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Introducing an Instructional Model in Undergraduate Electric Power Energy Systems Curriculum-Part (I): Authoritative vs. Dialogic Discourse in Problem-Centered Learning

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Introducing an Instructional Model in Undergraduate Electric Energy Systems Courses-(Part I): Authoritative vs. Dialogic Discourse in Problem-Centered Learning

Abstract
A Four-Practice instructional model for a new undergraduate electric energy systems curriculum is described and discussed. This study applies design-based research methods to advance the three goals of design, research, and pedagogical practices simultaneously. It focuses on pedagogical design considerations. In-class practice of the model provides several accounts of pedagogical strategies. The study shows that the Four-Practice Model has redefined the role of instructors in the new curriculum and facilitated classroom discourse. It shows that the model has empowered instructors to turn classroom interactions and communications into effective pedagogical tools in problem-centered learning.

Introduction

In light of statistics showing shrinking enrollment in undergraduate electric energy systems curriculum, electrical engineering programs nationwide have responded. Educators agree that the quality of engineering teaching needs to be improved, and the content and delivery of traditional lectures fail to motivate students to meet learning challenges and job requirements. The Department of Electrical and Computer Engineering at the University of Minnesota Twin Cities has developed a comprehensive plan to revamp the electric energy systems core courses. [1] The reformed curriculum has integrated the three sub-areas of electric energy systems, i.e. electric drives, power electronics, and power systems, into a single focus area. The new curriculum is able to cover a broader range of topics with greater depths while allowing students to explore complimentary areas, such as control systems, mechanical systems, and programming languages.

Even with the many significant changes in curricular content and structure, the success of the reformed curriculum also depends on how the curriculum is implemented and how the content is delivered. [2] The current study, conducted in one of the three core courses of the curriculum, Electric Machines and Drives, investigates innovative instructional strategies in STEM education. One of the fundamental changes in instructional approaches for the new curriculum is to utilize problem-centered learning during regular in-class sessions. Students are instructed to learn theories and content by watching online video modules before coming to the class, and solve problems with peers inside the classroom. There have been reports on teaching and learning in such settings where encouraging instructional experiences and learning outcomes, particularly better interactions between instructors and students, were discussed. [3] While technology-enhanced learning has changed perceptions and practices in engineering education and is expected to create opportunities to advance learning ,[4-7] traditional means of teaching have been challenged, and instructors are no longer considered the sole knowledge provider.

Despite the positive impact of active learning strategies on improving student learning, which has been demonstrated by numerous studies, engineering classrooms continue to be dominated by passive lectures, in part due to limited awareness and receptiveness of active learning among faculty members. [8,9] For decades, engineering instructors have built a strong sense of efficacy upon beliefs of their role as the knowledge provider using teaching practices of lecturing course content in a big lecture hall. [10] Efforts in educational practices to promote active learning have embraced changes in instructional approaches and confronted beliefs in the efficacy of traditional teaching methods in engineering. Yet, research that adequately addresses concerns, confusions, and even tensions arising from changes in engineering education is still lacking. There is an urgent need to advance research to support innovative instructional models that draw on active learning pedagogies. Research in these areas will help us understand what changes are needed in engineering education and how we can align these changes with the development of efficacy beliefs of instructors.

Our research establishes an instructional model for widespread dissemination of electric energy system curriculum and provides insights into how the new curriculum engages students in learning. We use the phrase *problem-centered learning* consciously to avoid invoking mistaken identification with problem-based learning and emphasize teaching practices that problematize the content. We examine several factors that impact student learning in real educational settings: how instructors teach, how students learn, and how the learning environment influences learning. In the first part of this study, we focus on instructions for problem-centered learning classrooms using design-based-research (DBR) methods to develop innovative learning activities and explore changing roles of course instructors in non-traditional classrooms. [11, 12] It will describe a Four-Practice instructional model that includes 1) anticipating, 2) monitoring, 3) connecting and contrasting, and 4) contextualized lecturing and explain how the model leads to an engineering classroom discourse that fosters interactive communications and engages students in meaningful learning. [13] We will discuss the degree to which classroom discourse is authoritative vs. dialogic, and how it enhances the contextualized lecturing in particular. We describe the changing role of instructors during different phases of learning and shed light on the nature of these changes as influenced by efficacy beliefs of engineering faculty.

