NSF IUSE: Enhancing Student-Centered Instruction in Middle and Upper-Level Engineering Courses

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Advancing Student-Centered Teaching and Faculty Community in Middle and Upper-Level Engineering Education: NSF IUSE

Abstract

This NSF-funded project (Award No. DUE-2215989) examined how teaching-focused faculty in middle and upper-division engineering courses enact student-centered instructional practices and how structured collaboration supports sustained pedagogical innovation. Engineering education research has largely focused on foundational courses and it left instructional decision-making in advanced courses comparatively underexamined [1], particularly in contexts marked by heightened disciplinary complexity, professional preparation demands, and diverse levels of student readiness. Guided by a participatory action research (PAR) framework [4], this project engaged exemplary engineering instructors across multiple departments in a large R1 institution in a sequence of interviews, focus groups, classroom observations, course consultation projects, and faculty development workshops. This poster paper foregrounds qualitative findings from faculty interviews and focus groups and illuminates how instructors make course design decisions, respond to persistent instructional challenges, and negotiate evolving expectations around assessment, content relevance, and emerging technologies such as artificial intelligence (AI). Faculty described aligning instruction with student maturity and professional preparation, prioritizing depth over breadth, and increasingly replacing high-stakes assessments with formative, low-stakes alternatives. Participants also identified structural constraints such as content overload, institutional inertia, and uneven instructional support that shape what is feasible in practice. A central outcome of the project was the emergence of a cross-departmental teaching community that fostered validation, experimentation, and shifts in instructional identity. These findings collectively highlight the value of sustained, collaborative engagement for advancing student-centered teaching in research-intensive engineering contexts.

Background and Motivation

Middle and upper-level engineering courses play a critical role in students' transition from foundational knowledge to professional practice. These courses often require students to integrate complex technical concepts, apply disciplinary reasoning in open-ended contexts, and develop professional competencies such as teamwork, documentation, and design communication [3]. Despite their importance, instructional practices in these advanced courses remain underrepresented in engineering education research, which has historically focused on introductory and gateway courses. Teaching-focused faculty members are uniquely positioned to shape learning in these contexts [2]. Their primary responsibilities center on instruction, curricular coherence, and student learning, yet their pedagogical work often occurs within institutional cultures that privilege research productivity and content coverage. As engineering curricula continues to expand and student populations diversify, instructors face increasing pressure to balance rigor, relevance, and accessibility. At the same time, rapid developments in educational technology such as the growing presence of AI are prompting faculty to reconsider long-standing assumptions about what content matters most and how learning should be assessed. This project was motivated by two interconnected needs: (1) to develop a richer understanding of how exemplary engineering instructors design and adapt student-centered teaching practices in advanced courses, and (2) to explore how collaborative faculty engagement can support the diffusion and sustainability of these practices across departments. Rather than treating teaching innovation as an individual endeavor, the project sought to examine pedagogy as a socially situated practice shaped by disciplinary norms, institutional structures, and peer interaction.

Methodology

Research Design - The study employed a participatory action research (PAR) design [4] and emphasized collaboration between researchers and faculty participants throughout the research process. PAR was well suited to the project's dual goals of knowledge generation and practice improvement, as it positions participants not only as sources of data but also as co-constructors of insight. Faculty engagement extended beyond data collection to include reflection, dialogue, and iterative experimentation with instructional strategies.

Participants - Participants were teaching-focused faculty drawn from ten engineering departments within a large R1 land-grant College of Engineering. Department heads nominated instructors who are recognized for their teaching effectiveness, and it resulted in a cohort of 18 faculty members, with two participants from the same department in some cases. Participants represented a range of disciplinary areas, course types, and class sizes, with most teaching required middle or upper-division undergraduate courses.

