Learning to Teach Engineering Capstone Design: An Analysis of Faculty Members' Experiences

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Abstract

The credentials required to teach engineering at the university level vary widely around the world. In the U.S., though many universities ask for a statement of teaching philosophy as part of job applications, U.S. faculty members are rarely, if ever, required to have any form of pedagogical training or credentials, and little is known about how many, to what extent, or with what frequency engineering faculty members engage in such faculty development around teaching and pedagogy. This study draws on interview data from a larger project examining capstone teaching, asking three questions: 1) What do faculty members need to learn to teach the capstone course? 2) How do they gain this learning? and 3) How does learning vary based on engineering discipline? Analysis revealed seven learning foci and three sources of learning and examined the relationships between them. Findings suggest that beyond general strategies for course design, assessment, active learning, and student motivation, capstone faculty members need to develop teaching practices such as structuring and mentoring teams, and such learning needs to be grounded in current industry practices. Given the central role of capstone courses in preparing students for engineering practice, departments and programs may need to think more intentionally about how they prepare new faculty members for the capstone teaching role, including explicit support for professional development.

1. Introduction and Background

The credentials required to teach engineering at the university level vary worldwide. While some countries, such as Norway, may require faculty appointees to university teaching positions to have "documented competence in relevant educational theory and practice" [1], in the United States (U.S.), the only credential needed to teach undergraduate courses is usually a graduate degree in a relevant field. Yet in engineering, as in many fields, graduate training typically focuses on preparation for research rather than teaching [2, 3]. Buswell's study on recent engineering PhD graduates, for example, found strong misalignment between participants' preparation for teaching and the classroom roles expected of them as faculty members. Notably, clinical or practice-based faculty tracks -as opposed to research-focused, tenure and tenure track tracks- often accept extensive work experience in lieu of graduate degrees, but this work experience in turn can be disconnected from higher education practices and the broader educational system [4]. Though many U.S. universities ask for a statement of teaching philosophy as part of faculty job applications, U.S. faculty members are rarely, if ever, required to have any form of teaching training or credentials. This situation raises concerning questions about how engineering faculty members in the U.S. learn to teach, including both what they learn and where they learn it. To begin to address this gap, we examine faculty learning in one specific teaching context: the senior-level capstone design course in U.S. institutions. Capstone design courses support students' transition to professional work [5, 6], and understanding how faculty members develop teaching expertise in this context can further inform larger conversations about how universities can effectively prepare students for engineering work. To that end, we address three key research questions:

1. What are the focus areas of capstone faculty members learning? That is, what do they need to learn to teach the course?
2. What are the sources of capstone faculty members learning? That is, how do they gain this learning?
3. How does learning vary based on engineering discipline?

1.1. Faculty Training in the U.S.

As noted, no teaching-specific credentials are required for engineering faculty members in the U.S. Not surprisingly, then, a 2009 survey of engineering faculty members from 31 U.S. institutions conducted through the Prototype to Production (P2P) study found that only 30% of respondents reported any formal teaching preparation prior to their first faculty position [7]. In many research-intensive institutions in the U.S. (which dominate engineering enrollment numbers), recruitment of faculty members in engineering departments is usually driven by their technical research and new faculty members receive resources and time to set up their research, yet one of their first tasks is to teach a class – many times one not related to their research . A more recent study in Canada found that novice engineering faculty members demonstrated lower levels of teaching skills than novice faculty members in disciplines outside of engineering [8]. The P2P findings regarding efforts to improve teaching were more encouraging, with 40% of respondents having read about educational topics and 30% having attended a teaching-related workshop. In addition, one third reported taking a class or working in industry to build their knowledge and skills more broadly. Overall, 60% of the P2P survey respondents reported making some "significant effort to improve [their] teaching" (p. 3) in the year preceding the survey. Still, the P2P data also suggests that many faculty members may not be pursuing teaching-focused professional development.

In the U.S., engineering faculty members who want to enhance their teaching have a range of resources available both at the national level and locally at individual institutions. Programs such as the National Effective Teaching Institute (NETI) and Bucknell University's Project Catalyst: How to Engineer Engineering Education represent efforts at the national level to provide faculty training. In addition, research by Mallouk et al. [9] demonstrates that networks such as the Consortium to Promote Reflection in Engineering Education (CPREE) and the Kern Entrepreneurial Engineering Network (KEEN), which focus on propagating specific pedagogies, are effective approaches to faculty learning across institutions. The American Society of Civil Engineers' ExCEEd (Excellence in Civil Engineering Education) workshop provides a similar initiative at the subdiscipline level [10]. In addition, many universities have highly active centers for teaching and learning that offer such training locally, including training specifically for engineering faculty members [e.g., 11]; current research on faculty development points to a number of effective practices for enhancing teaching skills [e.g., 9, 12, 13, as well as the many papers presented in the Faculty Development Division of the American Society for Engineering Education (ASEE) conference]. As Cutler et al. [14] point out, however, approaches to faculty development that isolate teaching from other domains of faculty work may create a sense of fragmentation and remain at odds with faculty members' needs and institutional priorities. A recent survey of engineering deans by Huerta et al. similarly pointed to the need for more holistic approaches to faculty development through efforts such as long-term engagement and mentoring relationships [15].

Collectively, research consistently demonstrates the value of faculty development for those who pursue it. And although less than a third of U.S. faculty members receive pedagogical training prior to entering the classroom, some are learning through faculty development training on the job. Still, we know very little about how many, to what extent, or with what frequency engineering faculty members engage in such development. Moreover, while general data on engineering faculty learning is limited, even less is known about faculty members teaching specific types of courses. The P2P project considered disciplinary variations as well as specific teaching strategies such as active learning [7], but we could find no reports exploring differences in faculty members' learning by course type (e.g., technical/theoretical courses, laboratory courses, design courses). Because different types of courses likely require different sets of skills and practice, and thus potentially different learning paths, we scoped the present study to a single domain: the senior design or capstone course. We selected this domain because of both the central role these courses play in students' transition to work [6, 16-18] and the distinctive features of these project- and design-based learning environments [19-21].

1.2. Capstone Design Teaching

Capstone courses began gaining prominence in U.S. engineering programs in the 1990s, largely in response to both industry concerns and accreditation requirements highlighting the need to balance the post-World War II emphasis on theory with a greater focus on practical application and the kinds of problems new graduates would encounter at work [5]. These courses are now ubiquitous and typically serve as the primary mechanism by which engineering programs satisfy accreditation requirements for "a culminating major engineering design experience" [22]. Trends in capstone course structures and outcomes have been tracked every five to ten years through national surveys [23-26], with the most recent data collected in 2015. Although some variation exists across programs, the 2015 survey [24] shows that capstone design courses typically span two semesters and rely on open-ended team projects, often with industry or client sponsors, and emphasize project management skills, conceptual design and selection, communication, and teamwork. Course pedagogies consistently emphasize professional practices related to teamwork, communication, and project management; reflecting instructors' focus on workplace preparation as a key goal [19].

