Contextual Influences on the Adoption of Evidence-Based Instructional Practices by Electrical and Computer Engineering Faculty

Amy L. Brooks, Prateek Shekhar, Jeffrey Knowles, Elliott Clement, and Shane A. Brown

***Abstract*—*Contribution:* This study aimed to improve understanding of context-based affordances and barriers to adoption of evidence-based instructional practices (EBIPs) among faculty in electrical and computer engineering (ECE). Context-based influences, including motives, constraints, and feedback mechanisms impacting EBIP adoption across six ECE faculty participants were documented using qualitative analysis.**

***Background:* Recent engineering education literature notes that the adoption of EBIPs by engineering faculty is lagging despite increased faculty awareness of EBIPs, belief in their effectiveness, and interest in integrating them. While researchers continue to investigate barriers to faculty adoption of EBIPs in science, technology, engineering, and mathematics education settings, few studies have dedicated examinations within a specific disciplinary context, particularly among ECE faculty members.**

***Research Question:* What context-based barriers and affordances influence adoption of EBIPs by ECE faculty members?**

***Methodology:* This study qualitatively analyzed data from in-depth interviews with six ECE faculty members from engineering programs throughout the United States. The study applied an iterative combination of case study and thematic analysis techniques to identify context-relevant and unique factors relevant to each individual participant and synthesize the process of decision making when incorporating EBIPs using a systems perspective.**

***Findings:* Overall, the approach identified drivers, constraints, and feedback mechanisms in regard to four emergent categories of EBIP adoption cases: 1) no use; 2) discontinued use; 3) in development; and 4) continued use. The study reports examples of context-based influences among the six participants in relation to their level of EBIP adoption, highlighting the substantial variation in faculty experiences with incorporating EBIPs.**

***Index Terms*—Computer science (CS) education, electrical engineering education, engineering faculty, evidence-based instructional practices (EBIPs), STEM education.**

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I. Introduction and Background

As technology continues to advance at a rapid pace, engineering will play an increasingly critical role in driving innovation and shaping various industries. Similar to other engineering fields, recent calls have been made to expand traditional electrical and computer engineering (ECE) education to include essential competencies among ECE students, including metacognitive, technical, breadth, and inter- and intra-personal skills [1]. To meet this need, educational and curricular approaches need revision to incorporate student-centered instruction in courses using traditionally passive instructional practices, such as lecturing, note-taking, and memorization. While passive learning methods may provide efficient means to convey substantial amounts of material to students, research has found that evidence-based instructional practices (EBIPs) are more effective for student learning and development of core engineering competencies that are necessary as they transition to professional settings [2]. Countering traditional teaching methods are several established learner-focused strategies that use techniques such as guided inquiry, frequent feedback, or student demonstrations to foster deep learning and knowledge transfer beyond what traditional approaches can offer. Such approaches include EBIPs (or research-based instructional strategies), which comprise teaching approaches that promote conceptual understanding and improve student learning outcomes based on empirical and theoretical support in a student-centered pedagogical environment [3]. Several studies have shown that while engineering faculty are aware of and interested in EBIPs, corresponding rates of adoption are lagging [4]. While recent research on barriers to adoption of EBIPs in discipline-based educational research have reported varied findings [5], there is growing consensus that EBIP implementation and subsequent barriers are contextual and need to be examined in the context of their implementation [6].

The present study examines EBIP adoption among ECE faculty. Compared to other engineering disciplines, ECE faculty have lower rates of awareness and adoption of EBIPs [4], and research addressing the use of EBIPs among ECE faculty specifically is limited [7]. Previous studies have demonstrated a range of benefits to incorporating EBIPs in ECE instructional contexts. Beyond strengthening student learning, EBIPs that encourage student interactions can bolster student development of social capital. In a study by [8], electrical engineering students built social capital through interacting with their peers to complete assignments, troubleshoot mechanical issues, getting help and clarification, and even personal topics. Further, like other educational settings, hands-on learning approaches in electrical engineering laboratory environments can generate opportunities for students to lead their own knowledge seeking, build skills in developing lab-based investigations, and build communication skills [9].

Despite the established benefits of educational innovations, ECE instructional approaches continue to reflect traditional methods of information transmission like lecturing and passive note taking [7], [10]. However, several studies have demonstrated prevalent uptake of EBIPs in ECE courses, including enhanced guided notes [10], instructional videos, active learning [11], inquiry learning, problem-based learning, supplementary learning, flipped classrooms, real and virtual experimentation, computer-based feedbacking, conceptual labs, team-based learning [12], incorporation of software or hardware like clickers, automatic grading, and relevant websites, and peer instruction, process-oriented-guided inquiry learning, jigsaw learning, and just-in-time teaching [13]. Rates of adoption may vary across disciplines. For example, one study from 2012 found that faculty in computer science (CS) had the highest EBIP adoption rate compared to other disciplines within the same institution [14]. However, EBIPs in CS are often used concurrently with traditional approaches rather than as standalone efforts [13].

Barriers to adoption of EBIPs among ECE faculty mirror that in the larger engineering and STEM settings. In a study among ECE faculty by Froyd et al. [15], familiarity and use of EBIPs in their courses varied due to the characteristics of different teaching practices. While most faculty in the study used and were familiar with EBIPs such as active and collaborative learning, most EBIPs had lower adoption rates with commonly cited barriers, including class time, preparation time, lack of evidence, and student resistance. Research led by Ni [16] found that ECE faculty adopters of innovative teaching practices were generally motivated by their own underlying philosophies and prior experiences with trying different teaching strategies. Hindering faculty innovation, however, were concerns about course content and demands on time related to preparation, lack of confidence in using new materials, and organizational and social issues like convincing colleagues and navigating departmental restrictions. A follow-up study [17] found that while faculty consider changing their instructional practices to address lagging student motivation, declining enrollment and retention, and participation among underrepresented students, their efforts can be dampened by a lack of autonomy around content coverage, competing professional responsibilities, student ability and background, discomfort around straying from traditional teaching values, and how changing the course might impact students' subsequent courses in their curriculum.

