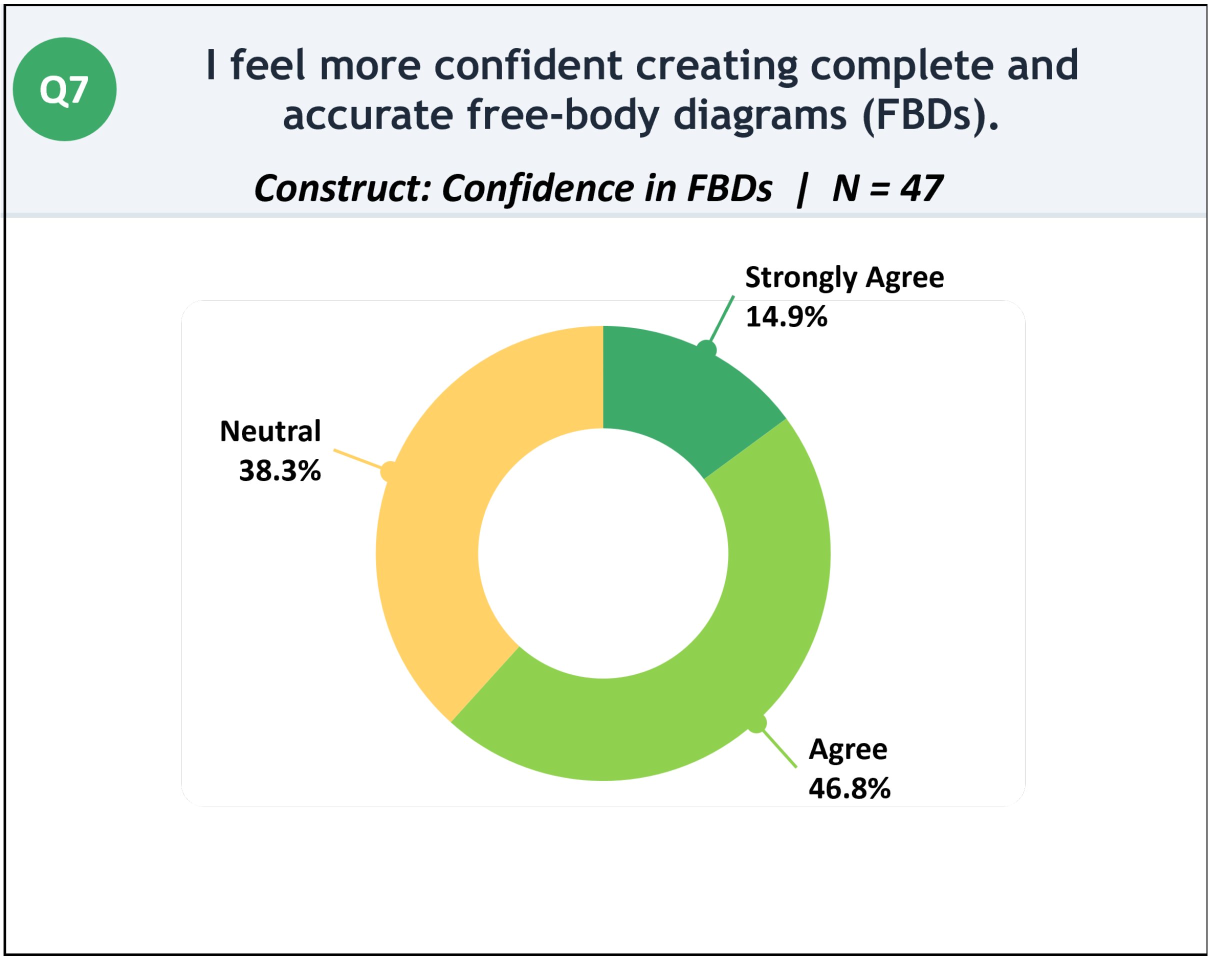

Figure 2: Pie chart showing student confidence in creating complete and accurate free body diagrams.