Much of the research on capstone courses has focused on structure, pedagogy, assessment, and student learning, but we know very little about the faculty members who teach these courses. At a demographic level, the data that do exist point to some differences from the larger pool of engineering faculty members. For example, the

2015 capstone survey data show that only 61% of responding capstone faculty members were tenured/tenure track, while 24% were permanent non-tenure-track [24], while 2018 data from the American Society for Engineering Education (ASEE) indicates that 74% of all engineering faculty members were tenured/tenure-track and only 14% were non-tenure track. Thus, the percentage of non-tenure-track faculty members appears to be higher in capstone courses than elsewhere in the engineering curriculum. At the same time, while existing data indicate that most engineering faculty members have limited or no professional work experience outside academia, those teaching capstone courses are much more likely to bring industry experience to their teaching practice. In the 2015 capstone survey, 92% of the respondents had at least one year of professional engineering work experience outside academia, 70% had at least 3 years, and 54% had at least 6 years. In contrast, the data from the 1988 National Survey of Postsecondary Faculty (the most recent large-scale survey available in the U.S., though considerably dated) showed that at that time, only 54% of engineering faculty members overall had any non-academic experience of professional engineering work [27]. More recently, a 2018 survey of engineering faculty members at a purposeful sample of 15 U.S. institutions indicated that only 12% of current engineering faculty members had five or more years of industry experience [28].

Beyond demographic characteristics, research on capstone teaching remains somewhat limited, although a number of studies have explored faculty members' engagement with evidence-based teaching practices in technical courses or in teaching generally [29, e.g., 30, 31, 32]. Specific to capstone, Perez et al. [33] developed a typology to characterize team supervision in computer science capstone courses, while Pembridge and Paretti [19] developed a general taxonomy of capstone teaching practices across engineering. Adams and colleagues [34] examined the pedagogical content knowledge involved in design coaching, highlighting the intersection between content knowledge such as design judgment, process management, and tasks strategies, and pedagogical knowledge such as cognitive apprenticeship and improvisation. Matthew and colleagues [35] examined capstone faculty members' practices and beliefs related to entrepreneurship in particular; their work highlighted key barriers to integrating entrepreneurship related to instructors' lack of understanding of and expertise with the relevant topics and issues. All of these studies highlight the intensive nature of mentoring, coaching, and monitoring in this project-based environment – practices that faculty members may have little training for or experience with. At the same time, the centrality of capstone courses in students' preparation for engineering practice suggests that a deep understanding of current industry practices should inform capstone teaching [e.g., 5, 6, 36].

But even as research has begun to illuminate what capstone faculty members do (or should do), we still know very little about how they learn to do it. Such understanding, we argue, is central in helping us better recruit and train capstone faculty members who can effectively support students' transition from undergraduate courses to engineering practice.

2. Methods

This study draws on data from a larger project examining capstone teaching. In the early 2010s, we conducted a national survey of capstone faculty members in ABET-accredited programs in the U.S. (1258 surveys sent, 503 responses received), followed by interviews with a purposive stratified sample of survey respondents (n=42) and subsequent case studies of selected capstone courses [19]. The present study focuses on the interview data, described in the following sections, which probed capstone teaching in depth. More details on the survey phase of the project are available in [37]; case study findings have been reported in [38]. In approaching this data, we adopted a constructivist perspective; that is, we considered how faculty members themselves described both *how* they learned and *what* they learned. Constructivist approaches emphasize, as Patton explains, that "what is defined or perceived by people as real is real in its consequences" [39]. In this context, how faculty members experienced their learning likely shaped how they continued to learn, what resources they drew on as they approached their capstone teaching, and how they guided other faculty members as they passed the course on to other instructors.

2.1. Positionality

As with all qualitative research, our positionality plays a role in our approach to this study. Collectively, we bring a mix of lived experiences, gender and racial makeup, and industry and course design experiences. Among the author team, Paretti, Schibelius, and Menon identify as women; Murzi and Lutz identify as men. Murzi and Menon identify as people of color; Paretti, Lutz, and Schibelius identify as white. At the time of initial data analysis, Murzi and Lutz were doctoral students but have since moved into faculty positions. At present, Paretti, Murzi, and Lutz are faculty members; Menon is currently a postdoctoral researcher, and Schibelius is a doctoral student. Of particular salience to this analysis are our experiences in industry and in design education. Paretti, Murzi, Schibelius, and Menon have substantial industry experience; Paretti has extensive experience teaching capstone design and Lutz has extensive experience with design education in the early years of the curriculum. Because the U.S. capstone course is so closely linked to industry preparation [5, 19], our collective industry experience (from two to four years each) may have influenced both the teaching practices we identified as salient (i.e., those related to professional skills and practices as well as technical work) and our awareness of the various ways participants' industry experiences intersected with capstone teaching. Our position as engineering education researchers made us familiar with the variety of conferences and workshops participants attended, as we have attended many of the events ourselves. Similarly, the research expertise of Paretti and Lutz related to capstone design specifically provided a deep understanding of the national context of this course, including both historical and current research. Given our familiarity with both industry and capstone contexts, authors who had not worked in industry and authors who had not taught capstone played critical roles in our sense-making to help ensure that no codes were overlooked in the analysis and that our final categories related to both learning sources and learning foci were fully representative of the available data.