Finally, there is some evidence that variation in EBIP adoption among ECE faculty may be related to faculty members' demographic identities, institutional background, and teacher training experiences. A study by Cutler et al. [18] among ECE and chemical engineering faculty found that most faculty participants were aware of and trying some EBIPs, however, there was variation in demographic background of faculty that was correlated with EBIP adoption. For example, women faculty and participants who attended teaching workshops or presentations were more likely to trial and use EBIPs. Similarly, Hovey et al. [13] found modest evidence that women faculty in CS used traditional lectures less frequently and adopted flipped classrooms, process-oriented guided inquiry learning, and conducted online student-centered discussions more frequently than men faculty. The same study also found evidence that EBIPs were more regularly adopted by faculty at two-year and minority-serving institutions than their peers at large institutions. This inconsistent adoption of EBIPs among ECE faculty highlights the need to improve understanding around how faculty members' local contexts may play into their decision making regarding EBIPs.

Given the broad range of factors that might influence faculty members' uptake of EBIPs in their courses, several studies have concluded that a one-size-fits-all strategy for EBIP adoption is not efficacious [3], [14]. As such, efforts to improve EBIP adoption may need to be tailored to meet local needs, which has been shown to greatly influence the fidelity of implementation of EBIPs [19]. Further, as more nuanced understanding around EBIP adoption grows, discipline-specific efforts for faculty development will be needed [20]. To build discipline-specific understanding of unique influences and decision-making practices among ECE faculty, this study is guided by the overarching exploratory research question: *What context-based barriers and affordances influence adoption of EBIPs by ECE faculty members?*

This study is grounded in situated learning theory (SLT) [21], which aims to explain the process of learning within communities of practice, in this case ECE faculty. Traditionally, engineering education involves learning via books, lectures, and passive notetaking which offer abstract and noncontextualized understandings. In contrast, SLT posits that learning is catalyzed through connections between personalized experiences and interactions with others [22]. With this theory in mind, innovative educational practices such as EBIPs and student-centered approaches can be fostered among ECE faculty and beyond by diverging from traditional conveyance of standardized teaching information and instead purposefully contextualizing faculty experiences in ways that support flexible instructional decision making that make sense in their unique personal, social, and cultural environments. Doing so will advance faculty abilities and professional development by holistic facilitation of EBIP adoption.

II. METHODS

A. Overview

Given the nuance of individual experiences that this study sought to garner from participants, thematic analysis informed by case study methodology was employed with respect to the context-focused perspective. The case study approach is a qualitative methodology that uses a range of data collection techniques to develop insights specific to individual cases—in this instance, EBIP adoption among ECE faculty.

Case studies are particularly useful for examining "specific application of initiatives or innovations to improve or enhance learning and teaching" [23, p. 191]. Case study methodologies have been used regularly in engineering education research. For example, studies have relied on case study methodology to examine the impact of instructional approaches, such as peer tutoring [24] and project-led instruction [25] among engineering students. Other studies have been conducted specifically among engineering faculty. For example, Garrote and Pettersson [26] generated a case study that investigated attitudes about learning management systems among Swedish engineering faculty members. In this study, the underlying case-based perspective encouraged attention to idiographic experiences and decision making around EBIP adoption described by participants, while also allowing the authors to identify broad patterns among their decision-making processes.

The present study similarly aims to identify patterns related to faculty decision making while attending to participants' individual experiences with EBIP adoption through the case-based perspective. As such, the authors refrain from drawing generalizations about EBIP adoption among ECE faculty but aim to highlight patterns of decision making within participants' unique contexts that led to their uptake or refusal of EBIPs. To accomplish this objective, qualitative interview data were collected and analyzed to understand participants' experiences with EBIP adoption reported across four different cases: no use, discontinued use, in development, continued use.

B. Study Participants and Data Collection

The authors conducted interviews with six faculty members on three different occasions. Participants were recruited using a study interest survey administered online via Qualtrics between May and June of 2022. A link to the survey was distributed via snowball sampling, a convenience technique that relies on researcher and participant social networks to assist with distribution to other potential respondents [27]. Using this technique, the survey was shared with department heads, chairs, and administrative staff at engineering programs throughout the United States for further distribution to their faculty colleagues. While the total number of faculty who received the survey link is unknown, the original target for recipients was 500 faculty members, and 400 responses were received. The survey elicited respondents' perceptions of barriers to adopting different student-centered teaching approaches ranging from time and effort for preparing and facilitating EBIPs to classroom logistics and student reactions. Additionally, the survey collected demographic information including gender, race/ethnicity, academic rank/position, teaching experience, and institutional type and region. Out of those faculty who responded, 69 participated in at least one interview and 33 participated in all three.

For the present study, criteria for inclusion required that respondents fully completed the study interest survey, participated in all three interviews, and indicated their engineering discipline was electrical and/or computer engineering. Following these criteria requirements, six participants were eligible for inclusion in this study. Given the situational perspective of this work exploring contextual barriers to EBIP adoption, the small sample size supported in-depth analysis of the participants as individual cases that may offer findings that are transferable to other contexts rather than generalizable to or representative of the broader engineering education community [23]. Further, past research supports the use of small sample sizes, particularly for interview-based methods in educational research [28], thematic analysis [29], and multiple-case studies [30].

TABLE I
SUMMARY OF PARTICIPANTS

Pseudonym	Academic position	Institution type	Gender	Race/ ethnicity
Clara	Assoc. professor	Large, polytechnic, teaching focused	Female	White
Catherine	Assoc. professor	Mid-size, regional, teaching-focused	Female	Asian
Cody	Assist. professor	Large, research-focused	Male	White
Erika	Assist. professor	Small, polytechnic, teaching-focused	Female	Asian
Ethan	Assist. research prof.	Large, research-focused	Male	White
Eli	Instructor/ lecturer	Mid-size, teaching-focused	Male	White

Demographically, three study participants represented electrical engineering, two represented the computer engineering discipline, and one participant listed both ECE as their discipline. Each participant was assigned a pseudonym to protect their confidentiality, with "E" names assigned to faculty respondents who indicated their discipline was primarily electrical engineering and "C" names for CS and engineering faculty members (Table I). All participants were from public universities located across the United States, with two participants based in the Southeastern region and one participant based in each of the Midwest, Northeastern, Pacific, and Rocky Mountain regions. Only one institution represented in the study was a minority-serving institution, which represents a limitation to the work and an opportunity for further research that includes a broader representation of institutional types. Finally, all the participants taught mid-sized classes with enrollment ranging from 16 to 50 students. Ultimately, the six participants provided 18 interviews for the study, lasting between 20 and 50 min and an average duration of 37 min.

