Characterizing Design Activity Engagement in Capstone Students and Working Engineers: Insights from NSF RFE

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Characterizing Design Activity Engagement in Capstone Students and Working Engineers: Insights from an NSF RFE Project

Abstract

This work, supported by the National Science Foundation (Awards No. 2138019, 2514040, and 2514067), is an NSF Research on Formation of Engineers (RFE) project that investigates design activity engagement and identity motives in civil and mechanical engineering capstone students (n = 36) and practicing engineers (n = 15). Capstone design courses bridge academic training and professional practice, exposing students to open-ended design problems essential for engineering careers. However, effectiveness depends on engagement with design activities, influencing skill development and workplace readiness. Limited research has explored factors shaping engagement in capstone settings, particularly alignments between academic and professional contexts. Understanding engagement across student and professional contexts can inform strategies to enhance capstone courses for authentic challenges. Using constructivist grounded theory informed by situated cognition and engineering practice engagement, we employ semi-structured interviews to develop contextualized models of how students engage in design learning in workplace or approximate workplace settings (e.g., capstone design). By exploring synergies, tensions, and alignments across academic and workplace contexts, this work informs cross-disciplinary engineering education improvements. The poster includes independent sections for each population, with unifying implications for capstone enhancement to better mirror professional engagement dynamics.

Introduction

Capstone design courses occupy a distinctive position in engineering curricula: they are intended to function as students' first sustained encounter with the ambiguity, collaboration, and iterative reasoning that characterize professional engineering work. Prior research has shown that experiences in these courses play a meaningful role in shaping how students understand engineering design and how they see themselves as emerging professionals [1], [2], [3]. Yet despite their importance, the mechanisms that support or hinder meaningful engagement in capstone design remain insufficiently theorized. In particular, little is known about how the conditions that influence engagement in academic settings compare with those that matter in professional practice, or how insights from one context might inform improvement in the other.

This project addresses these gaps through a multi-year NSF RFE study examining civil, mechanical, and industrial engineers' engagement with design activities across academic and workplace settings. Using Constructivist Grounded Theory (CGT) [4], [5], and drawing on situated cognition [6], [7], [8] and engagement with engineering practice [3], the study develops contextualized models of design activity engagement that foreground identity, motivation, and interactional dynamics [9], [10] Last year's work established a conceptual model describing how capstone students negotiate expectations, feedback, and evolving project realities as they adapt their engagement across the duration of the course [11].

The current phase extends this inquiry by incorporating a complementary investigation of practicing engineers working in consulting, governmental, and industrial environments. These interviews illuminate how workplace structures, team relationships, and the distribution of

responsibility shape professional engagement over time—often in ways that resonate with, but also diverge from, student experiences. Together, the academic and professional models enable a comparative perspective that highlights where capstone design supports authentic engagement and where systemic misalignments may limit its effectiveness.

By placing student and professional perspectives in dialogue, this poster offers a more comprehensive understanding of how engineers engage in design across contexts. These insights provide actionable guidance for strengthening the design of capstone courses, with particular relevance for cultivating identity development, supporting productive collaboration, and creating conditions that mirror the realities of engineering work.

Summary of Project Objective and Research Methods

This study is linked to a larger study aiming to develop models of design engagement and identity motives for students and professionals using CGT. The specific objectives of this study are as follows:

1. Develop a contextualized model of design activity engagement and associated identity motives for both capstone students and practicing engineers.

2. Explore synergies, tensions, and points of alignment and resistance between academic capstone settings and workplace design contexts, with the intent of identifying actionable implications for capstone course design.

The student dataset comprises the interviews collected during Years 1–3 of the project (72 semi-structured interviews with 36 capstone students). These interviews were conducted at multiple timepoints across the academic year, allowing analysis of how student engagement and identity trajectories evolve over the duration of capstone projects [11]. No new student interviews were conducted for this reporting cycle; analysis builds on the existing longitudinal student corpus.

The professional component consists of semi-structured, open-ended interviews with 15 practicing civil, mechanical, and industrial engineers drawn from consulting firms, government agencies, and industry employers. To date, participants have completed a single, initial interview; planned follow-up interviews will be conducted to deepen temporal and contextual understanding of workplace engagement.

All interviews, student and professional, used semi-structured, open-ended protocols designed to elicit participants' experiences with design activities, perceptions of feedback and outcomes, collaborative dynamics, and elements of professional identity. Student interviews occurred at multiple points across the academic year to capture changes over time; professional interviews to date are initial, broadly scoped conversations addressing recent design work and workplace practices, with more targeted follow-ups forthcoming.

We applied CGT methods [4] throughout (open coding, focused coding, memoing, and theoretical integration), consistent with prior project phases. Cross-case comparisons and iterative memo cycles were used to develop and refine conceptual categories within each population and to surface comparative themes across academic and workplace contexts. The

analytic approach remains the same as in Year Three [11], enabling continuity in the evolving model while accommodating new professional data.

Summary of Results

Findings from the student portion of the project, drawn from analyses conducted in previous cycles [11], reinforce earlier conclusions that three aspects of capstone courses strongly shape students' engagement in design activities: feedback, design processes, and design outcomes. Prior work has demonstrated that timely, expert-aligned feedback supports students' motivation and sense of progress, while meaningful opportunities for technical design work sustain involvement by highlighting the collaborative nature of professional practice [12]. Furthermore, when students see their design ideas incorporated into project decisions, it enhances their sense of ownership and allows them to feel "treated like an actual engineer" [13]. Together, these elements contribute to ongoing identity affirmation, which plays a central role in maintaining engagement over the duration of the capstone project.

Initial findings from the professional interviews highlight three interrelated influences on workplace design engagement. First, collaboration emerged as a primary driver of sustained involvement, with participants emphasizing the importance of team dynamics, cross-functional coordination, and shared responsibility within complex design efforts. Second, workplace structures and constraints—including project timelines, resource limitations, organizational processes, and regulatory expectations—shaped how engineers navigated design activities and stayed engaged under real-world pressures. Third, identity, mentorship, and belonging played a pivotal role: participants described how mentorship, peer recognition, and contributing to impactful design outcomes reinforced professional identity and long-term motivation within engineering practice.

Together, the student and professional results reveal both alignment and divergence in the factors that shape design activity engagement across academic and workplace contexts. While identity and meaningful participation are central across both groups, differences in collaboration patterns, sources of feedback, and the nature of design constraints highlight opportunities to strengthen capstone courses so they more authentically reflect the engagement dynamics characteristic of professional engineering work.

Discussion

Together, these findings deepen understanding of how capstone students and practicing engineers experience engagement in design activities and illustrate several points of alignment between academic and professional contexts. Across both groups, identity affirmation, meaningful participation in design decisions, and opportunities to contribute to impactful outcomes emerged as central to sustaining engagement. However, the comparison also highlights key differences—particularly the centrality of collaboration, mentorship, and organizational structures in professional settings—that are less consistently reflected in capstone environments. These differences suggest that while capstone courses replicate some aspects of engineering practice, important features of workplace engagement remain underrepresented.

These insights offer actionable implications for capstone planning and instruction. Incorporating more intentional structures for collaboration, increasing access to qualified feedback, and ensuring that students' design contributions shape project trajectories may help bridge gaps between academic and professional engagement. At the same time, recognizing how real-world constraints shape professional motivation can guide instructors in designing authentic challenges that develop resilience and adaptive problem-solving. By integrating lessons from both student and professional perspectives, capstone educators can create learning environments that better prepare students for the complexities of engineering practice while supporting the development of robust, sustained design engagement.

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