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Organizational Learning in Adoption and Adaptation of Reformed Instructional Practices of Engineering Instructors: A Case Study*

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Despite a large body of work devoted to understanding why instructors struggle to implement reformed instructional practices, researchers only understand part of the variation in instructor learning and implementation of the practices. This narrative inquiry case study explored how a mechanical engineering department adopted and adapted Freeform (Ff), which is a pedagogical system, that includes instructional resources and instructional ethos. Findings show that the department adopted Ff with a vision to standardize its dynamics course. The three instructors of four sections of the course had some shared and unshared mental models of engineering teaching and learning that somewhat aligned with the vision. While one instructor adopted all five critical components of Ff in her teaching, the other two instructors did not leverage all the components. The instructors shared some resources for the course and discussed their teaching with others but not sufficient to come to a consensus on the final exam. Consequently, the department could standardize the course materials, homework, quizzes, and schedule, but not the final exam. Via eliciting different dimensions of organizational learning that occurred at the mechanical engineering department, the research suggests ways to improve adopting reformed instructional practices. Moreover, our study contributes to the body of literature by revealing the complexity of instructors' decision-making to adopt and adapt Ff and the relationship and interaction among disciplines of organizational learning in the context of teaching the dynamics course.

Keywords: instructional practices; engineering instructors; adoption; organizational learning; mechanical engineering

1. Introduction

Instructional practices in engineering classrooms play an influential role in student learning outcomes [1-3]. Research has shown that engineering students learn better with instructional approaches that focus on active learning, cooperative learning, problem-based learning, or inquiry-based learning when compared to approaches that emphasize information delivery such as traditional lecturing [4–8]. However, student-centered instructional practices are not enacted often in higher education classrooms including engineering classrooms [9].

Despite a large body of work devoted to understanding why instructors struggle to implement reformed instructional practices [10–13], researchers only understand part of the variation in how instructors learn and how they implement the instructional practices [14, 15]. Some studies show that tensions might arise once instructors decide to adopt active instructional practices [16–18]. For instance, Van Barneveld and Strobel's study [18] found that the enactment of problem-based learning led to students' initial discomfort with the transition and instructors' discomfort with the shift in their role from content providers to facilitators. In other words, problem-based learning implementation disrupted comfortable classroom routines for both instructors and their students. In addition, the instructors reported a system-level tension of their teaching value (e.g., student-centered, learning-centered) and the organizational value assigned to teaching (e.g., content-centered) [18]. Similarly, Carroll et al.'s study [19] shows that engineering instructors' decision on implementing active learning affected by student preparation,

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instructional support, instructor comfort, and institutional rewards. Moreover, the misalignment of instructors' teaching beliefs (e.g., teacher-centered) with the values of reformed instructional practices (e.g., student-centered) might prevent them from enacting the approaches [20–22].

Effective implementation of reformed instructional practices often includes some extent of adaptation where instructors adjust their teaching according to student backgrounds, student needs, and the classroom contexts [23, 24]. However, there are several barriers to adaptive teaching such as lack of autonomy, high-stakes testing, instructor's beliefs, instructor's experience, and student readiness [23, 25, 26]. Moreover, adaptive teaching requires instructors to monitor students' understandings as well as their own thinking in determining how to adjust their instruction, which means instructors must be metacognitive [23, 27].

Besides factors regarding instructors and students, some studies have pointed out the essential role of organizational contexts in which the adaptation of reform-based instructional practices takes place [28–31], as well as the need to better articulate the role of context and how it affects instructional change [15, 32]. Collaboration among instructors has the potential to facilitate their adoption and adaptation of new approaches [33, 34]. Moreover, a culture of learning and adaptability can enhance organizations' ability to maintain a competitive edge, navigate uncertainties, and capitalize on opportunities; that is, they can become a 'learning organization' [35, 36]. Thus, some studies called for academic institutions to develop strategies and routines to become learning organizations that both learn and foster learning [37, 38]. Some studies pointed out obstacles preventing universities from becoming learning organizations such as structure, culture, and accountability to fulfill their aims [39, 40]. On the other hand, there are reports on successful applications of Senge's model of learning organization [41, 42].

Thus, this study examines the ways in which a mechanical engineering department adopted and adapted a new instructional system named Freeform (Ff) as a phenomenon situated within its organizational contexts. In engineering education, improving courses is a critical aspect of preparing students for the complex field of engineering [5, 43]. Improving courses within university departments often focuses on student engagement and educational outcomes. Common themes for targeted improvements include shifting toward student-centered approaches (e.g., tailoring courses to meet the needs and interests of students), enhancing active learning which encourages student participation and engagement, introducing inclusive teaching practices that accommodate diverse backgrounds and abilities, and technology integrating enhanced teaching practices with additional resources for students. The Ff system aligns with many of these themes by explicitly including in-person and online resources to promote active, blended, and collaborative learning.

Research objective: Informed by the learning organization model, this study aims to explore how a mechanical engineering department adopted and adapted Ff, which is a pedagogical system that includes instructional resources and instructional ethos, to standardize their dynamics course. The research question is: how do instructors of a dynamics course make instructional decisions while adopting and adapting the Ff system? It is worth noting that the goal of the paper is to understand instructor' decision-making processes and collective learning, rather than studying student outcomes.

2. Theoretical Framework

The study is framed by the learning organization model (Fig. 1) [44, 45]. We chose this framework for two major reasons (1) the focus of the study is at the departmental level and (2) many variables are involved in implementing reformed instructional practices and we wanted to maximize capturing the variables so our narrative can tell the whole story. A learning organization means "an organization that is continually expanding its capacity to create its future" [45, p. 14]. Even though the initial focus of the learning organization model is on corporate senior executives, it applies to university instructors, K-12 teachers, parents, and so on [45–47]. Organizational learning occurs at many different levels (i.e., individuals, groups, and the whole organization) [48]; this study focuses on organizational learning of a group of instructors who taught sections of a dynamics course offered during the same academic term. The model consists of five disciplines: shared vision, mental models, personal mastery, team learning, and systems thinking. Each discipline of learning organization is critical to the others' success; thus, the five disciplines need to be developed as an ensemble. It is worth noting that learning organization is not the same as learning community. While members of a learning community might belong to different organizations, members of a learning organization belong to the organization [49]. In addition, the goal of learning communities is usually professional development for the members, whereas members of a learning organization should aim to achieve their shared vision [45].