2.2. Participants

As noted, interview participants were drawn from respondents to a survey of U.S. capstone faculty members. Sampling was based on maximizing variation, using experience level and discipline as primary sampling criteria; secondary criteria included course role (e.g., course coordinator, project advisor), faculty rank, and institutional characteristics (size, public versus private). Table 1 summarizes the profile of participants:

Table 1. (reprinted from [19]; Creative Commons CC-BY-NC))

Participant Demographics

	Experience*			Position						Type of Institution		Size of Institution+		
Field	Low	Medium	High	Inst	Rsch Fac	Asst. Prof	Assoc Prof	Prof	DH**	Public	Private	Small	Medium	Large
CEA	1	8	0	1	0	0	5	3	0	5	4	1	6	2
CHE	2	4	2	2	0	0	3	2	1	7	1	1	5	2
ECE	1	4	2	1	0	0	3	3	0	4	3	2	2	3
ISE	0	6	3	1	0	0	2	5	1	8	1	1	4	4
MAO	3	3	3	2	0	1	3	3	0	6	3	3	4	2
Total	7	25	10	7	0	1	16	16	2	30	12	8	21	13
Percent	16.7	59.5	23.8	16.7	0.0	2.4	38.1	38.1	4.8	71.4	28.6	19.0	50.0	31.0

Field Abbreviations
CEA: Civil, Environmental, and Architectural Engineering
CHE: Chemical Engineering
ECE: Electrical and Computer Engineering
ISE: Industrial Systems and Manufacturing Engineering
MAO: Mechanical, Aerospace, and Ocean Engineering

*Experience measure includes years of teaching experience, years of industry experience, and scholarly activities related to capstone education
Low: More than one standard deviation below the mean expertise score
Medium: Within plus/minus one standard deviation of the mean expertise score
High: More than one standard deviation above the mean expertise score

**DH: Department Head

+Small: 5000 undergraduate or less
Medium: 5,001-20,000 undergraduates
Large: More than 20,000 undergraduates

Race and gender data were not collected in the survey and thus not used for sampling, nor were they explicitly addressed in the interview, though names typically considered masculine dominated the interview pool. For context, the Howe et al.'s decennial survey of capstone faculty members also does not include race and gender data [24], but data from ASEE indicates that currently, approximately 13% of U.S. engineering faculty members identified as female, 2.5% identified as African-American, 24% as Asian, and just under 4% as Hispanic [40].

Notably, interview participants were representative of the larger pool of survey respondents in terms of years teaching, years teaching capstone, and years of engineering work experience outside academia, as shown in Table 2, with 83% of interview participants having four or more years of experience teaching capstone and 69% having four or more years of engineering work experience outside academia. This profile, particularly in terms of industry experience, also aligns with findings from Howe et al.'s most recent survey [24].

Table 2

Experiences of Interview Participants (n=42) Compared to Survey Respondents (n=503)

	Teaching		Teaching Capstone		Engineering Work Outside Academia	
Years	Interview Participants	Survey Respondents	Interview Participants	Survey Respondents	Interview Participants	Survey Respondents
<1	0%	0%	5%	4%	12%	14%
1 to 3	7%	6%	12%	17%	19%	21%
4 to 5	2%	7%	21%	19%	14%	10%
6 to 7	14%	9%	17%	9%	7%	8%
8 or more	76%	77%	45%	51%	48%	47%

2.3. Data Collection

To explore capstone teaching, semi-structured interviews were conducted by phone (n=39) or face-to-face (n=3), audio recorded, and transcribed verbatim. The interview protocol adapted Klein's critical decision method (CDM) [41]: the interview began by asking the participant to describe their overall approach to teaching capstone, and then followed the CDM structure to elicit specific teaching practices by asking participants to describe a specific situation in which a student design team encountered problems related to design, technical content, or team dynamics that required their intervention. The interview prompts explored how the participant identified the problem, how they approached it, and – most relevant to this study – what experiences or training the participant had that helped them work through the situation with the team (e.g., *what experiences did you draw from to help inform [your actions]?)*. The interview protocol then probed whether the situation described was typical (and why or why not) to develop a broader understanding of teaching practices. Finally, the interview concluded by exploring general beliefs about capstone design teaching. All transcriptions were reviewed and identifying information (e.g., names of people, places, and project sponsors) were replaced with generic identifiers prior to data analysis. Given the number of interviews conducted, each participant was assigned an alphanumeric participant ID rather than a pseudonym.

2.4. Data Analysis

Analysis of the data followed the procedures outlined in Miles, Huberman, and Saldaña [42], using the qualitative coding software MaxQDA. The process was highly iterative. In the first coding cycle, excerpts related to faculty learning were identified and both descriptive and in vivo codes were developed based on the ways in which participants described experiences that informed their capstone teaching practices (e.g., consulting, undergraduate experiences, learning from peers). In addition, initial in vivo and descriptive codes were developed to capture the specific focus of learning (e.g., conflict resolution, project management, mentoring). Murzi conducted the initial round of coding, including memos on the coding process and emergent ideas and patterns. In the second coding cycle, Murzi and Lutz then worked together to check the coding (e.g., through peer debriefing and intercoder reliability checks), reduce and refine the codes, and group the codes into major categories related to the sources of learning. They worked collaboratively to reach consensus on all initial code and category definitions. Peer debriefing with Paretti served to further refine all definitions.

Paretti then completed a full review of all coded excerpts to finalize code and category definitions, ensure consistency of coding, and apply learning focus codes to each excerpt. Following peer debriefing, Menon reviewed a subsample of the final codes to ensure consistency and accuracy, and differences were discussed and negotiated to consensus. The process resulted in three categories to describe the sources of learning (encompassing 21 separate codes), and seven focus areas for learning; these categories and focus areas are described in detail in Results sections 3.1 and 3.2.

In the final phase of analysis, analytic tools in MaxQDA (e.g., Code Matrix Browser, Code Relations Browser, Document Statistics, Complex Coding Queries) were used to explore patterns in the data using a variable-centered approach to examine potential relationships among codes and relationships between codes and demographic variables. These patterns, where identified, are also discussed in Results Section 3.3.

2.5. Research Quality

Although the data was collected prior to the publication of Walther et al.'s quality framework [43], that framework provides a meaningful tool to describe the quality measures used in this study, as listed in Table 3.

Table 3.

Quality Measures (based on Walther et al. [43]

Criterion	Making the Data	Handling the data
Theoretical validation	Study used purposive sampling to select interview participants	Descriptive and in vivo codes were used to capture participants experiences; coding included participants with varying experience levels in terms of both capstone design and industry practices to help ensure that coding focused on participants experiences and all salient issues were identified.
Procedural validation	Participant responses focused on specific instances or experiences of learning to teach capstone, using critical decision-making (CDM) methods	To support interpretive awareness, coding was conducted by researchers with varying experience levels in terms of both capstone design and industry practices. As the coders engaged in a process of collective sense-making [44], their diversity of experience helped ensure that analysis focused on participants experiences and all salient issues were identified. The two authors who co-constructed the initial codebook discussed the emerging codes and themes and how their sensemaking evolved over time, and the revisions to the final analysis were discussed among the research team. The discussions not only focused on finding agreement on definition and application of the codebook but also on how the emerging results connected to their previous experiences.

