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Early Career Engineering Instructors' Perceptions and Practices Regarding Equity While Adapting an Instructional System: A Dual Case Study

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Abstract

When adopting an instructional system, instructors need to consider several factors during its adaptation, including both instructional resources and practices. During its implementation, the system must be adaptable enough to meet students' needs for successful learning, including the learning environment and issues of equity and inclusion. Instructors play a critical role in deciding how to meet the diverse needs of students in engineering courses based upon their knowledge of the student population, learning goals, and institutional culture. Researchers advocate for advancements in Diversity, Equity, and Inclusion (DEI) principles in engineering education, urging us to make education more equitable and inclusive. For that reason, discussions surrounding equity and inclusion during the implementation process of an instructional system could offer valuable insights into instructor decision-making and perceived limits to the system's adaptability for equity and inclusion. In this research, we present two instructional system adoption cases in order to describe and explain the nuances of how instructors think about equity and apply the principles to promote equity in teaching while adapting an instructional system. We focus on how themes of equity emerged naturally in a set of interviews with instructors about their process of adaptation in which the interview protocol did not specifically focus on equity-oriented decisions. The data consisted of 14 interviews with two instructors, followed by in vivo coding and thematic analysis. Both instructors saw equity as central to their decisions around instructional system adaptation across three main categories: decisions that were (i) directly about adopting the instructional system, (ii) nested between adopting the system and their usual instructional approaches, and (iii) independent from the adopted system. Across these categories, both instructors prioritized equity

in support of student outcomes. In category (i), Prof. Morris's concern focused on how to ensure the contexts of practice problems in the system's textbook were relevant to the lived experiences of diverse students in her classroom. Prof. Reed aimed to accommodate students' needs and leveraged the (blended) instructional resources to offer asynchronous review sessions so that commuter students could access the sessions (category ii). The practices independent from the instructional system (category iii) included typical decisions on content coverage and timing/format of office hours. This study's findings and implications would interest professional development designers, instructional system developers, and researchers who examine ways to promote the adoption of instructional innovations in light of instructors' commitments to and practices about equity in engineering classrooms.

Introduction

The adaptability of instructional systems for classroom implementation requires instructors to make many decisions about using the system's resources, making content adjustments based on student readiness, and addressing diverse learner needs (Birt et al., 2019; Walden et al., 2018) Adaptations to instructional systems can include adjusting the sequencing or scope of the content, adding new authors to highlight different disciplinary or personal perspectives, modifying textbooks and guidebooks to address specific needs, augmenting videos to add detail, introducing new formats (like a discussion board), all in the service of fitting the needs of the instructors and students. One element that must be considered when adapting pedagogical systems and tools is their ability to make it inclusive and equitable to students. We refer to equity in providing equal opportunity to students in diverse populations to benefit from the instructional system. What suits one group may not suit another, necessitating specific modifications for different populations. Adapting instructional systems requires modifying elements that can generally fit some populations but must be tailored for others (King, 2009).

Researchers suggest that STEM education has not prioritized equity, and teaching is not uniformly effective at promoting student learning (Russo-Tait, 2023). Also, membership in certain marginalized groups can potentially correlate to attainment and success (Holmes et al., 2023). This makes the adaptability of the educational systems critical as a way to address and provide support for students. Instructors routinely make decisions in their courses that attempt to ensure an equitable learning experience for all students, including day-to-day choices and wholesale revisions to a course (Love, 2024). These decisions span content inclusion/exclusion, assessment practices, student support, help-seeking, pedagogical approaches, and much more, all in light of perceived student needs and expectations (Martin et al., 2023; Tran et al., 2025). An equitable

learning experience is one in which all students have ample opportunities to learn, to seek help, to access learning and support resources, to engage and collaborate with peers, with the recognition that different students might need different manifestations of these elements of the learning experience (Jardinez & Natividad, 2024). Equity-oriented decision-making is especially important when instructors adopt and adapt new learning approaches and resources that may be unfamiliar to them—for instance, a new active learning approach, a new textbook, or a new series of instructional videos.