Shared vision means a shared picture of the future

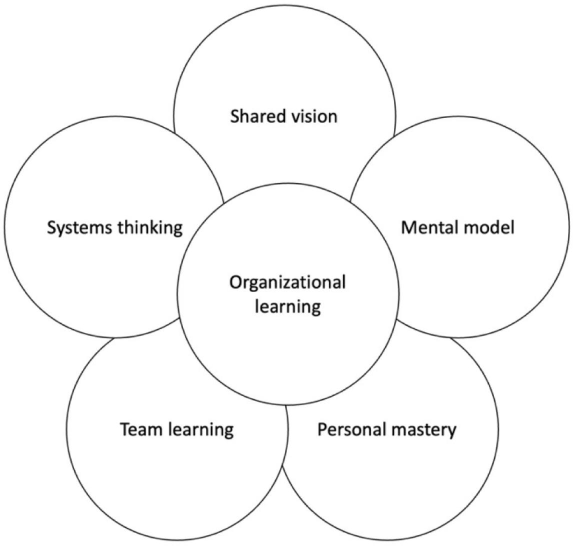

Fig. 1. The five disciplines of learning organization.

an organization seeks to create. The ability to establish a shared vision is critical for any organization. A shared vision helps bind members of an organization together around a common identity and sense of destiny. Moreover, a genuine shared vision facilitates people to learn and excel [45]. *Mental models* are a set of beliefs that affect how we understand the world and how to act. People are not often consciously aware of their mental models and the effects of the models on their behaviors. One's mental model might hold them back from growing. Similarly, many organizations fail to grow because the changes they need to make conflict with their mental models. Shifting our mental models starts with bringing them to the surface and holding them rigorously to scrutiny. When people expose their internal pictures of the world to the influence of others, there is a chance to align their mental models with the shared vision of the organization [45]. *Personal mastery* refers to self-realization that breaks through one's own limits or skillfulness. People with a high level of personal mastery realize the results that matter most to them and commit to lifelong learning. As Senge (2006) stated, "an organization's commitment to and capacity for learning can be no greater than that of its members" (p. 7). In other words, personal mastery is the foundation of the learning organization. Organizational learning, on the other hand, impacts on personal learning of its members.

Team learning leads to collective intelligence of a group that is higher than the sum of the individuals' wisdom. Individual members of a team that is truly learning grow more rapidly than could have happened otherwise. Dialogue is essential for team learning. Senge (2006) distinguishes dialogue from discussion. While discussion focuses on exchanging ideas back and forth, dialogue means a free flow of meaning through a group that allows the group to discover insights not attainable individually. Thus, dialogue leads members of a team to genuinely think together. Some patterns of interaction in teams might undermine team learning (e.g., defensiveness) or accelerate learning because those patterns prevent or facilitate dialogue. Senge (2006) states, "team learning is vital because teams, not individuals, are the fundamental learning unit in modern organizations" (p. 10). *Systems thinking* means integrating other cultivations into one [45]. Institutions and their endeavors are systems. Members of an institution are bound by invisible fabrics of interrelated actions. Since each member is part of the whole system, they tend to focus on isolated parts of the system instead of the whole pattern of change. Oftentimes, organizations' deepest problems require systematic changes [45].

In the context of this research, we operationalize the components of organizational learning as follows. A shared vision is a common understanding for what instructors want students to be able to do after taking the course. Mental models relate to instructor beliefs about what effective teaching and learning look like, including specific pedagogical or assessment tactics. Personal mastery relates to instructor competence in supporting students to achieve learning objectives of the course. Team learning addresses dialogue among the instructors to learn from each other on how to handle a certain aspect of the course, which increases the collective intelligence of the group of instructors. System thinking corresponds to the ways in which instructors organize different aspects of the course (e.g., course materials, instructional practices, schedule, exams, etc.) to serve the shared vision.

3. Method

We utilized a narrative inquiry case study approach [50] to make meaning of the experiences of the participants [51]. Besides helping researchers to understand individuals' lived experiences, narrative inquiry also facilitates exploring institutional and cultural narratives within which individuals' experiences occurred. Case study approach was chosen because the study focused on an environment where the boundaries between the examined phenomenon and context are not clearly evident [52]. More specifically, we utilized a single case study (i.e., the dynamics course at the department) to understand how different disciplines of learning organization affected the extent to which the mechanical engineering department adopted and adapted new instructional practices.

3.1 Context of the Study

3.1.1 Freeform Description and Prior Work

Freeform (Ff) is a system that consists of five critical components: a custom-written textbook, video solutions for both example problems and homework problems, an online discussion forum for asynchronous discussion, peer support and collaboration, and active, blended, and collaborative (ABC) pedagogies [53, 54]. Ff textbook includes content and narrative, practice problems, and conceptual questions at the end of each chapter. Even though Ff provides a lot of physical and online resources, it is not simply a set of resources; Ff is a pedagogical system that includes pedagogical and assessment approaches and resources. The system was developed for dynamics courses to enhance student learning and improve retention. Ff has been adopted and adapted to varying degrees by more than six institutions. Table 1 summarizes findings in the published studies from the project regarding Ff's instructors.

This study distinguishes itself from the listed studies in Table 1 by examining one mechanical engineering department at a medium-size teaching-focused institution where the Ff system was adopted and adapted by all the instructors of dynamics sections (i.e., new site, new set of instructors, new culture). The focus of the study is on how the instructors adopted and adapted Ff. Research data is analyzed via the lens of organizational learning.

Much of our prior and on-going work is explored through an anthropological lens, with an emphasis on context and culture as drivers of behavior. Our research does not focus on 'decision making' per se, in the sense of characterizing the actual deliberative process an individual undergoes when they weigh potential actions and their outcomes. Instead, our continued focus in this and related projects is to explore how instructional decisions can be understood within the cultural milieu of an academic environment. The organizational learning framework is a powerful and complementary tool when partnered with this anthropological perspective, because the underlying culture of the academic unit can be a significant enabler of or barrier to development of, say, a shared vision or team learning. Indeed, our cultural perspective aligns closely to Hora's [17] 'organizational factors' in both scope and detail.