Criterion	Making the Data	Handling the data
Communicative validation	The interview established rapport with participants through generalized opening questions, and the CDM approach to interviewing focuses on enable participants to narrate their experiences with careful prompts from the interview to probe for narrative details. Contrasting accounts were present in the data given that participants came to capstone teaching from a range of different backgrounds (with and without industry experience, varied disciplines, varied levels of training in pedagogy).	Data analysis included both descriptive and in vivo coding, with extensive peer debriefing and review of codes by multiple members of the team.
Pragmatic validation	The research design, and particularly the use of purposive sampling across discipline, institution, role, and participant background, ensures a diverse study pool that aligns with other national samples of capstone faculty.	The findings of the study can be used to help enhance future training of capstone faculty members, and are grounded in a broad national sample of those most impacted by training (i.e., capstone faculty members themselves).
Process reliability	Interviews were audio-recorded, transcribed verbatim, and checked for accuracy. A single interviewer collected all interviews, and the interview protocol was documented.	All analysts kept ongoing memos regarding coding, grouping of codes into categories, and pattern analysis. The results focus on the descriptive findings, with interpretation occurring primarily in the discussion section of the paper.

One final quality consideration for this study is the age of this data, which was collected in the early 2010s. Although the data is a decade old, we consider it still relevant to the engineering education community because although research on faculty development has continued in the intervening years and many innovative new approaches have emerged, no large-scale changes in the preparation requirements for engineering faculty members have occurred in the U.S. That is, institutions do not require pedagogical training for university faculty members, teaching and learning centers were already in wide existence at the time of the data collection, no major new national or disciplinary pedagogical workshops have emerged, and the percentage of capstone faculty members with industry experience has remained relatively consistent at least through the late 2010s according to the most recent available data. In addition, while there are increased options available for graduate teaching assistant (GTA) training at many universities, including at institutions with engineering education doctoral programs and graduate certificates, graduate engineering education in the U.S. continues to focus heavily on research and technical training.

Finally, capstone course requirements and pedagogies have also remained relatively consistent in the intervening decade, though as noted earlier, the most recent decennial national survey was in 2015 [24].

2.6. Limitations

The study was designed to provide a representative sample of capstone faculty members in the U.S. based on institution type, discipline, and experience to support generalizability of the findings; however, we did not collect race or gender data, and thus cannot determine whether the data are representative in those terms. In addition, generalizability may be limited by the fact that the interview pool was drawn from a national survey that yielded responses from 40% of ABET-accredited programs and 53% of ABET-accredited institutions in the U.S. [19, 26], and neither gender nor race were considered in sampling. Faculty members from institutions or programs not represented in the survey may have different learning experiences, and learning may vary by gender and race. Still, the saturation reached in the analysis of the interviews suggests that the findings are robust for the sample. In addition, because the data were collected in the U.S., the findings may not be generalizable to other countries. Finally, as noted, the age of the data represents a potential limitation; while new broad sources of learning and new learning foci would be unlikely to emerge given the scope of the findings, more recent data could show different patterns (e.g., which sources of learning are most prominent, which are linked to each foci), as well as additional details regarding the kinds of faculty development experiences individuals engage in. Novel delivery methods such as communities of practice and faculty learning groups, as well as increased focus on topics such as problem-based and experiential learning and inclusive pedagogies (which may relate to team dynamics) may shift where and how faculty members learn, as well as what they learn about team dynamics in particular, are not captured in this data set.

3. Results

We begin by describing the seven focus areas for faculty members' learning and the sources of that learning, then summarize the interactions between sources and foci, and conclude with an analysis of patterns by discipline.

3.1. Learning Focus

Faculty members discussed learning in terms of seven focus areas, summarized in Table 5.

Table 5.

Focus of Faculty Learning[1]

Focus Area	Definition	Sample Excerpts
Team Dynamics	Learning how to support and manage teams, including conflict resolution, peer-to-peer interactions, and workload imbalances	It was a group of three and two people really took it and ran and the other person was sort of spectating. And I made it clear that they all had to understand all aspects of the design. While they might assign certain tasks to certain people they all had to be contributing and they all had to be working on it.
Technical Topics	Learning how to support teams in developing the technical knowledge needed to complete the project	They would come to me with questions. I mean sometimes they would just essentially throw up their hands and say "[…] we don't know how to size this reactor, we don't have any data, all [sponsor] has, for example, is they had a beaker and they stirred the thing and they said it took an hour, so what do we do, does that mean it's going to take an hour in our process?"
General Capstone Pedagogy	Learning related broadly to how participants approach design and teaching the course	It really seems that everybody's got a different way of doing it. And some of these ways of doing it are just drastically different than what I'm doing. I just like to go [to conferences] and listen to what other people are doing, and you know, kind of pick up a little bit here a little bit there and uh. So mainly for ideas. I come back with a long list of ideas of things to try in my class. I've got a lot of experience in industry in design positions, and what I try to do is I try to create within an educational setting a microcosm of what exists in the real world. I like the students to basically come out of senior design feeling as though, even if they haven't had an internship or co-op experience, that they've had a project that would be very much like initial design project that they might have in a company
Project Management	Learning related to how participants both manage projects themselves and how they help teams learn to manage projects	A big challenge for just about all of them is just-in-time project management and managing the project so that they can get prototype done in

		time to have some time for testing. The typical thing is they don't allow enough time or they don’t allow enough time to get the prototype done early enough so that they can work out the bugs, do some testing, and those kinds of things.
Project Scope	Learning related to how participants scope projects both initially and as the projects develop over the course.	Basically we just sat down and had a meetings and said,’ ok let’s look at the specs and at your management plan. Let’s hear your input on what you think you can accomplish.’ Basically we just guided them in revising the project to get a successful conclusion. [T]he two objectives, of course, are to help the client resolve a real-world problem and to provide a good learning experience for the student. So, to me that means I have to have solid problems. I have to have problems that they have a reasonable chance of completing in a semester. I want problems that allow them to use at least some of the tools that they have been subjected to during their undergraduate education.
Design	Learning related to design processes and practices	I had, myself, worked in the industry a little while and done some design work and so on. So I had my own ideas as to what that was about
Professional Skills	Learning related to how to teach professional skills other than teamwork, (most often, communication and general professionalism)	Some folks coming out of school take for granted the secretaries, the draftsmen, and so on. In that, what I point out to them is you want to make, what I tell them almost word for word, is what you want to do you go to start a job someplace is you want to be best friends with the secretary and the person who knows some of these other things. Because they’re the people who know things like, who gets a copy of any correspondence you send out? Do they go to the boss? Do they go to the boss’s boss? Does someone in another department get a copy? They’ll get those copies done. They’ll get them sent to the right person in the appropriate format if there are conventions. The other thing I point

out to them is you want to absorb the culture where you go to work

[1] Note that because of the length and detail of participants' descriptions of issues in their capstone teaching, we provide only brief excerpts here to illustrate each domain.

