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Are All 'EBIPs' Created Equal? An Exploration of Engineering Faculty Adoption of Nine Evidence-Based Instructional Practices

Dr. Amy L Brooks, Oregon State University

Dr. Amy Brooks is a Postdoctoral Scholar at the Oregon State University School of Civil and Construction Engineering and member of the Beyond Professional Identity lab at Harding University. Her current research is using interpretative phenomenological analysis to understand well-being and experiences with professional shame among engineering faculty. She is also part of a research team investigating context-specific affordances and barriers faculty face when adopting evidence-based instructional practices in their engineering courses. Amy's research interests meet at the intersection of sustainable and resilient infrastructure, emotions in engineering, and engineering identity formation.

Jeff Knowles

Dr. Jeff Knowles is an engineering instructor at Oregon State University who began teaching courses in 2015. His current pedagogical research is related to barriers associated with implementing Evidence-Based Instructional Practices (EBIPs) in STEM-related courses and determining what affordances can be granted to overcome such contextual obstacles. Jeff's interests also include the numerical modeling of nonlinear wave phenomena.

Elliott Clement, Oregon State University

Elliott Clement is a doctoral student at Oregon State University. His current research is using grounded theory to understand identity and motivation within the context of capstone design courses. He is also part of a research team investigating context-specific affordances and barriers faculty face when adopting evidence-based instructional practices in their engineering courses.

Dr. Prateek Shekhar, New Jersey Institute of Technology

Prateek Shekhar is an Assistant Professor - Engineering Education division at New Jersey Institute of Technology. His research is focused on examining translation of engineering education research in practice, assessment and evaluation of dissemination initiatives and educational programs in engineering disciplines. He holds a Ph.D. in Mechanical Engineering from the University of Texas at Austin, M.S. in Electrical Engineering from University of Southern California and B.S. in Electronics and Communication Engineering from India.

Dr. Shane A. Brown, P.E., Oregon State University

Shane Brown is an associate professor and Associate School Head in the School of Civil and Environmental Engineering at Oregon State University. His research interests include conceptual change and situated cognition. He received the NSF CAREER award in

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Abstract

It is well-established that evidence-based instructional practices (EBIPs) can improve student learning and success in the classroom. Previous research has highlighted a substantial gap between awareness of EBIPs among engineering faculty and their consequent adoption in their courses. Several broad barriers and affordances have been identified by past studies, but there is growing recognition of context-specific influences on engineering faculty's decision to pursue and persist with integrating EBIPs in their courses. As part of a larger, ongoing study examining context-based influences on engineering faculty adoption of EBIPs, the present study is guided by the overarching exploratory research question: How do barriers and affordances to adoption of EBIPs by engineering faculty vary between EBIP types? To address this research question and provide contextual insight into variation of adoption approaches between EBIPs, we analyzed open-ended survey responses from engineering faculty participants who described specific challenges related to nine EBIP types including active learning, case-based teaching, collaborative learning, concept tests, cooperative learning, inquiry learning, just-in-time teaching, peer instruction, and problem-based learning. We report situational and individual patterns identified for each EBIP type and provide a cross-case analysis exhibiting how the patterns vary across them to inform a larger effort to address contextual challenges to EBIP adoption and develop solutions which may be modified to satisfy requirements on a classroom-by-classroom basis.

Introduction

Evidence-based instructional practices such as active, problem-based, and case-based learning have widely been shown to improve student learning and success in the classroom. Previous research has found that most engineering faculty have some knowledge or awareness of EBIPs and the benefits of using them in their courses. However, uptake of EBIPs in engineering courses is lagging among engineering faculty, with fewer faculty members reporting the consistent incorporation of these instructional methods in their classrooms. Research has pinpointed challenges to adopting EBIPs in engineering courses such as the perception of lacking evidence to support using instructional practices, requiring too much time to prepare or implement in class, negative reactions from students, or scarce institutional resources or support. While these are common barriers tied to engaging non-traditional forms of pedagogy, a thorough investigation of the challenges frequently associated with individual EBIPs is a distinguishing factor that warrants further exploration within the engineering education setting. To this end, the present study is guided by the overarching exploratory research question that aims to inform faculty decision-making around EBIP adoption: *How do barriers and affordances to adoption of EBIPs by engineering faculty vary between EBIP types?*