3.1.2 Ff On-Boarding for New Instructors

Ff design team usually supports Ff adopters via formal onboarding and on-going support. For this particular institution, the onboarding meeting was executed virtually because of COVID-related travel restrictions (typical practice is to arrange an in-person site visit during which an extended on-boarding process takes place). The on-boarding meeting covered the Ff ethos around ABC pedagogies, the scope of available Ff materials, and common use cases for maximally aligning the pedagogies and resources based upon the Ff team's experiences. The on-going support included providing at least one homework set and being on-call to consult with adopters and answer their questions about the practice of Ff. The instructors sometimes asked questions during implementation interviews; the nature of those questions was about how the Ff design team would handle a certain

Table 1. Summary findings of past publications from the project

Publications	Main findings
[67]	This study investigates lived experiences of an instructor and her students when adopting Ff. The findings indicate that both the instructor and her students had to navigate tensions between their previous instructional preferences and the Ff ethos and resources.
[68]	The publication delineates the development and application of a classroom observation protocol to code the duration and sequencing of ABC instructional elements. The findings show that the use of the protocol supports researchers in examining ABC instruction and its effects.
[69]	This study focuses on faculty, student, and staff perceptions of faculty-student interactions at a large research-intensive institution. The findings identify social distance between faculty and students due to their unequal status and discuss methods that some faculty used to increase the interactions.
[70]	This paper explores effort of 12 grassroots problem-solving teams, which included engineering school faculty, engineering school staff, and non-engineering school staff, at a large research-intensive institution to promote student outcomes. The findings show that organizational change and continuity are intertwined with cultural alignment, clashes, and individual agency.
[71]	This publication describes the goals, assumptions, methods, and inferences made about faculty culture within an engineering department at a large research-intensive institution while also introducing a formal method to characterize culture. The findings indicate two subcultures: change-oriented, which seeks large-scale changes but feel disempowered to pursue them, and continuity-embracing, which seeks modest changes and feel empowered to enact them.
[72]	This study focuses on adjustments that instructors in an engineering school of a large research-intensive institution made during the pandemic. The findings show that despite the instructors prioritized their teaching responsibilities, increased the accessibility of course materials, and being more available to students compared to pre-pandemic times, students struggled to adapt to online learning contexts.

situation (e.g., how to approach a certain topic in the course) and why would they do it that way. The instructors also asked questions about the content of chapter 6 of the Ff textbook (an introduction to mechanical vibrations), a topic not typically covered in a sophomore dynamics course. Ff adopters also posed questions via email. Even though the Ff design team provided consultation, we also respected and encouraged Ff adopters' autonomy to make appropriate adaptation suitable for their educational setting and student needs.

3.1.3 Dynamics Course at the Mechanical Engineering Department

Even though the institution where the study occurred was a primarily teaching-focused university, the dynamics course "was treated as a stepchild". Since the course was a service course for multiple departments, it was largely any department's responsibility. While a few other service courses such as statics and mechanics were taught by other departments (e.g., civil mechanical, biomechanical department), dynamics was taught by the mechanical engineering department. The department was at a medium-sized university in the Midwest region of the United States.

3.2 Participants

Three mechanical engineering instructors participated in this study. Prof. Scott (pseudonym) had 31 years of teaching experience, and he taught the dynamics course five times (without Ff). At the time of data collection, Prof. Scott was a tenured professor, but he mentioned that he would be the next department chair (we will come back to this point in the discussion). Therefore, Prof. Scott worked closely with the current department chair to set up a vision for the dynamics course. For Prof. Morris and Prof. Collins (pseudonyms), it was their first time teaching the course as instructors; and they both were new instructors at the university. Prof. Morris was the only woman in the department, and she was younger compared to most of her colleagues. She had experience with Ff as a student in the dynamics course, worked as a teaching assistant for a dynamics course, and then co-taught the course with a senior instructor at a large research institute using Ff. Prof. Collins took the dynamics course (without Ff) as an undergraduate student. While doing his Ph.D., Prof. Collins worked as a teaching assistant and did some guest lectures but not for a dynamics course.

3.3 Data Sources

Data for the study came from onboarding interviews, implementation interviews, syllabi, and a limited set of artifacts of the sections (such as instructor-generated problems). The onboarding interviews were to get some background information about the instructor, the students, and the course, and to answer the instructor's questions about Ff, all of which supported our understanding of the instructor's mental model for teaching and learning. Implementation interviews occurred approximately every 2–3 weeks throughout the semester of implementation, and they focused on instructor impression of how the teaching and learning were progressing, how the instructor made adaption decisions about Ff, and how the instructor collaborated with other instructors of the course. We interviewed each instructor at least six times during the semester. The interviews were conducted over Zoom with a duration of 23 minutes to 62 minutes (40 minutes average). Recordings of the interviews were transcribed and cleaned by the interviewer before being uploaded into Dedoose for analysis.

The interview protocol was constructed, piloted, and finalized in the early stages of the Ff project, which dates to 2016. The protocol focuses on contemporaneous data collection about instructor actions as they cover specific course content, create and deliver assessments, grade student work and provide feedback, and assign final course grades. The backdrop for the protocol stems from our anthropological lens, and the protocol is designed to probe how instructors adapt Ff to the local educational setting (i.e., students characteristics and needs, classroom facilities, course policies, pre/co/post-requisite structures, and so forth). Early in the Ff project, we tested the protocol with more than a dozen instructors across four institutions, making small revisions to the question framing or language as appropriate. We also relied on the research team's collective experiences as both qualitative researchers and content experts in dynamics to guide these adjustments. The protocol used for this study has been unchanged for the past several years.

Even though the learning organization model was not used to guide the construction of the interview protocol, most of the interview questions aligned well with the framework. For instance, the interview questions regarding the extent and the ways the instructor collaborated with other instructors of the course aligned with team learning in the framework. Another example was a set of questions that asked instructors to describe their experience regarding how Ff conflicted or aligned with their usual teaching practice and the actual actions they took in class regarding instruction and assessment, the instructors' responses to those questions included information about their metal models of how good teaching looked like in engineering classroom.