Among the seven focus areas, the first three are the most prominent. Team dynamics emerged most frequently (31 participants), closely followed by technical topics (27 participants) and general capstone pedagogy (25 participants). We note, however, that these patterns may be influenced by the structure of the interview, which asked participants to describe their general approach to the capstone class and then discuss a critical incident related to team issues, design issues, or technical issues. At the same time, the interviews allowed participants to talk about the extent to which the issues they discussed were representative and prompted them to talk about how they learned to approach both the problem and the course. The frequency with which team dynamics surface in the interviews, in particular, suggests that it is one of the most important issues capstone educators face. As noted in a previous publication [45], issues related to team dynamics included conflicts over design decisions, imbalances in workload across team members, conflicts among team members who struggle to get along with one another, miscommunication problems, and gaps in team members' competencies that result in conflicts or project disruptions.

Technical topics also emerged as a prominent area of learning in terms of the knowledge needed to complete the project. Because most capstone faculty members in this study intentionally create challenging, open-ended projects where the solution, and sometimes even the approach, is unknown [19], both faculty members and students typically find themselves learning extensively throughout the life of a project. As a result, faculty members often support students in learning new information, sometimes drawing on their own knowledge base and sometimes learning themselves.

Participants also linked their learning to the general approaches they took in teaching the capstone course, centered on how to mentor or coach students through different kinds of problems and how to create an environment designed to help students transition from school to professional engineering practice. Mentoring and coaching are critical components of capstone teaching, with 24 interview participants explicitly using "mentor" or "coach" when describing their approach to the course as a whole and to individual issues they address.

The other four learning foci (project scope, project management, design, and professional skills) were each cited by fewer than a quarter of participants but still represented key areas in which faculty members drew on a range of learning experiences.

3.2. Learning Source

Faculty learning relative to design education emerged from three key sources, as summarized in Table 4.

Table 4

Sources of Faculty Learning

Source of Learning	Definition	Sample Excerpts
Faculty work	Learning resulting from participants' experiences as an academic faculty member	Part of it is just experience with these classes I'm very quick to call other folks in the department. I get feedback from the students […]. Included in the team evaluation I ask them to write their recommendation of how we can improve teamwork. So the different input that I get from the students has been helpful. Every year things get better and better.
Industry work	Learning resulting from participants' experiences in industry, including both full-time work and consulting	I spent 30 years in professional practice before I came to the university, so we have a lot of experience I still maintained a consulting arrangement with them, and I would come in and do design reviews, you know, just provide technical reviews, technical guidance.
Personal Life	Learning resulting from experiences outside of participants' professional work, including family life, education, and non-work travel	I was a Peace Corps volunteer many years ago in Africa, in the mid eighties. And working with a lot of the project teams that I had there, you know work crews, survey crews, construction crews, research personnel and things like that, it was very useful to me I think through my graduate advisor, you know, and working with him uh he was an excellent coach of exploring things and asking questions and so I was modeled there and along all through grad school.

By far, the largest sources of learning were participants' experiences as faculty members; 38 of the 42 participants cited knowledge gained through their university work as key in their approach to capstone teaching. The most prominent sources of learning in faculty life were experience teaching the capstone course itself (29 participants) and informal interactions with peers both within and beyond their department (20 participants). Both new and experienced faculty members highlighted learning through teaching; as one senior faculty member explained,

> Alright, well, this is my 27th year of teaching. And every year you learn. And every year that I taught a course that involves students working in teams, I learned what works and what doesn't over the years. And the things that work I try to enhance. And the thing that doesn't work, I try to kind of…in some form I share it with the students. I'll ask, what are the key to success and failures? You know, how to avoid this every year and how to succeed. But it's a culmination of years and years of teaching

Participants also frequently cited colleagues as sources of help in learning how to address the course, responses such as "talking with my colleagues," "a suggestion from another colleague," and "it's a matter of the faculty sitting down together" and reflecting on common issues. In short, a majority of our participants learned to teach capstone by teaching capstone and by talking with their peers about experiences with teaching capstone.

Approximately a quarter of the participants also cited their interactions with students as a key source of learning, including both feedback from students in the course and learning about students by working with them in previous courses. As one participant explained,

> [T]ypically by the time students get to their senior year, I've taught them in one or two other classes as well as advised them for four years. And so, even though we have a large class I feel like I know most of the students well in terms of their background, their past performance, you know, issues that they've had. So that does inform my teaching in the design class.

Multiple participants cited such previous interactions based on other courses taught and/or roles such as undergraduate advising or departmental administration.

Similarly, a quarter cited more formal kinds of training experiences, including workshops (general teaching workshops, engineering education workshops, and topic-specific workshops), conferences (technical and education conferences), and their own independent reading on specific topics. One participant explained, for example,

> "[T]he school where I started my teaching career had […] two, or perhaps even three, workshops that the college set up where we invited outside engineering experts, engineering education experts, to come in and do a workshop. And we learned about learning styles and other things that you don't typically study, say, in graduate school in mechanical engineering. So that helped.

Another, talking about a strategy for managing teams, noted, "I got this idea from going to the, uh, capstone conference in Boulder this year." Finally, a small number of participants also cited experiences as administrators (3 participants), experiences running research projects (1 participant), and experiences advising graduate or undergraduate students (3 participants).

Almost as prominent, and not surprising given the nature of the capstone course and the prominence of industry experience among participants, were experiences gained through working in industry. Of the 42 participants, 28 cited experiences in industry as key in their capstone teaching, including full-time industry work, consulting, and/or owning their own companies. One participant noted that part of his approach to teaching "gets back the industrial experience, some of the project management things I saw myself when I was working in industry after my bachelor's degree and picked that up then." Another explained, "I had a long career and system engineering design and management and so in the process of that career, I went to a number of programs for you know, increasing sophistication in management techniques all the way from basic management up through very high level senior executive management."

Six participants cited formal training in communication, teamwork, or leadership received while working in industry. One noted, for example, "As an engineer at [Company] I was a group leader, a supervisor, so I had direct supports. And I received some training in industry on various aspects of supervising people, you know, one of which would be kind of conflict resolution and just, you know, coaching – coaching in general." Others cited related training such as getting an MBA or a professional engineering license. Importantly, a number of participants who did not have direct experience in industry themselves cited the importance of maintaining strong contacts with industry practitioners as key in their work.