Although different researchers have discussed the adaptability of educational systems with a focus on Diversity, Equity, and Inclusion (DEI) in engineering education, our research focuses on equity for the learning experiences and inclusion of individuals in the classroom. Equity and inclusion could be enhanced by the participation of students through pedagogical strategies, curriculum, and assessment adaptations, for example, by leveraging and including cultural diversity and gender diversity in the classroom (Forbes et al., 2024; Rambo-Hernandez et al., 2019; Yunus, Nurul Azhani et al., 2023). Supportive environments can also be created by catering to diverse learning preferences and cultures (Notaroš et al., 2019; Rice & Mays, 2022). Other approaches include implementing more inclusive strategies, such as active learning (Galvis et al., 2019; Theobald et al., 2020).

Advocates promote equitable STEM education for diverse demographics, including race, gender, socioeconomics, and disabilities (Holmes et al., 2023). While many efforts focus on curriculum design and teaching approaches, such as active or problem-based learning, little about equity and inclusion decisions regarding instructional systems adaptations is mentioned. For instance, challenges to add captions in instructional videos to address the needs of deaf students, modify printed materials to address the needs of blind students, or even provide support to students

with significant demands on their time (ex.: adult learners with families) by offering asynchronous learning opportunities. Also, it is important to provide insight into how instructors address students' needs during instructional adaptation and what elements they find helpful for improving their instruction, aligning it to the ample DEI spectrum.

This research explores the navigation and decision-making processes of two instructors who integrate their DEI principles while implementing an instructional active learning system. We focus on how these instructors implemented and adapted the system, in which DEI themes emerged naturally, and how these instructors' views align with a framework for equitable and effective teaching.

Theoretical Framework

This study is guided by *a framework for equitable and effective teaching in undergraduate STEM education* (Holmes et al., 2023). The framework defines equitable and effective teaching as the provision of learning experiences that are student-centered in which course goals are clear to the students, the student's role in learning is recognized, and students have the agency to engage in the course material in ways that respect their identities (Holmes et al., 2023). Even though equitable and effective teaching depends on changes to the larger higher education system, instructors play a crucial role in serving their students. The framework consists of seven principles: (1) students need opportunities to engage in disciplinary learning actively, (2) to connect to and leverage students' diverse interests and goals, prior knowledge and experiences enhance learning, (3) STEM learning involves affective and social dimensions, (4) identity and sense of belonging shape STEM learning, (5) multiple forms of data can provide evidence to inform improvement, (6) flexibility and responsiveness to situational and contextual factors are

important, (7) intentionality and transparency support more equitable opportunities (Holmes et al., 2023).

Methods

This study utilized dual cases (Yin, 2018) to describe the nuances of how instructors think about equity and enact the principles to promote equity in teaching while adapting an instructional system consisting of digital resources, specific active learning approaches, and an ethos of blended and collaborative learning. We focus on how themes of equity emerged naturally in conversations with instructors about their adaptation process.

Overview of the instructional system: Freeform

Freeform (Ff) is an innovative instructional system for teaching undergraduate engineering mechanics (dynamics) that provides physical and online resources (i.e., a custom-written textbook, video solutions for both example problems and homework problems, an online asynchronous discussion forum, peer support, and collaboration). It also has pedagogical and assessment approaches (i.e., active, blended, and collaborative (ABC) pedagogies and exam question sets). The system was developed for dynamics courses to enhance student learning and retention by two experienced instructors at a large Midwestern university (Berger et al., 2022; Rhoads et al., 2014). One of the two primary goals of Ff is student empowerment through providing various instructional resources and blended learning opportunities. Ff offered students the affordance and flexibility to tailor resource use to fit their needs (Tran et al., 2024, In press), which aligns well with the principles of promoting DEI.

