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Factors Precluding the Adoption of a Pedagogical Innovation: An Engineering Case Study Showcasing the Implementation of *Freeform**

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Pedagogical innovation efforts in engineering education and other STEM fields highlight some of the inherent challenges and opportunities in the process of strengthening undergraduate education. While interactive pedagogical approaches involving peer teamwork and a mix of in-person and online resources have strengthened the quality of teaching/learning, few studies provide a close-up examination of how faculty members navigate the implementation of new learning systems developed in other institutional settings. In this paper we examine factors contributing to the lack of sustained adoption of an engineering learning system called *Freeform* in a new academic context. We found that while students lauded the learning system's potential for deep learning practices, the lead instructor encountered several challenges in its implementation which precluded him from adopting the system in the long term. While the lead instructor recognized the pedagogical value of *Freeform* in helping students engage deeply with engineering concepts, he found its implementation to differ too greatly from his traditional teaching trajectory in addition to increasing his preparation workload and having other logistical barriers. Ultimately, *Freeform* was not compatible with the specific institutional culture of the engineering department where the study took place. We offer some potential solutions to ameliorate issues of compatibility when attempting to diffuse and implement pedagogical systems in different institutional contexts.

Keywords: pedagogical innovations; diffusion; case study; blended learning; active learning

1. Introduction

Calls for pedagogical change in engineering education and other STEM fields [1–5] highlight some of the inherent challenges and opportunities in the process of strengthening undergraduate education. While interactive pedagogical approaches involving peer teamwork and a mix of in-person and online resources have strengthened the quality of teaching/learning, few studies provide a close-up examination of how faculty members navigate the implementation of new learning systems developed outside of their institutions [5–7].

This case study discusses the experiences of Professor Aldo Ferri, a veteran mechanical engineering professor as he experimented with a learning system called *Freeform*. As some instructors begin to reflect on the issue of student disconnection in the classroom [8], it is imperative to understand the role of pedagogical innovations in stimulating class engagement and student agency. This paper also underscores the importance of institutional cultures on the ways in which new pedagogical approaches are adopted, adapted, and potentially discarded.

1.1 The Freeform Learning System

Freeform was developed in Purdue University's Schools of Mechanical Engineering and Engineering Education in 2008 [5, 6, 9]. This system integrates active, blended and collaborative (ABC) pedagogical approaches with both in-class and virtual components [6, p. 665]. The *Freeform* concept was implemented in several classes in the College of Engineering. The goal of *Freeform*'s development was to increase teaching and learning efficacy taking into account different kinds of learners while encouraging students to take more

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responsibility for their own learning. Similar to blended classroom approaches implemented at other institutions [10], *Freeform* emphasizes in-class problem-solving guided by a hybrid textbook that is supported by online learning resources such as video solutions (developed by the researchers) and virtual forums. After five semesters of implementation in Basic Mechanics I and seven semesters in Basic Mechanics II one of the most important findings is that the DFW (D or F grades or Withdraws) rates for students in one of these courses fell from 32% in previous semesters to 18% during the semesters that *Freeform* was implemented. The other course saw a similar trend, going from a 21% DFW rate in semesters prior to the implementation of *Freeform* to 11% after its implementation [9].

In 2015, researchers experimented with the introduction of *Freeform* to a small teaching-focused university in the Midwest to get a sense of how the system would work at a culturally-different institution. Their study focused on elucidating the experiences of a faculty member as she adopted and navigated a new teaching and learning system. The authors found that adopting *Freeform* resembled the process of adopting any other textbook. However, as *Freeform* does not include teaching-aid materials (e.g., lecture slide decks and unsolved homework problems) that often accompany more traditional textbooks, adopting such a system involved more effort on the side of the instructor. On the other hand, the authors found that as *Freeform* was designed to work best in active learning settings, such a setup afforded the instructor the opportunity to reduce lecture time while increasing time spent on solving problems collectively. Ultimately, because of the wealth of online solved problems included in *Freeform*, students were given the opportunity to hone their skills as problem solvers [5].

1.2 Recruitment and Onboarding Process

Based upon our prior experiences studying adoption and adaptation of the *Freeform* system, we expanded our set of partners so that we could study this process in other academic settings. We were particularly interested in notions of adoption (the initial decision to use the *Freeform* system) and adaptation (other decisions adopters make about how to actually use the *Freeform* system in their environment). In particular, our prior work showed that 'partial adoption' of some of *Freeform*'s components for specific learning environments was a possible outcome. For example, adopters might de-emphasize the online resources in environments that have a strong in-person help-seeking culture between instructors and students.

1.3 Single-Site Case Study

In our larger-scale project, we explore the (partial) adoption of *Freeform* in multiple environments, and each implementation followed a chronological order of events once the faculty member agreed to participate. Each participating faculty member received a small grant to be used at their discretion as they implemented the learning system. For this case study, first, our research team executed a site visit in Fall 2021 with adopters for onboarding purposes. Two faculty members agreed to teach a Dynamics course using the *Freeform* learning system in Spring 2022. The main goal of the campus visit was to help each adopter grasp the full scope of resources and pedagogical approaches available via *Freeform*, as well as best practices to ensure a successful implementation. It is important to point out that during our site visit we experienced some technical difficulties during the onboarding presentation delivered to the participating faculty members. These challenges presented limitations in terms of the scope of onboarding topics we were able to cover during the presentation. Once the participating instructors had completed the onboarding process, we conducted periodic interviews throughout the semester, to get a sense at how the instructors were navigating the system, using the resources, and making instructional decision about content, pedagogy, or assessments.

The interviews emphasized topics such as workload, assessment design, student performance, and the comparison of experiences in relation to other semesters of instruction without the *Freeform* system. Once interviews were completed with the faculty members, we invited students to participate in brief interviews. This paper revolves around the experiences of the lead faculty member as he had a longer trajectory teaching Dynamics and could provide more comparative accounts of his experiences.

1.4 Research Questions

This case study revolves around two research questions:

1. What does the process of implementing a new learning system look like from the perspective of instructors?
2. How do students' perceptions of a pedagogical innovation compare to those of the teaching faculty member?

In the same vein as other studies conducted by team members in our research group, we employ a social constructivism approach in our analysis [6, 11, 12]. We acknowledge that each set of participants in this study reported on their own and unique lived experiences during the experimentation phase of *Freeform* for one semester. In this sense, this paper sheds light on the experiences of Professor Ferri and also his students. Previous findings on *Freeform* implementations across other institutions emphasize the value of ABC pedagogical approaches in terms of reducing DFW rates and increasing in-class active learning. In this essay, however, we underscore the complex journey of learning-systems adoption at the intersection of institutional culture, faculty agency, and logistical obstacles. In other words, we offer a closer look at some of the obstacles that preclude innovative pedagogical systems from being adopted despite some of their strengths.