Finally, 17 participants cited experiences in their personal lives that informed their teaching, including their own undergraduate learning experiences (11 participants), their graduate studies (5 participants), and general technical expertise (5 participants). Parenting and international travel were also cited by 2 participants each. Key undergraduate experiences were the most common source in this category; as one participant explained,

> I can think of a couple specific instances of professors when I was in undergraduate where professors really sat me down and walked me through some analysis so I could understand it better. So, I'm pretty sure this [approach] would come from prior experience, when I was on the other end, when I was on the learning end instead of the teaching end.

Other participants specifically referenced their own undergraduate capstone experiences, as well as other undergraduate coursework, suggesting that a number of participants in this sample drew on teaching practices that had helped them as learners.

3.3. Patterns

3.3.1. Interactions Between Learning Sources and Learning Foci

At least as important as how and what faculty members learned are the interactions between learning sources and learning foci. For each learning focus, Table 6 presents the intersection of learning sources and learning foci as a percent of participants citing that focus. Each cell represents the percentage of the number (n) of participants citing a given focus (column) who linked that focus to the corresponding learning source (row). For example, of the 31 participants who discussed team dynamics, 15, or 48% of those 31 participants, cited their workplace experience as a source of learning that helped them address team dynamics. Similarly, of the 8 participants who discussed project scope, 5, or 63% cited their experiences teaching the capstone class as a key source of learning related to project scope.

Table 6.

*Relationships Between Learning Foci and Learning Sources as a Percent of Participants Citing Each Focus Area**

	Team Dynamics (n=31 participants)	Technical Topics (n=27 participants)	General Capstone Pedagogy (n=25 participants)	Project Management (n=9 participants)	Project Scope (n=8 participants)	Design (n=7 participants)	Professional Skills (n=6 participants)
Personal Life							
Industry Awareness	0%	0%	0%	11%	0%	0%	0%
International experience	3%	0%	4%	11%	0%	0%	17%
Technical expertise	0%	7%	8%	0%	13%	0%	0%
PhD	6%	11%	0%	0%	0%	14%	0%
Undergraduate experiences	6%	22%	12%	33%	13%	0%	17%
Parenting experiences	3%	4%	0%	0%	0%	0%	0%
Faculty Work							
Administrative experience	6%	0%	4%	0%	0%	0%	0%
Research Experience	3%	0%	0%	11%	13%	0%	0%
Student Interactions	32%	11%	8%	0%	13%	0%	0%
Advising Experience	3%	7%	0%	11%	0%	0%	0%
Peer Interactions	39%	26%	32%	33%	13%	43%	67%
Independent Reading	26%	11%	4%	11%	25%	14%	17%
Workshops/Formal Training	19%	22%	4%	11%	13%	0%	0%
Conferences	16%	4%	16%	0%	13%	0%	0%
Capstone Teaching Experience	48%	52%	20%	11%	63%	29%	17%
General Teaching Experience	16%	22%	0%	0%	0%	0%	0%
Industry Work							
Business/MBA graduate school	6%	4%	0%	0%	0%	14%	0%
Engineering license	0%	0%	4%	0%	0%	0%	17%
Contacts in industry	6%	7%	8%	11%	38%	0%	0%
Workplace Training	19%	4%	0%	0%	0%	0%	0%

Workplace Experience	48%	67%	44%	56%	50%	57%	67%

* Each cell represents the percent of the n participants citing a given focus who linked that focus to the corresponding learning source

Notably, industry experience was the most prominent source of learning across all learning foci except team dynamics, where capstone teaching experience was equally prominent, and project scope, where capstone teaching experience was more prominent.

3.3.2. Patterns By Engineering Discipline

In addition to considering the interactions between *how* capstone faculty members learned and *what* they learned, we examined the interactions between their learning and their engineering field. While some patterns did emerge in this data set, the relatively small number of participants in each disciplinary group precludes meaningful statistical analysis; these patterns only suggest potential areas for further exploration in larger-scale studies. Table 7 presents the percentage of participants by discipline citing each learning focus and each major category of learning.

Table 7.

Patterns by Engineering Discipline

	CEA N=9	CHE N=8	ECE N=7	ISE N=9	MAO N=9
Learning Focus					
Project Scope		13%	29%	11%	11%
Team Dynamics	67%	75%	86%	67%	78%
General Capstone/Course Pedagogy	78%	75%	43%	44%	67%
Professional Skills	44%	0%	0%	11%	11%
Project Management	22%	13%	14%	11%	44%
Technical Topics	67%	75%	57%	56%	67%
Design	11%	13%	0%	11%	44%
Learning Source					
Personal Life	56%	50%	14%	33%	44%
Faculty Work	78%	88%	86%	100%	100%
Industry Work	89%	75%	57%	67%	56%

As noted, patterns here should be viewed cautiously, but they suggests several areas for further exploration:

- Civil/environmental and chemical engineering faculty members in our participant group were notably more likely to cite industry experience than electrical/computer and mechanical/aerospace faculty members.

- Similarly, civil/environmental and chemical engineering faculty members were more likely to talk about learning related to general capstone pedagogy and to professional skills than the other three disciplinary groups.
- Chemical engineering faculty members were mostly likely to discuss learning related to technical topics.

These disciplinary patterns in capstone faculty learning may be linked to larger disciplinary patterns. For example, the prominence of industry work among civil engineering faculty members could be attributed to the importance of obtaining a professional engineering license (PE) among civil engineers. The prominence of technical topics among chemical engineering faculty members may be linked to underlying differences in both what chemical engineers design and how design happens in that field; the design of chemical plants, for example, tends to differ markedly from traditional mechanical product design. But as noted, these patterns are only tentative based on limited data by discipline; further research is needed to establish and understand these and other emergent disciplinary variations.

3.3.3. Patterns by Previous Experience

We also examined whether having or not having prior industry experience influenced the ways in which capstone faculty members learned, though as with discipline, the numbers in each category were low, with only five participants having less than 1 year of experience in engineering practice. Apart from the obvious fact that those without industry experience did not cite such experience as a source of learning (though one made a general reference to learning from "past jobs"), the only notable pattern that emerged was that none of the participants without industry experience cited learning related to either professional skills or project management, as shown in Table 8. The percent in each column represents the percent of faculty members at that engineering practice experience level who reported a given learning source or learning focus. For example, of the five faculty members with less than one year of experience in engineering practice, 20% (1) reported learning about project scope while 80% (4) reported learning about team dynamics.

Table 8.