Context of the study and participants

This study is part of a larger research project with participants from more than six institutions. The two instructors considered in this paper taught at a small, primarily teaching-focused university in the Southeastern region and a medium-sized Carnegie R2 university in the Midwest of the United States. Prof. Reed (pseudonym) was in her third year of teaching at the institution. She had no experience with the instructional system but had experience teaching the dynamics course (without using the system). Prof. Morris (pseudonym) was a new instructor at the university and taught the course for the first time as an official instructor/instructor of record. Before accepting her faculty role, she had experience with the instructional system as a student in the dynamics course, worked as a teaching assistant for a dynamics course, and then co-taught the course with a senior instructor at the large research institution she attended for her degrees. These two instructors are in the first stages of their instructing career, making their experiences as early career instructors valuable.

Data sources

The data source included seven interviews with Prof. Reed in Spring 2020 and 14 with Prof. Morris in Fall 2021. The initial interviews gathered background information about the instructor, students, and course, addressing the instructor's questions about Ff to understand their teaching and learning perceptions. Later, 'implementation' interviews were conducted throughout the semester, focusing on the instructor's views on teaching progress, adaptation decisions, and collaboration with other instructors. Although the protocols did not explicitly address DEI questions, follow-up questions were asked when instructors brought up these equity and inclusion topics. The interviews were conducted over Zoom and lasted 25 to 62 minutes (41 minutes average). Recordings of the interviews were transcribed and cleaned before being uploaded into Dedoose for analysis.

Data analysis

We conducted in vivo coding, using short phrases from the instructors' responses as codes (Miles et al., 2014). The codes reflected the instructors' descriptions and explanations of their perceptions and practices regarding equity. Then, we used guidance from the *framework for equitable and effective teaching in undergraduate STEM education* (Holmes et al., 2023) to conduct a thematic analysis that identified themes shared across the two cases and specific to an individual case (Miles et al., 2014). Finally, we read the excerpts of the in vivo coding to choose sample responses for each theme.

Limitation

This study relies on interviews with two instructors at a specific university, limiting our ability to represent the broader engineering educator population and the generalizability of our findings. The protocols did not focus on DEI themes, so some relevant DEI factors that could interest other researchers may not have been addressed in the interviews. These themes naturally emerged during discussions about system adoption and adaptation, limiting our control over the conversation's direction. Additionally, the study was conducted over two semesters, which may restrict our interpretation of changes in equity practices over time. We also exclude student feedback and outcomes, focusing solely on the instructors' views.

Findings

Perceptions regarding equity

The two instructors brought up the terms diversity and equity several times (in four out of seven interviews and six out of 14 interviews) while reporting their teaching. Our analysis revealed that

both instructors saw equity as an important part of their instructional decisions and practices and that promoting DEI is part of effective instruction. For instance, Prof. Morris said:

> I think it's maybe twofold. So, the first bigger piece is, for me, the impetus for an inclusive classroom is going to be critical for us to advancing any sort of diversity, equity and inclusion for our students. We're not going to be able to help minoritized student retention, or recruitment for that matter, if we don't create classrooms that are inclusive.

The instructors saw equity as multidimensional, so they needed to consider multiple factors, such as gender, race, socioeconomic status, first generation, extrovert/introvert, etc., to ensure they created inclusive learning environments. In addition, the instructors considered their learning to enact DEI principles in the classroom as a process in which they engaged in reflective practice and frequently asked themselves "is that the most inclusive teaching practice?" They shared that they did not want to just 'check the boxes' but sought to create a safe, trusting, and inclusive classroom environment where all students can learn effectively.

Practices regarding equity

The instructors' practices regarding equity while adopting and adapting the instructional system fell into three categories: those that were (i) directly about adopting the instructional system, (ii) nested between adopting the system and their usual instructional approaches, and (iii) independent from the adopted system.