3.4 Data Analysis

Transcripts of the interviews were the main data source for data analysis. Syllabi and artifacts of the sections were used as supplement data sources to make sense of the content of the transcripts. We start our analysis by reading the interview transcripts to get ourselves familiar with the data. Then, a codebook was developed of a priori codes [55] based on the learning organization model [45]. The initial coding using the codebook helped identify excerpts in the data that are relevant to each of the a priori codes. While doing the initial coding, we added emerging child codes and grandchild codes under the a priori codes (Table 2), we also created memos for reoccurring statements. Then, we read excerpts and memos belonging to each code to find narrative threads. Finally, we conducted pattern coding [56] to weave narrative threads from each instructor's data into the final narrative threads of our findings. By engaging in the analysis process, we hoped to reveal the complexity of instructors' decision-making to adopt and adapt Ff and the relationship and interaction among disciplines of organizational learning in the context of teaching the dynamics course.

We took several approaches to ensuring the quality of the data analysis processes. First, our initial codebook was established based on a detailed framework - the learning organization model [45] and our careful read of the data. Second, we used more than one source of data (i.e., interviews, syllabi, and classroom artifacts) to better analyze and interpret meaning in the instructors' responses. Third, reliability in our data analysis was based on consistency of the coder's use of codes over time, who had extensive experience with qualitative coding and the learning organization model [57, 58]. Finally, we took a cyclical approach to coding to ensure in-depth qualitative reading and analysis, and throughout each cycle the coding findings were discussed across our team to ensure agreement. Across the coding process, we also relied on the background knowledge of several long-term research team members who have developed deep contextual understanding of the research project, prior interviews with Ff adopters, and the specific institution described here.

Table 2. A priori codes, emerging child codes, and emerging grandchild codes

A priori codes	Emerging child codes and grandchild codes
Shared vision	Vision of the school Vision for the course
Mental model	Engineering teaching View on the roles of quizzes
Personal mastery	Ff adoption/ adaptation • Ff textbook • Video solutions • Online discussion forum • Peers • Active, blended, and collaborative pedagogies • Other reformed instructional practices implementation
Team learning	Resources sharing Discussion (idea exchange)
System thinking	Course materials Assessments Instructional approaches Schedule

4. Findings

The mechanical engineering department had a shared vision for adopting Ff which was to use Ff to facilitate standardizing the sections of its dynamic course. However, except for using the Ff textbook, not all three instructors leveraged other critical components of Ff. There was some team learning occurred, but the frequency and quality of the learning were not sufficient to align the instructors' mental models and personal mastery with the shared vision. The department achieved some systematic results toward its goal but did not make the vision its reality. In the following sections, we detail the findings regarding each discipline of the department's organizational learning. Since the five disciplines of organizational learning (i.e., shared vision, mental model, personal mastery, team learning, and systems thinking) are intertwined, we acknowledge that one or two of the findings we describe below might also fit into another finding subsection.

4.1 Shared Vision

The instructors were well aware of the vision of the College of Engineering, which was not only to advance engineering but also to change the base of engineering education to be more about the people engineers serve. Pedagogical innovation was part of a larger shared vision within the College of Engineering and was shared by faculty, staff members, and students. Our data collection about this institution indicated that this shared vision stemmed from a deep commitment to student support and care. This institution aimed to train students not only in the technical components of engineering but also in the roles of engineers in addressing societal challenges. The latter component emphasized the strengthening of social skills which include leadership, conflict resolution, openness to failure, risk tolerance, teamwork, and forward thinking. Thus, this institution focused on forming engineers who were both technically competent and also interested in serving the world. Prof. Morris summarized the vision in her first interview, "So there's less emphasis on the element of 'go be a good engineer,' and there's more on the element of 'go be a good person and use engineering to do it.'"

The department's vision for the course was to have a uniform standard for teaching dynamics, and adopting and adapting Ff was a vehicle to achieve that vision. As Prof. Scott said, "So part of him putting himself [the department chair] and me into that course is trying to get uniformity in terms of what the expectations are across the curriculum" (interview 3). Before adopting Ff, the instructors used different textbooks, taught the topics in different orders, and had different expectations for exams. More importantly, the instructors emphasized different topics based on their background and what they thought was important for students to learn. The below excerpt from Prof. Collins's second interview showed the variation of dynamics sections.

> "From what I have heard, each instructor would use a different book. They would use different homework. They would cover things in a different order. They would put different emphasis on things. . . I know their exams were totally different from each other."

The lack of uniformity across the dynamics sections made students who took dynamics in the past frustrated. The students wanted a uniform standard across sections of the course; as Prof. Scott said, "he [the department chair] met with students and he's asked them what would they change if they were Department Chair. And one of the things they've asked for is more standardization in terms of the mechanics' sequence" (interview 3). Thus, the department wanted to have one standard for all sections of the dynamics course, and they thought adopting Ff might facilitate achieving that vision, "if we all agreed on the same textbook, then I thought we would get there" (Prof. Scott, interview 3). Adopting shared resources was only one step of creating a shared vision within a learning organization, as described next.

4.2 Mental Models

There were some shared and unshared mental models of different aspects of engineering teaching among the three instructors. Prof. Scott and Prof. Collins put problem-solving skills first and did not mention diversity and equity; Prof. Morris paid attention to both problem-solving skills and making her teaching more equitable for students with different backgrounds. While it seems like Prof. Scott thought materials of the course were what mattered most, Prof. Collins and Prof. Morris put their effort into encouraging students to collaborate. Similarly, Prof. Scott's view on the role of quizzes was for him to decide on the content, while Prof. Morris and Prof. Collins considered quizzes more as learning opportunities for students. Table 3 summarizes the instructors' mental models. The following sections will further describe the findings and provide evidence for these findings.