Data Collection - This poster paper draws primarily on qualitative data collected through semi-structured interviews and focus groups. Interviews explored participants' teaching philosophies, course design decisions, experiences with instructional change, and reflections on project participation. Focus groups, conducted during two summer faculty workshops provided a forum for collective sense-making around shared challenges, innovative practices, and institutional constraints. Among the various data sources (surveys, classroom observations, and course consultation artifacts) used in the broader project, interviews and focus groups offered the richest insight into faculty reasoning, identity, and professional learning. All sessions were audio-recorded and transcribed for analysis. This study was reviewed and approved by the Institutional Review Board (IRB) at Virginia Tech prior to data collection (IRB #22-675). All participants provided informed consent and were informed of the voluntary nature of their participation. Data were anonymized during transcription and analysis to ensure confidentiality.

Data Analysis - Qualitative data were analyzed using an iterative thematic analysis approach. Transcripts were first reviewed holistically to identify recurring patterns related to instructional decision-making, challenges, and sources of innovation. Codes were then refined through constant comparison, with attention to both convergence and variation across participants. Analytic memos were used to trace connections between individual experiences and collective themes. Findings presented here reflect themes that emerged consistently across interviews and focus groups.

Findings from Interviews and Focus Groups

Analysis of interview and focus group data revealed seven interrelated categories that characterize faculty instructional decision-making in middle and upper-level engineering courses. These categories described in detail below reflect how instructors design courses in response to student development, navigate persistent instructional constraints, adopt strategies to support learning, and reconsider content and assessment in a rapidly evolving technological landscape.

Course Design as Developmental and Contextual - Faculty described course design as intentionally aligned with students' academic maturity, professional trajectories, and readiness for self-directed learning. Many emphasized the importance of establishing clear expectations early in the semester, particularly in upper-level courses where accountability and independence are assumed but not always present. Several participants reported structuring courses around threshold concepts; ideas that fundamentally transform students' understanding of the discipline rather than attempting exhaustive content coverage. Intentional use of struggle also emerged as a design principle. Some instructors incorporated planned "failure points", reflective prompts, or metacognitive frameworks (e.g., Bloom's Taxonomy) to help students recognize gaps in understanding and take ownership of their learning. These strategies were described as especially important for preparing students for professional environments where ambiguity and iteration are the norm.

Persistent Instructional Challenges - Across interviews and focus groups, faculty identified several recurring challenges that shape instructional choices. Student disengagement was frequently mentioned, particularly among seniors who had already secured employment or internships. Participants also noted the lingering effects of the COVID-19 pandemic, including reduced self-regulation, organizational skills, and attention spans. Institutional barriers further constrained instructional innovation. Faculty described resistance to curricular change, especially when courses had long-standing content expectations tied to accreditation or departmental tradition. Content overload was a persistent concern, with many instructors' expressing frustration at being expected to "add" new skills or technologies without removing outdated materials.

Strategies for Maximizing Student Learning - In response to these challenges, faculty reported adopting a range of strategies aimed at increasing engagement and supporting learning. A common shift involved moving away from high-stakes exams toward more frequent, low-stakes assessments such as quizzes, reflections, and minute papers. These approaches were valued for providing timely feedback and reducing student anxiety. Active and collaborative learning strategies were also widely discussed, including peer instruction, project-based work, and structured in-class problem-solving. Faculty emphasized the importance of formative assessment for identifying misconceptions and adjusting instruction in real time. Several participants described experimenting with AI tools to manage feedback in large classes, summarizing student responses, or support reflection while remaining cautious about equity and overreliance.

***Reconsidering Course Content in an AI Era* -** Faculty conversations revealed growing reflection on what content remains essential in an era of widespread computational tools and AI assistance. Participants described prioritizing workplace-relevant skills such as documentation, teamwork, design communication, and professional responsibility. Some questioned the continued emphasis on manual, calculation-heavy tasks and suggested that conceptual understanding and judgment may be more critical for future engineers. This reassessment often involved difficult trade-offs between breadth and depth. Faculty acknowledged that not all content could be retained and that curricular decisions should be guided by what would be most meaningful for the majority of students rather than historical precedent alone.

***Assessing Student Learning* -** Participants reported relying heavily on formative indicators of learning, including quizzes, reflective writing, and analysis of failed attempts. Capstone projects and authentic tasks were viewed as particularly strong indicators of applied learning. While some instructors mentioned using facial cues or classroom observation to gauge understanding, these were widely recognized as unreliable and supplemented with more structured checks for understanding. Scaffolded reflection and online quizzes were increasingly used to surface misconceptions and support iterative learning. Faculty emphasized that assessment practices needed to align with instructional goals and professional outcomes, rather than serving purely evaluative functions.