The authors employed an in-depth qualitative interview approach with the participants to identify contextual components of their course development experiences [28], [31]. The interviews were semi-structured and were conducted by multiple research team members before, during, and after the fall semester of 2022 using a shared interview protocol. Semi-structured interviewing is common in engineering education research because it combines the structure of an interview protocol with the flexibility of adapting interview questions in response to participants during the course of interviews [32].

For this study, the interview protocol centered on examining why and how the faculty participants incorporated

TABLE II
OVERVIEW OF INTERVIEW GOALS AND EXAMPLE INTERVIEW QUESTIONS

Goal	Elicit description of…	Example questions and prompts
1	Teaching experience, assignments, and approach	Can you tell me a bit about your teaching experience? What are you teaching this term? How would you describe your teaching philosophy?
2	Process for trying new teaching strategies and response to doing so	Can you tell me about the last time you tried something new in your course? Where did you get the idea to try that? How did it go?
3	Barriers and affordances of adopting new strategies	What made that challenging? You mentioned [an activity] was difficult/easy for students. Why do you think so?
4	Direct perceptions toward the study	We are trying to learn about factors that encourage or discourage faculty from adopting student-centered teaching practices. Do you feel that you have spoken to that, or would you like to add anything?

new instructional practices and elicited information regarding factors that influence their choices in selecting course materials, processes for modifying courses, their individual contextual constraints that influence EBIP adoption, and resources they rely on to inform their decisions to make changes to their courses. Using the semi-structured approach allowed the authors to ask unscripted questions to elicit further information from participants particularly when specific barriers or affordances to EBIP adoption were introduced. For example, when a participant referred to difficulty having sufficient time to cover material, the interviewer could probe for further description of why the participant felt all the material needed to be covered, how institutional changes might help mitigate the challenges, or how adoption of EBIPs might help or hamper the situation. Additionally, while the overarching goals of the interview protocol summarized in Table II were consistent throughout the first, second, and third interviews, given the semi-structured nature of the interviews, questions were adapted in real time to reflect the phase in which interviewees were in their semester (i.e., planning phase, mid-semester, or after the semester). For example, the final interview with participants encouraged more reflection of how their courses went, how the prior interviews influenced them or not, and how they might change their courses going forward.

C. Data Analysis

Given that decisions about instructional innovations and course revisions can hinge on local contexts, each participant and their respective interviews were qualitatively analyzed as individual cases. An inductive approach was used to analyze the interview data, resulting in emergent codes and themes. The first author acted as the codebook editor, however, the codes themselves were developed collaboratively with the third and fourth authors. Once the codebook was finalized, the first author coded all interview transcripts and convened with the third and fourth authors to obtain collaborative verification of coding decisions. The second and last authors provided oversight and input into coding results serving as an external check to establish trustworthiness of the coding process [33].

An iterative combination of first and second cycle coding approaches were applied per Saldaña [34]. First cycle coding comprised Attribute and Values coding, which together generated an inventory of salient features of the participants' decision-making processes and experiences. Attribute coding is a notation approach used to identify common settings among the participants, in this case examples included courses taught, academic position, enrollment size, or classroom features. In many ways, attribute coding facilitated defining contextual features of the participants' experiences within the data corpus. Values coding identified participants' values, attitudes, and beliefs. Through this approach, participants' evaluative statements were coded as *attitudes*, statements signifying importance attributed to various tangible features of their teaching as *values*, and intangible features that were often connected to actions and behaviors as *beliefs*. Second cycle coding then comprised Focused coding, which generated a connection between the interview data and an explanation of their meaning [35] by combining first cycle codes into operational units. Some examples of coded data are provided in Table III.

Driven by the coding process, four broad thematic categories of the EBIP adoption process were identified: 1) *continued use*; 2) *in development*; 3) *discontinued use*; or 4) *no use*. Within these categories, contextually relevant drivers, constraints, and feedback mechanisms that contributed to participants' decision to keep their current approach (i.e., continue use or continue not trying) or make a change (i.e., discontinue use or develop a new practice) were examined. Motives and deterrents included both intrinsic and extrinsic drivers. Constraints included physical, temporal, topical, and resource-based constraints as well as student-related constraints and personal constraints relevant to the individual participants. Feedback mechanisms reflected formative and summative assessments participants described in determining whether an approach worked or not. Together, these three elements converged into a process by which participants made decisions regarding inclusion of EBIPs in their ECE courses. Using these categories, several commonalities and emergent differences were identified that lead to varied adoption of innovative teaching practices, which ultimately informed a cross-case summary [36].

III. RESULTS

A. Overview of Results

In the following sections, findings are presented based on the four different response scenarios identified through thematic analysis. For each case, participants' unique processes for coming to similar decisions to try, quit, develop, or continue using EBIPs are described. For the *No use* response, three participants' processes of considering case-based teaching, but ultimately refraining from using it are described. For the *Discontinued use* response, several contrasting examples show participants' experiences with attempting to incorporate various learning strategies in their courses including flipped classroom and team-based learning.