Research methods and theoretical background

Design-based-research (DBR) deeply intertwines the three goals of research, design, and pedagogical practice. [11, 12] It requires a productive partnership between the course instructor and researchers, enabling iterative cycles to improve learning activities. Because traditional lectures are no longer appropriate in classrooms under the study, we need to design classroom activities and instructional strategies to make effective use of in-class lecture periods for learning course content. Problem-based learning (PBL), a research-based learning model, seemed to be our logical choice because it is an active model that engages students in learning.[8] However, we quickly realized that the PBL approach was not able to support the curriculum goals unless other instructional interventions were introduced. An instructional model developed for math teachers

to orchestrate group discussions in inquiry-based classes helped us redefine our approach [13]. The model, situated in a theoretic framework that addresses how productive disciplinary engagement can be supported in the classroom, allows the instructor to select and organize activities for cognitively demanding learning tasks around the pedagogical principles. [14]

For design considerations, on the one hand, we want to understand many variables during the processes to improve design. For research considerations, on the other hand, we need to focus on key questions that are critical to issues in design and pedagogies to be productive. The DBR method creates a unique opportunity that allows questions of design, research and practice to feed one another. During the process of designing and enacting instructional interventions, the instructor and researchers met regularly, talking about pedagogical assumptions and how these pedagogical assumptions influenced classroom interactions. These meetings helped define the following research questions:

(1) In what ways does the role of the instructor change in a non-traditional lecture hall?

(2) What are the factors that influence these changes and why are these changes important?

(3) In what ways do classroom interactions, in particular verbal interactions/classroom communications, function as a pedagogical tool in our current setting?

Data collected from classroom observations by researchers as well as from weekly meetings between the course instructor and researchers are descriptive and qualitative by nature. A framework, supported by the sociocultural theory that re-conceptualizes classroom interactions is applied to data analyses.[15,16] Quantitative data are gathered from student responses to the end-of-semester survey questions and are analyzed using frequency counting. Sixty out of 111 students who enrolled in the course participated in the study.

Results and analyses

(I) Prototyping PBL

Table (I) shows activities in a typical lecture period when the prototype PBL was employed. A problem was posted after the instructor presented a brief introduction of new content. Students were instructed to work on problems within small groups. The degree of engagement in group activities varied: some were fully involved asking questions and answering those of their peers regarding course content, while others were quiet and seemed less engaged. The overall level of student engagement was lower than what was expected for PBL, a learning model that emphasizes participation.

Table (I): Classroom activities under PBL

Activity	Time allocation	Goals	Interactive/non-Interactive
Lecture	15 min	Introducing new content	Non-interactive
Small group discussions	25 min	Problem solving	Interactive
Big group discussion	10 min	Solving problems to reach the solution; understanding underlying concepts	Interactive

Prototyping PBL analyses

PBL is an instructional method where relevant problems are introduced at the beginning of the instructional cycle and used to provide the content and motivation for the learning that follows. [8] It emphasizes active leaning and seemed to be a logical choice for our design. However, it requires a significant commitment to self-directed study and mastery of problem-solving skills from students. The PBL label covers many different approaches and inconsistent learning outcomes result from these PBL model variations [17]. In our early practices under PBL, the instructor applied a variety of instructional methods to facilitate the subsequent learning: lecturing, answering student questions, raising questions to provoke students' thinking, guiding big group discussions, etc. similar to what has been described in previous research.[8,17] Classroom observations indicated that our PBL failed to engage more students in classroom activities due to the fact that some core elements of active learning were not in play. Many factors can affect the extent of students' involvement. For example, we learned from the survey that only 1/3 of the group indicated that they prepared as instructed before coming to lectures while 1/3 never did. More than 40% of the survey participants almost never read the textbook before class. Even though 75% of the students reported that they were informed that solving problems in groups would be one of the activities during the lecture period and 94% indicated that they understood that they should prepare before coming to lectures, many were not ready to meet the demands of self-directed study (see Figure 1). We also discovered other issues from the survey: (1) students' previous experiences in group work influenced group dynamics and learning interests, and (2) students' belief that learning is mostly about receiving information from the authority and taking home notes provided by the instructor impacted their attitude toward active learning (see Table (II)).