(i) Directly about adopting the instructional system

Prof. Morris repeatedly talked about the real-world context present in many of the lecturebook examples and videos, as well as its equity effects. She expressed that the problem contexts may not have connected to the lived experiences of all students: "I also think it's not just female versus

male, but international students who maybe had different childhood experiences versus domestic students, and all sorts of different things." Prof. Morris thought using lived experiences to help students understand was important. She believed that the contexts of the problems caused disadvantages for some students and suggested diversifying the contexts to resonate with more students (not one subset of students, e.g., lived experiences of male, middle-class suburban students). On the other hand, Prof. Reed paid attention to showing the link between the concepts of the course and their real-world applications, emphasizing the importance of making these connections explicit for students, allowing them to see the relevance of their learning.

Both instructors cared about equitable access to resources/materials. For instance, Prof. Morris explicitly said that one of her instructional goals was to make her teaching more equitable for students with different backgrounds, such as how to make the video solutions of the course (which do not have captions) more helpful for English language learners, "Maybe some students whose first language is not English, for them the captions [of video solutions] are really helpful..." This perspective also applies to students with hearing impairments.

(ii) Nested between adopting the system and their usual instructional approaches

The instructors leveraged the system's resources to ensure students got the support they needed. One example of these practices was that Prof. Reed decided to have asynchronous (recorded) review sessions that integrated Freeform materials so that commuter students could access the sessions as their schedules allowed. Prof. Reed aimed to accommodate students' needs and leveraged the (blended) instructional resources to offer asynchronous review sessions so that commuter students could access the sessions. This approach exemplifies the nestedness between adopting *the system* and the instructors' usual approaches. Prof. Reed often used asynchronous review sessions because her student population includes commuter students and adult learners with

time commitments and constraints that limit their availability. In this nested example, Prof. Reed's usual practice was augmented with some of the affordances of the Freeform materials (video solutions, discussion forum – inherently useful in asynchronous contexts) to create a more equitable experience for her students. She commented:

> This demographic fits with my general philosophy in some ways. So there are certain things. I don't do review sessions for equity reasons. I don't do review sessions because not all of my students can make it to review sessions. And so unless I'm going to record it or find some way to do an online, something that would be asynchronous, I try not to require specific time things outside of class. In our first-year courses, including the engineering mathematics course, we require our students to do a certain amount of community service and professional development outside of class. And so I try to be much more available to do sort of accommodating things. So students that can't make it to scheduled events, what can we do to make sure that you are still able to meet these requirements that we had, even though the timing doesn't necessarily work?

Another example of these practices was the enactment of active and collaborative learning: Prof. Morris reported that her students often engage in think-pair-share and collaborations in small groups. Prof. Reed mentioned her students' preferences various times and tried to ensure they got what they needed regarding instructional approaches. Students at Prof. Reed's institution were used to collaborative learning starting in their first year because of the institutional culture for instruction, "they're also expecting that there's going to be that kind of collaboration and working together. And they might be expected to do things in class, not just sit there and listen. They're expected to actually participate and work with others." Prof. Reed also shared that she and the other instructors at the institution encouraged students to collaborate with

their peers. The instructional ethos of the system is active and collaborative learning, and Ff resources supported students' collaborations (e.g., online asynchronous discussion forum), which align well with students' preferences and the instructors' aims.

(iii) Independent from the adopted system

The practices independent from the instructional system included typical decisions on (1) content coverage, (2) pacing, (3) group work, (4) format of office hours, and (5) the extent of availability to accommodate students' needs. Prof. Reed said that she had a lot of rural students and a lot of non-traditional students, so during the first few weeks of the semester, she asked them for their suggestions on the styles of instruction and classroom activities they preferred or if something did not work for them, "if something's not working, you need to tell us. And we're open to that idea." She also shared that she did her best to accommodate her students' preferences.