TABLE III
OVERVIEW OF THEMES/CATEGORIES

Themes/Sub-themes	Definition	Exemplary quotes
Motives/deterrents		
Intrinsic motives	Reasons leading to adoption of instructional changes that emerge from internal interest or satisfaction	*I try to, I try to make my classes fun and I think that's also why I, I've been working a lot on this, trying to make my classrooms inclusive and I feel big piece of that is people need to know each other. (Clara)*
Extrinsic motives	Reasons leading to adoption of instructional changes that emerge from external influences	*Um, that one I think is going pretty well. We are, I'm using one of the new rooms and, um, in a university, which it's set up to be like a group learning, uh, with some new, new, uh, equipment from the Covid fund, <laugh>. (Catherine)*
Intrinsic deterrents	Reasons leading to resistance to making instructional changes that emerge from external pressures	*Because I think like, uh, really our engineering is about the problem solving. So it's slightly different from like, uh, the sociology or criminal justice. I have other, uh, faculty members from criminal justice. They do a lot of discussion because for the like lawyer, like, like law related case, it's not always the one or zero. It's just like a really just in between. Yeah. But for our engineer, it's just like a really, if you follow this procedure and get this problem answers. (Erika)*
Extrinsic deterrents	Reasons leading to resistance to making instructional changes that emerge from external pressures	*…the school of computing at [my institution] is much more, is a fairly research focused, um, department. And so generally my interactions with other faculty are gonna be more research oriented. Um, we don't spend a lot of time talking about teaching practices. (Cody)*
Constraints		
Temporal	Temporal boundaries in which the instructor made course decisions	*Um, so there were definitely, there definitely would've been times where in the 15 minutes between class I would sit down and work something out to try and put it together ahead of time. (Cody)*
Resource-based	Resource-based boundaries in which the instructor made course decisions	*…we will also have some funds to purchase some like new hardware to better be assist this, uh, efforts to like, um, uh, help with this, uh, build up a hy-flex classroom. (Erika)*
Physical	Modal and physical boundaries in which the instructor made course decisions	*Maybe it's not a, maybe the classroom just isn't, you know, equipped to handle demos like that or, you know, they could have provided you with something to make all of that more accessible and easier to, to work with (Ethan)*
Student-related	Student characteristics and needs in and outside of class	*And so I'm covering a lot of content, um, especially if they have no background in cad, which they rarely do have that background since they're freshmen. (Eli)*
Topical	Instructional requirements and limitations derived from course content and topics	*I think, I think that is harder to do in those, like in the circuits and signals courses because it's like, here's a list of topics you're supposed to cover. (Clara)*
Personal	Personal boundaries in which participants made course decisions	*…it's been a little bit difficult, uh, not to mention I have two young kids at home, so I really don't have time on the weekends or at night to really do anything. (Cody)*
Feedback mechanisms		
Formative	Measurable impacts both in and outside of class for both students and instructors (e.g., quantity of time and material coverage, student grades and attendance, observation of behaviors, direct feedback, etc.)	*And also, um, because most graduate students, this is their, like first, first semester, so they don't, they're not too familiar with the other students in the class that will foster some of the like classroom atmosphere, <laugh> I would say. (Catherine)*
Summative	Intangible but apparent impacts to the instructor, students, and/or class atmosphere (e.g., emotional responses, changes in autonomy or flexibility, changes to participants' social or cultural settings, participants' perceived ability to incorporate or complete a practice, etc.)	*Um, at least from attendance, it's almost every time they, uh, everybody is there <laughs>, so that's a lot better than last year. (Catherine)*

For the case of *In development*, one participant's detailed experience illustrates their process of implementing innovative teaching strategies and iterating on their attempts to restructure their course to keep up with rapid technological advances. Finally, the *Continued use* of EBIPs is described through one participant's adaptation of just-in-time teaching. For each case, drivers, constraints, feedback mechanisms and relevant interpretations of participants' individual processes are summarized and supported with quotes from participants. Finally, a cross-case analysis provides a comprehensive discussion of commonalities and distinctions found between the four cases.

B. Case #1: No Use

Motives/Deterrents: Four participants reported several perceived difficulties associated with case-based teaching that led to them refraining from trying it. One participant, Cody had difficulty discerning whether or not he tried the method, concluding that his efforts were not made in any formalized sense. Rather, he conceptualized his use of the practice as an informal attempt at tying course concepts to his own experiences or knowledge of industry applications rather than a defined effort to try the specific teach practice. Context-based drivers diverged among the other three who spoke to their decision-making process to not use the method, despite interest in it.

Clara was generally driven by an innate interest in creating opportunities for social connection among her students who were in her foundational, introductory courses in CS: *I spend a lot of time in my lower division courses trying to get students to know each other because they're all new to college and they do not know people in their major."* In turn, she reconciled that case-based teaching might take time away from those opportunities because students in those courses may lack rapport with one another. There is some evidence that case-based teaching is correlated with faculty use of group assignments, suggesting the approach could be adapted such that cases are discussed among student groups [19] or assigned as class presentations [37], to potentially boost student interactions and provide opportunity for social connections.

Ethan was the only participant in a fully research-based role with no teaching requirements as part of his appointment. As a research professor, *"teaching is an option"* rather than a requirement. While discussing case-based teaching, Ethan positioned his hesitancy to use the method within his limited teaching experience. As an early career faculty member, he was actively seeking out teaching opportunities for professional exploration to determine whether he enjoyed it. Citing little prior exposure to teaching, Ethan did not feel that he had sufficient resources to develop a case-based teaching approach: "*I do believe there are some re—resources here, but I do not know how to access them. So that would probably be helpful if I knew where to, where to find those."* The influence of Ethan's career stage in relation to his use of EBIPs may illuminate the importance of developing communities of practice for teaching. When it comes to developing such communities, one recent study found that faculty that use EBIPs are more likely to talk with other EBIP users [38], [39] rather than colleagues that do not, suggesting that targeting faculty interactions may improve networking and social connection that could potentially encourage diffusion of the practices. This finding is consistent with broader literature that has underscored the importance of developing communities of practice to facilitate sustained adoption of EBIPs [40], [41].

Unlike Clara and Ethan's intrinsic motives that were unfulfilled by case-based teaching, Eli spoke to intrinsic deterrents involving pressure to be the expert in the classroom for case-based teaching. His primary hesitancy around the method emerged from feelings of insecurity and fear of not having control in the classroom: "*…if you start trying to talk about the [case] and you just run into some rogue student that for some reason has better grasp on that history than you do, you kind of—all of a sudden you're up there feeling kind of foolish. So I think that's part of it, is picking the right study that you feel like you really have the expertise in, the control over, so that you can kind of be the expert in the room about it… So, I think of that as an obstacle. I'd feel uncomfortable if I didn't really feel pretty secure about the particular case study."* Anxiety is one of the strongest predictors perceived success in teaching and research [42]. Further, negative emotions, like anxiety, have been linked to faculty decisions to maintain traditional, teacher-focused practices [43].

Constraints: There was some consensus around relevant constraints to case-based teaching between two participants. While acknowledging the appeal of teaching through real-world scenarios, Clara and Eli both alluded to difficulties with adapting case-based teaching to their ECE course content, illustrating topical constraints associated with the practice. For instance, Clara felt that it may be more appropriate for other engineering applications: "*Um, but maybe the, it lends itself more toward the material they teach. So I do not know. I think that would be something I'd have to read more about, see how to fit it in, um, with the material I teach… And so it's like, I see the application there, but that wouldn't fit in my course. So I think it's helpful to have very discipline-specific examples."* Similarly, after observing a colleague successfully implementing case-based teaching in a civil engineering context, Eli questioned the approach's relevance to his own discipline: "*And so I've kind of been looking through my curriculum and saying, where would this, where would this fit?"* These concerns about discipline-based applicability of case-based teaching are common among extant literature on the subject. One study focused on the use of case-based teaching among science faculty found that "lacking relevant case studies" was one of the most frequently cited obstacles by faculty after "lack of preparation time" and "assessing student learning" [44].