Adoption of EBIPs in engineering education

EBIPs, sometimes referred to as research-based instructional strategies (RBIS), are approaches to educational instruction that have empirically and theoretically been demonstrated to promote conceptual understanding and improve student learning outcomes [1]. In engineering education, EBIPs are commonly used, however, some techniques have historically garnered more interest and attention in the engineering education domain. There is an abundance of research demonstrating the utility and effectiveness of EBIPs and their useful applications in engineering domains. However, rates of adoption of EBIPs in engineering courses lag behind faculty members' awareness of them [2].

Several factors can lead to decreased uptake of EBIPs including both situational and individual influences. Situational barriers include lack of pedagogical training, perceived time for effective implementation, and institutional support and incentives [3]. For example, there can be situational barriers like disciplinary differences or institutional influences that promote or discourage the use of EBIPs in science, technology, engineering, and mathematics (STEM) courses [1, 4]. Further, engineering faculty have reported concern about the time required for both preparation and implementing EBIPs in class. In contrast, individual barriers include instructional beliefs, values, goals, self-efficacy, motivations, and awareness [4, 5]. For one, many educational theories and research studies can be perplexing or inaccessible to the typical engineering educator who may have technical background in their own engineering discipline but less fluency in educational research [6]. Further, beliefs can play a substantial role in decision-making around instruction. For example, faculty beliefs about sustainability can influence their level of integration of sustainability topics into their courses [7]. Taken together, situational and individual influence lead to context-specific barriers among engineering faculty including individual challenges with adapting EBIPs to engineering topics in their courses, keeping up with rapidly changing technologies and institutional demands, and pressure to sacrifice time used for teaching preparation and innovation for both professional and personal needs [8].

Given the variation in EBIP approaches, situational influences, and individual needs, it stands that barriers to adoption likely vary from EBIP to EBIP. In one recent study by Gardner, et al. [9], over 80% of STEM faculty participants demonstrated awareness of PBL, followed by 68% for collaborative learning, and 58% for inquiry learning. In contrast, only about 45% of participants indicated awareness of concept mapping and only 24% knew about just-in-time teaching. Like awareness, uptake of these methods varied as well, with the highest EBIP use (60% of participants) seen in collaborative learning, 55% in inquiry learning, and only 53% in PBL despite high awareness of the practice. To strengthen efforts to bridge the gap between EBIPs and their uptake in engineering education, more research is needed to understand context-specific barriers and affordances that are relevant to the features of individual EBIPs. To this end, the present study is guided by the overarching exploratory research question: How do barriers and affordances to adoption of EBIPs by engineering faculty vary between EBIP types?

Summary of data collection and analysis

The present study reports on findings from an ongoing broader study investigating faculty adoption of EBIPs in engineering classrooms [8]. To address our research question aimed at generating contextual insight into variation of adoption approaches between EBIPs, we distributed an online survey to engineering faculty members across the USA that was administered between April and June 2022. The survey was administered online via Qualtrics.

Our recruitment strategy included snowball sampling which is a convenience sampling approach that utilizes researchers' social networks to recruit participants based on "specific characteristics or membership of a group" [10, p. 4]. In this case, we sought respondents who were engineering faculty members by first identifying programs throughout the USA that offered degrees in engineering or engineering technology based on listings in the 2021 American Society of Engineering Education Engineering & Engineering Technology by the Numbers report [11]. After identifying institutions, we searched their departmental websites to find administrators and staff to whom we could request to send the survey link to faculty in their respective departments. While we do not know the final number of people who received the survey link, we originally targeted five hundred survey respondents to reach potential participants for a later phase of the project, ultimately garnering four hundred responses to the survey.