1.5 Institutional Context

Research for this paper took place at The Georgia Institute of Technology (Georgia Tech). Georgia Tech is a large, public, and research-intensive university, that grants undergraduate, masters and doctoral degrees. The Institute's engineering college consists of eight engineering schools with approximately 8,000 residential undergraduate students enrolled (35% women) as of Fall 2022. The School of Mechanical Engineering, which offers multiple Dynamics sections, has approximately 1,700 undergraduate students, over 850 graduate students, over 100 faculty, and 70 staff members. Rigid body dynamics is regularly taught by approximately eight faculty members and the class sizes range between 30 and 60 students.

2. Literature Review

In his celebrated book *Diffusion of Innovations* [13] sociologist Everett Rogers explores the complex role of culture in the adoption or rejection of innovative practices. Rogers' premise is that new ideas, even when proven advantageous to the innerworkings of a given social system, are difficult to implement and even when successful, such innovations can take a long time to adopt. Rogers describes a famous case study wherein sanitation-related innovations were introduced in a Peruvian village by Peru's public health service. One of these innovations was the practice of boiling drinking water to diminish the incidence of infectious diseases. Despite the two-year water-boiling initiative, which included talks by doctors and a designated "persuader", only 5 percent of the population adopted the practice. Due to the low percentage of adoption, the campaign was considered a failure.

The main factor behind the low rate of adoption was the high level of incompatibility between the innovation and villagers' beliefs, values, and behaviors. In addition to disliking the taste of boiled water, native villagers associated drinking boiled water with people experiencing any sort of illness. The norm was for healthy individuals to consume regular water (that is, water that was not boiled). Furthermore, only people who were not members of the village's local networks (e.g., people who had moved to the village from other regions), were able to resist the established norms of the village and support the health initiative of boiling their water prior to drinking it [13, pp. 3–5]. Another important consideration was the person leading the water-boiling campaign. As a community outsider, the change-agent possessed little social capital to lead an effective persuasion movement in addition to being distrusted by most villagers. As Rogers explains, "How potential adopters view a change agent affects their willingness to adopt new ideas" [13, p. 5].

Some of the conclusions reached by Rogers are also applicable across other social contexts. Hence this paper is centered around a "diffusion of innovations" approach [13, 3]. Borrego & Henderson [4, p. 222] argue that for decades "higher education leaders have been considering questions of how to change faculty instructional practices". Similarly, in engineering education, Borrego et al. [3] argue that since the 1990s, significant strides were made toward the improvement of pedagogical approaches. For example, during its 2006 Annual Meeting, the American Society for Engineering Education (ASEE) introduced a project titled "Advancing the Scholarship of Engineering Education". The goal of the initiative was to encourage conversations within ASEE's members about the significance of pedagogical innovations in the quality of education offered to engineering students. ASEE's initiative led to a follow-up project in 2007 sponsored by the National Science Foundation with the intent of initiating wider conversations among engineering educators across the U.S. about the creation of innovative pedagogical practices [14].

Indeed, change has ensued at many engineering departments. However, despite the implementation of student-centered teaching approaches, assessment innovation, and retention strategies for underrepresented students, an NSF study reported that such adjustments did not lead to significant "systemic change" [3, p. 185]. The lack of widespread changes resulting from these innovations, demonstrated that "propagating these innovations from the institutions at which they were developed to more widespread use requires additional attention" [3, p. 185]. Some of the issues precluding change from happening, included the lack of "rigorous" research on the innovations. However, other publications on the subject such as *The*

Engineer of 2020: Visions of Engineering in the New Century [15] and *How People Learn* [16], suggested that research results alone were not enough to create change. Instead, with time, researchers learned that "focus on the innovation itself must, be supplemented by gaining feedback, adjusting the innovation, and providing on-going support to faculty members" [3, p. 185]. Similarly, Adams & Turns advocate an in-depth examination of innovative practices in engineering education that would lead to more recognition and support of educators engaged in innovative pedagogical practices [17].

Another well-known research trend on the subject of change in STEM pedagogy began with the literature review by Henderson et al. [18]. In their initial findings, Henderson and colleagues identified 4 categories of pedagogical change:

1. A curriculum and pedagogy disseminating phase wherein a change agent is responsible for informing and teaching instructors about innovative teaching approaches and supporting their implementation.
2. A reflexive, instructors' development phase in which the change agent encourages and offers support to instructors in the development of innovative pedagogical practices.
3. A policy phase in which the change agent endorses innovative environmental elements (at the organizational level) that both encourage and compel the creation of innovative pedagogical practices.
4. A shared vision development phase in which the change agent helps to inspire and offer support to "stakeholders to collectively develop new environmental features that encourage new teaching conceptions and/or practices" [4, p. 224].

2.1 Curriculum Pedagogy

Most relevant to our research project, is the first change category or Curriculum and Pedagogy phase. According to Henderson et al. [18, p. 228], the Curriculum and Pedagogy is the category most typically examined and implemented. In STEM, the goal is for change agents to create innovative, well-structured and easy-to-implement teaching strategies and transfer these to faculty members who are understood to have limited bandwidth to develop new strategies themselves. The main rationale behind this change category is that instructors would change their typical teaching behaviors once they are introduced to an optimized pedagogical intervention. However, the successful diffusion of a given pedagogical innovation would depend on both compatibility and complexity factors. Compatibility refers to the degree of consistency between the elements of a given innovation and the principles, knowledge, and requirements of the would-be adopter [3, p. 186]. Another determinant of success is "complexity" which has to do with the apparent or recognized effort involved in implementing the innovation. Building from Rogers' [13] work, Borrego et al. explain that "the higher the perceived complexity of an innovation, the lower its rate of adoption" [3, p. 187].

2.2 Complexity, Relative Advantage and Networks

Rogers' [13] "complexity" perspective is consistent with other studies that have applied the Technology Acceptance Model (TAM) to educational innovation settings. The model proposes that an individual will normally display openness toward the adoption of a given innovation if they perceive the innovation to be valuable and not difficult to implement. In the same vein, Rogers' "Relative Advantage" element of innovation, suggests that the adoption of innovation would be impacted by whether or not a potential adopter understands the innovation as being of higher quality than its predecessor [19, pp. 385–389].

More recently, some studies [20] highlight the complex nature of the dissemination and propagation of pedagogical innovations in engineering. According to the authors, the process of dissemination assumes that when innovations are offered to a given community, members of such a community "will pick it up and find a way to fit it into their curriculum at will". Conversely, the practice of propagation aims to connect prospective adopters with "pedagogy developers" who can offer support in the implementation of an innovation [20]. This relationship between networks of support and adoption of innovation was examined earlier by Rogers [13]. For example, Rogers contends that:

> ". . . at the heart of the diffusion process is the modeling and imitation by potential adopters of their near peers' experiences with the new idea. In deciding whether or not to adopt an innovation, individuals depend mainly on the communicated experience of others much like themselves who have already adopted a new idea. These subjective evaluations of an innovation flow mainly through interpersonal networks" [13, pp. 330–331].