Table 3. The instructors' mental models of teaching and learning

Instructor	Mental model
Prof. Scott	• Put problem-solving skills first • Did not explicitly consider diversity and equity • Cared most about materials of the course • Used quizzes as formative feedback for the instructor
Prof. Collins	• Put problem-solving skills first • Did not explicitly consider diversity and equity • Encouraged students to collaborate • Used quizzes as learning opportunities for students
Prof. Morris	• Paid attention to problem-solving skills • Paid attention to diversity and equity • Encouraged students to collaborate • Used quizzes as learning opportunities for students

4.2.1 Views on What Important in Engineering Classrooms

Prof. Scott mentioned his industry experience a few times in different interviews and emphasized the importance of problem-solving and communication skills for engineering students. Prof. Scott thought at work his students might not use a certain technology that the curriculum prepared them for, but they would definitely solve problems and communicate results. So, the courses students were taking should be a means to foster those two skills. Prof. Scott shared, "I kind of view engineering education as really teaching them how to solve problems and communicate results. And we use dynamics and other materials. Those are all just vehicles in order to do that" (interview 2).

Similar to Prof. Scott, Prof. Collins emphasized problem-solving skills. However, Prof. Collins did not mention the role of communication. To foster his students' problem-solving skills, Prof. Collins created a procedure called 'problem-solving checklist', which "write out the problem statement, identify what you're looking for, identify what you know already, and then create a plan, including identifying what types of equations will be relevant and then executing that plan" (interview 1). He thought the other instructors all used something similar to the checklist but not in an explicit way as he did. Prof. Collins said, "The difference is that I'm putting it in an explicit checklist form so that they're able to have this next to them as they work" (interview 1).

Prof. Scott and Prof. Collins did not mention explicitly diversity and equity in their interviews. Prof. Morris brought in those topics and was concerned about how to make her teaching more equitable for students with different backgrounds (a matter of educational equity). For instance, she expressed her concern on how to make the video solutions of the course (which do not have captions) more helpful for English language learners, "Maybe some students whose first language is not English, for them the captions [of video solutions] are really helpful for them" (interview 4).

While Prof. Scott cared more about instructional materials, Prof. Morris and Prof. Collins paid attention to teaching practices and learning environments. Prof. Scott had positive comments on available materials for students, "I like the fallback position for the students that they have multiple resources available to them for learning material. They have examples from the class, they have the video examples, and they have the textbook itself" (interview 2). One shared teaching philosophy between Prof. Collins and Prof. Morris was that they both valued collaborative learning. Prof. Collins said that he aimed to include collaborative activities in all his classes because the activities facilitated his students' learning: "if I don't do that, then I end up with a lot of nodding heads and not much learning" (interview 1). Prof. Morris often gave her students opportunities to collaborate with their peers as she emphasized, "I had tried to encourage them to work together" (interview 3).

4.2.2 Views on the Role of Quizzes

Prof. Morris' and Prof. Collins's views on the role of quizzes were somewhat similar, while Prof. Scott's view was different. Prof. Morris and Prof. Collins used quizzes as opportunities to make students collaborate. Since Prof. Morris preferred active and collaborative teaching, she wanted her students to work together in the classroom. However, she was not very successful in encouraging students to do so until the first quiz, "It was the first time that students really were incentivized to work together... So, by allowing them to have a partner or even a group of three on this quiz, it encouraged a lot of communication amongst the students" (Prof. Morris, interview 3). Prof. Morris gave quizzes with a small contribution to the overall course grade, "I use quizzes regularly, low consequence. They're only five percent of the course grade" (Prof. Morris, onboarding interview). This was the same as the way Prof. Collins credited quizzes. In addition, Prof. Collins used quizzes as a means for students to find out and then look closer at problems that they had not fully understood.

> "What the quiz does is it forces them to confront the issue by themselves in a fairly stress-free way. The quizzes I give out are partner quizzes. So, they do it with someone else. So, if there's a disagreement, they can talk about that. That helps. But also, the quizzes aren't worth a lot of points... I want them to look at specific things that might be giving them trouble so that they can identify that early and be able to study that or whatever they need to do to correct that problem they have" (Prof. Collins, interview 3).

Besides helping students be ready for exams, which was the same as Prof. Collins did, Prof. Morris saw quizzes as a way to evaluate how she had been teaching and make adjustments. Prof. Morris shared, "It's more so I can see how I am doing as an instructor. How are they grasping the concepts and how do I need to pivot my delivery mechanism or spend more time on a topic" (onboarding interview).

Prof. Scott used assessments as a way for him to make instructional decisions on the content. For instance, when his students did not do well on questions regarding relative motion of particles on the same body, Prof. Scott was hesitant to move to motion within a rotating reference. He said:

> "I was reluctant to go there based on the two quizzes I had given. . . If you're having difficulty getting the motion of a particle on the same body, how am I going to do this when you're going to have rotating reference frame and you have motion within that reference frame" (interview 2).

Additionally, Prof. Scott gave less percentage for homework and more for quizzes because he observed that students might copy their peers' homework solutions. Since Prof. Scott credited classroom attendance and used quizzes as a form of exam, he gave pop quizzes (unannounced quizzes) and students did them individually (not group quizzes), "What I did is because I wanted to diversify my perspective in terms of their actual knowledge. Rather than take up a lot of class time, I thought quizzes would be a better way rather than having more exams" (interview 2).

4.3 Personal Mastery

Based on the background of the instructors, we believe that they were experts on the content of the course. Since the shared vision was to use Ff as a means to standardize sections of the dynamics course, our analysis of the instructors' personal mastery focused on adopting and adapting Ff. The three instructors adopted and adapted the five Ff critical components to different extents. While Prof. Morris leveraged all five components of Ff, Prof. Collins used four of them, and Prof. Scott used only the textbook and some of the video solutions.

4.3.1 Ff textbook

Prof. Scott used some problems in Ff textbook as homework for his students. Compared to the design of Ff, Prof. Scott's class spent more time on some topics; so, he needed more homework for students and used some from Ff resources and some he created. Prof. Scott shared:

> "Probably half the problems using for homework are [Ff-supplied] homework. The rest are ones I generated because, for example, we're spending more time on a lot of the single topics than [instructors at other Ff adopting institutions] do, so I need more homework in that topic. So I'm making them up, or I'm using ones I had previously [used when I taught the class prior to Ff adoption]" (Prof. Scott, interview 2).

Prof. Collins and Prof. Morris also used some homework that was not included in the Ff textbook as Prof. Collins said in his first interview, "they're very similar to the [Ff-supplied] homework set. We use that, but we also use a combination of homework problems that Prof. Scott [changed to pseudonym] wrote up, I think, several years ago now."