The survey was adapted from existing research in EBIP adoption among engineering faculty and gathered information about respondent demographics, teaching practice and experience with EBIPs, and interest in participating in future research activities [12]. For the present study, we focused on a portion of the survey comprising open-ended survey responses from engineering faculty describing challenges associated with their experiences or perceived hesitation around adopting nine different EBIPs into their engineering courses including active learning, case-based teaching, collaborative learning, concept tests, cooperative learning, inquiry learning, just-in-time teaching, peer instruction, and problem-based learning. For each of these EBIPs, we provided a brief description (summarized in Table 1) and a textbox for the participants to describe factors that might influence their adoption of each EBIP into their courses. For example, after providing the EBIP definition, we prompted respondents with the following: "If applicable, please describe factors that have or could prevent you from adopting [EBIP (e.g., active learning)]." This question was repeated for each of the nine EBIPs and we specified that respondents could leave the question blank. Of the four hundred responses to the survey, 149 respondents answered at least one open-ended question regarding their use of EBIPs. The number of responses to each EBIP question ranged from forty responses about peer instruction to eighty-seven responses about active learning resulting in a data corpus of 10,952 words and a total of 506 coded comments (Table 1).

To reach a purposefully diverse group of survey participants, we used maximum variation sampling, which aims to support collection of data from a wide range of perspectives [13]. We had a large response pool from a broad variety of institutions, disciplines, and individuals, allowing for our results to be useful to a broad set of educational contexts. Respondents' teaching background spanned several engineering disciplines including civil, mechanical, computer, biomedical, chemical, industrial, electrical, aerospace, and multi-disciplinary backgrounds. Most respondents were from Doctoral/Professional Universities (D/PU), and minority-serving institutions (MSIs) represented 18% of those in the sample. Further, most respondents were in early-career, tenured positions, or instructor/lecturer positions (Table 2). Demographically, 52% of respondents identified as male, followed by 42% female, and 2.0% did not specify. Further, 59% of respondents were Caucasian, 15% were Asian, 7.4% did not specify, 5.4% were Black or African American, 5.4% were multiracial, 4.7% were Hispanic or Latinx, and 2.7% were Middle Eastern or Arab American.

The response data were initially analyzed thematically using an inductive approach treating each EBIP as an unique case. First cycle coding methods comprised initial coding through descriptive and process codes that inventoried challenges mentioned by participants such as finding resources, navigating course modality, assessing uneven student performance, etc. Second cycle coding methods comprised of focused codes that informed the development of salient barriers to adoption of EBIPs described by the participants. Codes were ultimately reduced to themes that illuminated variation in descriptions of barriers that are relevant to the features of each of the nine EBIPs. Lastly, themes were organized into individual and situational barriers for easier interpretation. Because there were several commonalities and emergent differences leading to varied adoption of each EBIPs, we performed cross-case synthesis [15] to compare the emergent barriers to adoption across all EBIPs.

Table 1. Definitions of EBIPs from Borrego, et al. [14] and number of corresponding responses to open-ended survey questions

EBIP	Description	No. responses
Active learning	A general term describing anything course-related that all students in a class session are called upon to do other than simply watching, listening, and taking notes.	87
Case-based teaching	Asking students to analyze case studies of historical or hypothetical situations that involve solving problems and/or making decisions.	65
Collaborative learning	Asking students to work together in small groups toward a common goal.	65
Concept tests	Asking multiple-choice conceptual questions with distracters (incorrect responses) that reflect common student misconceptions.	50
Cooperative learning	A structured form of group work where students pursue common goals while being assessed individually.	42
Inquiry learning	Introducing a lesson by presenting students with questions, problems or a set of observations and using this to drive the desired learning.	44
Just-in-time teaching	Asking students to individually complete homework assignments a few hours before class, reading their answers before class and adjusting the lessons accordingly.	55
Peer instruction	A specific way of using concept tests in which the instructor poses a conceptual question in class and shares the distribution of responses with the class. Students form pairs, discuss their answers, and then vote again.	40
Problem-based learning	Acting primarily as a facilitator and placing students in self-directed teams to solve open-ended problems that require significant learning of new course material.	58
Total		**506**