In the absence of peers with direct experience, other kinds of networks become crucial in the dissemination and adoption process. Riley et al. [20], for example, argue that dissemination and propagation are typically conceived of as "extremes on the ends of a spectrum" and they examine the rise of engineering education "guilds" as groups that can bridge these practices. The authors describe engineering education guilds as "professional development groups that aim to bring pedagogical best-practices into engineering classrooms" [20]. The authors describe, for example, the work of guilds such as the Consortium to Promote Reflection in Engineering Education (CPREE) and the Kern Entrepreneurial Engineering Network (KEEN). Because these networks offer different kinds of resources (e.g., workshops, publications, online content, and conference papers) their innovations have a deeper reach and higher likelihood of implementation in comparison to the publication of findings in journal articles alone. Moreover, the authors found that instructors who used the resources offered by guilds, their own knowledge of research findings (e.g., books, journal articles, conference papers), and collaborated with other peers, described being able to use teaching innovations in their classroom consistently. Furthermore, the authors argue that the successful dissemination and adoption of teaching innovations is determined by the strength of a given instructor's interpersonal connections (e.g., coworkers, mentors and mentees) [20].

It is evident that change constitutes a longstanding goal in engineering education [21]. Pedagogical innovations comprise an important component of these larger change initiatives. However, issues of compatibility, the disruption of already-established teaching practices, and instructors' competing responsibilities, can get in the way of embracing meaningful pedagogical innovations. As our case study shows, pedagogical innovations are intrinsic to deep learning in everchanging teaching/learning landscapes, and it is crucial that we understand what are the necessary factors that can aid or preclude in the adoption or adaptation of such innovations.

3. Methodology

In this paper we employ a combination of case study research with focused ethnography. Unlike conventional, long-term ethnography, focused ethnography comprises short-term visits to a given research site where data can be collected rapidly within a span of a few days. The succinct nature of these field visits, however, is "typically compensated for by the intensive use of audiovisual technologies of data collection and data-analysis" [22; Cf. 23–24].

As a case study approach, this paper sheds light on the experiences of one individual during one academic semester as reported via individual semi-structured interviews conducted remotely following an in-person site visit. Case study research with a focus on education, concentrates on the comprehensive documentation of specific segments within larger educational contexts (e.g., engineering education) with the goal of advancing theoretical knowledge and practical applications. As Freebody [25, p. 81] explains, "Researchers in a variety of professional and practical domains use case studies as a way of conducting and disseminating research to impact upon practice, and to refine the ways in which practice is theorized". Moreover, the value of a case study approach, rests on its emphasis of comprehensive examination of a given phenomenon or phenomena in "its real-life context" [26, p. 1]. Lastly, this paper is centered around a constructivist approach wherein meaning is subjectively constructed in the interactions between researchers and participants [27].

3.1 Sampling and Data Collection

Although this study is based on the experiences of the instructor who taught the *Freeform*-based course, we also interviewed seven of the students enrolled in his class using a convenience sample [28, p. 191–192]. One researcher conducted all of the interviews with the instructor and the same researcher along with two other team members conduced the interviews with the students. Professor Ferri, the faculty member in this study, is an award-winning faculty member in the School of Mechanical Engineering at Georgia Institute of Technology where he has been teaching since 1985. He is a professor and former Associate Chair for Undergraduate Studies. Currently, Professor Ferri serves as Director of Assessment and Student Success. The semester during which this study took place, Professor Ferri was one of two faculty members teaching a *Freeform*-based dynamics course in the School of Mechanical Engineering for the first time.

3.1.1 Background Context

The semester during which we collected interviews with Professor Ferri was an irregular one. Since this course followed an in-person format, COVID-19 social distance guidelines were still in place, which meant that, at least for the beginning of the semester, Professor Ferri was not comfortable with students working collaboratively in the classroom, which was his traditional mode of delivery. Hence, in addition to impacting the interactions among students and between students and Professor Ferri, Professor Ferri also had to record his lectures and make them available to students receiving class content virtually.

With regard to pedagogical compatibility, the semester prior to the experimental implementation of *Freeform*, the Mechanical Engineering department had agreed on the adoption of a new *Wiley*-

PLUS textbook [29] after having had used a different textbook for over 30 years. This previously-used textbook is the basis for two freely available Coursera courses in Dynamics, which were used extensively to supplement classroom instruction in dynamics at the institution. The newly-adopted textbook prior to *Freeform*, included more in-book problems and solutions. Thus, experimenting with *Freeform*, constituted significant time effort for the instructors who had already expended considerable effort in adapting to a new text. Moreover, the video solutions offered by *Freeform*, did not provide numerical answers (instead reporting solutions in terms of symbolic quantities, a pedagogical choice made by the *Freeform* developers), which instructors at Professor Ferri's institution preferred to work with.

Instructor interviews: We conducted six semi-structured interviews with Professor Ferri lasting 45 minutes on average over the course of the semester. The interviews were conducted virtually, and audio recorded for later transcription. The semi-structured interview protocol allowed researchers to elicit information from the instructor that pertained to specific times during the semester (e.g., at the beginning of the semester, after an assessment, or when introducing a challenging piece of course content). For a list of interview questions see Appendix I.

Student Interviews: The seven interviews we conducted with students included two women and five men and lasted 29 minutes on average. These interviews were conducted virtually, and audio recorded for later transcription. The students received a \$20 gift card for their participation in the study. For a list of interview questions see Appendix II.

3.2 Data Analysis

The audio recorded interviews were transcribed using a professional service and then checked by at least one team member for accuracy. One researcher read and compiled preliminary reports for each interview. These reports, which were shared with team members during weekly meetings, comprised general themes and salient preliminary findings. Once the same researcher read and created preliminary reports for all of the interviews, he then coded all of the interviews using NVivo.

An initial round of open coding produced 77 codes for the interviews with the faculty member and 86 codes for the interviews with the students. Additional meetings and discussions with other team members enabled us to verify and validate our initial themes. Then, a second round of NVivo data analysis was conducted in order to group different codes into specific themes. For example, codes such as "*small class size made it easy to meet people and study together*" and "*student collaboration & group work were encouraged by the instructor in this class*" were grouped under a parent code titled "*Relationships and Sense of Community in the Class*".

4. Findings

We present our findings of the interviews with the faculty member followed by our findings based on interviews with the students. On the side of the instructor, we will group the findings based on three themes, (a) the obstacles encountered by the instructor with regard to *Freeform*, (b) some of the positive aspects of *Freeform*, and (c) the instructor's concluding reflections about his overall experiences during the semester in which *Freeform* was implemented. On the side of the students, our findings outline a list of salient student experiences during the semester. In the discussion section, we synthesize the commonalities and disparities across faculty-student perspectives.

4.1 Faculty Member's Experiences

4.1.1 Obstacles in the Implementation of Freeform

Throughout our conversations with Professor Ferri he discussed some of the obstacles he encountered while using the *Freeform system*. Some of the recurring topics include work overload issues related to class preparation, the perception that some segments of the course seemed fast-paced, and incompatibility issues between *Freeform* and the teaching resources and structure used by Professor Ferri in previous semesters.