4.3.2 Video solutions

Regarding the Ff video solutions, Prof. Scott used some videos but did not find them very helpful because some of his students took some information from the videos and used it in the wrong ways (i.e., some students misapplied what they learned from the videos).

> "The other thing is they [students] learned some bad habits from what they'd see in the videos. And it's not that the videos are giving them bad information, it's that they're taking information and using it badly. So, for example, there was a problem where I had a system of particles, and it was just a Newton equation type of solution. So rather than draw the individual free-body diagrams for the bodies, they drew the system and didn't consider the interaction of forces between them" (interview 4).

Different from Prof. Scott, Prof. Collins said that the Ff videos were helpful for him as well as for his students. He found that the videos were helpful for him because (even though he was a content expert in dynamics) he did not have *teaching* experience with all the topics of the course and that watching the videos helped him show his students the correct way to solve the problems. He admitted:

> "I've made I think two mistakes in my notes, not counting little things where I said the wrong variable or something like that, two mistakes in my notes so far that forced me to stop and basically say, 'Okay, the rest of my solution is invalid.' And I think both of those cases were cases that I felt comfortable enough with the problem that I didn't watch the example videos, which I probably would've caught if I had watched the example videos" (interview 3).

Prof. Collins's students told him the videos were helpful for them, "I think they generally are pretty good solutions and I know the students have found them to be very helpful. At least they've told me they're very helpful" (interview 3). From his observation, Prof. Collins thought his students made good use of Ff videos, "Just looking at the way they've done their notes and things in class, I have reason to believe that they're using them [Ff videos] pretty well. I'd say they make pretty good use of those resources" (interview 3). In addition, Prof. Collins stated that Ff videos were especially useful when one student missed a class and needed support to catch up with the lesson. However, Prof. Collins also pointed out that the videos would do better in guiding students to identify what the problems really ask them to do and to decide on how to approach the identified problems. He explained, "they [the videos] tend to not include what I was saying before, where they're not including much information on 'how do you identify this problem as...' 'How do you match the problem to your solution methodology'" (interview 3).

Prof. Morris shared that Ff videos saved her time while preparing for her teaching, "That does help speed things up. If there's something in there that's what I'm looking for then I don't have to go to YouTube and watch videos on end until I find the one that's actually what I want" (interview 4). Moreover, Prof. Morris thought Ff videos were helpful for students because they enhance students' understanding of the application of the concepts in real-world problems, "I think for the most part it helped them. . . I think anything where they get to move beyond just a problem in a class, and actually see a real-world application for it is good" (interview 4).

4.3.3 Online Discussion Forum, Peers, and Ff Ideology

Prof. Morris was the only instructor who used an online discussion forum, and she did not often interact with students on the online discussion forum, as she shared, "We had the blog [an online discussion forum] although I didn't really manage it or interact with it very much. I just made sure that the resources were there and then the students handle it themselves" (onboarding interview). The nature of the online discussion forum was for students to seek help from their peers, provide help to their peers, and exercise their social network. Moreover, because of her experience with Ff, Prof. Morris enacted not only Ff materials and practices but also Ff ideology; "I like to use the free-form ideology to give conceptual questions when I do my quizzes, so that's going to work to my advantage" (interview 2). The conceptual questions Prof. Morris mentioned were a specific set of questions in each chapter of the Ff textbook, rather than conceptual questions developed by this instructional team.

4.3.4 Active, Blended, and Collaborative Pedagogies

Prof. Scott said that many of the ABC pedagogies of the Ff ethos aligned with how he normally taught in his other (non-Ff) classes. Based upon interview evidence and pedagogical self-descriptions, we suspect that his teaching may be less active and less collaborative as compared to Prof. Morris's and Prof. Collins's teaching. For example, even though questioning was part of Prof. Scott's classroom practices, the interactions caused by his questioning were mostly between him and his students. Interactions among students (e.g., think-pair-share) rarely happened in Prof. Scott's classroom. Moreover, the objective of his questioning was to address students' misunderstandings, not to create learning environments where students felt comfortable exchanging ideas, "I'm trying to encourage like the Socratic method. I'm trying to encourage debate because I told them my objective and homework is to have them expose their misunderstandings, such that they can be rectified before they take summative assessments" (onboarding interview).

Prof. Collins paid attention to making his lessons more active and collaborative. Prof. Collins usually used think-pair-share in his classrooms as he said, "So one thing that I do in my class is I do a lot of think-pair-shares." While Prof. Collins wanted his students to interact and discuss assigned work with their peers, he aimed to engage students by not overwhelming them. Prof. Collins expressed:

> "So I'm trying really hard, whenever possible, not to overwhelm a group with too much work. Because otherwise it tends to have a negative effect because instead of feeling like they need to dig in and try to figure out what's going on, they have a tendency to just give up too fast. To be fair to them, we're doing problems on something we probably just learned. I expect them to be only slightly familiar with it and not be master of it at that point. So, I want them to have plenty of time to look into it" (interview 3).

Prof. Morris aimed to promote active learning that enhances students' ability to explore the learned topics by themselves. Prof. Morris minimized lecturing but provided resources and asked students to discuss with their peers to explore the topic. While students worked with their peers, Prof. Morris acted as a facilitator who was willing to answer their questions. Prof. Morris's teaching practice aligned with her mental model of good engineering teaching. She also said that the Ff textbook facilitated promoting active learning in her classroom.

> "My philosophy of teaching is very much an active learning experience that allows students to explore their own learning. I think that giving them the support system and the resources and the information they need, but then allowing them to fumble around with the topic or the course material in a safe environment is how my teaching style works. And so the Freeform book, which has lots of examples, allows me to stop and let the students do the next step, and low consequence evaluations like that" (onboarding interview).