This suggests that while students improved their identification of forces, the process of synthesizing them into a final, professional-grade FBD remains a challenging skill that requires further practice. Nevertheless, the majority described the experience as a visual breakthrough, with one representative comment stating: "Finding free-body diagrams in a real-world setting helped visualize class concepts better than lecture exercises." The shift from symbolic arrows to "seeing" forces in everyday objects appears to have strengthened the students' spatial reasoning and their awareness of boundary definitions, a cornerstone of engineering modeling.

5.3 Connecting Classroom Theory to Physical Systems

The bridge between theoretical equilibrium and physical reality was the most pronounced outcome of the Scavenger Hunt. Quantitative results from the 47-student cohort indicate that (Question 9) 87.3% of participants (41 out of 47) agreed or strongly agreed that the project helped them visualize how statics concepts apply to real-world structures. Furthermore, (Question 10) 87.2% reported a strengthened understanding of the relationship between theoretical models and physical systems. The responses are summarized in Figure 3.

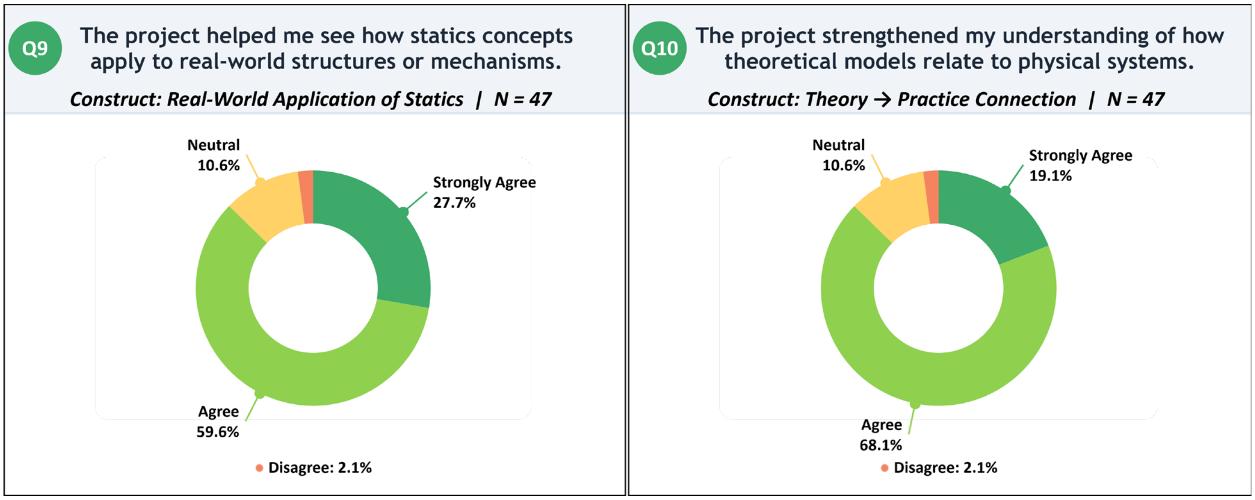

Figure 3: Pie chart showing Q9) students' improved understanding of how statics concepts apply to real structures or mechanisms and Q10) students' understanding of how theoretical models relate to physical systems.

A critical component of this connection was the act of physical observation. (Question 11) 85.1% of students indicated that photographing or observing a real object helped them understand the assumptions, such as neglecting friction or assuming rigid bodies, used in engineering modeling. One student's qualitative reflection captured this shift in perspective: "Photographing real joints and seeing the actual materials made me realize why we assume some constraints are smooth or frictionless. It's hard to see that in a textbook." This reflexive insight was particularly evident for students analyzing complex machinery or large-scale infrastructure. For example, a student analyzing an aircraft wing had to research typical wing spans, lift distributions, and aircraft weights to reasonably approximate aerodynamic loading. Because lift is not directly visible, the student abstracted the wing as a beam with a distributed load, estimating magnitudes and load shapes from real aircraft data, an approach that mirrors how practicing engineers translate complex physical phenomena into solvable structural models. The results of this work are shown in Figure 4.