Patterns by Years of Engineering Practice

	< 1 year N=5	1-3 years N=8	4-5 years N=6	6-7 years N=3	≥ 8 years N=20
Learning Focus					

Project Scope	20%	25%	17%	0%	20%
Team Dynamics	80%	75%	67%	67%	75%
General Capstone/Course Pedagogy	60%	50%	50%	33%	70%
Professional Skills	0%	25%	17%	0%	15%
Project Management	0%	25%	50%	33%	15%
Technical Topics	40%	50%	100%	67%	65%
Design	0%	25%	33%	0%	15%
Learning Source					
Personal Life	20%	38%	83%	67%	30%
Faculty Work	100%	100%	100%	100%	80%
Industry Work	20%	50%	83%	33%	90%

Interestingly, learning related to professional skills was also absent in the two participants with less than one year of capstone design teaching, though both participants in that group cited learning related to project management, as shown in Table 9. The percent in each column represents the percent of faculty members with at that capstone teaching experience level who reported a given learning source or learning focus. For example, of the nine faculty members with four to five years of capstone teaching experience, 11% (1) reported learning about project scope, while 78% (7) reported learning about team dynamics.

Table 9.

Patterns by Years of Capstone Teaching

	< 1 year N=2	1-3 years N=5	4-5 years N=9	6-7 years N=7	≥ 8 years N=19
Learning Focus					
Project Scope	0%	20%	11%	0%	32%
Team Dynamics	100%	60%	78%	57%	79%
General Capstone/Course Pedagogy	0%	60%	67%	57%	63%
Professional Skills	0%	40%	0%	0%	21%
Project Management	100%	20%	11%	14%	21%
Technical Topics	0%	80%	44%	86%	68%
Design	50%	20%	11%	14%	16%
Learning Source					
Personal Life	0%	60%	22%	29%	53%
Faculty Work	100%	60%	89%	86%	100%
Industry Work	50%	60%	44%	57%	90%

4. Discussion

The sources of faculty learning identified through this study are not, in themselves, surprising; anecdotally, for example, many of us would likely identify peers and workshops either at our own institutions or at conferences as sources of learning. Nonetheless, empirical data supporting these anecdotal impressions remains scarce, and our findings do link perceptions to such data in the capstone teaching context. Similarly, the findings regarding what faculty members learn about teaching are consistent with current research on capstone design teaching practices. Project planning, for example, has consistently been among the top five topics covered in the capstone course nationally since the 1990s [24, 26] and teamwork was among the top five in the most recent national survey [24]. The prominence of learning related to technical topics is likely linked to the wide variation and open-ended nature of capstone projects as faculty members consistently seek to provide students with challenging, authentic projects [19]. Because capstone courses typically rely on real-world, often industry-sponsored, projects characterized by ambiguity and complexity [19, 24], capstone faculty members do not routinely teach a set list of established technical topics; instead, their ability to coach and manage multiple new, diverse projects annually means that they are continually updating their own technical knowledge in order to effectively guide student teams to success.

These findings suggest that beyond general strategies for course design, assessment, active learning, and student motivation, faculty members engaged in capstone design teaching need to develop teaching practices related to structuring and mentoring teams – including supporting effective conflict resolution and facilitating equitable and inclusive teaming practices that have been well-studied in cornerstone design teams [46-48] – along with both general and design-specific coaching and cognitive apprenticeship practices for project-based learning [21, 34, 49]. While on the job, participants noted their interactions with students as a key source of learning, whether through previous interactions in courses which informs their teaching in capstone, or feedback from students in the course. Student voices, in particular, are an essential component for faculty learning and in shaping the capstone course experience for continuous improvement. For example, in a recent study, focus groups conducted with capstone students echoed the critical need for faculty members to consider teaming practices and mentoring student teams – with emphasis on project management and professional development [50].

At the same time, such learning needs to be grounded in current industry practices, including expected modes and genres of professional communication, project management, and field-specific design practices, as well as an openness to ambiguity and a commitment to lifelong learning. Work on the transfer between capstone design courses and industry work in the U.S. [6, 16, 17, 51] highlight the importance of industry-oriented education in supporting students' success. Similarly, in Europe, research by Magnell and colleagues [52-54] points to the importance that faculty members themselves place on workplace-oriented learning (even when they do not feel prepared or lack the knowledge to support such learning). This "knowledge about the profession" [55] is critical in helping prepare engineering students for the transition to engineering work.

In the U.S., workshops such as NETI, Project Catalyst, and WPI's Institute on Project-Based Learning address PBL teaching and learning at general levels, while workshops and panels at the biannual U.S. Capstone Design Conference often include problem- and project-based teaching practices specific to engineering capstone courses. But as noted in the results, only a quarter of the participants in this study reported learning about these issues via such workshops (with the same pattern holding for those with and without industry experience). Instead, most capstone faculty members in this study are learning on the job – both through the experience of teaching capstone itself and through their workplace experiences. Given these findings, particularly related to team dynamics, workshops for capstone faculty might productively consider addressing issues related to conflict management, intercultural collaboration, and inclusive pedagogy are especially critical in helping capstone faculty members support their student teams. Examples of such workshops include Ryan et al. [56], Bergman [57] , Murzi [58], and others [59, 60].

Industry experiences clearly played a substantial role in shaping teaching practices for those with such experience; these faculty members were consistently bringing what they had learned and done at work into the classroom – findings that are also consistent with Magnell et al.'s work on European faculty members. What is not clear from the data is how well or how easily those coming from industry are able to translate their workplace experiences into student mentoring and coaching; the near universal reliance on learning by teaching the course suggests that the transition from one domain to another is not a seamless process. Equally unclear in this data is how those without industry experience build their knowledge of current practice apart from years of teaching the course, talking with colleagues, and working with industry-sponsored projects.

5. Conclusions and Implications

The findings from this study illuminate both specific topics capstone faculty members need to learn to support student success and their current ways of developing that learning. Teaching capstone design requires an understanding of how to foster effective team dynamics, how to scope and manage open-ended projects (and guide students to do the same), how to mentor students in addressing complex problems, and how to develop students' professional skills.

With respect to the sources of faculty learning, the findings here align with expectations in that peers and faculty development opportunities played prominent roles. Of particular importance to the capstone domain, however, is the role of industry experience in helping faculty members learn to both mentor and manage teams as well as to scope and manage projects. The critical nature of industry experience in capstone teaching emerges clearly in our findings, and that experience is more challenging to replicate for faculty members who have not had the opportunity to work outside academia for a sustained period. While existing faculty development programs offer many opportunities for industry practitioners to learn contemporary teaching methods – and thus help translate mentoring and management practices learned in industry to the course environment – few structured opportunities are available for capstone faculty members to learn contemporary industry practices. While some faculty members pursue research for industry sponsors and/or choose sabbatical work that embeds them in industry, no systematic data exists to indicate how common it is for faculty members to access those opportunities. As indicated in Table 2, among the respondents to our national survey, 14% had less than a year of industry experience and 21% had only 1-3 years, and data from other studies cited earlier suggest these percentages are even higher for faculty members outside the capstone course. This gap suggests important questions for faculty developers and workshop leaders to consider: How can we help novice capstone faculty members who lack industry experience gain insights into current engineering practice? How can we help existing faculty members stay current as industry practices evolve? Given that a key goal of capstone design courses is to prepare students for industry practice, our collective efforts in this area need to move beyond generalized support for problem/project-based learning and consider how to build faculty members' awareness of contemporary engineering work.

