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Orchestrating a culture-aligned adoption and adaptation of an instructional innovation: A story of an engineering professor's pedagogical decisions between innovation and school culture

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Abstract

Engineering education researchers and practitioners have driven instructional innovation in undergraduate engineering instruction. Much of the research about educational innovation has focused on undergraduate classrooms in large enrollment courses and/or research-intensive institutions. Propagation of innovations across settings, especially those quite unlike the original context, has received less attention in the literature. This includes liberal arts institutions, which collectively educate a large number of undergraduate engineering students in various contexts. Therefore, this study focuses on the implementation of an instructional innovation in a liberal arts institution that started a new engineering program to educate a regional engineering workforce. This qualitative study documented the experiences of one engineering instructor who adopted and adapted a blended learning environment for undergraduate dynamics designed to promote active and collaborative learning in undergraduate engineering courses. We analyzed interviews, documents, artifacts, visual materials, and field notes to examine the propagation of the instructional system in context with cultural features in local institution settings. Our findings show how an engineering instructor orchestrated a culture-aligned adoption and adaptation of an instructional innovation. Using reflective practice, the research participant adapted the implemented innovative instruction to their hands-on institution culture, such as adjusting expectations in content, adapting resources to students' individual needs, adjusting uncertainty of problem solving, and adapting to a hands-on institution culture. This research highlights the important role of institutional culture in local adaptations of educational innovations, and it provides the community with an expanded way to think about innovation propagation.

Improving teaching and learning has been an important issue in undergraduate science, technology, engineering, and mathematics (STEM) education. Alternative to traditional engineering instruction that focused on delivering content knowledge, researchers have promoted active learning that focus on increasing student participation and engagement learning [1], [2]. However, despite consistent efforts to disseminate active learning pedagogies, traditional lecture still dominates undergraduate STEM education [3]. Many researchers contend that various challenges hinder instructors from adopting using research-based instructional strategies (RBIS) due to student resistance, limited time for course preparation, and lack of institutional support and rewards [4] - [6].

To promote the use of RBIS for instructors, Froyd et al. [7] maintain that researchers aim to implement RBIS to fit local contexts through collaboration with potential adopters. They emphasized the importance of fit in local context and individual instructors' decisions to adopt and adapt the original RBIS. However, despite their attentions to general needs in local context for instructional innovation, little attention was paid to what specific local context were associated with individual instructors' instructional adaptation. The aim of this study was to explore an engineering instructor's pedagogical decisions between innovation and institutional culture.

Related Literature

Increasing the use of evidence-based teaching strategies is an important issue to enhance student learning for educational reform [8]. [9]. When adopting these evidence-based teaching practices, instructors want to improve their student outcomes. Thus, instructors commonly strive to adopt the original teaching practice to their classroom and/or institutional contexts. Some researcher argues that high implementation fidelity on adopted instructional strategies seem to have positive impacts on their outcomes [10], [11]. Previous studies argued that student resistance to instructional innovation may hinder instructors from implementing new instructional strategies [12], [13]. Student resistance to instructional innovation affects not only educational outcomes, but may also undermine student morale, instructor-student relationships and trust, and overall satisfaction with the course experience.

However, other researchers argue for considering different institutional contexts during scale-up research [14]. They argue that instructors need to adapt instructional practices relevant to their local environments because the original implementation can be associated with numerous personal, social, and cultural factors of the original institutional context. Alternatively, some researchers suggest a two-step research implementation that combines high implementation fidelity with instructor's decision-making that adapts the implemented practices. In doing so, instructors first implement core components of the implemented instructional practices and then adapt it to align with the local environment. This customized implementation to institutional context enables instructors to increase student outcomes in K-12 schools, such as reading education [15], [16], special education [17], and early childhood education [18].