Additionally, Clara focused on student background and class size in relation to her refraining from the method. As mentioned above, in her context, case studies were not perceived as useful for introductory courses where students have not yet developed foundational knowledge necessary to analyze cases effectively: "*I haven't seen a direct correlation between the material I teach and case studies cuz I'm teaching, you know, fundamentals."* Later she posited that the approach might work better in upper-level courses and larger groups who have sufficient background and are able to generate *"bigger designs."* Some EBIPs are more likely to be compatible with ECE topics than others. For example, one EBIP called Artifact Dissection, is more common among mechanical and civil engineering faculty who are often affiliated with design. In contrast, dissection of physical artifacts may be less frequent in ECE curricula, demonstrating a lacking compatibility with the artifact dissection method [4].

Feedback Mechanisms: Although there were no attempts of case-based teaching that participants could speak to in terms of evaluation of the method, one participant, Ethan, described uncertainty related to knowing if the method made any difference in his course: *"I mean there's no proof of just be trying it, is it any better than what I do? You know, um, it just sounds kind of, it sounded kind of like, uh, fresh and a new, a new thing to try a new way to teach, you know. So I do not know if the outcomes would be better."* This concern with confidently knowing whether an instructional approach works can lead to discomfort with investing time into trying a new approach [45]. Case-based teaching has been shown to be an effective approach in electrical circuits courses [46]; however, despite having a high rate of fidelity of implementation [19], the practice can require intensive planning, which may confirm nonusers' perceptions of the effort that is required to integrate the method [47], ultimately leading to their refraining from trying it.

C. Case #2: Discontinued Use

Motives/Deterrents: There were several varying pressures behind faculty participants' efforts at trying, but ultimately discontinuing EBIPs. For example, Clara saw the flipped classroom and just-in-time teaching approaches as potential outlets for accommodating large quantities of course material, while Cody tried the flipped classroom approach as an opportunistic reaction to his class shifting online due to the pandemic. At the time, he described having heard of the approach and believed it to have *"strong, uh, pedagogical roots. And so, it seemed like it would be a, a good chance to shift things up a bit."* Similarly, team-based work was discontinued by Clara and Erika. Both participants described intrinsic motives that contributed to their trying to incorporate group work: building student social networks and improving students' conceptual understanding of complex topics. Clara looked to group work as an opportunity for students, particularly those in lower-level fundamental engineering courses as opportunities to *"get to know each other"* after observing that she would *"walk into my freshman level course and it's dead silent."* In contrast, Erika tried integrating group discussions into her course to help students with their conceptual understanding: "*I think at first, I want them to have better understanding or have like their own opinion about this concept. So why is this concept like that? And how can we apply this concept into our area?"*

Constraints: After Cody tried the flipped classroom approach, he pointed to personal and student-related constraints leading to his discontinuing the practice. After trying the method online, the participant pointed to both his own lack of experience with the approach and his students' familiarity with it as an underlying reason for its failure. While the lack of student familiarity with EBIPs is often noted as a reason for negative student response, techniques such as explaining the purpose of the EBIPs can be used to mitigate students' negative response [48], [49], [50]. For Clara, student background and experience ended up being restrictive factors for her attempt to incorporate team-based learning in her first- and second-year courses, however, it was students' early phase in their education that ultimately led this participant to move away from the approach because *"these are still, these are like freshman, sophomore level courses that I teach. So it's still a lot of teaching fundamentals and the projects in the labs are small that you can't like give this part to one person and this part to another and this part to another, like they all have to do the same thing. And if you have too many people, I don't know. It just didn't work as well."* Further, Clara experienced having to choose between technical and nontechnical content in her course in relation to temporal limitations: *"...I didn't have time. And so I thought, 'Okay, maybe I put those back in, take out ethics. But then 'Why don't you have ethics?' So, um, there's always that tradeoff, but I do not know, I, I, I think I'm learning more that—I'd like to lean in more to the discussions and maybe cut out more technical. It's really tricky because it's like you could get an interview question on a specific technical topic and they could be like, 'What? You didn't learn that?!' And that's like core to that class and, I don't know."* In this instance, Clara was torn between pressures to incorporate a dense list of technical topics and content related to CS ethics, which her students enjoyed. This experience highlights the difficulties faculty face in having to meet technical requirements set out for their courses at the expense of topics that are important or meaningful aspects of engineering education. Relevant constraints can play a significant role in faculty continuation of EBIPs. In one study among ECE faculty, abandonment of EBIPs varied across EBIP types, with active and collaborative learning having the lowest rates of abandonment. In contrast, case-based teaching had one of the highest rates of discontinuation, which the study authors attributed to the time and curricular materials needed to support them [15].

Feedback Mechanisms: Participants' discontinued use of EBIPs was influenced by both negative formative and summative feedback relative to their motives and constraints. Clara determined the utility of her attempt of team-based work through observing student interactions, ultimately finding that large classes of students with little experience were not the appropriate context for the approach because students had yet to develop rapport with each other to foster interactions. In contrast, Cody sought direct feedback from his students regarding his use of the flipped classroom approach, with students reporting that the practice required more time and preparation. Similarly, Erika measured the outcome of her team-based approach by asking students directly: *"So do you like it? Or, uh, do you think it's just, uh, uh, a little bit too wasted, too much of time? And they probably would like to dive more deep into the questions, just like problem solving questions. And they told me, yes, they, they like example pro—practice and so, problems. They don't like discussion. So then I, so I only include this like discussion in my class once. Then I just, uh, let it go."* Erika attributed students' dislike of concept discussions to their background in STEM, ultimately nodding to dominant narratives that suggest engineering education is without feeling. Erika's feedback mechanism demonstrates a close connection between drivers for trying EBIPs. Beliefs, identity, prior experiences, and knowledge can heavily influence faculty dissatisfaction with and choice to abandon EBIPs [51]. If faculty do not believe that STEM students like discussions, for example, then it may discourage them from utilizing approaches that rely on student interactions and teamwork.