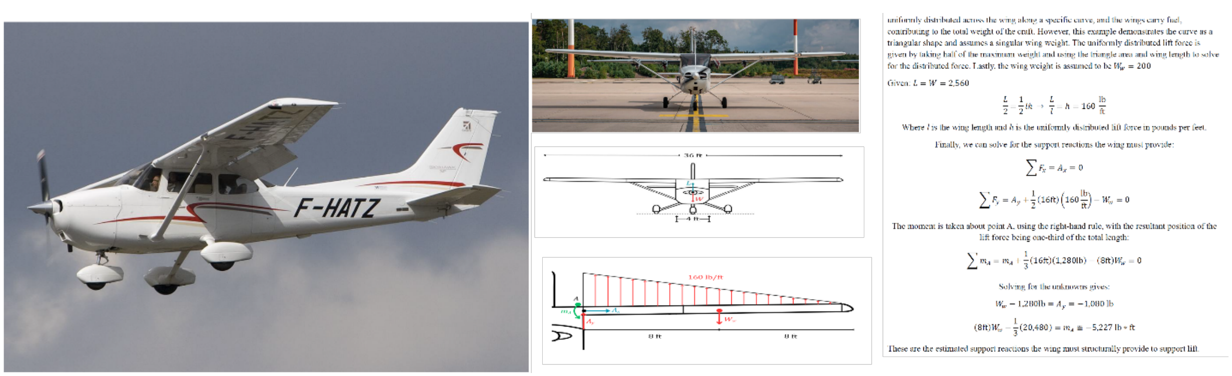

Figure 4: A photograph and free-body diagram of an aircraft wing showing estimated distributed lift, wing weight, and support reactions.

By requiring students to look for "equilibrium in the wild," the project successfully transformed passive classroom content into a lived experience. As one student summarized, "I start looking for trusses in real life a lot now. It also made more sense drawing FBDs when you know how real-life things [actually work]." This indicates that the scavenger hunt did not just teach a concept; it provided a permanent analytical "lens" through which students now view their physical environment.

5.4 Impact on Confidence and Independent Learning

The ultimate goal of the Scavenger Hunt was to support students in transitioning from guided classroom exercises to independent engineering analysis. The data from the 47 participants indicates a marked increase in student self-efficacy. (Question 13) 78.8% of respondents strongly agreed or agreed that the project improved their general understanding of key engineering concepts, and (Question 14) 74.5% felt an improved ability to apply those concepts to solve problems. The responses are summarized in Figure 5.

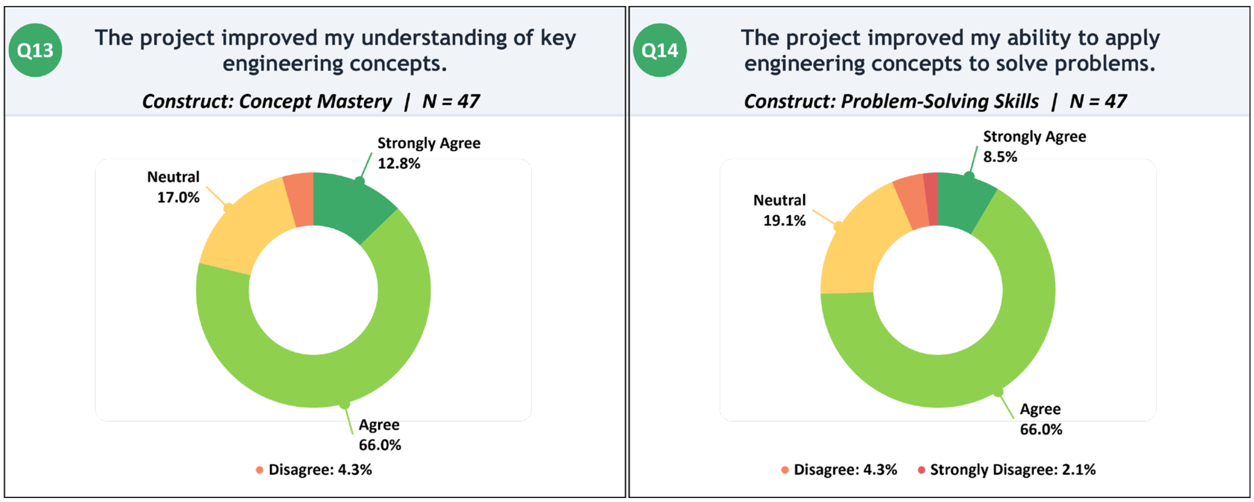

Figure 5: Pie chart showing students' improved understanding of key engineering concepts and students' ability to apply engineering concepts to solve problems.