Researchers emphasized the important need of a fidelity of implementation framework to measure the effectiveness of RBIS implementation in undergraduate STEM classrooms [8]. Borrego et al. [8] used the percentage of critical components from each RBIS that instructors used during class time to measure fidelity of implementation for RBIS and suggested to researcher relevant adaptation of RBIS implementation in local contexts. As Borrego et al. contribute to applying fidelity of implementation as a theoretical framework, it is important to examine which approach is most beneficial to students in specific institutional contexts [19], [20]. Particularly, Froyd et al. [7] stressed the importance of adaptable RBIS implementation aligned with local contexts. They argued that educational researchers should change the paradigm to implement research from *dissemination* to *propagation*. However, the research community would benefit from a deep understanding of how this propagation occurs in a real institutional context. In this paper, using a propagation paradigm, we examine how an engineering instructor adopted and adapted an instructional system to their local context with a focus on instructor decision making and alignment with institutional culture.

In this manuscript, we contend that local adaption is critical when an instructor implement an instructional system, which is more complex than a single instructional strategy, such as RBIS. Moreover, it is more important to adapt the complex system to local culture than to replicate it with high fidelity of implementation. Our main purpose of this study is to understand how instructors make decisions about local adaptations of instructional innovations. We do this by focusing on an instructor's pedagogical decisions and cultural alignment. In this study, we ask the following research question: *How does an engineering instructor adapt an instructional* *innovation to the local context when the original and new contexts are very different, as are the student population?*

Methods

Freeform as a pedagogical system

Freeform is an instructional system developed at Purdue University [21]. Freeform integrates various resources to support instructors and students for teaching and learning. Based on active, blended, and collaborative (ABC) learning frameworks, Freeform has five core components: (1) The Lecturebook that includes key core engineering concepts, many problem examples, and spacious margins in the book for note-taking, (2) video problem solutions in which an instructor guides real-time problem-solving procedures from problem explanation to solution, (3) the Dynamics course blog that provides course information, video links, and online spaces for student-to-student communication. The course blog is particularly useful for peer instruction by exchanging questions and answers about homework assignments. (4) ABC is an integrated learning pedagogy that instructors use to foster student participation and collaboration in online learning environment as well as in classroom, (5) Peers who collaborate with each other in and out of the classroom. These components are interconnected to afford instructors and students the opportunity to engage in the Freeform system, In this interconnected instructional system, participants can choose how to use these resources, and they are likely to use them in ways that align with their local culture and usual work practices.

Research Context

When the ABC learning environment was implemented for Dynamics at Purdue University, its student culture at Purdue University emphasizes student agency and collaboration [22], [23]. In comparison, student culture at Green Valley University emphasized hands-on learning, using project-based approaches for teaching small classes.

Purdue University is a large public institution in the Midwestern U.S. with an undergraduate student population of about 37,000. Its undergraduate student recruitment is international. Purdue is in the highest Carnegie classification for research. Over 1,500 undergraduate students were enrolled in the mechanical engineering department in Fall 2020. The enrolled undergraduate student population at Purdue by race is 64% White, 10% Asian, 6% Hispanic or Latino, 3% Black or African American, 4% two or more races, 0.1% American Indian or Alaskan Native, 0.1% Native Hawaiian and Pacific Islander, and 12% non-resident alien [24] (Purdue, 2020). Purdue reports that 26% of students are female, and 74% male in college of engineering. The average class size of a Dynamics course at Purdue was about 120 students for one section, with up to four sections taught in a typical spring semester. For Dynamics courses, the mechanical engineering department provided students with a teaching assistant (TA) help room available for drop-in tutoring for about 40 hours per week. At the time Freeform was developed, two mechanical engineering instructors with 30 and 7 years, respectively, of teaching experience developed the Freeform ABC learning environment.

