RFE-NLI: A Collaborative Approach to Advancing Sustainable Engineering Education

Dr. Medha Dalal, Arizona State University

Dr. Medha Dalal is an assistant research professor and associate director of scholarly initiatives in the Fulton Schools of Engineering at Arizona State University. Her research seeks to transform and democratize engineering education by exploring ways of thinking, identifying effective professional development approaches, and uncovering pedagogical techniques to enhance students' engineering curiosity, engagement, and learning.

Dr. Roneisha Wynette Worthy, Kennesaw State University

Dr. Roneisha Worthy, Ph.D. is currently the Assistant Dean of Student Success within the Southern Polytechnic College of Engineering and Engineering Technology at Kennesaw State University. In addition to her administrative role, she remains actively engaged in teaching and conducts research with a focus on increasing the representation of minorities in Engineering. Before joining the university, Dr. Worthy served as a Research Assistant at Vanderbilt University, contributing to a group funded by the Department of Energy. Her primary research focused on the long-term evaluation of near-surface waste disposal under climate change impacts at nuclear waste sites. With a background as an environmental engineer/planner at Gresham, Smith, and Partners, as well as General Motors Corporation, Dr. Worthy brings a wealth of industry experience to her academic roles. She has a proven track record of addressing critical environmental challenges. In her recent endeavors, Dr. Worthy is actively collaborating with the Lemelson Foundation to institutionalize the Engineering for One Planet framework at Kennesaw State University. This initiative reflects her commitment to sustainability and innovative engineering practices.

Dr. Bridget M Wadzuk, Villanova University
Mrs. Deeksha Seth, Villanova University

Deeksha Seth is an Assistant Professor in the Mechanical Engineering department at Villanova University. Her primary research interests include bio-robotics, mechatronics, engineering design and STEM education. Her current research includes the developmen

Dr. Nadia N. Kellam, Arizona State University

Nadia Kellam (she/they) is Professor of Engineering, Engineering Program Chair, and the Associate Director for Strategic Initiatives within The Polytechnic School of the Ira A. Fulton Schools of Engineering at Arizona State University. She is a faculty in the Engineering Education Systems and Design PhD program. Dr. Kellam is an engineering education researcher and a mechanical engineer. She was recently deputy editor of the Journal of Engineering Education and is currently co-chair of ASEE's Committee on Scholarly Publications. Her research employs narrative inquiry, arts-based methods, and futures thinking to explore the culture of engineering education—especially the experiences of marginalized undergraduate students and faculty.

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Background

Engineering education is at a critical juncture as global challenges such as climate change, resource depletion, and environmental degradation increasingly demand a workforce capable of designing with sustainability considerations [1], [2]. Integrating sustainability into engineering curricula is therefore essential for preparing engineers to address complex, interconnected problems [3], [4]. National and international efforts, including the Engineering for One Planet (EOP) Framework, have articulated clear sustainability learning outcomes for engineers [5]. Yet, despite this widespread recognition, faculty continue to face challenges in translating sustainability goals into concrete classroom practices, including limited curricular space, uncertainty about how to assess sustainability learning, and a lack of discipline-specific resources [1], [6], [7].

This need motivated the creation of the Collaborative Research in Engineering with Action Toward Environmental and Social Sustainability (CREATESS) network. This network brings together engineering faculty from three institutions (Arizona State University, Kennesaw State University, and Villanova University) as teacher-researchers (TRs) to collaboratively design, implement, and study sustainability-focused instructional interventions in their own classrooms. Working across institutional contexts, the program seeks to build an evidence base about which curricular and instructional practices most effectively support students' learning of sustainability concepts, while also documenting the motivations, supports, and challenges faculty encounter as they integrate one or more topic areas of the EOP Framework. By positioning faculty as classroom-based researchers and encouraging data-driven course modifications, the project allows us to investigate not only what instructional approaches emerge, but also how professional learning communities and local support structures shape sustainability integration.