Work overload issues: One of the main recurring issues faced by Professor Ferri during the implementation of *Freeform* was the amount of time he invested preparing for class as a result of adjustments he needed to make. For example, he explained that "The order of the topics is very different [from his usual ordering], so it's been taking a lot of time to integrate in my notes and to change my homework assignments because the material is now coming in a different order". In addition to having used a different order of topics in other books, Professor Ferri spent significant time solving the problems offered by the course's textbook to show the students (using numerical values) how to arrive at the solutions. Whereas the video solutions provided an avenue for students to learn how to solve problems using symbols, Professor Ferri thought that using numerical values might have some advantages for novice learners. Pedagogically, Professor Ferri felt that numerical answers were an effective way to facilitate the "instant feedback" that aids students in learning and understanding. He used the numerical aspect of problem-solving in two ways: first, his homework assignments always included the numerical answer, allowing students to know immediately whether they were understanding the material when working alone. Second, the numerical values at intermediate points in a long solution allowed students to more easily "debug" where they had made their conceptual errors. So, the reliance on numerical answers for novice learners was deemed to be important and useful. Another more subtle point is that when teaching large sections in an active-learning mode, it is useful for students to have a numerical answer to "shoot for," as the instructor is often overwhelmed with helping students who are struggling, while those students who are not struggling can validate their understanding independently of the instructor interaction.

By mid-semester Professor Ferri indicated that he was still having issues of work overload due the *Freeform* book lacking written solutions. As he explained "I still have issues with the problems that are in the book. They don't have written solutions and they don't have numerical answers, so I had to work them all out". Professor Ferri also indicated that, while video solutions were available, it was time-consuming to watch them in preparation for a classroom worksheet activity. Moreover, it is worth noting that Professor Ferri did not have a teaching assistant who could help with grading in his class.

At times the course seemed fast-paced: Another theme that Professor Ferri brought up several times during interviews was that, at times, segments of the *Freeform* system seemed fast-paced; he remarked that in comparison to the way he taught Dynamics in previous semesters, the semester in which he used the *Freeform* system felt fast-paced, partially attributable to the fact that he was covering topics usually covered in the last third of the class in the early weeks of the semester. He noted "I feel like the pace of the material I'm going through here is very fast. I feel like we're on a very brisk pace, so that concerns me a little bit. I'm giving a test next week and I think I might find that what I've been teaching has not been learned very well". In the end, Professor Ferri noted that students did not do as well as they would hope in this first exam. Furthermore, he explained that students' inability to participate in group work (due to social distancing restrictions) even though they were eager to, added more stress to the fast-paced structure of the class.

Differences in textbooks: One more issue brought up by Professor Ferri was the structural differences between the textbook he was used to using in comparison to the *Freeform* textbook. He noted that traditional textbooks have several worked-out examples embedded in each chapter, whereas the *Freeform* book only provides video solutions using problem variables rather than numerical values. He explained that while video solutions are useful, they are more time-consuming for students to review as compared to having a written solution provided in the textbook. Specifically, readers can scan a written solution much more quickly than a video, even if the video is watched at double speed. A concise written solution is faster to digest, especially if the student is merely trying to confirm their understanding of a concept or solution technique. Professor Ferri also noted that the textbook he had used earlier constituted a more "complete learning system". He explained that traditional textbooks have numerous "back-of-chapter" unsolved problems to select for homework assignments and have an index to quickly find topics. Furthermore, textbooks developed by publishing companies were sometimes able to provide companion videos, advanced systems of grading, assessments, online problems with randomly assigned parameters, multiple choice exercises with automatic grading, and options to fold the learning system into platforms like Canvas and Blackboard. *Freeform* currently offers only a subset of these capabilities.

Freeform's impact on exams: During conversations after Professor Ferri administered the first exam, which he prepared by himself, he said it felt strange to administer an exam with the topics covered in a different order in comparison to how he usually put together his exams and provided study materials for students. In particular, it lessened the value of posting sample tests from previous semesters. Instead of posting sample tests from previous semesters, he separated previous test and exam questions into individual files that were grouped into categories appropriate for the new ordering of topics covered on each test. The individual problems were placed in folders (modules) and shared on the learning management system. By mid-semester Professor Ferri administered a second exam and implemented some changes to the class; for example, he explained that since COVID-19 concerns had abated somewhat, he felt more comfortable with students working together in groups and how he began to cover fewer class topics but to cover them in a more comprehensive way. The students did better on the second exam in comparison to the first. He explained that the class:

> "started working collaboratively on worksheets [the practice problems provided in the lecturebook] during class, which we hadn't been doing. And so, we started doing a worksheet in almost every class session and students would work in groups . . . I think they learn more effectively that way. Although I think that I cover less material, I think the material that is covered, is covered better."

Repercussions of missing topics: Professor Ferri pointed out that the official syllabus of the dynamics course at Georgia Tech included a number of topics which were not included in the *Freeform* book. The biggest content omission was in three-dimensional (3D) kinetics, which includes inertia matrices, products of inertia, principal axes, Euler's equations, and the parallel axis theorem in 3D. However, even in the area of kinematics, the Lecturebook did not cover Euler angles, 3D positional analysis, or rotational transformation matrices which are used in downstream elective classes such as robotics. As a result, he had to use lectures (pdfs and PowerPoint slides) from previous semesters in order to supplement this gap.

Unable to get used to the order of topics: The atypical order of topics according to Professor Ferri, continued to be a source of frustration as he felt he had to provide students with review information of topics they covered earlier in the semester. He said that traditionally, a Dynamics textbook covers "the kinetics principles in 1D, and then work energy in 1D, and then revisit the concepts in 2D, and then again with 3D. Each time, you are kind of circling back," which he believed was an effective way of scaffolding and reinforcing the concepts for novice learners. He continued to make the distinction between the order in which he typically teaches Dynamics and how it is organized via *Freeform*:

> "So, traditionally, we cover all the planer or 2D material. And then, about two-thirds of the way through the class, I start doing 3D. We start with the kinematics of 3D motion and then we do 3D kinetics [sometimes called 'dynamics']. So, the 3D concepts are closer together in time, and fresh in the students' minds. When we go to the dynamics part, we have a very recent exposure to how we can describe three-dimensional velocities and accelerations, especially angular velocities and angular accelerations. In the case of *Freeform*, we did 2D motion, then 3D motion, and then a long departure into 1D and 2D Newtonian mechanics, 2D work energy, etc. It's a long departure. And by the time that we came back to 3D, the students had forgotten a lot of what they had learned early on."

Later in the interview he explained that "it's very typical in ME programs at other universities to require a dynamics course that does no 3D and it's somewhat normal to have a course that does 2D dynamics followed by 3D dynamics. But there's no course I've seen that does what this lecture book does, which is do 2D and 3D [kinematic] motion followed by 2D-only dynamics".

Unable to cover some material: Professor Ferri indicated that one of the biggest challenges toward the end of the semester was navigating the lack of some topics in *Freeform* which he wanted to cover. He stated, "The biggest problem was that when I could not use content in the *Freeform* textbook, there was nothing else I could grab that the students had access to". This issue also came up while he was putting together the final exam. He wondered "can they handle that? . . . No, we didn't cover that. . . . No, we can't put that on the exam". He explained, "I had to pull back from what I would normally be able to challenge them with. That's probably more attributable to the fact that I did not cover as much material or as thoroughly as I normally do". In the end, he indicated that "There were maybe a larger number of students that bombed the final than in a typical semester".