Interestingly, while (Question 15) 63.8% reported increased confidence in performing analysis independently, this category saw a higher percentage of neutral and dissenting responses (36.2%) compared to other sections. Qualitative feedback provides the context for this: many students felt "confused about what reactions were taking place" without immediate instructor feedback. One student noted, "I think it would be useful to present a draft... I feel as though some feedback would have been very useful to keep me on track." This suggests that while students value the independence, the "real-world" complexity is a significant leap that creates a healthy, yet challenging, cognitive dissonance. Despite these challenges, the project succeeded in making students feel like active practitioners. One student reflected: "It was one of the very few things that was based on applying concepts on unique situations to each student." This uniqueness encouraged a sense of ownership over the data. Unlike textbook problems where all parameters are predefined and every student converges on the same solution, this scavenger hunt required students to justify their own measurements and assumptions based on real systems. In this example, shown in Figure 6, a student analyzing a construction crane researched realistic boom lengths, counterweight masses, and load magnitudes to model the crane in static equilibrium. Because these values are not directly provided, the student relied on self-directed research and engineering judgment to estimate forces and moments, an activity that 10.6% of students explicitly referenced in their qualitative reflections and that reflects authentic, professional engineering practice.

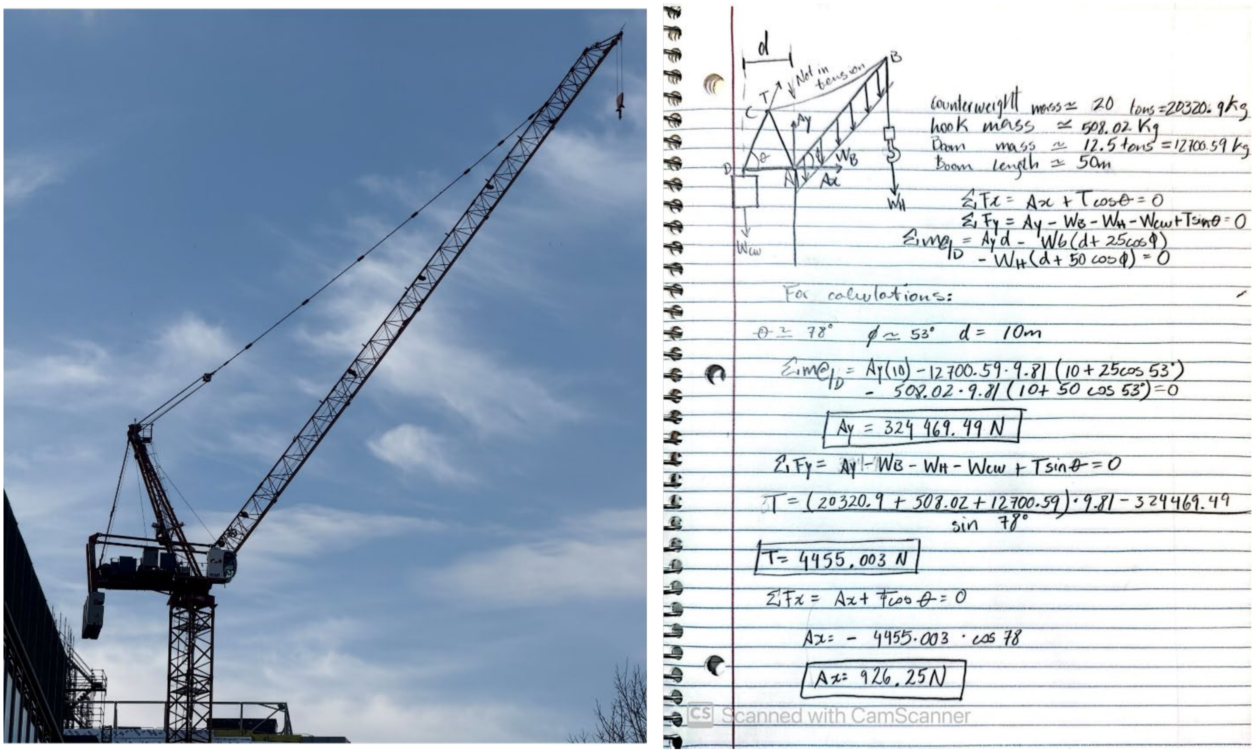

Figure 6: A photograph of a construction crane alongside a student's handwritten free-body diagram and moment calculations showing estimated loads, boom geometry, and reaction forces.

By the conclusion of the project, the majority of the cohort expressed a stronger sense of "engineering identity," with many suggesting that similar application-based projects should be introduced even earlier in the curriculum to set expectations for professional-level analysis.

5.5 Student Use of AI Tools

Survey Question 4 asked students whether they used artificial intelligence tools to assist with the project. Results indicated that 80.9% of students reported not using AI tools at all, while 19.1% reported using AI "a little." No student reported using AI "a lot." Open-ended responses suggest that those who did use AI employed it primarily for background research, looking up structural properties or checking terminology, rather than for generating FBDs or written reflections. It is worth acknowledging, however, that the accuracy of self-reported AI use may be affected by students' uncertainty about classroom norms around AI. Without explicit prior discussion about what constitutes appropriate AI assistance, students may underreport usage. Future iterations of the project will include a brief upfront conversation establishing transparent expectations around AI tools, which should both improve the reliability of this data and encourage more thoughtful, intentional use.

5.6 Qualitative Themes: Reflection and Realism