Conceptual Framework

We use a Community of Practice (CoP) structure and a Collaborative Action Research (CAR) model to support faculty in implementing, studying, and refining sustainability-focused teaching. The CoP provides social and professional infrastructure, creating a space where faculty can collaboratively develop ideas, build confidence, and normalize the challenges of curricular change. CAR provides the methodological backbone for this work by enabling faculty to systematically design, implement, and study sustainability-focused interventions in their own courses, generating evidence to guide instructional refinement and build knowledge about what works [8].

CAR overarches three complementary theories that guide our work: (i) a CoP perspective, which emphasizes collaborative experimentation and risk-taking in a supportive environment [9]; (ii) a social theory of agency, which positions faculty as active agents in shaping curriculum change and their own professional growth [10]; and (iii) situated learning theory, which emphasizes applying new knowledge within

authentic classroom contexts [11]. Together, these theories create a dynamic framework where faculty engage in iterative cycles of planning, acting, observing, and reflecting to meaningfully integrate sustainability.

Methods

The research design for this study is divided into micro- and macro-level approaches. At the micro level, the Principal Investigators (PIs) and TRs work together to examine how well the CAR projects promote student learning of sustainability concepts, uncovering effective curricular and instructional practices. At the macro level, project PIs collect data to better understand faculty motivations, challenges, and opportunities for integrating sustainability education in engineering classes. Interviews and focus groups with TRs, PI reflections, and CoP artifacts are used to discern patterns, reasoning, and opportunities for enhanced engagement to encourage more widespread integration of the EOP Framework and sustainability topics into engineering curricula.

During the first year of the project, the team established the core structures necessary to support faculty as they engaged in sustainability-focused instructional transformation through CAR. This included recruiting eight engineering faculty or TRs across three institutions and launching a cross-institutional CoP designed to foster collaborative learning, reflective inquiry, and disciplinary innovation. Across six virtual CoP sessions, three institutional CoPs, and the first in-person retreat, TRs developed foundational knowledge of the EOP Framework and were introduced to tools such as the Test Card method [12], an inquiry design workbook, and structured reflective prompts to support the development of context-specific sustainability interventions. The in-person retreat provided a pivotal opportunity for TRs to articulate sustainability goals, align course learning outcomes with EOP learning outcomes, and draft preliminary inquiry plans with corresponding assessments and data collection strategies.

Across monthly CoP sessions, PIs worked closely with TRs on advanced professional learning experiences, including research methods training using a structured workbook approach, exploration of research design through a facilitated Article Club, and iterative opportunities for reflective practice. Institutional CoPs provided space for tailored support within disciplinary and departmental contexts, while cross-institutional meetings cultivated peer-to-peer feedback, collaborative troubleshooting, and the sharing of emerging classroom intervention plans. A focus group was conducted at the in-person retreat, dividing TRs into two sub-groups. Data were analyzed qualitatively with an inductive approach and constant-comparison method [13] to uncover emergent themes.

Findings

Thematic analysis revealed three key findings that inform both faculty development and broader curricular transformation: (1) desire for practical tools and resources; (2) uncertainty around assessment design; and (3) community and peer support as a motivator. In the following paragraphs, we elaborate on these themes, embedding participant quotes.

Desire for practical tools and resources

TRs asked for practical tools and materials they can adapt quickly. They suggested that access to curated, discipline-relevant resources could help reduce barriers to implementation, as evident in the following quote: "I think even just like a dictionary or a library of things like that would be really helpful. Like, oh, here's stuff that you can take and plug in, whether assessments or like different types of tools to do like ROIs or whatever, because I feel like, at least for me, that can be a barrier to entry sometimes." Suggestions included "some examples of how this is done… for different, similar scenarios," publications, guidelines, "handouts to share with the students — like, this is how different things that you can use to address different topics, broader impacts of design," and a shared database of EOP-relevant tools and "wow" cases/examples to spark student interest.