4.1.2 Positive Aspects of Freeform

Despite some of the obstacles he experienced, Professor Ferri identified some elements of *Freeform* as positive for the students.

Value of workbook and solution videos: Professor Ferri noted that after each class session, students would share with him how they had been using the workbook that is embedded in the *Freeform* textbook, which he thought was a sign of engagement. About half of the students made extensive use of electronic tablets, so they just scanned the worksheet problems and worked on their tablets. This avoided the aversion that many students feel towards writing directly into a textbook. Additionally, Professor Ferri lauded the quality of the video solutions. He explained:

> "the video solutions are really very, very good. I don't know whether my students are actually finding the time to investigate them or not, but I think that that's certainly something you don't see with a lot of textbooks where. . . every single problem in the . . . lecture book has a video solution."

Furthermore, even though it was time-consuming for Professor Ferri to create written solutions for the problems, he mentioned that it was useful for him to work out the problem solutions. He explained that "there is some utility of having the problem fresh in your head that you've solved it all the way through, every detail before you went into class".

Student engagement: Upon reflecting on some of the issues he navigated with *Freeform*, Professor Ferri also brought up the larger, nation-wide, issue of student disengagement. He referenced McMurtrie's *Chronicle of Higher Education* article "A 'Stunning' Level of Student Disconnection: Professors are reporting record numbers of students checked out, stressed out and unsure about their future" [8]. The article was important for him in the sense that he could identify with some of the concerns raised by instructors, and he could also see how, despite some of the obstacles he experienced, *Freeform* seemed like an ideal system to address some of the disengagement scenarios explored on the article. Professor Ferri pointed out, in relation to the article:

> "Some of the professors that they interviewed were saying things like, 'Well, in order to combat this, I'm doing a lot more group work, project work. I'm trying to get students to work, much more open-ended problems'. Things that are maybe more ambiguous. So, I thought to myself, 'Well, this lecture-book is in that mold and it's a learning system is more consistent with engaging students so that if they're coming to class, they're feeling more pulled along'."

Realized value of Freeform: During our last interview with Professor Ferri, we discussed some of the conversations we had with his students. We shared with Professor Ferri that most of the students we talked to seemed satisfied with both the *Freeform* system as well as the quality of instruction. Thus, we wanted to discuss some of the differences in perception about how the class went between Professor Ferri and his students. Professor Ferri explained that upon reflecting on how the semester went, he had a greater appreciation of how the order of topics were structured on the *Freeform* system. He also said that he would be using some elements of *Freeform* in his future courses. With regard to this topic, he stated:

> "Every time you become acquainted with another textbook, you invariably find things about the textbook that you like. And the next semester that I teach this returning to the WileyPLUS textbook, I'm probably going to use some of the examples that I liked [*in Freeform*], some of the treatment, maybe even the order of some concepts. Covering 3D kinematics before covering 2D planer kinetics, I might even give that a try again."

Lastly Professor Ferri commented on a positive note about the problem solution videos; despite being time consuming to watch these video, they were useful and of high quality.

4.1.3 Instructor's Concluding Reflections

In our last conversations with Professor Ferri he reflected on the topics of student engagement, the value of *Freeform* in the specific institutional contexts and the motives behind his inability to adopt the system.

Feelings about student learning and classroom rapport: Toward the end of the semester, Professor Ferri felt as though the semester had not gone as he wished it had, from a variety of perspectives. He explained:

> "I feel pretty discouraged and wish that things could have gone better. I feel that the quantity of material that I was able to cover has been less than previous semesters. I can't unravel entirely the impact of the book versus COVID versus a lot of students not wanting to actually physically be in the classroom. It's hard to untangle everything."

Overall, Professor Ferri also felt he was having a hard time connecting with students as well as he did in previous semesters. Part of that, is that he felt that working with a new learning system precluded him from predicting situations for which he already had experience providing solutions. He explained:

> "If you change things significantly, you don't have your experience to draw back on. You don't have the awareness that, 'yeah every semester when I do this, they always have this question. So, let me head it off and do this'. It certainly does make you feel a little bit like you're operating without a net. You're taking some risks, and you don't quite know what students are knowing and why they're having trouble with certain topics because you didn't approach it the same way [in previous semesters]."

Overall satisfaction with Freeform: Despite some of the obstacles he faced during the semester, Professor Ferri indicated that in the end, students did well with the material he delivered (even if he did not cover as much material as he typically did). As for those students who did not perform well in the class, Professor Ferri did not think it could be all attributed to the *Freeform* system, as there were issues with disengagement and disconnections caused by other factors such as the COVID-19 pandemic.

The importance of context: Professor Ferri pointed out that he understood how the *Freeform* system might work exceptionally at Purdue University where the product was developed. His main argument was that Purdue's engineering curriculum might be set up in a way that students take specific prerequisite courses that prepares them to navigate a course like Dynamics taught using the *Freeform* system. However, when transferred to other institutional contexts, students might not have the same background experiences. He explained:

> "Right now, *Freeform* was developed to be something that was perfectly tuned to the way they were teaching at Purdue. It's a perfect complement to what they wanted to do, the objectives of the course, the type of student they were addressing, etc. Everything was in tune. And so, this study is perfect because it's asking why does a learning system not propagate? You don't quite realize you designed something that was perfect for your curriculum. It filled a gap in your curriculum with a student body of high-achieving students like the Purdue students who had a particular Physics I background, and a particular Physics II background, etc. The *Freeform* developers designed a book that had just the right depth and breadth of coverage. And then you transfer the book to another environment, and it's bound to not fit as well."

No future plans for adopting Freeform: After all of his experiences, Professor Ferri shared that there was little chance of adopting the *Freeform* system in future semesters. He stated that the *Freeform* system was not a suitable match in terms of the breadth of topics covered in the Dynamics course offered at his institution. He did point out that he was very pleased with the worksheets and the active learning emphasis of *Freeform*. He stated that the *Freeform* system is "much more tied to the 'learning side' of instruction as opposed to the 'teaching side.' I think that's a plus, and I think that's why it has worked well at Purdue. It has worked well because it's a system that incorporates active learning in a very natural way". He also argued that *Freeform* had the potential of working effectively for novice instructors having little experience teaching Dynamics because they could follow the workbook structure and simply incorporate all aspects of *Freeform*. More experienced instructors, however, would have to decide which *Freeform* elements would work best for them in comparison to other learning systems they have used in the past.

Motives behind non-adoption of Freeform: Professor Ferri explained that he would not be adopting *Freeform* due to additional factors. He said that the most important reason did not have to do with pedagogy but with logistics. He explained how there are approximately eight different instructors teaching Dynamics in the School of Mechanical Engineering and how it took several meetings to agree upon the Wiley textbook after using a different textbook for over 30 years. Thus, it would be difficult to continue using *Freeform* when everyone else is using a different book. Additionally, the cost of the WileyPLUS textbook was lower than the cost of the *Freeform* workbook. In fact, Professor Ferri explained how he had to use some of the funds he received to teach Dynamics using *Freeform*, to subsidize part of the *Freeform* textbook cost for students.