Inductive content analysis of the open-ended responses from the 47 participants revealed four predominant themes that characterize the project's impact on student learning. These themes illustrate a transition from rote calculation to critical engineering judgment. Visualization of Invisible Forces: Students consistently noted that the project made abstract concepts "tangible." One student remarked that the most helpful part was "relating it to something I can see and feel and relate to the work I am doing on paper." The process of identifying forces on a physical body rather than a 2D sketch helped them distinguish between applied forces and reactionary forces, which are often conflated in theory-only exercises.

Relevance and Environmental Awareness: The assignment prompted a shift in how students perceive their surroundings. Multiple respondents mentioned that they now start looking at "statics" structures in real life or observe everyday objects like trusses, signposts, and door hinges through the lens of static equilibrium. This "real-world connection" was cited as a primary driver for engagement, with students appreciating the opportunity to analyze "unique situations" rather than standardized textbook examples.

Development of Modeling Assumptions: A sophisticated theme emerged regarding the difficulty of simplification. One student reflected on the struggle to create a model, noting it "exposed the underlying assumptions which engineers make in order to analyze mechanisms." By encountering over-constrained structures or complex joints in the field, students learned to recognize the "limits of statics" and the necessity of making informed engineering assumptions to make a problem solvable.

The Critical Role of Feedback: Approximately 20% of the cohort expressed a desire for instructor checkpoints. While the independence of the project was valued, students noted that "having no feedback can be dysfunctional," as they feared constructing FBDs incorrectly early in the process. This suggests that while students gained confidence, they still highly value professional validation when transitioning from theoretical models to "messy" real-world applications. These qualitative results indicate that the "Fun Statics Scavenger Hunt" cultivated both technical proficiency in force analysis and metacognitive growth regarding the nature of engineering abstraction.

6. Discussion

6.1 Pedagogical Effectiveness

The findings demonstrate that the Scavenger Hunt successfully addresses the "abstraction gap", the cognitive disconnect students experience when moving from physical reality to mathematical symbols. By requiring students to "seek" equilibrium in their environment, the project moves beyond the "plug-and-chug" mentality often found in Statics. Qualitative feedback regarding the difficulty of simplifying real joints into pins or rollers suggests that students were engaging in high-level engineering judgment. As noted in the results, the struggle to identify forces in "messy" real-world structures is a key indicator of conceptual change; it forces students to move from rote memorization to active inquiry. The findings demonstrate that contextual, visual assignments can address long-standing issues of disengagement and abstraction in Statics education. The scavenger hunt prompted students to engage in cognitive modeling, where they iteratively observe, abstract, and verify equilibrium conditions, a process aligned with experiential learning theory and conceptual change models [18], [19]. The strong student response mirrors earlier research demonstrating that the ability to generate representations (FBDs, schematics, models) correlates closely with conceptual understanding in mechanics. By physically interacting with structures, students link symbolic diagrams to tangible referents, strengthening conceptual stability.