Green Valley University is a medium sized private liberal arts institution in the Southeastern U.S. with 3,719 undergraduate students. Its undergraduate student recruitment is regional. In terms of undergraduate student characteristics, its race/ethnicity distribution was 60% white, 15% Black or African students, 10% Hispanic or Latinx, 5% two or more races, and 2% non-resident alien [25]. Green Valley reports that 53% of students are female, and 47% male. Green Valley started a new engineering program in Fall 2016. About 200 undergraduate students were enrolled in the engineering program in Fall 2020. The class size of the Dynamics course at Green Valley was typically about 30 students. For Dynamics courses, the college of engineering provided an instructor with an undergraduate teaching assistant. Green Valley strives to build innovative hands-on education, using project-based learning since its inception in 2016. The faculty members collaborated to design hands-on classroom spaces integrated with lab facilities. This class-lab in which Dynamics was taught enabled students to learn engineering through working with projects with hands-on experience for all school years. Sarah, the instructor who participated in this study, had three years teaching experience and taught Dynamics for one semester. See Table 1 for institution information of Purdue University and Green Valley University.

Participant

For this manuscript, we selected Sarah as a critical case [25], a purposeful sampling strategy used in qualitative research [26]. According to Patton [25, pp. 273], purposeful sampling is particularly useful to understand a small number of participants in depth. The analysis of Sarah's experience focused on extensively identifying her decisions of adapting the Freeform system in her institution context. Sarah was one of several research participants (dynamics instructors) from multiple institutions who agreed to implement the Freeform system as part of a large research project awarded to Purdue University. In our interviews, Sarah articulated decision-making processes about her instructional adaptations with specific reasons and examples. As a result, we chose Sarah as an excellent case to explore our research question. At the time of our data collection, it was the second semester of her Freeform implementation.

Data Collection and Analysis

In the Fall 2021, our team collected data from multiple sources in Sarah's classroom setting, including student surveys of demographic background and attitude, a fundamental exam (i.e.: concept inventories) related to Dynamics, and instructor interviews with Sarah. This study focuses on the instructor interview data. In particular, we had seven semi-structured interviews with Sarah over a semester, using a video conferencing program, and each interview had two goals: data collection, and instructional support for better propagation. In biweekly interviews, we provided Sarah with opportunities to reflect on her own teaching practices [27]. Researchers argue that this reflective practice enables STEM educators to change and improve their teaching strategies [28], [29]. In each interview, we asked Sarah to reflect on her teaching, using interview questions that covered different aspects of her teaching, calibrated according to the progression and content coverage of the class. During each interview, we asked: "What moments of experience stand out to you from the last two weeks?" As appropriate throughout the semester (based upon the course syllabus), we asked questions about assessments (example: "How did the process of starting to develop the exam go?") and specific course content (example: "How has the process of transitioning to content on kinetics gone for you? For your students? How has this conflicted with your usual practice, and how did you resolve those conflicts?")

Our data analysis focused on interpreting how Sarah's decision about instructional adaptation of the Freeform system were associated with the local setting at Green Valley University. To analyze her interview data, we used a constant comparative analysis [30]. We used a qualitative data analysis software (NVivo) to analyze transcripts with codes and categories through constant re-reading procedures. This approach helped us systematically organize a large number of codes, memos, and annotations. For example, analyzing each interview transcript, we wrote memos to capture researcher reflections about Sarah's experiences and made annotations to focus on Sarah's particular phrases for follow-up data analysis. Then, we repeated reading the transcripts to examine overarching themes and stories associated with the implementation of the Freeform learning environment across the semester. The analysis of critical moments enabled us to identify the main statements that represented Sarah's decision making processes for her instructional adaptations. These interpreted themes were checked by three independent trained readers who were experienced engineering education researchers, including two experienced mechanical engineering instructors who were familiar with the data in Dynamics courses, using the Freeform learning environment.

Findings

In the following, we present the patterns in Sarah's approaches to orchestrate a culture-aligned adoption and adaptation of the Freeform system. Her decision making was shaped by her understanding of local culture and her extensive pedagogical knowledge.