Table 2. Academic and institutional background of respondents

Academic and institutional background	n	%
Institution region		
Southeast	40	27
Pacific	30	20
Southwest	24	16
Northeast	20	13
Midwest	18	12
Rocky Mountains	12	8.1
Not specified	5	3.4
Institution type		
Doctoral/Professional University (e.g., R1, R2)	100	58
Undergraduate/teaching-focused	37	19
Not specified	5	3.4
Associate's College	2	5.4
Other	2	4.0
Minority-serving institutions	18	12
Hispanic Serving Institution	12	8.1
Asian American Native American Pacific Islander-Serving Institution	4	2.7
Historically Black College or University	2	1.3
Academic rank		
Assistant professor	42	28
Instructor/lecturer	36	24
Associate professor	35	23
Other	20	13
Full professor	11	7.4
Not specified	5	3.4

Results and discussion

The results are organized to demonstrate patterns reflected in participants' descriptions of situational and individual barriers to faculty adoption of nine different EBIPs. Salient situational barriers included logistical challenges, difficult student dynamics, navigating institutional and classroom environments, and adapting EBIPs to specific course contexts. In contrast, individual barriers included past experiences and knowledge, developing effective activities, and confusion around assessing and grading with EBIPs. Not surprisingly, participants frequently described common barriers to adoption of EBIPs throughout their responses to the open-ended survey questions such as time management, student resistance, and familiarity, but the prevalence of these barriers were notably varied across the different EBIP types.

Situational barrier #1: Logistical challenges

Among the situational barriers, common logistical challenges included class size/enrollment, course modality, and class duration. Class sizes were mentioned as a barrier to implementation across all nine of the EBIPs. Consensus among participants was that EBIPs were too difficult to facilitate in courses with large enrollment without support, particularly when it came to grading individual student performance. However, some respondents emphasized that technology like personal-responses systems ('clickers') can potentially offset some of the difficulties with efficiently assessing individual students. Similarly, concerns about modality were particularly prevalent among active learning and interaction-based approaches like collaborative learning, cooperative learning, and peer instruction. Conducting these approaches were described as *'awkward,' 'challenging,'* and *'extremely difficult'* due to experiences with encouraging and monitoring student participation amid reluctance. Unsurprisingly, several participants attributed these challenges to their experiences with adapting course modality to accommodate educational impacts from COVID-19, highlighting the need for developing and adapting EBIPs to fit virtual environments. Although online and hybrid modalities may present challenges to faculty, some studies have demonstrated that these environments can be harnessed to conduct engaging learning experiences and contribute to improved conceptual understanding through virtual laboratories and experimentation [16, 17].

Additionally, participants discussed class duration often in conjunction with concern about sacrificing time to implement EBIPs at the cost of covering enough material. This concern appeared among most of the EBIPs but was especially prevalent among responses discussing active learning. For example, one assistant professor respondent highlighted the perceived risk around not fulfilling material coverage expected of them: *"Preparing active learning activities takes a lot of time and it's often not clear how much class time they will take up, or if they will be effective. As a new faculty member, I am somewhat hesitant to use active learning strategies because I need to make sure I cover the required material, and it feels risky to try new things."* This concern highlights some of the pragmatic considerations of faculty who must balance the risk of innovation in their courses with meeting the demands of institutional requirements. For many, there is pressure to cover as much material as possible, and traditional lectures are the easiest path to do so. This presents a dilemma wherein faculty must choose to either sacrifice student learning for increased coverage or sacrifice coverage for improved learning outcomes [18]. These dilemmas illustrate the nuances of adopting EBIPs. Faculty may have awareness that these strategies work, at least 'on paper,' however, the surrounding pressures can generate uncertainty around whether it is effective to invest the effort to do so. This unease was highly evident in responses to JITT, with many faculty expressing distress over scheduling challenges for themselves and their students. These concerns were particularly relevant for early morning classes, with one participant responding to JITT with the following: *"I teach many 8:30 am classes. It's already a struggle for students to make it to class that early, let alone complete homework a few hours before."* The combination of the short turnaround logistical challenge and the struggle with students shows how interconnected and nuanced barriers to adoption can be.