D. Case #3: In Development

All participants described ongoing attempts at revising or improving their courses. The nature of actively revising their courses, or parts of them, meant that many descriptions of actions were contemplative or abstract. Throughout his interviews, Cody provided a rich description of his efforts to restructure and iteratively revise his virtual reality (VR) course that he has continued to teach after several years.

Motives/Deterrents: Both intrinsic and extrinsic motives drove Cody to modify his course. Much of his efforts were driven by innate interest in the subject of VR, willingness to explore instructional approaches that he found appealing, and his belief that he had *"enough experience to revisit everything*." Several extrinsic benefits led him to make changes as well. His early approach in his course was driven by a desire to give his students foundational experience. Later, as he gained more experience teaching the course, he adjusted his project-based approach to help students gain big picture understanding of VR applications within a human-centered design context: *"... a big goal of [the project] is for students to see other people using their project so they can get a sense for, What did we do that worked well? What did we not think of? What did we forget about what should we have done? Um, and really, that's just more to give them a sense of the value and the importance of those, that human-centered component. Cause that's not something a lot of computer developers think about."*

Additionally, he spoke to the influence that inheriting the course from previous instructors played in his developing the class. Specifically, he received support from the previous instructors by "*bouncing ideas off them, getting a sense for what had worked and what didn't work."* Concurrently, Cody did not feel pressure to "*adhere to expectations"* of the course that might have otherwise limited his outlets for examining ways to improve it. Finally, the nature of VR as a newer technology means that Cody frequently faced pressure to update the course: "*...one of the consequences of that is I pretty much have to redo a significant chunk of the practical material every year.*" Similarly, he expressed concern over helping students understand the "*interaction between the person and the hardware*," ultimately describing the VR class as a *"strange"* context for CS students because of their exposure to other topics like psychology, optics, and human perception. Notably, VR may provide a particularly flexible outlet for exploring instructional approaches that meet faculty's intrinsic motives, in this case human-centered design. One review study found that VR use in educational settings was motivated by both pedagogical factors like collaboration, gamification, constructivism and intrinsic factors related to students, such as desire for increased immersion, motivation and enjoyment, deeper learning and personalization for students [52].

Constraints: The combination of complex foundational knowledge, vast VR applications, and human-technology considerations meant that material content for his course grew into a significant constraint guiding his course planning. In response to feeling that "*it's gotten to the point where the class workload is immense,"* Cody restructured projects to incorporate individual portions and increased structure by limiting project topics "*so I could guide them a bit, uh, more directly in terms of leading [the students] to a project that was likely to succeed."* Additionally, as he planned to continually teach the course, he considered modifications such as changing the number of weekly class meetings, adding a practicum component, and capping the enrollment to meet equipment and computing limitations.

Logistics, enrollment, and equipment were significant constraints around which Cody balanced his course decisions. Per Cody, equipment can be costly for instructors and departments to procure for their courses, and although historically VR equipment "*cost $50,000 to get access to it... over the last five years that's changed dramatically*," giving Cody more flexibility to incorporate hands-on instruction for his students. Naturally, equipment costs are connected to student access: "*And so I've—students struggling, cause they don't have that. And so, we're gonna be trying out using this in a classroom where they actually have those computers and can follow along."* As such, Cody explored several ways to improve students' access to important hardware that would equip them for future work and employment. Cody was carefully considering how to optimize the course schedule and enrollment size to further improve availability of equipment for students. Additionally, to help mitigate the challenges with acquiring costly equipment, Cody spoke to his interest in taking advantage of "*research grants that I've added some money in to purchase these headsets,*" and exploring institutional funds to help support electronic equipment for students as well. Cody's experience with careful consideration for revising his VR course highlights opportunities for examining compatibility and adaptability of EBIPs based on technological constraints.

Feedback Mechanisms: Generally, Cody relied on observation of his students' attention in class ("*...that observation that shows up both as just during class—how much blank stares do you get···)* and student performance on assignments and exams, asking questions in class, and attending office hours. Together, these sources of evaluation provided a signal to Cody, "*queuing me into, okay, I wanna talk about this, but the way I was planning on doing it isn't as effective as it could be. Something's missing."* Notably, student resistance to EBIPs is a common concern of faculty, however, in the case of Cody's course the topic of VR may have been well received. One benefit of VR in education is that students view the technology favorably in educational settings [53], which may drive positive feedback from students. Several contextual factors contributed to Cody's ability to examine ways to innovate in his course. For one, the course was an upper-level elective, which comprised more experienced and generally interested students: "*Um, but I think because of its nature as a more, again, more niche and elective oriented class, the students who came into it were better equipped to deal with that less structured paradigm.*" Additionally, Cody's instructional autonomy was met with outlets for assistance and brainstorming with experienced and supportive peers in his department. Further, Cody's university is a large research-intensive university, which may have scaffolded his efforts to look for funding sources for equipment. Finally, Cody exhibited an innate interest in both the VR content and his students' success, which underpinned his willingness to dedicate time and effort to improving upon his course.

E. Case #4: Continued Use

Motives/Deterrents: Catherine was a mid-career faculty member whose attempts at integrating learner-centric approaches in her courses were driven by her openness to trying new things, availability of resources to do so, and innate interest in facilitating student learning and fostering teamwork in ways that consider student needs outside of class. She frequently detailed proactive ways that she tried new things, including attending training provided by her university and her e-textbook publisher. Additionally, she integrated the use of team-based learning in a course after gaining access to an upgraded classroom through her institution and pandemic-related funds, which provided improved technological capacities: *"... our school had some design, new, some new interactive classrooms and with the group setting and some new, um, technologies in there. So I'm trying to, I booked one of the room there and see how the peer learning thing can help."* Provision of instructional resources was a frequent catalyst for course revisions for Catherine, who described receiving help from a course coordinator in a large first-year course, access to a center for teaching and learning (CTL) and workshops at her university, as well as availability of course consultants.