4.4 Team Learning

4.4.1 Resources Sharing

The instructors shared some resources for the course with each other. Especially, since Prof. Collins was a new instructor, he received support from other instructors including the ones who taught dynamics that semester and the ones who taught the course before. For instance, Prof. Morris shared her tentative course schedule with Prof. Collins. Prof. Collins also received help from other instructors:

> "I did get a lot of help from the faculty in the department though, both Prof. Scott [changed to pseudonym] and Prof. Jackson [changed to pseudonym, the chair] helped quite a bit. Prof. Morris [changed to pseudonym] was very, very helpful at the beginning. I didn't want to bother her the whole semester, but she was very helpful at the very beginning and also had a couple other faculty that I approached and some that approached me to help out. I would say on the whole, I felt like I was very strongly supported" (interview 5).

While Prof. Scott shared his homework problems with Prof. Morris and Prof. Collins, Prof. Morris shared video solutions that she created with the two other instructors, Prof. Scott said, "Prof. Morris [changed to pseudonym] had actually generated two that I used. But I haven't done my own videos of those" (interview 1). The resource sharing contributed to achieving the shared vision of standardizing sections of the course. According to interview data, this kind of resource sharing did not happen prior to adoption of Ff because instructors of the course worked much more independently.

4.4.2 Discussion (Idea Exchange)

The instructors talked about the course with each other to some extent. There was an occasion when Prof. Scott talked to Prof. Morris because he forgot how to solve a problem that he had given to students as homework and had solved previously. For that type of problem, Ff suggested drawing a system of free body diagrams. Prof. Scott usually just went through his diagram for the individual elements and used equations; so, he missed a force that was external to the system, which he had not caught before. Prof. Scott talked to Prof. Morris and the talk was helpful to him. Prof. Morris reminded Prof. Scott of drawing free-body diagrams. Prof. Scott realized what he missed and appreciated the approach in the Ff textbook after the event. He said, "I now see some value in doing that [drawing a free-body diagram], whereas I'd never done that before. . . So that influenced me because I overlooked the external force that I had not recognized previously" (interview 3).

In addition, since all three instructors used the Ff textbook, they talked to colleagues about their teaching and how to engage students; as Prof. Morris shared in her second interview: "It has motivated some conversations with my colleagues in terms of how they choose to manage their class, and what they choose to do to engage students from underrepresented populations, and randomly calling up students and stuff like that." Furthermore, to achieve the goal of having a uniform standard for the course, the instructors had one meeting at the beginning of the semester to talk about how to teach the course moving forward. The instructors of the course and the department chair attended the meeting.

4.5 Systems Thinking

The department thought somewhat systematically about how to meet the goal of unifying the sections of dynamics course. The vision of standardizing sections of the dynamics course was thought of as the same content coverage, assessments, and schedule. Evidence from the interviews showed that reformed instructional practices were not included as part of the standardization. The department thought that when all the instructors used the same instructional materials, had the same schedule, and used the same exam questions, then the course would be standardized. The department did not think deeply about how the instructors enact the materials in the classrooms and the instructional practices they implemented to achieve the learning objectives of each topic.

The result of the effort was that the course was standardized to some extent but not at the level that the department wanted. Three instructors of four dynamics sections taught at the same speed, assigned the same homework, and used the same assessment format (except for the final exam). Prof. Collins admitted that keeping different sections of the dynamics course consistent was a big difference from the past and that the change facilitated student help-seeking from the tutoring center.

> "It's very different what we're doing this semester, in that we're all using the same book, we're all using the same homework assignments, and we're covering the same material on the same days [same schedule]. In the past, I know they might have two or three professors teaching dynamics, the same class in name, but they will each use a different book, they will each be covering things in a completely different order, they'll use their own symbology, and it has been very difficult, especially for additional resources such as tutoring center and that sort thing to keep up, because each professor is looking for a different format for the homework problems and that sort of thing. And in this case, we're keeping that all consistent. So that's a very big difference" (Prof. Collins, interview 1).

Most of the time, the instructors aimed to keep aspects of their teaching consistent with the team. Prof. Collins shared in his second interview that the instructors tried to give the same homework to students, "We're trying to stay consistent on homework. All four sections use the same homework." Since Prof. Scott had taught the course many times, to uniformly teaching the course that semester, he had to change the order of a few topics; "Normally I go from particle kinematics to particle kinetics. But I'm going with the book structure, to be consistent with the other faculty" (Prof. Scott, interview 1). Nonetheless, it was easy for Prof. Scott to make the change, as he stated, "it was not a difficult transition to switch to that" (interview 1).

However, the instructors did some aspects of their sections differently from the others. One example of the differences was the distribution of percentages for each type of assessment (e.g., homework, quiz, exam). While Prof. Scott took into account who was participating in class, and he called it a professionalism grade, Prof. Morris and Prof. Collins did not include participation grades. More importantly, the instructors could not come to a consensus on what a fair exam would be across the sections, so they gave separate final exams. The instructors did aim to set a meeting to write the final exam together. However, they could not agree with each other on the types of questions to include (e.g., conceptual questions, and closed-ended questions, or open-ended design-type questions).

5. Discussion

The findings revealed important insights about how the mechanical engineering department adopted and adapted new instructional practices. The department decided to adopt Ff to standardize sections of its dynamics course. The instructors worked toward the shared vision but only achieved part of their goal. To fully achieve its vision, the department might need to (1) have deeper systems thinking on the vision they want to achieve, (2) find a way to align the instructors' mental models and personal mastery with the shared vision, and (3) pay more attention to improving the frequency and quality of team learning among the instructors.

5.1 Deeper Systems Thinking

From our analysis of the data, it seems like Prof. Morris and Prof. Collins were involved with the department chair less than Prof. Scott in setting up the shared vision and systems thinking to achieve the vision for the course. Our findings show that Prof. Scott cared more about content and instructional materials while Prof. Morris and Prof. Collins cared more about instructional practices. Each member of an organization tends to focus on isolated parts of the system instead of the whole pattern of change [45]. We wonder whether deeper and broader systems thinking would occur if the department equally involved all instructors of the course in the process. We also wonder if the dynamics of gender and seniority hindered equal engagement of all instructors.

Systems thinking facilitates administrators and instructors to better understand the dynamic relationships among various components of educational systems [59, 60]. In the context of this study, systems thinking could help the instructors to better understand the roles of different components of the courses such as materials, assessments, and reformed instructional practices in achieving the shared vision. The department paid attention to course materials and assessments, and they did achieve their goal of standardizing the materials and assessments to some extent. However, reformed instructional practices were not explicitly considered as part of the needed change.