In addition, Prof. Reed had some adult learners (i.e., those completing their degree after some time away from school), so she made some adjustments that she thought worked better for them, such as spending more time on foundational topics to help students sharpen their prerequisite knowledge. She expanded:

> And so especially the first time that I taught the engineering mathematics course, I learned that it [the pacing] was not necessarily the best for the students that I had in that classroom. The pacing was a little bit off, and you needed to slow some things down, focus on a couple more background definitions of things before moving up. Our students are hard workers overall, but they're not generally the kind of student that you could ... Like I said, a lot of students that go [to a high-prestige school], a school that's difficult to get into, are the kind of students that you can just lock them away in a closet with a

> textbook, let them out for final exam, and they'll probably pass. Whereas here, we have a lot of students that really do kind of the experiential learning, the global learning, the kind of, "How does this fit together?" explanations are extremely helpful for a large number of our students.

Prof. Reed also shared that she often randomly grouped her students for the group quizzes (about 10 minutes). Since the course did not require students to work together on "long-term in-depth" projects, she did not need to facilitate students "to get to the level of group comfort, at levels of really good working together." Prof. Reed's goals were "to have students work with different people to see different perspectives potentially and explain what they understand to different people in the class or in different ways." Another reason for randomly grouping students was to avoid situations where students encounter difficulty in joining a group, "I don't ever want any students to feel like they're the last kid being picked, like they have to go find a team and they're kind of unwanted and don't have a sense of belonging." Prof. Reed also wanted more even distributions among the groups regarding the level of understanding of the course materials. In addition, she noticed that the grouping got "different students talking to different people in the group." That way, they got "a mix of discussions and concerns." Moreover, the instructors offered flexible formats for office hours and great availability to accommodate students' needs.

Discussion

The early career engineering instructors' perceptions and practices regarding equity while adapting Ff align well with the principles of the framework

The instructors' perceptions regarding equity align well with the *framework for equitable and effective teaching in undergraduate STEM education* (Holmes et al., 2023). Promoting DEI goes hand in hand with effective teaching. Our findings reveal that Prof. Morris's perception of the role of promoting equity in engineering classrooms goes beyond enhancing student learning. For her, it also includes recruitment and retention, aligning well with the framework, and showing a commitment to equity.

While adapting Ff, the instructors aimed to enact most of the seven principles of the framework, as shown in Table 1. The two instructors provided opportunities for students to actively engage in learning activities, which aligns well with the first principle. Prof. Morris's concern regarding the contexts of practice problems in the system's textbook shows her aim to connect the course materials with students' prior knowledge and experiences, which aligns with the second principle. Both instructors asked students to collaborate in small groups, which provided them with opportunities to work together and learn from each other, which aligns with the third principle. The instructors modified the course materials and their pedagogical approaches to reflect different identities and enhance students' sense of belonging, which aligns with the fourth principle. They paid attention to students' backgrounds to broaden and deepen awareness of student characteristics, which is part of the fifth principle. Instructors built flexibility into the course's office hours and formats (i.e., in-person or virtual) to accommodate the situational and contextual factors, which is part of the sixth principle. Finally, they sometimes illustrated the connections between course content and career competencies, which is part of the last principle (Holmes et al., 2023).

Table 1. ***Examples of enactment and categories of practices of the seven framework principles for equitable and effective teaching in undergraduate STEM education.***

Principle	Category of the practices	Example of enactment	
		Prof. Morris	Prof. Reed