Situational barrier #2: Difficult student dynamics

Along with logistical pressures on students, difficult student dynamics involved managing uneven student performance and securing buy in among student resistance. Uneven performance was particularly prevalent among collaborative and cooperative learning, with several references to group challenges with students *'slacking off'* and being *'free riders'* as well as *'one student doing all the work'* and *'dominating*' teams. In other words, faculty participants expressed challenges with managing group dynamics and student relationships that consumed time otherwise needed for coursework and inconsistent outcomes for students based on their roles in their assigned groups. According to one participant describing challenges to collaborative learning:

> *"Group dynamics are always challenging, and a significant amount of time is spent with "relationship" work, and managing the collaboration, rather than with the assigned coursework. Many of the challenges faced by student groups are difficult to resolve in the time constraint of a single semester. For some student groups, they are never able to resolve these difficulties, and leave the course with a sub-optimal experience; either they performed a greater amount of work than their peers, and had to "carry" the group, or at times they were unable to fully participate because another peer dominated the work, and thus they were unable to learn the material as deeply."*

While group work created relational pressures among students, many faculty also attributed student resistance to group work as a barrier, particularly when students *"don't feel like they're learning if the faculty member isn't lecturing."* Similarly, in a discussion on inquiry learning, one faculty member noted that students *"tend to act like passive observers of information and seem to want to be on the receiving end of a transference model of education."* With a perceived preference for traditional lectures, the resistance to innovative or active participation strategies like group work can be discouraging and pressure faculty to negotiate student buy-in. Researchers have noted that students may not fully engage based on their perceptions of engineering classrooms environments to be lecture-based [19]. In discussions about implementing active learning strategies, participants focused on pervasive negative attitudes observed among students in the form of *'disinterest'* and acting *'too-cool-for-school,'* which was met with concern that students might misinterpret faculty efforts as *'treating them like children.'* Navigating the balance between desire to innovate in their classrooms met with negative student responses was commonly mentioned in relation to collaborative, cooperative, and problem-based learning, largely in the context of student opposition to group work and interacting with their peers. One recent study comparing anxiety among different instructional practices found that those that employ interpersonal strategies such as group quizzes, think-pair-share, and group activities caused greater anxiety among community college students in comparison to individual work and personal response systems, and that students perceived little benefit associated between the anxiety they felt and the learning outcomes of the activities [20].

Situational barrier #3: Institutional and classroom environments

Institutional environments and resources played a role in faculty participants' uptake of EBIPs through provision of funds, assistance, and incentives. Both funds and teaching assistance were used to incorporate active learning strategies in engineering courses, with the cost of tools and materials highlighted as a financial constraint. While cost burdens faced by students to adopt tools for classes were not discussed by participants (likely due to the focus on their own barriers as faculty), one respondent highlighted inconsistent Internet access for some students, which was seen as a limitation to implementing home-based activities associated with JITT. Teaching assistance and support were similarly discussed in conjunction with course sizes, with many faculty suggesting that they could more easily implement active learning exercises in their large classes with the help of institutional support. One faculty from an undergraduate/teaching focused university described isolation in trying to innovate in their classroom: "*It's exhausting* *being one of the main people doing active learning. While my colleagues are not actively hostile, I feel like many are resistant to implementing active learning."* Along with lacking support, some participants pointed to lacking incentives for implementing EBIPs in their courses. For example, one respondent's attempt to integrate inquiry learning in a large class was met with being *"told in the review process that it wasn't valuable."* Despite faculty members' care and dedication to innovate in their classes [21], higher education cultures often fail to value, support, and reward effective pedagogy in comparison to the levels of recognition and endorsement that faculty receive for research productivity. Anderson, et al. [22] suggested seven outlets for countering this imbalance including faculty education on instructional research, generating rewards and research support for outstanding teachers, requiring excellence in teaching for promotion, creating teaching discussion groups (i.e., community), creating cross-disciplinary programming, supporting effective science teaching, and engaging with departmental and institutional leadership. While most of the participants focused on specific barriers to each EBIP, few alluded to having adequate support or encouragement toward innovation in their classrooms.