Benefits of Wiley's textbook: in relation to the previous topic, Professor Ferri indicated that even though the *Freeform* system included high quality worksheet problems and easy to access video solutions for students, the WileyPLUS textbook has a lot more content from which different faculty members could choose to customize their own lectures. He indicated "at the end of the day, a little bit of variability between instructors is also something that is supported by a textbook that has more content". In a way, this also reveals one of the reasons that traditional textbooks are so large and typically more costly to print: they may be trying to accommodate the largest variety of courses taught across a spectrum of institutions. A side note observed by Professor Ferri is the large amount of "blank space" in the lecturebook on which students are intended to write their solutions. This adds to the cost and "heft" of the book and might be unnecessary as more and more students prefer to work on their electronic tablets and to use texts in the e-book format, which the *Freeform* lecturebook does not have available at this time.

4.2 Students' Reflections

In this section we outline the salient findings from interviews conducted with seven students enrolled in Professor Ferri's Dynamics class. This section is divided in three overarching themes: (1) Student experiences; (2) Interactions in the classroom and (3) Course comparison to other classes.

4.2.1 Students' Experiences in Dynamics

All of the students interviewed for this project indicated that they had a positive experience in the Dynamics class as a result of the quality of instruction, *Freeform* digital resources and useful knowledge gained in the class. Salient codes, which include those agreed upon by 5 out of 7 students interviewed:

(a) The instructor was effective and passionate about the topic.
(b) Students watched *Freeform* video solutions which helped them understand the material better.
(c) Students felt that the class prepared them well for future courses.
(d) The Piazza and GroupMe platforms were useful to student learning.

With regard to teaching effectiveness, one student commented:

> "I think Professor Ferri also did a very good job teaching this course because he kept it light, and fun, and interesting. It's a pretty long class, one hour, 15 minutes, so it can get pretty rigorous just doing straight practice problems and dynamics for that amount of time. But no, it didn't feel too bad. I think it was a pretty good course overall."

Another student remarked:

> "I actually really enjoyed the class. I heard from a lot of people that it was very difficult, a lot of algebra, very not computationally heavy, but it's a lot of work and . . . I heard that it was going to be pretty difficult, but I actually really enjoyed it. My professor, Professor Ferri, he was very passionate about it for something that I feel like he recognized could be a little bit dry at times, but he definitely showed real-world applications."

In terms of taking advantage of video solutions, one student remarked that when she needed to understand concepts better, she would "sit down and study. And when I watch the videos, that whole morning, I just went through and wrote out the practice problems for those videos, which was helpful for me in learning. So, I think just taking time aside, and instead of studying the traditional resources, I just sat and . . . watched the videos". Another student, in response to whether or not he watched the online video solutions, responded "I watched them pretty often, especially if I was confused about some material and wanted additional practice or a different way of hearing it explained".

With regard to how well the class prepared students for future courses, one student stated:

> "I feel pretty prepared . . . I didn't make like a hundred, but I think I learned the information pretty good [sic] . . . the concepts are really difficult. But sometimes, that's just a lack of doing problems. And going to office hours I think are [sic] super, super helpful . . . and there are also tutoring review things that were also twice a week that I would go to that are basically like office hours from a student. You can just go and ask questions. I went to those, so I think it's prepared me a lot."

About the same topic, another student remarked:

> "I feel pretty good heading out of the course, not only in terms of the grade. There's been courses, even this semester, where I might have had the grade, but the knowledge is very maybe temporary because I didn't study properly . . . but this was a very progressive course . . . I think I have a very solid foundation now. So, if I took a class, like system dynamics or some other dynamics class, I think I would be able to relearn it or remember it a lot."

Another set of codes, which include statements agreed upon by 3 out of 7 students, include:

(a) Students used the *Freeform* workbook to solve problems in class.
(b) Students watched the lectures recorded by Professor Ferri.
(c) A mix of recorded lectures and *Freeform* resources were useful to student learning.
(d) Students did not have any issues with the order of topics covered in the *Freeform* textbook.
(e) Students enjoyed the class.
(f) Attendance was low in the class due to lecture recording being available to students.
(g) Students had the chance to work significantly on practice problems.
(h) Instructor uploaded PDFs of lecture notes and solutions to the course's website, which was useful to students.
(i) There was wide use of the app GroupMe because it was easy to access help in such way (the use of GroupMe is not part of *Freeform* and it was initiated by students)

In relation to the usefulness of practice problems, one student stated, "The most helpful portion of the class was doing the homework". Another student said "the extent of pure studying that I did was an hour or two of practice problems before each of the exams. I think that it definitely confirms that the practice problems are probably one of the best [ways] to verify understanding and study for these classes".

Similarly, another student talked about the usefulness of *Freeform* online resources for studying. The student noted "the textbook, I pair with online resources because the solutions to the textbook are online. . . so I'll go and look at those. . . I think it's probably made me more prone to check out the online resources more, just because I don't always do that, but that did help me". In the same vein, another student stated:

> "It was a very well planned out course in that we covered a lot of different topics, and I learned a lot of different things. The pace of the course was well designed so that I was never bored in the course, but it was also not that I felt like I was being rushed too much. There were parts where I was confused a little bit, but I was able to catch up through recordings or watching videos or doing practice problems. It didn't feel like I was ever being dragged or being left behind."

In terms of being satisfied with the order of topics in the class, one student stated:

> "Doing 2D dynamics before 3D dynamics makes a lot of sense. Doing work energy and conservation and all that as a separate unit made a lot of sense, too. Also, just his teaching style was very conducive to learning. . . we didn't feel rushed or pushed to where it was hard to learn. It was very positive experience overall."

About the same topic, another student explained:

> "The second time around that we touched on 3D, I got it. I felt like I really did understand it. I mean, I feel like it showed on the final. We had a 3D kinetics problem that I think I got, I mean, I never saw my graded exam, but I think I did pretty well on it. It was weird. I heard some people complain about it, about it feels like we're covering these concepts out of order, but I actually did kind of like it. I thought it made sense for the class."

4.2.2 Relationships and Sense of Community in the Class in Relation to Freeform

General statements about relationships and sense of community, on account of the structure of the course, were voiced as follows:

(a) 5 out of 7 students interviewed indicated that group work and collaboration among students was encouraged in the class.
(b) 4 out of 7 students indicated that a sense of community was aided by the use of the student app GroupMe which allowed students to communicate about class-related topics.
(c) However, the other 3 students interviewed indicated that they were not able to make any friends in the class.
(d) 3 out of 7 students also indicated that the sense of community was made possible because,

typically, only 50% of the class was physically present in the classroom.

In terms of group collaboration in the class, one student said "homework collaboration was very much encouraged in this course, which is a good thing, because that definitely helps you learn more. Because it's not like we're collaborating on a test. It's just homework. I feel like that should definitely be allowed to help each other on".

In relation to the sense of community facilitated by technology, one student stated:

> "I had a few people I became friends with, that we would do a study group together where we did the homework. And then when we all got stuck, we would consult the GroupMe, and other students would help each other through there with questions. And like I said, he also did that on Piazza, where we could post questions there and he [Professor Ferri] would answer, as well, and we could answer each other."