Adjusting expectations in content and pacing to reflect the local curriculum

Sarah adapted the Freeform environment to her institutional context by adjusting her expectations about content coverage and pace to reflect the local curriculum for her students. She elaborated a key intention of her instructional adaptation. Sarah said, "the biggest change is I did not understand the difference in our students versus Purdue students." At the beginning of the semester, Sarah found that many of her students had difficulties in understanding fundamental concepts of the Dynamics. Thus, instead of covering planned contents, she decided to spend more time teaching her students the fundamental concepts in Chapter Zero from the Lecturebook (which reviews prerequisite material including calculus content). Sarah articulated the important lesson she learned, using the Freeform learning environment at Campbell:

> I am intentionally going a bit slower and explaining a bit more, but I feel that my students are coming along much better…Green Valley tends to be a very hands-on place, and dynamics tends to be not one of the most hands on classes that you tend to get. I love the freeform materials because we do have the videos, and I've been looking back at the kind of freeform side. I love how there's a few things that have even been added to kind of help understand the path, polar Cartesian coordinates, better. Which I've been showing my students, and they're very pleased about those materials. I'd say the biggest difference between last time and this time is I have a better understanding of how to introduce my students to these topics. Rather than just kind of going and breezing through that first bit.

> I can't do that, and so I did. I feel that we're, the students are, having fewer problems this time around.

Sarah revealed that that she was not only aware of the critical need to adapt the Freeform learning environment but also had responded to meeting her students' individual needs. She made an explicit statement that the Freeform learning environment was developed for "Purdue students," which motivated her to focus more on her students' understanding of the course content she covered. Sarah made her purposeful pedagogical decisions to promote her students' conceptual understanding aligned with Campbell's institutional context different from that of Purdue.

Adapting resources to students' individual needs by using realistic examples

During interviews throughout the semester, Sarah appeared to be satisfied with most core components of the Freeform learning environment she had used in class. Sarah perceived that most core components of Freeform provided students and teachers with useful resources, including the Lecturebook, visualizing mechanics, and the ABC learning approaches. However, Sarah addressed her adaptation of the Freeform learning environment to help her students learn content:

> Everything works really well. The only thing that I change, adapt somewhat, is creating some of those videos…Redo them such that they have more explanation about why each piece is happening...Especially for places where positives and negatives might be confusing. I feel that that's something that is particularly left off. So, 'why are we using the negative here? Why aren't we using the positive here? Where do things go together and fall out? How do I know if the answer is correct or not?' And then some more examples that are a bit more realistic and less direct to find so that there's potentially more information than is needed.

Sarah indicated that she continuously solicited feedback from students, and then responded to their needs—in this case by creating new video support resources. She found the need for additional explanation to enhance her students' understanding of specific Dynamics concepts. Her additional explanation videos showed that she made her students a priority when implementing the Freeform learning system. Over a semester, Sarah continued to reflect on her use of the Freeform system and adapt it to align with specific needs of students at Green Valley (and to Campbell's hands-on learning approach) by using 'more realistic' examples.

Adapting problem solving with variables to problem solving with numbers

Sarah also adapted Freeform assessment resources to meet her students' needs. When asked to describe her experience resolving conflicts between her previous teaching and new teaching with Freeform, Sarah shared her observations of her students' level of comfort when they used the Freeform video solution. In the videos, an instructor showed necessary steps with explanations to students, but did not complete all algebraic steps to arrive at a final numerical solution. The problems were completed using variables, rather than substituting numerical values into the equations. Sarah explained why she asked her students to calculate numbers as a final answer instead of aligning with the videos and using a symbolic format:

> I do find at times a bit of a conflict with the student comfort with the problems…For Purdue related resources…one of the questions on exam two was something that was taken from an old Purdue exam. And the version that the Purdue exam used was basically just, "Use the variables and create the basis of the equation," which is something that happens often. And it's actually one of those tensions for me is that I find that my students, they don't like it when they're just using variables. They like to have that final number. "Is the number right?" They don't like getting the equations…especially in an exam, they feel very uncomfortable leaving it in variable format. Something that I try not to do is to ask them to leave things in variable format in an exam because I know that makes them uncomfortable. So, I would rather give them very simple numbers to make that math. Because even though, "You guys are finding the equation, just leave it in variable format," that just really makes them uncomfortable. So, I try not to do that.