In addition to institutional environment, participants also navigated barriers to adopting EBIPs in the context of their specific courses. For many, adapting EBIPs to traditional math, physics, and engineering topics seemed tenuous, particularly for case-based teaching and active, inquiry, and problem-based learning. For example, one participant noted, *"I'm not convinced that it applies to the core math and physics courses that I teach"* in relation to inquiry learning, which presents problems and questions to students prior to conceptualization. Many respondents alluded to having an easier time adapting activities to upper- and graduate level courses that have a design focus and/or smaller enrollment. One participant described PBL as "*more useful for more applied courses like Machine Design than fundamentals,"* where students have demonstrated adequate background in core classes that have prepared them for more advanced studies. Self-efficacy, which derives from mastery experiences, social persuasion, vicarious experiences, and physiological states [23], can increase over time among engineering students [24] and contribute to student openness to active learning [25], leading to improved engineering competency and ability to cope with challenging learning situations. As such, faculty may perceive that experienced engineering students in upper level and/or graduate courses have greater self-efficacy and therefore a greater tolerance for non-traditional learning approaches, which could lead to less pressure to convince and secure student buy-in.

Individual barrier #1: Past experiences and knowledge

Participant understanding of what EBIPs are and how to implement them in their courses varied between EBIP types. Participant described general confusion over the concepts, uncertainty around alignment with the EBIP definitions and their own approaches, discerning between EBIPs, and doubt around what material to use to meet the needs of EBIPs. While the degree of understanding varied across all the EBIPs, inquiry learning seemed to be the most challenging EBIP to interpret. Some respondents indicated *"vague understanding"* and simply did not know how to do it. Several others suspected their current strategies might be considered inquiry learning but did not know how to evaluate as such. For example, one participant stated, *"I formulate a lot of questions for organizing class discussions after I introduce the materials, not sure whether those could be part of inquiry learning."* Similarly, some respondents noted that they were unable to discern between some of the EBIPs. One respondent stated, *"I don't think I* *fully understand the nuances of how collaborative and cooperative learning are different,"* while another lamented that collaborative learning "*...sounds like engineering education jargon. What is the difference between this and active learning strategies?"* These descriptions of uncertainty allude to the impact that faculty members' fluency of EBIP terminology, concepts, and application scenarios may have regarding when and how they choose to incorporate them. Literature on fidelity of implementation of EBIPs suggests that there are critical structural and process components that influence their effective application [26], and faculty's enactment of EBIPs may differ from the way EBIPs are disseminated in faculty development efforts [27]. Further, there is evidence that fidelity varies across EBIPs. For example, Borrego, et al. [14] found high rates of fidelity among JITT, case-based teaching, and inquiry learning, while peer instruction and concept tests suffered from conceptual misinterpretations.

For PBL and case-based teaching, few faculty exhibited conceptual confusion, however, uncertainty among these EBIPs revolved around faculty's personal knowledge and expertise. Participants discussed their own lack of existing knowledge of scenarios and problems that would be useful for these EBIPs, citing real-world experience as a necessity for adopting those strategies: "*Any faculty who have zero previous industry experience or lacking applied research might find the problem-based learning difficult to implement."* Content and pedagogical knowledge are considered structural-educative components of fidelity of implementation based on the conceptual framework developed by Century, et al. [28], and professional development and training are key interventions to strengthening them.