Uncertainty around assessment design

While TRs were somewhat confident about designing activities, they were less certain about measuring outcomes like systems thinking and sustainability mindset. They indicated a need for more guidance in developing meaningful and manageable assessment strategies that are valid, scalable to large sections, and aligned to EOP outcomes. The following quote captures the overall sentiment of the group: "I have the vision… I don't have the tools to do it." Many flagged grading load as a barrier and requested examples of efficient, low-overhead strategies. Several also raised the idea of a common instrument, for example, a short pre/post that avoids survey fatigue and fits large classes. A few recognized that "activities and our assessments and assessment tools" are linked together and "we need to do our assessment of the assessment tools." Overall, TRs seemed to agree that most engineering courses reward only the technical work; so "broader impacts" like sustainability get bolted on at the end, if at all. To change that, both learning assessments and faculty mindsets need to shift so sustainability is treated as integral across disciplines, not just an add-on for environmental or civil engineering. The following quote captures this theme: "We've only taught them. We've really focused and valued the technical information primarily, because that's what they're getting points and grades for, right? Like, in a lot of courses, you're not getting the checks for these broader impacts. It's just not what we're doing in our, in many of our engineering courses. I don't want to, like, paint with too broad of a brush, but I know in my courses it's been that way, and we've allowed it to be acceptable to just kind of tack this on to the end. And so, hopefully, we can change the thinking, but I think our thinking also needs to change."

Community and peer support as a motivator

Finally, the community of peers itself emerged as a powerful motivator that fostered collaboration, accountability, and shared problem-solving. TRs credited the cross-institution CoP structure with helping them move ideas from concept to implementation. They valued (a) "critical friend" feedback on test cards; (b) brief peer review of instruments before fielding; and (c) seeing parallel implementations in other disciplines to spark transfer. Several asked to formalize this with small working groups by assessment method or topic. The community not only accelerated implementation in the

short term but also built the habits and relationships needed to sustain iterative improvement over time.

Discussion

As early-stage work, these findings primarily reflect progress on two project objectives: (i) establishing and sustaining a CoP that builds TRs' understanding of the EOP Framework; and (ii) using CAR and CoP structures to help TRs design classroom inquiries. The focus group data reported here constitute the first dataset in a longer, iterative process. Preliminary findings suggest that faculty are more likely to engage in sustainability integration when they have access to concrete, contextually relevant tools along with established frameworks [3], [6]. Faculty development must move beyond awareness of the EOP Framework to co-construction of adaptable materials and design patterns. This need is not a deficit but a design cue. Structuring the CoP as a space where TRs can collectively author and refine these artifacts, rather than simply receive them, aligns with agency theory and key tenets of action research by positioning faculty as designers and researchers, not just implementers [8], [14], [15].

The uncertainty around assessment and the centrality of community speak directly to faculty motivations, challenges, and opportunities. TRs' concerns about "how to know" whether students are developing systems thinking or sustainability mindsets echo long-standing tensions in engineering education between preferences for easily graded technical tasks and the need to assess complex, socio-technical outcomes [1], [7], [16]. Our results suggest that demystifying assessments through shared examples, low-overhead methods, and collaborative analysis in the CoP is almost essential to sustaining faculty motivation.

In the next phase, each TR will implement their action research project, iterating through cycles of planning, acting, observing, and reflecting across the Fall 2025 and Spring 2026 terms in collaboration with local PIs and the broader network [17]. Future data collection will include additional focus groups, reflective interviews, classroom observations, and artifacts from implemented activities, enabling us to co-construct dissemination products and strategies that support wider adoption of successful practices in engineering education. Designing faculty development that explicitly leverages this peer infrastructure via thematic working groups, shared instruments, and co-constructed and co-authored dissemination may be a key mechanism for scaling sustainability integration work beyond early adopters and across diverse institutional contexts.

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