***Sources of Teaching Innovation* -** Faculty identified multiple sources of pedagogical inspiration, including professional development workshops, teaching and learning centers, and informal peer conversations. Cross-departmental dialogue was particularly valued, as it exposed instructors to alternative approaches and normalized experimentation. AI emerged as a growing area of interest, with participants eager for future workshops focused on ethical and effective integration into teaching. Iterative course redesign supported by feedback from students, peers, and consultations was described as an ongoing process rather than a one-time intervention.

***Community Building and Professional Identity* -** A defining outcome of the project was the development of a faculty learning community that extended beyond individual events. Participants described feeling validated in their teaching efforts and more confident in trying new approaches. Many reported shifts in professional identity, moving from seeing themselves primarily as content transmitters to facilitators, mentors, and designers of learning environments. Faculty expressed strong interest in sustaining collaborative engagement through departmental initiatives, teaching exchanges, and future workshops. Several noted that structured opportunities for reflection and dialogue were rare but essential for long-term pedagogical growth.

Although this study focused on faculty perspectives, participants frequently reflected on student experiences and responses to instructional changes. Faculty described how students initially resisted increased responsibility for learning but gradually adapted to more active and collaborative approaches. Several instructors noted improved engagement when low-stakes assessments and interactive strategies were implemented. Participants also highlighted variability in student readiness, particularly in relation to self-regulated learning and time management which influenced how student-centered approaches were enacted. Faculty interpretations of student feedback, both formal and informal played a key role in shaping iterative course redesign. These insights provide an indirect but meaningful representation of student experiences within student-centered learning environments.

Discussion and Implications

The findings of this study align with a substantial body of research on student-centered teaching in higher education. Prior work has shown that instructional approaches such as active learning, formative assessment, and reflective practices significantly improve student engagement and conceptual understanding, particularly in STEM disciplines [5], [6]. Faculty in this study similarly emphasized aligning instruction with student development, fostering metacognitive awareness and incorporating collaborative learning strategies that are widely supported in the learning sciences literature [7]. Participants' emphasis on prioritizing depth over breadth and focusing on threshold concepts is consistent with established curriculum design principles that promote meaningful learning over extensive content coverage [8]. Concerns regarding content overload and resistance to curricular change further reflect challenges documented across higher education where institutional structures and disciplinary traditions often constrain pedagogical innovation [9]. These parallels suggest that the barriers identified are not unique to engineering but are indicative of broader systemic issues.

The emergence of a cross-departmental faculty learning community as a catalyst for instructional change aligns with research [10] highlighting the effectiveness of sustained, collaborative professional development. Communities of practice have been shown to support instructional innovation, encourage pedagogical risk-taking, and contribute to the development of teaching identity [11]. In contrast to one-time workshops, ongoing engagement appears to provide the conditions necessary for meaningful and sustained change in instructional practices. Faculty reflections on the role of AI in reshaping course content and assessment are consistent with emerging scholarship on digital transformation in education [12]. As AI tools become more prevalent, educators are increasingly reconsidering the relative importance of procedural knowledge and emphasizing higher-order thinking, professional skills, and ethical considerations. These shifts are particularly relevant in upper-level engineering courses where preparation for professional practice is a central goal.

Conclusion

This NSF-funded project contributes to a growing body of research on teaching-focused faculty by centering their voices and experiences in middle and upper-level engineering education. Interview and focus group findings reveal how instructors navigate competing demands, adopt student-centered strategies, and reimagine teaching in response to evolving professional and technological landscapes. Importantly, the project demonstrates that collaborative engagement can strengthen instructional confidence, foster innovation, and support long-term cultural change in engineering education. Future efforts will focus on expanding cross-departmental communities of practice, offering targeted professional development on AI and assessment, and promoting institutional structures that recognize and support high-quality teaching in research-intensive contexts.

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