Individual barrier #2: Developing effective strategies

Time consuming preparation associated with EBIPs was ubiquitous among the distinct types in this study. While many participants simply acknowledged the reality associated the effort needed to design new courses and/or reconfigure established ones, several respondents also pointed to concern over time spent finding material that was *'good'* or *'appropriate'* enough for EBIP application. For concept tests and peer instruction, respondents described difficulty with finding questions and generating reasonable distractors. Turpen, et al. [29] similarly found that barriers to adopting peer instruction included difficulty finding good questions among physics faculty. Likewise, for case-based teaching and problem-based learning, participants described difficulties accessing cases and problems that were relevant, realistic, and comprehensive enough. While finding appropriate material was one salient step toward adopting EBIPs, the ability to assess EBIPs was a frequent question among participants. There were several instances of uncertainty related to fidelity of implementation and ability to assess effectiveness across EBIP types. Capturing many of the challenges faced by faculty when it comes to developing EBIP-related activities, one participant listed the following as key barriers: *"Coming up with effective ideals, time to develop the activity, not sure if I am doing it correctly, and desire a clear way to access effectiveness of active learning activity compared to traditional approach it replaces."* Lack of time is one of the most perceived barriers to adopting EBIPs in STEM, however Dancy and Henderson [21] suggest that feelings of frustration, confusion, and uncertainty around innovations may underly this perception.

These feelings were apparent in descriptions about preparing activities for class. Respondents reported difficulty in knowing how to assess student performance as part of several EBIPs. Like the situational barriers associated with uneven performance in collaborative and cooperative learning, the ability for faculty to distinguish *"which student learned what"* led to discomfort with not being able to guarantee equitable grading. Further, although it was only mentioned by one faculty respondent, case-based teaching often does not *"come with assessment"* specific to the case used, suggesting that some EBIPs could be more easily adopted with predetermined assessment tools. Grading and student assessment were similarly reported as a resource barrier to EBIP adoption by Sansom, et al. [5], who noted that faculty described how assessment materials aligned with EBIPs were lacking, which led to the perception that grading EBIPs would take more time. Unsurprisingly, time was a consistent hurdle for faculty decision-making around developing and incorporating EBIPs in their classroom. All EBIPs in this study were associated requiring substantial time and effort among the faculty respondents. Overcoming time challenges appeared feasible for only new courses that had not yet been developed, as several participants expressed weariness over reconfiguring an established course. For one participant, active learning *"requires thinking outside the box,"* which stood in contrast to traditional approaches that provide the *"path of least resistance."* Time is a well-established barrier to EBIP adoption and many strategies for intervention include prescriptive changes for individuals that make EBIPs easy to incorporate into courses [30]. For example, Montfort, et al. [31] found that faculty were likely to adopt an assessment instrument in a senior capstone course based on compatibility of the tool with their own values and goals. While compatibility does not directly address time constraints, it may reduce the magnitude of how challenging EBIPs are perceived by engineering faculty.

Cross-case comparison and takeaways

Through cross-case comparison summarized in Table 3, we found that logistical challenges, familiarity, and developing activities for courses were commonly seen across all of them EBIPs in the analysis and may provide insight to faculty regarding which EBIPs may or may not be appropriate for their unique context. There was ubiquitous concern across all nine EBIPs that related to challenges with facilitating them in large courses, ensuring that EBIPs did not consume time needed to sufficiently cover required material, lacking training and familiarity with EBIPs, and managing the perceived time demands needed to prepare EBIP integration into their courses. Notably, these challenges may be addressed through boosting faculty resources at the institutional level. Numerous studies have highlighted the role that institutional resources can play in encouraging faculty adoption of EBIPs. For example, Brent, et al. [32] offered the SUCCEED faculty development model that includes multiple features such as a faculty development coordinator, campus-wide faculty development programs, learning and networking opportunities, programs for new faculty and graduate students, and institutional incentives. Taken together, these efforts could target the common concerns seen among the nine EBIPs in this study through facilitation, coordination, and education that can reduce the time and effort needed to investigate and adapt EBIPs to course contexts and provide more structured opportunities for learning about EBIPs and best practices.