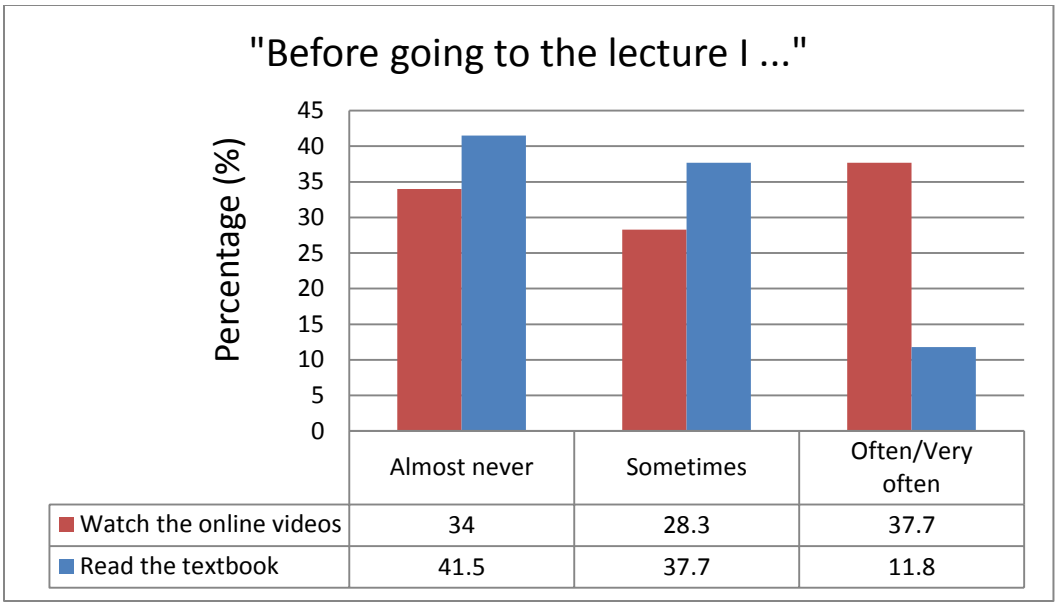


Figure 1. Students' readiness for self-directed study

Table (II): Representative comments on PBL during lecture periods (selected from the end-of-semester survey)

Perceptions toward learning	"This teaching method is helpful, but I would like to get a little more of notes. More information in the notebook so when I look back to review, there is a little bit of meat of the information."
	"Problems don't help me learn, but they do get me engaged. The real learning should come from the professor describing the solution after the class attempts to solve it."
Group dynamics & disciplinary participation	"I do like the class time to work on problems though. Just have to be careful because if too much time is given, people start to get talkative and it can easily get off topic."
	"When I get stuck on a problem, or don't know how to do it, there is much time just sitting there doing nothing."

(II) Four-Practice instructional model for problem-centered learning

The need for instructional interventions was obvious because several learning issues in PBL were not properly addressed within the model itself. The question of how to initiate and support active learning in the classroom became critical to our new design. We resorted to practices situated in a framework that fosters productive disciplinary engagement. [13] Four principles have been identified in the framework: problematizing content, giving students authority, holding students accountable to others and to disciplinary norms, and providing relevant resources. While

the PBL model allowed us to problematize content and motivate students to learn, it was not effective when students were not ready to take on their responsibilities in learning. We needed to design instructional interventions and establish practices based on principles that support active learning. A Four-Practice Model that includes Anticipating, Monitoring, Connecting and Contrasting, and Contextualizing, based on the Stein, Engle, Smith, and Hughes model[13], is formulated to meet our instructional goals and curriculum requirements. We employ the model and design pedagogical strategies to facilitate classroom learning activities. Table (III) describes the main features of the Four-Practice Model and defines roles of instructors while applying the model.