With regard to same topic, another student stated:

> "We had a GroupMe . . . that was where we discussed homework problems or if someone had a question. I like that part of the course that he kept collaboration very encouraging. There's [sic] many courses where it's like if you ask a question about the group or the homework on a chat or something, that's just a straight academic dishonesty. But, homework collaboration was very much encouraged in this course, which is a good thing because that definitely helps you learn more."

In terms of how class size and attendance impacted the sense of community in the class, one student remarked:

> "It was a relatively small to midsize class. Maybe I would say 30 students [the actual enrollment was 47]. It wasn't chit-chatty. Everyone there, I think, for the most part, was there to learn. Of course, not all students came to class. Sometimes we would only have maybe half students come into class or 60, 70, 80%. But the people there did seem to ask . . . People ask questions or ask their neighbors if they have a question."

5. Discussion

In order to synthesize our findings, we turn to our research questions:

5.1 Question 1: What does the Process of Implementing a New Learning System look like from the Perspective of Instructors?

Three salient points are evident in our data: (a) familiarity with the learning system and compatibility with previous approaches; (b) level of teaching experience in terms of the subject matter; and (c) the institutional context and circumstances under which the learning system is implemented.

5.1.1 Familiarity with the Learning System and Compatibility with Previous Approaches

Professor Ferri's experience reveals the importance of the level of familiarity a potential adopter should have with a given pedagogical innovation, as well as how compatible such an innovation is to the systems previously used by the prospective adopter. In Professor Ferri's experience, first we recognize a set of obstacles that are related to the little experience he had with the *Freeform* system. Because it was the first time Professor Ferri experimented with *Freeform*, he had a difficult time with the order of topics, the way in which the problems were solved (e.g., use of symbols) and uncertainty about the breadth of student-learning resources available to him via *Freeform*.

The lack of experience with the system led to some surprises which not only required adjustment, but also more hours of work involved in order to make the system more compatible with Professor Ferri's teaching philosophy. Both of these points reinforce Rogers' assertion that an individual's decision to adopt an innovation would be influenced by their perceived complexity of such innovation [13]. This point is also relevant to the topic of compatibility brought up by Borrego et al. [3]. Our findings confirm the authors' assertion that a prospective adopter's decision to adopt an innovation would also be influenced by factors such as the adopter's previous experiences, knowledge of the innovation and personal values. For example, the inconsistency in the order of topics in the *Freeform* book and previous textbooks used by Professor Ferri not only created workload challenges for him, but also some confusion about whether he had the freedom to change the order of topics to fit with his previous method of teaching.

Another issue related to the topic of compatibility emerged because of misconceptions regarding *Freeform*. Throughout interviews with Professor Ferri, time and again he voiced some of his frustrations over the *Freeform* book specifically. It was evident that when a comparison was made with his previous experiences teaching Dynamics, the focus was on the textbook and not the learning system as a whole. As explained before, our team had some technical difficulties during the onboarding session with Professor Ferri which cut the onboarding session short and likely contributed to his limited knowledge about all of the learning resources available via *Freeform*. In other words, when Professor Ferri discussed *Freeform*, he did so with the perception of it referring to a textbook, rather than a learning system inclusive of a number of additional assets (e.g., large repositories of solution videos, experimental demonstrations of core concepts, etc.).

5.1.2 Level of Teaching Experience in Terms of the Subject Matter

A relevant point raised by Professor Ferri regarding his experiences with *Freeform* was that the system could work effectively if implemented by novice instructors with little experience teaching Dynamics. Teaching the subject of Dynamics for the first time using *Freeform* would potentially eliminate the compatibility obstacle faced by seasoned instructors with well-established teaching approaches and who have spent years creating educational content (if the novice instructor is teaching *Freeform* in a single-section context). Even though this paper focuses on the experiences of Professor Ferri and the institutional culture of his department, our findings from research at other engineering departments confirms this assertion.

We found that junior faculty members at two other engineering departments not only adapted well to the experimentation phase of the *Freeform* system, but also ended up adopting it institutionally. One common factor between these two junior faculty members, however, is that both of them have strong relationships with the system's developers, on account on having had graduated from the engineering school where *Freeform* originated. Furthermore, at least one of these junior faculty members had personal experience with *Freeform*. This finding also supports Riley et al.'s [20] assertion that a potential adopter's interpersonal connections (e.g., connection to co-workers and mentors) would play a role in the successful dissemination and adoption of a teaching innovation. Conversely, while Professor Ferri has an open working relationship with *Freeform* developers, he did not possess a long trajectory working with them, which could have contributed to both a lack of frequent communication and in-depth knowledge of the system.

5.1.3 Institutional Context and Circumstances

In addition to the experiences of Professor Ferri, the *Freeform* system faced other obstacles that were related to specific elements of the institutional context of this particular engineering department. While there were not any administrative obstacles present (e.g., Professor Ferri had the freedom to experiment with *Freeform*), collectively the instructors had decided on the adoption of a Dynamics textbook that was arguably more affordable for students.

In other words, as Professor Ferri explained, despite some of the perceived pedagogical advantages of *Freeform*, logistically it would have been difficult to adopt the *Freeform* textbook. Not only was the *Freeform* textbook more costly than the book previously adopted by the department, but the other instructors usually teaching dynamics were using the same publisher's textbook as such textbook provided more content that instructors could draw from according to their specific preferences. This was an issue that adopters at smaller engineering departments did not face. For example, when only two or three faculty members taught a Dynamics course, it was easier for them to coordinate sharing *Freeform* resources and talk about their experiences.

As far as Professor Ferri's institutional context, as explained before, adopting the Dynamics textbook (the semester prior to the implementation of *Freeform*) was a collective decision that took years to agree on. Hence, any chances of permanent *Freeform* adoption, even if such books presented more pedagogical advantages, would have been slim due to the logistical limitations. This point is related to Henderson et al.'s [18] 4th category of pedagogical change related to a shared vision of change. As explained before, in order for change to occur, a given change agent should inspire and provide support to "stakeholders to collectively develop new environmental features that encourage new teaching conceptions and/or practices" [4, p. 224]. In this case, despite the support provided to Professor Ferri, the project never advanced to an adoption phase wherein all of the faculty members teaching Dynamics would be collectively inspired and/or exposed to the new learning system.

Now we turn to our second question:

5.2 Question 2: How do Students' Perceptions of a Pedagogical Innovation compare to those of the Teaching Faculty Member?

In answering this second question, we build directly from the lived experiences reported by Professor Ferri and his students. The most salient point of discussion is the discrepancy between Professor Ferri's perception of *Freeform* and that of his students. In line with the social constructivist approach mentioned earlier in this paper, we recognize that Professor Ferri's unique position as the instructor responsible for structuring multiple learning activities, invariably contributed to the emergence of a different perspective of, and experience with, *Freeform*. As an experienced instructor, who also worked collectively with members of his department to adopt a textbook the semester prior to the implementation of *Freeform*, we argue that the chances of adoption of *Freeform*, were already slim.