Constraints: Catherine worked around several constraints in her courses including topical, physical, and student based. For one, she described how her efforts to try new things were course dependent. Traditional courses were *"a little harder"* to innovate in, while she found programming and application courses to have more flexibility for exploration. Additionally, access to what she deemed to be a good textbook made a significant difference in continuing use in her courses. She was content with an e-textbook for her data structure courses which included, "*animations and also there, uh, part—participation, um, like problems, um, in there, like multiple choice, other type of problems—can work on that... you can rework, reclick on different options. They'll give you hint and then feedback and then they will, even if you were lost, you can say, show me the answer <laughs>. And so those will help them understand."* For Catherine, flexibility in the textbook provided improved learning experiences for her student through supplemental and automated support. With that, she described constraints related to meeting her students' unique needs *"... because our, um, our university, it's not a big student body. And then a lot of our students actually, um, do part-time work, part-time job, and some even do full-time jobs. So it's, it's not, um, does not work for them to do heavy things out of class."* As a result, Catherine frequently examined ways to make learning efficient and flexible for her students.

Finally, physical constraints influenced her decision-making around innovating in her courses as related to logistics and equipment access, equitable instruction among students with different needs, class environment, student background, and topical limitations/requirements. In her classroom that received technological upgrades via institutional funds, she noted how the smaller space created unity among the class: *"It's not a huge room, it's, it's a small compared to like small rooms. So they, it's not a, uh, like a, you feel, you, you, you, you get lost in enrollments. It's not. So it, that setting is pretty good."* Physical classroom space has been linked to student behavior, and modifications that minimize distraction and crowding can improve the instructional environment [54].

Feedback Mechanisms: Direct feedback from others was particularly important to Catherine, who cited reaching out to colleagues and teaching consultants at her institution as well as frequently asking students for input on her teaching approaches. Additionally, she determined success of an innovation based on student attendance, participation, and performance in her course. Attendance positively reinforced Catherine's course changes. Prior to her transition to the technologically compatible classroom, she described the negative impact that low attendance had on both her class atmosphere and her own confidence as an instructor: *"... it's not encouraging for others who are there as well, they feel, oh, 'Why, why am I here?' And then, so the, the, the atmosphere is not good. Even for me. <laughs> That affects my, my attitude as well. I, if, if the classroom is just a few students in there, um, sometimes they, they may think it's it's you sometimes it's, it's not, not the professor, it's something else. But, but seeing that few students there sometimes is that maybe it's it's me, but maybe part of the reason is me as well."* Following the classroom upgrades and revisions, she described feeling happier: "*I think overall, um, I'm pretty happy about the data structure course. "Um, at least from attendance, it's almost every time they, uh, everybody is there <laughs>, so that's a lot better than last year. Last year the attendance was, was a big thing for me."* Confidence in pedagogical ability may be correlated with teaching style. For example, one study among chemistry faculty found that those who were more confident in their pedagogical ability used more interactive instructional approaches and literature-based lectures on complex topics [55].

Further, the instructional space encouraged her continued use of team-based learning because she could seek out feedback in real time: *I usually stop by each day and see how they're going so I can, I can show 'em, 'Oh, okay, uh, what, what did you do wrong?'··· So I, I can get a sense of how they're doing, what, what they are, uh, doing wrong. And so that, that went on pretty good and they cannot like, hide themselves in the corner like that. So I'm pretty happy with that one."* The pattern of flexibility as a positive feedback mechanism was reflected in her textbook choice as well: "*the E-Book is pretty good. So I'm still using that. I'm just trying to, because I can configure that site book, so I can say, 'Oh, this, this section is optional'. And if I don't have time to go into more detail and I can readjust the sequence and, um, so, so that, that is working pretty good."* Flexibility and adaptability played a key role in the successful implementation of EBIPs for Catherine. Despite ample efforts to develop 'plug-and-play' curriculum, these approaches can limit faculty's ability to adapt modules to their local context [56], [57]. With freedom to adapt her course regularly, she was encouraged to continue her use of the modification.

F. *Cross-Case Summary*

Through thematic analysis across the six participants, this study identified commonalities and differences among how and why ECE faculty adopt EBIPs or not. Across the four adoption cases, faculty described driving motives/deterrents, constraints,

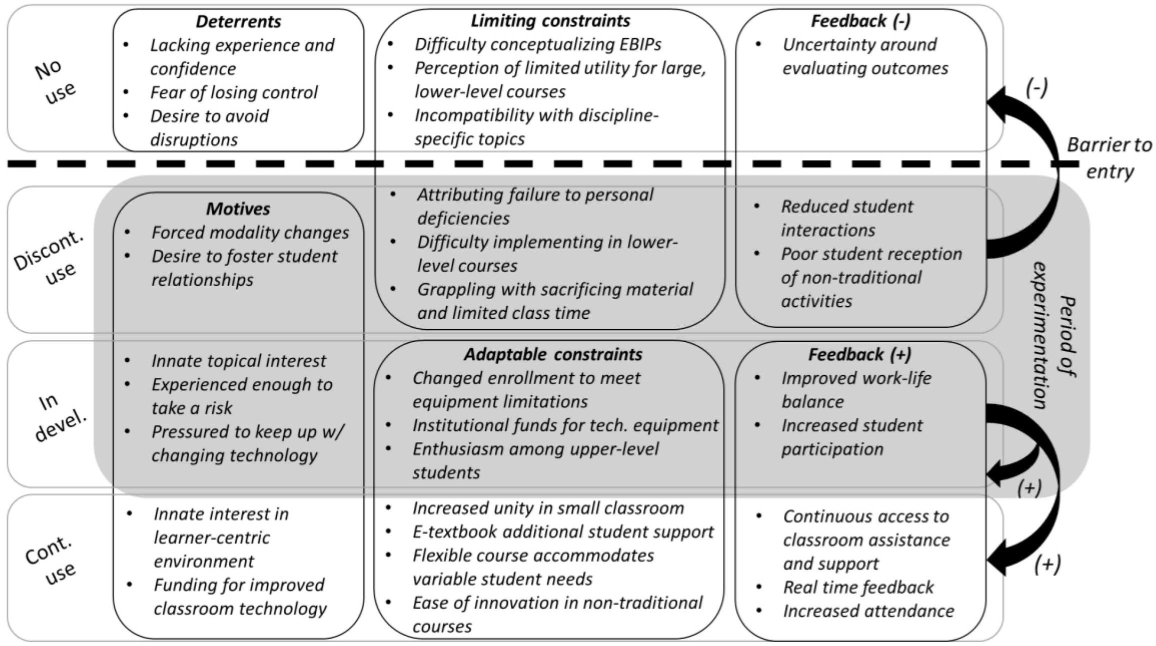

Fig. 1. Patterns and examples of context-based motives, constraints, and feedback mechanisms by use case described by participants.

and feedback mechanisms that led to or dissuaded them from incorporation of innovative teaching practices and EBIPs. Although this study aimed to attend to individual experiences, general patterns regarding motives/deterrents, constraints, and feedback mechanisms related to EBIP adoption across the four adoption cases are summarized in Fig. 1. Both convergence and dissonance in participants' experiences are noted here, however, the authors caution against drawing generalized conclusions among ECE faculty given the rich context-based settings and experiences described by them.