Sarah's description about her assessment revealed that her adaptation of Freeform video problem solutions aimed to meet her students' needs. In the above statement, Sarah noticed that her students felt uncomfortable solving Dynamics problems with variables without mathematical calculation. Sarah's statement, "They like to have that final number" shows that her students preferred operating on numerical values rather than variable symbols when they solved Dynamics problems. Thus, Sarah adopted one question of an old Purdue exam and adjusted it to her students' expectations for having a final answer as a numerical value in mathematical problem solving.

Adapting a hands-off approach to a hands-on institutional culture

When adapting the Freeform learning environment, Sarah often decided to make a small adjustment, as she described, to her students' understanding of fundamental concepts to better learn Dynamics. This small adjustment did not require Sarah to change the ways that she used Freeform resources but to add a little detailed explanations, activities, and resources adapted to students at Campbell. For example, Sarah explained her decisions that added two students' course projects to her existing lesson plan:

> If you're kind of giving a continuum of the course that is not particularly well designed, you're just kind of picking up the book and throwing some best practices as you can. For a course you have gone through a full backward design of content-assessment-pedagogy analysis, it gets much closer to that end of the spectrum wherein the things that I'm dealing with are more of "How do I kind of turn up the gain and make this a little bit better?" rather than "How do I put this stuff together so my students actually learn something?" Right? The things that I'm working on tend to be, "Okay, which examples could use some more explanation to help the students out?" rather than "I need to go through and find some good examples and figure out a good thing that fits here." I'm going through the Purdue stuff and saying, "Okay, what can I kind of tweak and make better?" I'm adding two projects this semester. One of them was the kind of find images to better connect to coordinate systems. And one is going to be a flip book. So, create using any kinetics idea. Create a flip book to show kind of what happens during the actual motion.

Sarah articulated that her decision of instructional adaptation resulted from an evidence-based rationale using the content, assessment, and pedagogy (CAP) framework [31]. Using her pedagogical knowledge, Sarah scrutinized the Freeform learning system and adapted it to her own course design. The rich resources of the Freeform system enabled her to maximize her advanced pedagogical knowledge to 'tweak and make (the system) better.' For instance, Sarah added multiple course projects to connect core Freeform materials and approaches to the hands-on learning ethos of Campbell. At Purdue, instructors used 'visualizing mechanics videos' to demonstrate Dynamics concept to students in class (these are live-action videos of laboratory experiments used to illustrate specific dynamics concepts). The visualizing mechanics videos are particularly useful in large-enrollment classes because instructors may not be able to conceive of, design, implement, or grade hands-on activities or projects with prototypes in such a large class. This project-based adaptation aligns with Campbell's local culture (small classes) and learning approach (hands-on).

Limitation and Future Research

We acknowledge the limitation of our single-person study relied on Sarah's interview without our observation of her classroom. Although it is critical to examine instructors' experience of instructional adaptation through their reflection [27], multiple data sources could enhance the trustworthiness of our findings by documenting Sarah's decisions of instructional adaptation in her institutional context. Future research could integrate student surveys and artifacts into Sarah's interviews to deepen our understanding of her decisions to adapt a new instructional system. Sarah's instructional adaptation shows that local institutional settings are associated with individual engineering instructors' adoption of an instructional system. For our future research, we will examine additional engineering instructors who have used the Freeform system in various institutional settings.

Discussion

Sarah's instructional adaptations show that implementing an instructional innovation may require changes to align with specific institutional settings. Using an instructional system in a small, undergraduate-focused institution can be different from doing it in large doctoral universities. Our analysis of Sarah's experience demonstrates how her instructor knowledge and the hands-on culture of the engineering school affects her instructional adaptation. This study contributes to making connections of theory concerning engineering education and propagation of innovations [7] with the culturally-aligned adoption and adaptation of an instructional innovation.