6.2 Student Motivation and Identity

The high engagement levels (Question 1) (85.1%) suggest that the project fostered a shift toward an authentic engineering identity. Seeing everyday equipment, like an excavator or a Tobin Bridge truss, through the lens of Statics allowed students to perceive themselves as analysts of systems rather than just students of a course. This sense of authenticity is critical in the second year of undergraduate engineering; a period often associated with high attrition rates. The project transformed the environment into a laboratory, reinforcing the idea that engineering principles are omnipresent. Engagement gains reflect more than enjoyment, they signify a shift toward authentic engineering identity formation. Seeing everyday equipment through the lens of forces and equilibrium allowed students to perceive themselves as analysts of real-world systems, not mere equation solvers. This sense of authenticity is critical in the second year of undergraduate engineering, when retention and confidence often decline [20].

6.3 Lessons for Implementation

Despite the project's success, the feedback regarding instructor checkpoints is vital. Future iterations should include a "Modeling Proposal" phase where students submit their initial photos and proposed support types for brief feedback. This would alleviate the anxiety reported by the 20% of students who feared their initial FBD assumptions were incorrect, ensuring that the independent analysis phase is built on a solid conceptual foundation.

6.4 Connection to Broader Educational Practices

From a curricular perspective, this activity fits within the shift toward inquiry-driven instruction in engineering fundamentals. Similar to design projects and laboratory modeling, the scavenger hunt invites integration of theory, observation, and communication, skills emphasized in ABET outcomes related to problem identification, experimentation, and lifelong learning. These outcomes suggest potential for adaptation across disciplines, including civil and aerospace Statics courses or even introductory physics contexts focusing on equilibrium.

7. Limitations and Future Work

The primary limitation of this study remains its single-instructor, single-course context. While the sample size of 47 students provides a strong baseline, further research is needed to determine if these self-reported confidence gains translate to higher scores on standardized assessments like the Statics Concept Inventory (SCI). A natural next step would be to compare exam performance or SCI scores between a section that completed the scavenger hunt and one that did not, offering a more direct measure of the project's effectiveness, a design the author intends to pursue when teaching multiple parallel sections in a future semester.

The voluntary nature of survey participation also warrants acknowledgment, as it may introduce selection bias: students with particularly strong or particularly negative experiences may be more likely to respond than those with moderate impressions. Future implementations should consider in-class administration to maximize response rates.

Regarding the group-based structure: while teams of two to three were chosen to support collaborative modeling discourse, future work could explore whether requiring each student to individually analyze a unique structure, perhaps alongside a shared group discussion component, would better ensure that all students engage substantively with the modeling process.

Additionally, the role of students' prior knowledge from prerequisite Physics and Mathematics courses on their performance in open-ended modeling tasks like this one warrants future investigation. Understanding how prior preparation moderates engagement with the scavenger hunt could help instructors provide more targeted scaffolding and may also offer useful feedback to colleagues teaching those prerequisite courses. Future work will also examine the long-term retention of these modeling skills as students transition into more advanced courses such as Mechanics of Materials.

8. Conclusions

The Fun Statics Scavenger Hunt successfully bridged the gap between abstract Statics theory and real-world engineering observation. Quantitative data revealed that over 85% of the 47 participants found the project engaging, and over 87% saw the direct relevance of classroom concepts to the physical world. By encouraging students to synthesize observation, modeling, and reflection, this exercise fulfills more than just technical course outcomes; it cultivates the critical habits of the practicing engineer. The project demonstrates that even in traditionally theory-heavy courses, authentic experiential pedagogy can transform passive learners into active investigators of the built world.