Table (III): Defining Instructor's Roles in the Four-Practice Instructional Model

Practices	Description	Instructor's role
Anticipating (before lecture)	Analyze students' learning demands and foresee students' responses to determine ways of problematizing content	Being authoritative and responsive
Monitoring (during lecture period)	Circle around and probe students' responses; engage in conversation with students; keep group discussions on track; determine when discussion format shifts.	Sharing the authority with students; encouraging students to take the ownership over learning.
Connecting & Contrasting (during lecture period)	Collect students' work; display and make students' responses available to the whole class; make connections or contrast students' views to the discipline.	Reassuring students' authority; holding students accountable to the discipline norms.
Contextualized Lecturing (may run beyond the current period)	Present lecture based on students' responses available to the class.	Being authoritative and responsive.

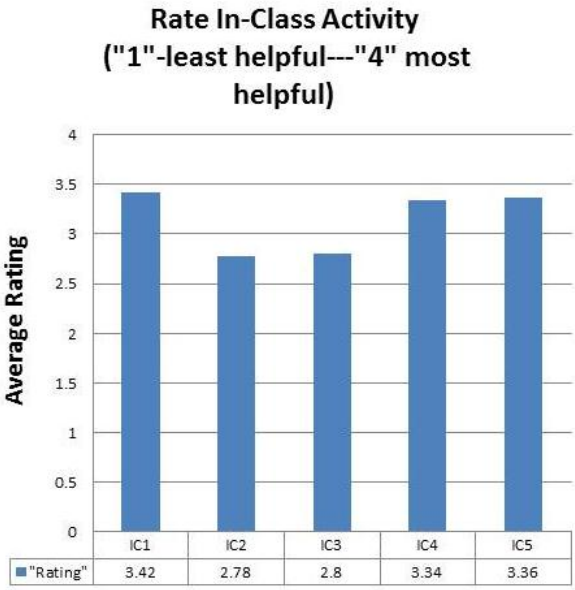
For the next four weeks, the instructor and the researcher met once a week for 15 minutes before the class and 60 minutes after the class to help enact the Four-Practice Model design. The instructor, who analyzed students' learning challenges and predicted student responses to course content, was primarily responsible for the practice of anticipating. The instructor also made sure that the problems were framed properly to challenge students' existing points of view. In meetings with the researcher, the instructor shared the research focus and paid close attention to classroom interactions in teaching and learning process. Anticipating how these problems might engage students in classroom interactions helped the instructor to develop ways to initiate and enforce teacher-student and student-student interactions and classroom communications. Thus, these interactions and communications have the potential to motivate students and to draw them into problem-centered active learning.

The goal of monitoring is to probe how students respond to and approach a problem. It requires the instructor to be fully open to different views so that students are encouraged to express their opinions comfortably. It gives students the authority over their own learning while allowing the instructor to keep track of the direction and progress of learning. The instructor also has the opportunity to interact with students individually. Monitoring gives the instructor indications as to when to shift the discussion format from small groups to the whole class, a key factor for building the classroom discourse. Prior to the whole class discussion, it is very important that the instructor connects and contrasts available responses from students to the discipline content and norms. In practicing Connecting and Contrasting, the instructor collected group discussion results, and displayed the responses from individual groups on the board. Connecting and contrasting their views with the whole class allows students to explore and critique both their own work and their peers' work. At the same time, the instructor knows very well what needs to be said and done to conclude class discussions.

We deliberately term the fourth practice "Contextualized Lecturing", and will discuss the concept and its implications in the following section. Contextualized lecturing provides students with a summary and a full-scale review of classroom discussions. After students were invited to engage in dialogic explorations of a problem's solutions and attempted to interpret the phenomenon under study, there must be subsequent authoritative interventions where the scientific point is introduced and clarified. This follows from the fact that science and engineering themselves are an authoritative body of knowledge, which involves recognized ways of thinking and talking about problems and phenomena.[16] In the following, we describe one such contextualized lecture to illustrate how contextualized lectures are driven by students' learning needs as revealed by group discussions, and how they impact students' learning in a significant way.