Beyond these common concerns, however, challenges related to adoption of these EBIPs diverged, with some barriers to adoption limited to only one or two EBIPs. For example, JITT was the only EBIP in which class scheduling was a resounding concern. If a class is scheduled early in the morning or it is known that students in the class have substantial extracurricular demands, faculty might consider that JITT could be a poor fit for their scheduling context. Likewise, some EBIPs had limited flexibility in terms of dependence on students' topical knowledge, suggesting that EBIPs like peer instruction and PBL, which rely on students' existing understanding, may not be appropriate for first year courses or modules that occur early in the semester. Similarly, participants alluded to greater institutional support and incentives among only three EBIPs: active learning, inquiry learning, and PBL. Further investigation is needed to understand this variation, particularly at the individual scale; however, one explanation may be simply that some EBIPs have greater perceived value at the institutional level due to higher visibility in educational literature and resources. By building understanding around contextual affordances and barriers to EBIP adoption, we can inform concrete steps that may be taken by institutions and individuals that improve faculty access to resources and their understanding of EBIPs, facilitate transitioning to using them in their courses, and reward efforts for innovation.

Table 3. Cross-case comparison of common themes across all EBIPs

	EBIPs*								
Situational barriers	AL	CBT	CLL	CT	COL	IL	JIT	PI	PBL
Logistics									
Configuring online modality	X		X		X			X	
Large courses	X	X	X	X	X	X	X	X	X
Class duration	X	X	X	X	X	X	X	X	X
Class schedule							X		
Student dynamics									
Uneven performance			X	X					
Resistance and buy-in	X							X	
Open-ended problem struggles						X			X
Institutional and classroom environments									
Funds, assistance, and rewards	X					X			X
Student background and level								X	X
Adapting EBIPs to course contexts	X	X				X			X
Individual barriers									
Experience and expertise									
Topical knowledge		X							X
Fluency and understanding of EBIPs	X		X		X	X			
Need for more training	X	X	X	X	X	X	X	X	X
Developing effective activities									
Identifying quality material		X		X				X	X
Confusion with grading and assessment			X		X		X		X
Managing time	X	X	X	X	X	X	X	X	X

*AL = Active learning; CBT = Case-based teaching; CLL = Collaborative learning; CT = Concept tests; COL = Cooperative learning; IL = Inquiry learning; JIT = Just-in-time teaching; PI = Peer instruction; PBL = Problem-based learning

Conclusion and next steps

This study aimed to investigate variation in affordances and barriers to adopting student-centered teaching practices across nine EBIP types. Despite several past and ongoing investigations into the gap between faculty awareness and uptake of EBIPs, the reluctance and hesitation around doing so persists among engineering educators and higher education in general. Driven by the abundance of evidence demonstrating the positive impacts student-centered learning strategies have on learning outcomes, incorporating EBIPs into engineering courses may seem deceptively easy to do. In reality, there are myriad combinations of contextual and individual barriers that may influence whether full, partial, or mixed adoption of EBIPs are feasible in a given classroom, if at all.

While the findings reported here provide initial insight into faculty members' experiences and perceptions of adopting various EBIPs in their courses, there are some limitations to this study. Primarily, the nature of the response data to the open-ended online survey meant that respondents' answers were not exhaustive and so more detailed examination of variation in EBIP incorporation is needed. As a qualitative study, we caution drawing generalizations regarding faculty decision-making regarding EBIP adoption, but rather seek to contribute further knowledge around contextual influences that may promote or discourage integration of EBIPs into engineering courses. To improve understanding of context-specific experiences and perceptions of faculty, future research should expand on qualitative data collection through interviews and observations which can yield rich experiential insights. For example, Borrego, et al. [19] reported that student focus groups provided access to in depth understanding of engineering students' attitudes around and resistance to nontraditional teaching methods that were otherwise less directly measured through surveys. To this end, future efforts of this ongoing research project include collection of in-depth qualitative data from a subset of participants through observation and/or interviews that will seek to gain descriptive, experiential insight into individual and interpersonal processes toward implementing EBIPs into engineering courses. Additionally, the project will generate longitudinal data through working with faculty participants over the course of a class term in order to gain understanding of fluctuating demands and needs that may influence class activities and assignments throughout the term.

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