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Appendix: Survey Questions and Results ($N = 47$)

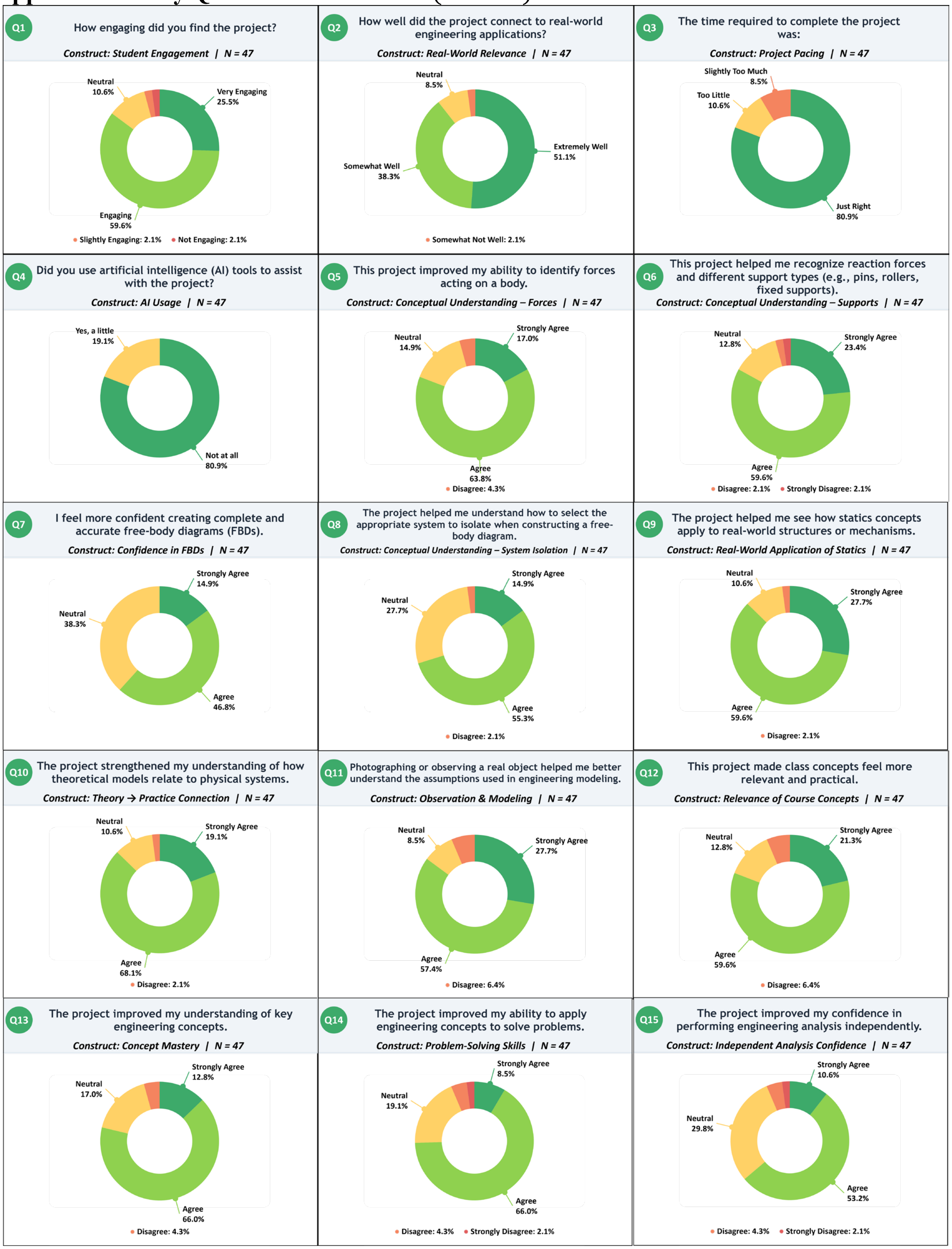

Figure 7: Color-coded distribution of student responses for Questions 1–4 (engagement, real-world relevance, project pacing, and AI tool usage) and Questions 5–15 (learning outcomes, conceptual understanding, and confidence gains) (N = 47).