In addition to the efforts Professor Ferri had already invested in the adoption of the *WileyPLUS* Dynamics textbook [29], he did not find in *Free-*

form, a system that was easy to prepare for (in terms of lectures) nor one that was compatible with his typical teaching structure (especially the order of topics). The lack of compatibility not only led to frustration over work overload, but also constant reflection of whether or not student learning was suffering. In addition to these obstacles, Professor Ferri implemented *Freeform* during a time where COVID-19 social restrictions were still enforced, which discouraged a large part of his class from attending in-person sessions. Having a classroom with just half of the students attending in person, played an important role in Professor Ferri's inability to take full advantage of the active learning element that is called for in the *Freeform* system.

Conversely, Professor Ferri's students' experiences produced a distinct reality. In addition to praising Professor Ferri as a passionate and effective instructor, the students were also pleased with *Freeform* as a system that promoted more in-depth learning in comparison to other engineering courses, they had experienced. For example, statements about the course's online video solutions such as "I watched them pretty often, especially if I was confused about some material and wanted additional practice or a different way of hearing it explained," exemplify the students' effective use of *Freeform* blended resources. The students not only took advantage of the online resources available to them, but also took the initiative to form an academic support community (facilitated by GroupMe) to navigate the course's requirements. In this sense, the students did not experience any overt struggles with the learning system, despite the system requiring more student responsibility for their own learning.

We argue, then, that Professor Ferri's efforts, while at times difficult for him to employ, helped the students navigate a different kind of learning system without disruption to their typical learning routines. Furthermore, toward the end of the semester, as we explained earlier, Professor Ferri did begin to recognize the value of the *Freeform* system with respect to student engagement, especially after reflecting on McMurtrie's article on student disconnection [8]. Despite acknowledging the pedagogical potential of *Freeform* to create a more engaging classroom experience, the adoption of the system faced far too many logistical roadblocks that precluded its adoption.

This case study has confirmed some of the findings outlined in other studies that there are certain conditions that must be met in order for an innovation to be successfully propagated and adopted. In our case, lack of complete knowledge and previous exposure of the innovation played a partial role in the potential-adopter's inability to adopt *Freeform*. This essay, however, also shows that some of the roadblocks experienced by potential adopters can be exacerbated by the unique institutional context under which pedagogical innovations are implemented. We argue that regardless of faculty buy-in, a pedagogical innovation would face adoption obstacles when a department is too large to collectively agree on a single pedagogical approach. Moreover, a potential adopter's disposition to adopt an innovation, seems to, at least in part, be related to their personal support connections with the corresponding change agents and the ability to communicate freely and frequently about the innovation being implemented. Finally, it must be stated that the adoption of various aspects of the *Freeform* system, such as the integrated use of active learning in engineering courses, is undoubtedly more widespread than adoption of the Lecturebook, per se.

Ultimately, we contend that pedagogical innovation systems, such as *Freeform*, have the potential to transform student learning and classroom engagement but several conditions must be met in order for its implementation to be successful:

(a) The instructors' willingness to invest significant time to both learn and implement different dimensions of the system.
(b) The instructors' understanding of the system as a learning approach (rather than just another textbook) that includes both a specific way of teaching and a way learning (namely active, blended, and collaborative learning environments).
(c) The instructors' encouragement of students to take advantage of the full spectrum of resources offered by the system.
(d) The instructors' willingness to experiment with the system over several semesters in order to adequately adapt such system to the particular cultural and institutional needs of the department where the system is being implemented.

6. Conclusion

It is evident that "change" in engineering education constitutes an issue with a long history of experimentation from practitioners and academics. The many dimensions and efforts of change outlined in the different case studies and examples in this article, signal the occurrence of some progress. Pedagogical change, as examined in the studies discussed in this work, involves a process that need the support of educators and administrators across the board. Our case study, however, indicates that the implementation of pedagogical change, not only depends on educators' and administrators' buy-in, but also on the particular circumstances that can support or preclude a given change approach. An innovation and diffusion approach offers a useful analytical lens through which the implementation of pedagogical innovations (outside their institutional context of origin) can be examined. As this ongoing research initiative yields more findings across other institutional cultures, we will have a better idea of the impact of *Freeform* at both smaller and teaching-oriented engineering departments.

6.1 Limitations

We recognize that this case study is limited in scope as we only examined the implementation of *Freeform* for the duration of one semester and during social distancing guidelines resulting from COVID-19. Different findings could have emerged if the system would have been implemented across several semesters with the participation of more instructors. Recruitment challenges for student participants also impacted our student sample size. A larger sample size could have expanded the study of student perceptions about *Freeform.*

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Appendix I: Questions for Instructors

1. What moments of experience stand out to you from your first week? These can be anomalies that necessitated immediate or distant reactions, patterns that you noted, or other experiences that stand out.
2. How did you navigate the (week number) week with *Freeform*? Can you think of one or two examples in which *Freeform* conflicted with your usual teaching practice, and how did you resolve those conflicts?
3. How have you managed the workload associated with delivering the course, including class preparation, grading, and classroom management? In what ways has *Freeform* support or conflicted with your usual practices for these issues?
4. How did the process of starting to develop the exam go (either individually or in collaboration)? Can you think of one or two examples in which this exam prep process conflicted with your usual practice, and how did you resolve those conflicts?
5. How did the process of collaboratively developing and then delivering the exam go? Can you think of one or two examples in which this exam prep and delivery process conflicted with your usual practice, and how did you resolve those conflicts?
6. What experiences preparing for the final exam have stood out to you? How does your feeling right now compare to the way you would typically feel at this point in the semester?
7. Can you talk about your feeling of "treading water" (i.e., the feeling of conflict as the instructor transitions from past practices to new practices associated with the *Freeform* system)? How has your course prep gone this semester, overall and week to week? How has this conflicted with your usual practice, and how did you resolve those conflicts?
8. As we near the end of the semester, can you reflect on relationships you have developed with this set of students? How does your feeling about this group of students now compare to the way you would typically feel about students in this class? How would you characterize this group of students? How would you describe your relationship with them? Has class attendance been any different this semester, as compared to past semesters?

Appendix II: Questions for Students

1. I am interested in understanding your individual experience in (ME 2202) this semester. Can you tell me about the experience? What is it like to be a student in this class?
2. We say that this class is a "blended" class because it uses both online and in-person activities. Have you ever taken a blended class before? How do the online resources in this course compare to those in your other blended classes? Are the online materials for this course better or worse? More helpful or less? More plentiful or less? Better production values or worse?
3. What do you do in a typical class meeting?
4. Can you tell me about the class community during your formal class meeting times? Do you work with other students? Can you give me an example or tell me story that helps me understand the ways in which you work with other students?
5. What were your expectations coming into the course? What were your expectations about the grade you would get, your instructor, the workload? Given your experience in other courses, are there any ways in which (ME 2202) has surprised you?
6. How would you compare your experience in (this course) to your experiences in other courses?
7. What might you change about this class in the future? Can you give me an example of something you would prefer to change about this class? What are your pet peeves about this class?

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