1. Opportunities to engage in disciplinary learning actively.	Nested	Talked repeatedly about the real-world context present in many of the lecture book examples and videos, and its equity effects.	Asked students for their suggestions on the styles of instruction and classroom activities they preferred or if something did not work for them.
2. Connect to and leverage students' diverse interests and goals, prior knowledge and experiences to enhance learning.	Direct	Emphasized using lived experiences to help students understand the material.	Focused on showing the link between course concepts and real-world applications.
3. STEM learning involves affective and social dimensions.	Nested	Ensured equitable access to resources, such as providing captions for video solutions.	Offered asynchronous review sessions to accommodate commuter students and adult learners.
4. Identity and sense of belonging shape STEM learning.	Direct	One of her instructional goals was to make her teaching more equitable for students with different backgrounds, such as how to make the video solutions of the course (which do not have captions) more helpful for English language learners.	Randomly grouped students for group quizzes to avoid situations where students encounter difficulty in joining a group.
5. Multiple forms of data can provide evidence to inform improvement.	Independent	Paid attention to students' backgrounds to broaden and deepen awareness of student characteristics	Asked students for their suggestions on instructional styles and classroom activities.
6. Flexibility and responsiveness to situational and contextual factors are important.	Nested	Built flexibility into the course's office hours and formats (i.e., in-person or virtual) to accommodate the situational and contextual factors.	Aimed to accommodate students' needs and leveraged the (blended) instructional resources to offer asynchronous review sessions so that commuter students could access the session.

7. Intentionality and transparency support more equitable opportunities.	Independent	Shared concerns regarding the contexts of practice problems in the system's textbook to connect the course materials with students' prior knowledge and experiences.	Shared that she and the other instructors at the institution encouraged students to collaborate with their peers.

Instructional systems can facilitate or hinder the promotion of equity

Prof. Morris' comments on the contexts of practice problems and the lack of captions for the solution videos show that instructional systems might offer limited affordance for enacting DEI principles. These comments reaffirm how making instruction relatable to students' experiences can foster a sense of belonging and relevance. On the other hand, the system's resources can facilitate instructors' aim to accommodate students' needs, like the way Prof. Reed leveraged the (blended) instructional resources to offer asynchronous review sessions, showing responsiveness and consistency by considering her students' background and context. By doing this, both instructors show how STEM instruction is not limited to content but also requires efforts to make supportive and inclusive learning environments.

One important strategy to make courses more equitable and diversified is the promotion of active learning strategies (Galvis et al., 2019; Theobald et al., 2020). Additionally, some authors argue that it could be possible to make instruction more inclusive if instructors provide multiple possibilities for learning based on students' backgrounds and identities by modifying the content, the process, and the instructional materials (Estaiteyeh & DeCoito, 2023). Freeform provides a foundation for including active learning strategies in the classroom and a system that allows instructors to adapt and modify it according to their needs.

By using the *framework for equitable and effective teaching in undergraduate STEM education* (Holmes et al., 2023), it is noticeable that making instruction more equitable requires a system that facilitates the adaptations and reflective instructors who want to support their students. In this case, we highlight how these adaptations require practices that sometimes are directly aligned to the instructional system, such as including captions to videos, or recording classes to accommodate students with many competing obligations. At the same time, other practices are nested into the adoption and the current practices or are independent of the system in the adoption. Efforts such as providing opportunities to connect with others, feel belonging, provide flexibility on access to resources, and intentionally be supportive align with other principles. This study shows how instructors play an essential role in adapting an instructional system to make instruction more equitable and the importance of an instructional system's adaptability. This adaptability allows modifications directly on the materials and enables instructors to make decisions that align with the student population's needs.

Conclusion

The findings revealed important insights for promoting the adoption of instructional systems in light of instructors' commitments to and practices about equity in engineering classrooms. In our study, both instructors presented a strong commitment to equity in their teaching, actively seeking the system's adaptation to meet their students' needs. The instructors' ability and knowledge about their students allowed them to reflect on their practices and look for opportunities to improve the system and their pedagogy, which could positively impact their students' experiences and outcomes. Freeform as a system presents diverse learning resources and promotes active, blended, and collaborative pedagogies. Its adaptability enables instructors to shape the system to their students' needs based upon contextual and situational factors. Instructors can use different

resources, modify and even shape their activities to foster a diverse and inclusive environment, adapting it to their specific needs. We highlight how adaptable instructional systems like Freeform allow instructors to promote equity and effective teaching in engineering education, rethink the instruction and its flexibility, and meet different students' contextual needs. We hope this study provides useful insight into instructional system adaptability and influences professional developers, instructional systems designers, and researchers.

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