Even though the department adopted Ff to facilitate achieving the vision of setting one standard for all sections of the dynamics course, which has the potential for enhancing student learning outcomes [61], the instructors and the department chair might not fully understand Ff as a pedagogical system that includes pedagogical and assessment approaches and resources. At some points, the adoption was reduced as, "If we all agreed on the same textbook, then I thought we would get there [achieve uniformed sections for the course]" (Prof. Scott, interview 3). The department needed more attention to instructional practices, not only standardizing the content of the course. The vision for the course was clear but the systems thinking on how to achieve the vision was not sufficiently thoughtful. Moreover, to fulfill the vision of the college on creating good engineers who serve society, reformed instructional practices play a role. The case of the dynamics course at the mechanical engineering department we present here is not unique, the lack of systems thinking is quite common in higher education planning [62]. Nonetheless, it is possible to apply systems thinking in higher education [63, 64].

5.2 Mental Models and Personal Mastery Matter

Most of the instructors' mental models of engineering teaching (e.g., valuing problem-solving skills and collaborative learning) align well with the rationale for adopting Ff. However, Prof. Scott's focus on the content might have prevented him from paying more attention to instructional practices. Mental models are the underlying driving force that forms the basis for instructional decisions [25, 65]. It seems like Prof. Scott did not really value ABC learning so he did not spend time and effort to adapt the practices. The Ff ethos encourages instructors to use the system's resources in concert with ABC learning to promote student engagement, collaboration, and agency during class meetings. Thus, Prof. Scott missed the main aim of Ff.

Besides varying in the extent of adopting Ff, the instructors' responses to Ff were different. Prof. Morris and Prof. Collins accepted Ff better than Prof. Scott. Prof. Scott's mental model of teaching and learning might hinder him from some aspects of the change (e.g., adopting ABC pedagogies). Additionally, the fact that Prof. Scott did not leverage all five components of Ff might prevent him from seeing the benefits that Ff could offer. The department and the instructors thought that using the same materials was sufficient for achieving the vision of standardizing the course. We would argue that besides using the same instructional materials, aligning mental models and personal mastery of the instructors with reformed instructional practices was needed to achieve the shared vision for the course. Team learning could ease shifting mental models and improving personal mastery.

5.3 Frequency and Quality of Team Learning Have the Potential to Make a Difference

Evidence from the interviews with the instructors showed that some team learning happened. The instructors did share resources and talked about the course with each other to some extent. However, it was high likely that the nature of those talks was closer to discussion (i.e., exchanging ideas) than dialogue (i.e., genuinely think together). Dialogs in team learning have the potential to change mental models [45]. In addition, Senge (2006) states, "team learning is vital because teams, not individuals, are the fundamental learning unit in modern organizations" (p. 10). Thus, increasing the frequency and quality of team learning has the potential to help the team achieve its vision.

The instructors did not give the same final exam because they had different views on the appropriate type of exam and the questions to include (even though they had a meeting to write the exam questions together). There was a need to align the instructors' mental models to come to a consensus on the final exam. More team learning (i.e., dialogues among the instructors) might facilitate the instructors to challenge and update their mental models (i.e., beliefs and assumptions). Moreover, team learning is a collective effort, which emphasizes the importance of collaboration, open communication, and knowledge sharing among team members. In other words, team learning enhances individuals' openness to change toward more adaptive and innovative mindsets. Again, the need for more team learning that we present here is not unique to the department. In academics, even though instructors do learn at work and learn through peers [66], they are generally individualistic in their work [39].

5.4 Onboarding and On-Going Support Can Help

The Ff design team learned from the findings of this study that new adopter onboarding (which in this case was limited by COVID travel restrictions) could be strengthened. More thorough onboarding would facilitate conversations at the beginning to determine the scope of the shared vision (i.e., does it include pedagogical practices, or not?) and promote deeper systems thinking. In addition, deeper onboarding from the Ff design team would help the instructors better understand the intention of Ff design. Interview data confirms that there were moments where the instructors mistook the intention of Ff. For example, Prof. Collins did not get that the components of Ff should be used in an integrated way. He thought some of the videos would do better at guiding students to identify problems and decide the approach to solve them. It would be a pedagogical opportunity to discuss in the classroom and show students why a particular approach is the 'right' one for a particular problem. On the other hand, in a few cases, the way the instructors adopted Ff was perfectly aligned with the Ff design, but they thought they did not do well. For instance, Prof. Morris did not involve much in the online forum discussion and her response seemed like she thought she should be involved more deeply. However, the Ff design team's experience over many years has been that as soon as an instructor replied to students' questions, discussion among students stopped.

More involved on-going support from an outsider, which would be the Ff design team or perhaps the adopting institution's center for teaching and learning, would enhance equal engagement of the instructors in setting up the shared vision for the course as well as other instructional decisions. Moreover, a neutral facilitator would also mediate the conversations among the instructors and help resolve differences such as the views on the final exam. More involved on-going support might have the potential to shift the instructors' discussions to dialogues that facilitate changing mental models and increasing team learning.

6. Limitation and Future Work

This study has several limitations. Even though we aimed to maximize capturing variables that affect the department's organizational learning, we did not have data on some other factors that might play a role such as the way the institute evaluates engineering teaching or the role of students. In addition, the research data came from only three instructors of four dynamics sections. Future research might further explore organizational learning of larger groups of instructors and collect data from different sources such as classroom observations and student data. It would also be helpful to better examine the role of leaders such as department chairs and college deans in efforts to adopt reformed instructional practices.

7. Conclusion

The findings revealed important insights about organizational learning within higher education departments. Even though several studies aimed to understand how instructors adopt and adapt reformed instructional approaches, most of them focused on one certain practice such as problem-based learning or active learning. Our study contributes to the body of literature by revealing the complexity of instructional decisions involved in adopting and adapting Ff, which is an instructional system consisting of ABC teaching and instructional resources, and the relationship and interaction among disciplines of organizational learning in the context of teaching the dynamics course. Our findings show that the extent to which the instructors teach their sections the same way as other sections of the course and the effectiveness and sustained adoption of reformed instructional practices depends on the commitment to five disciplines of organizational learning.

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