In this manuscript, Sarah's implementation process was similar in form to reflective teaching practice [27], an approach to teaching that requires identifying one's own teaching practices, assessing teaching effectiveness, considering student engagement, and subsequently revising one's teaching practices. In this way, instructors are constantly examining their own pedagogy and making changes as needed – an essential practice whether they are adopting a new approach or using their own preferred methods and curriculum. Applied to Sarah's situation, after an initial adoption decision she was continuously making adaptation decisions in an effort to meet her students' individual needs, and by extension to better align with her local context. Sarah quickly recognized the need for such adaptation and, instead of implementing the original innovation as it was, she orchestrated her own curriculum and pedagogy by adopting and subtly adapting many aspects of the Freeform system. Her use of multiple hands-on group projects, creating additional course resources (and augmenting existing ones), and 'tweaking' the given resources that adapted students' course project to better reflect her institution's interest in experiential learning all reflect, in part, these adaptations at work. The findings are consistent with previous literature that addressed the importance of instructors' adaptations of instructional innovations aligned with local institutional contexts [9], [32].

We believe that instructors' deep understanding of their students' particular needs and institutional culture foster their active adaptation of instructional systems they implement. Disseminating or propagating instructional innovation is critical for educational reform in engineering education. In our findings, Sarah showed that propagation of instructional innovation is associated with an individual instructor's factors, such as belief, experience, knowledge, and reflection during their use of implemented instructions, institutional contexts, and other diverse factors [33]. However, Sarah's instructional adaptation focused on supporting students' particular needs based on her pedagogical knowledge.

Sarah's advanced pedagogical knowledge and teaching experience as well as her active learning experience as a student are the critical factors to propagate the innovative instruction in this study. Before participating in this research, Sarah had experienced active and collaborative learning in diverse institutional contexts by learning, teaching, and doing research. Based on her instructor knowledge and student experience, Sarah adapted the original resources and instructional approaches with confidence to meet her students' particular needs in her institutional context by adding explanations, creating solution videos, replacing variables with numbers, and tweaking course activities. Her orchestration of instructional adaptations relies on the combination of her concrete understanding of the ABC learning system and advanced pedagogical knowledge.

In this paper, our findings show that engineering instructors' pedagogical decisions can be closely associated with the culture of teaching and learning in diverse institutional settings. Sarah's implementation of Freeform indicates the critical role that institutional cultures play in their instructors' adaptation of instructional innovation In different institutional settings, engineering instructors should consider their instructional adaptations to address their students' particular needs.

Sarah's experience can be an example of the positive effect of scaffolding fidelity and adaptation in educational program implementation [15], [16]. Quinn and Kim [16] argue, Sarah orchestrated instructional adoption and adaptation based on her concrete understanding of the Freeform learning system and advanced pedagogical knowledge that balanced implementation fidelity and adaptation. Sarah shifted initial adoption phases to adaptation phases by changing instruction strategies, creating resources, and applying hands-on group projects aligned with her students' needs in her institutional contexts.

The literature on implementing active learning reports that student resistance to active learning is one of the biggest barriers that engineering instructors cope with to adopt an innovative instruction [3]. Recent studies recommend instructors use explanation and facilitation strategies that foster student engagement in active learning. However, though these specific active learning strategies are easy to use and practice, instructors need to use these explanation and facilitation strategies closely aligned with their institutional cultures. Sarah's advanced pedagogical knowledge of engineering instruction based on her training and mastery of CAP principle enabled her to make pedagogical decisions with confidence to adopt and adapt the relevant to her students in each class. Some instructors with little formal training and pedagogical knowledge of engineering instruction may not feel that same confidence, and perhaps be more reluctant to make significant changes [33].

Individual instructors have agency to orchestrate their courses, and propagation of any instructional innovation must allow (or even encourage) adaptation. Our research aimed to encourage instructors to make their best decisions to adapt an instructional system originally developed elsewhere to align with their institutional culture and approach, as well as student expectations. Because educational interventions may affect student learning, implementing an innovative instruction should value individual instructors' pedagogical decisions as experts in their institutional context. This single-participant study reveals that this Freeform implementation at an institution quite unlike the institution of Freeform's origin is associated with significant adaptation to local institutional context.

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