Finally, the patterns that emerged from this data with respect to engineering discipline suggest important ground for future work. As noted, the small numbers of participants in each disciplinary grouping indicate suggestive rather than conclusive patterns, but these suggestive patterns point to the need to better understand how distinct disciplines and various disciplinary faculty members engage with and connect to practice in the field.

Certainly, developing expertise in both teaching and engineering practice takes time and repeated engagement. Still, given the central role that capstone courses play in preparing students for engineering practice, departments and programs may need to think more intentionally about how they prepare new faculty members for the capstone teaching role since "give it a few years" potentially limits the learning outcomes of several graduating cohorts of students, potentially leaving them underprepared to enter the engineering workforce relative to those taking classes from more experienced faculty members. Such preparation may mean explicit support for professional development – encouraging and funding new faculty members (including those entering teaching after working in industry) to attend relevant conferences and workshops and engage in discussions with more experienced capstone educators, as well as supporting faculty members without industry experience, to shadow, collaborate with, or otherwise engage with practicing professionals. At the same time, as noted, those responsible for faculty development also need to consider ways to help engineering faculty members continue to engage with and learn from contemporary engineering work.

Moreover, given the tight links between engineering education and engineering work, such training should start with the graduate student and be included at the post-doctoral level. Most PhD graduates in engineering do not receive formal training in pedagogy, nor do they necessarily gain industry experience; when they assume new faculty roles, they can often be overwhelmed by the multiple demanding duties of the new job. Addressing their development as educators *before* they become faculty members can ultimately be more effective in the long run. Our findings show that many of the faculty members we interviewed, whether new or more experienced, were often actively seeking ways to improve their capstone teaching through mentorship, reflective practice, conferences, or other professional development, but more work remains to ensure that all capstone educators have the support and experiences needed to promote student learning in this critical course.

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Biographies

Marie C. Paretti is a Professor of Engineering Education at Virginia Tech and founding Co-Editor-in-Chief of *Studies in Engineering Education*. She received a B.S. in chemical engineering and an M.A. in English from Virginia Tech, and a Ph.D. in English from the University of Wisconsin-Madison. Her research focuses on communication and collaboration, design education, and identity (including race, gender, class, and other demographic identities) in engineering. She was awarded a CAREER grant from the National Science Foundation to study expert teaching in capstone design courses, followed by a multi-institution collaborative grant to follow new engineering graduates from their capstone design courses through their first year of work. She is PI or co-PI on numerous NSF grants exploring communication, teamwork, design, professional identity, and inclusion in engineering. Drawing on theories of situated learning and identity development, her research explores examines the ways in which engineering education supports students' professional development in a range of contexts across multiple dimensions of identity. She is the 2022 recipient of the Ronald S. Blicq Award for Distinction in Technical Communication from the IEEE Professional Communication Society.

Homero Murzi is an Associate Professor in the Department of Engineering Education at Virginia Tech with honorary appointments at the University of Queensland (Australia) and University of Los Andes (Venezuela).

Homero is the leader of the Engineering Competencies, Learning, and Inclusive Practices for Success (ECLIPS) Lab where he leads a team focused on doing research on contemporary, culturally relevant, and inclusive pedagogical practices, emotions in engineering, competency development, and understanding the experiences of traditionally marginalized engineering students (e.g., Latinx, international students, Indigenous students) from an asset-based perspective. Homero's goal is to develop engineering education practices that value the capital that traditionally marginalized students, bring into the field, and to train graduate students and faculty members with the tool to promote effective and inclusive learning environments and mentorship practices. Homero aspires to change discourses around broadening participation in engineering and promote action to change. Homero has been recognized as a Diggs Teaching Scholar, a Graduate Academy for Teaching Excellence Fellow, a Global Perspectives Fellow, a Diversity Scholar, a Fulbright Scholar, a recipient of the NSF CAREER award, and was inducted into the Bouchet Honor Society. Homero serves as the American Society for Engineering Education (ASEE) Past Chair for the Commission on Diversity, Equity, and Inclusion (CDEI) and the Incoming Chair for the Research in Engineering Education Network (REEN). He holds degrees in Industrial Engineering (BS, MS) from the National Experimental University of Táchira, Master of Business Administration (MBA) from Temple University, and Engineering Education (PhD) from Virginia Tech.

Ben Lutz is an Assistant Professor of Mechanical Engineering at Cal Poly San Luis Obispo. He is the leader of the Critical Research in Engineering and Technology Education (CREATE) group, which supports undergraduate and graduate research projects. His research interests include engineering design teaching and learning; critical and inclusive pedagogies; sociotechnical thinking and development; and school-to-work transitions for new engineers.

Maya Menon is a Postdoctoral Research Associate at New Jersey Institute of Technology. She received a B.S. in Computer Science from Arizona State University, an M.Tech. in Robotics and Automation from Amrita University and a Ph.D. in Engineering Education from Virginia Tech. Her previous roles included Software Consultant and Project Manager at CA Technologies and Assistant Professor at Amrita University. Her research focuses on the faculty perspectives, exploring the factors and influences behind their teaching decisions and engagement in engineering education.

Lisa Schibelius (she/her) is a Doctoral Candidate in the Department of Engineering Education at Virginia Tech (VT). She holds both B.S. and M.S. degrees in Mechanical Engineering with an aerospace concentration from the University of South Alabama. Prior to beginning her studies at VT, she worked as an engineer for 4 years at Airbus in the retrofit of aircraft cabins with experience in project management, automation, airworthiness, and additive manufacturing. Her research interests are influenced by her experiences in industry and are centered on team dynamics, conflict management, professional skills development, and intercultural awareness. She aims to leverage her industry experiences to bridge academia and industry through her research, teaching practices, and interventions aimed towards student and faculty professional development. As an artist, she is also interested in art, creativity, and expression in engineering. Her research also centers on non-traditional methods, transformation, and critical reflection - aspiring for more equitable and inclusive practices in engineering.