Faculty participants described various beliefs and pressures that encouraged or discouraged their exploration and uptake of EBIPs. Unsurprisingly, intrinsic and extrinsic *deterrents* were common among the *No use* and *Discontinued use* cases, as these led participants to cease using EBIPs or refrain from trying new approaches entirely. When examining the overall process of transitioning from refraining from trying course modifications to continued use, it is evident that faculty may experience "barriers to entry" that discourage them from trying something new in the first place (Fig. 1). The concept of entry barriers has origins in economics literature for describing negotiation behaviors in response to perceived imprecise or inflexible pricing associated with goods, services, or property [58]. In the case of faculty negotiating course modifications, the participants in this study were unlikely to elect potential changes when deterrents combined with limiting constraints led to lacking incentives to make changes, held imprecise definitions of EBIPs and uncertainty related to configuring and evaluating them in their specific contexts, and fear that of bad outcomes like negative student reactions or losing control of the classroom. Further, when courses were seen as already working adequately, there was little incentive for participants to explore making changes, despite acknowledging their preference to do so.

In contrast, the *Discontinued use* and *In development use* cases were marked by participants' willingness to overcome such barriers to entry so that they could enter a period of experimentation with changing their courses or maintenance of previous modifications (Fig. 1). In these cases, participants were sufficiently motivated to try and maintain course changes when they were driven by innate interest, desire to make course improvements, or experiences of fluctuations that forced adaptations like modality changes or advancements in technology. All participants acknowledged that adjusting their courses was challenging and described significant efforts made to explore options, organize implementation, and respond to their changes in class. However, unlike the *No use* case, participants were not fully dissuaded by internal uncertainty or anxiety around doing so. Once they tried something new in their courses, flexibility within constraints and characteristics of feedback mechanisms played an important role in their decision making around abandoning their modifications or not.

In the case of *Discontinued use*, restrictive constraints and negative feedback mechanisms tended to discourage course modifications. Participants attributed failures to their perceived personal deficiencies like lacking sufficient teaching experience. They also faced difficulty in configuring course modifications particularly in lower-level courses, which may have confirmed perceptions that would otherwise convince them to refrain from trying something new (e.g., losing control or disrupting the course). These constraints were then exacerbated by negative, and often formative, feedback mechanisms such as personal discontent with their efforts, and student-focused observations of frustration and confusion, direct indications of their dislike of the instructional approach, and resistance to what they saw as nontraditional engineering instruction methods.

The *In development* case was similarly marked by experiences with roadblocks during periods of experimentation that required course reconfiguration, but these were countered with adaptable constraints and positive feedback that ultimately led to a cycle of continued pursuit of a desired change. The *In development* case described in this study was characterized by a combination of the participant's innate interest in his course material that was met with pressure to keep up with rapidly changing technology. These motives were then scaffolded by institutional funds, buy-in from enthusiastic upper-level students, and development of confidence in instructional risk-taking. When iterating on his course changes, the participant experienced improvements to managing teaching with personal childcare responsibilities and noted increased student participation. This positive combination of motives and feedback encouraged the participant to actively address constraints through modifying his course schedule (i.e., adding more time for hands-on instruction), capping course enrollment to meet equipment limitations, and identifying and securing funding to support technology needs through his large, research-focused institution. Notably, these changes were made possible because of the participant's perceived and real autonomy over his course, as well as access to institutional support through funding mechanisms and encouragement from peers.

Finally, the *Continued use* case reflected a maintenance phase of course modifications that were made in reaction extrinsic motivations that aligned with her individual beliefs and values. Her changes also culminated in her constraints being adequately addressed. For example, her use of an e-textbook made grading more efficient and provided additional learning support to students. Similar to the *In development* case, this participants' experience with maintaining course adaptations was strengthened by autonomy and flexibility both in and outside of her classroom. Further, while the participant received a variety of formative and summative feedback, much of her interpretation of feedback was focused less on accommodating student preferences or negotiating buy-in, but rather focused on overall unity, happiness, and class atmosphere that were improved by her course modifications.

IV. Conclusion and Future Work

Although the study sample is limited to six participants, this work aimed to build understanding of context-based variation in faculty members' decision making around adopting EBIPs. As such, the use of qualitative inquiry provided rich, contextual insights to identify similarities and nuances across the faculty participants. Further, the participants included in this study represented only two racial and ethnic backgrounds, leading to a gap in understanding of broader perspectives of engineering faculty who do not come from those backgrounds. Most ($n = 4$) faculty were based within teaching-focused universities, while only two were from research-intensive institutions. As such, future research might examine the influence of research responsibilities on context-based decision making around instruction and examine faculty from diverse demographic and institutional backgrounds. Additionally, the nature of this study means that participants may have had a preexisting, underlying interest in trying new things. Future research might examine the beliefs, attitudes, values, and resulting instructional practices of those engineering faculty who are resistant to or uninterested in incorporating EBIPs in their courses.

Implementation of EBIPs varied substantially among participants, reinforcing the challenge of one-size-fits-all solutions for improving adoption of innovative teaching practices. Across each EBIP adoption case, faculty described a range of driving motives and deterrents, constraints, and feedback mechanisms that led to their decisions around using EBIPs. This complex interplay of influencing factors points to the ways in which faculty decisions work like a system, with pressures, boundaries, and responses leading to status changes or equilibrium. Based on findings from this study, it is evident that contextual influences drive effective and adaptive incorporation of EBIPs in ECE courses. These findings highlight the importance of avoiding overly prescriptive or generic applications of EBIPs, given the wide range of factors that may influence how and why faculty decide to try EBIPs, endure challenging experiences with them, and successfully create course modifications that work well for their context. Further, our findings illustrate how complex the process for course changes can be for individual faculty members.

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