The class started with a problem about a PMAC (permanent magnet alternating current) machine. Students were instructed to solve the problem to learn important properties of the PMAC machine and other concepts and skills applied in problem-solving, for example space vectors, phasors, diagrams, and other representations. The class was divided into six groups, and challenged to find solutions during a period of 25 minutes. The last group report came in 10 minutes later than the first one. When numerical solutions from different groups were displayed on the board, the big group discussion began. Gradually, it was turned into a lecture presented by the instructor. It was evident that students were expecting the type of lecture that would introduce concepts, clarify their views, and connect strands of ideas they had expressed during both small and big group discussions. The lecture fully captured students' attention. The momentary silence when the instructor showed a diagram that connected pieces of students' points of view and contrasted approaches between expert and novices was noted by both the researcher and the instructor. The effect that contextualized lecturing had on the students was evident. What happened after the class was even more remarkable. Twenty or more students stayed in the lecture hall. Some talked among themselves while others discussed with the

instructor for another 40 minutes or so. The class returned to the topic of the PMAC machine the following lecture. Students got another chance to revisit the subject and expanded their knowledge through another round of classroom interactions, starting with small group discussions followed by a big group discussion, and a brief summary provided by the instructor. Students' responses to "contextualized lecture" and other in-classroom activities gathered from the end-of-semester survey are shown in Figure 2. A scale of "1" to "4" was applied with "1" as "least helpful" and "4" as "most helpful". Descriptions of these survey questions are displayed in the figure as well. The average rating of "lectures and summaries by the instructor at the end of the problem-solving" is atop the list.

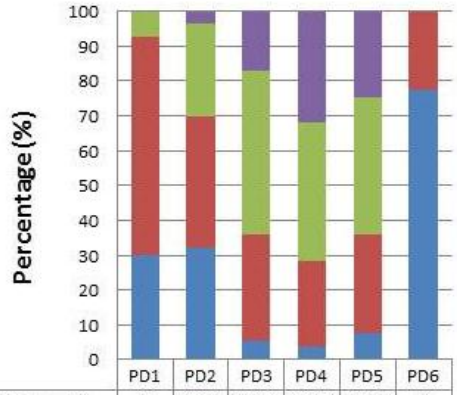


IC1	Lectures/summaries by the instructor at the end of problem-solving.
IC2	Asking questions concerning lectures/summaries of the instructor during the class
IC3	Working problems with my classmates during the lecture.
IC4	In-class demonstrations by the instructor.
IC5	Watching the instructor solve problems.

Figure 2. Ratings of in-classroom activities

Students also reported other factors that contributed to learning. When asked about the difficulty of posted problems during the class, most indicated problems were adequately phrased and

problems motivated them to learn. See Figure 3.



	PD1	PD2	PD3	PD4	PD5	PD6
Almost Always (4)	0	3.77	16.98	32.08	24.53	0
Most of the time (3)	7.55	26.42	47.17	39.62	39.62	0
Some of the time (2)	62.26	37.74	30.19	24.53	28.3	22.54
Almost Never (1)	30.19	32.08	5.66	3.77	7.55	77.36

PD1	Problems are too difficult. I don't know how to solve them even when the instructor gives us hints.
PD2	Problems are difficult because I am not prepared coming to the lecture
PD3	Problems are suitable and challenge me to identify/correct my prior misconception(s).
PD4	Problems are suitable and help me learn the content.
PD5	Problems help me relate what I learn in this course to real-world situations.
PD6	Problems are too easy and don't really help me learn.

Figure 3. Evaluate helpfulness of problems

Discussion

The Four-Practice Model provides fresh opportunities to redefine instructor roles in non-traditional classrooms. Understanding how instructor's roles are in line with non-traditional teaching models that support active learning is important and essential to sustain new and innovative practices. In problem-centered classrooms, instructors play a key authoritative role, which is vital due to the fact that science and engineering produce knowledge that is authoritative by nature. [16] Instructors have the knowledge and expertise to problematize course contents and motivate and engage students in disciplinary learning. They are capable of expanding the range of problems beyond textbooks and online video modules in non-traditional classrooms. The fundamental difference between traditional and reformed teaching is that instructors are no longer the sole knowledge provider thus teaching is no longer about lecturing. To characterize roles of instructors requires a genuine appreciation of teaching. Teaching is about facilitating students' acquisition of knowledge and skills and engaging students in productive disciplinary learning. Our current study offers several accounts of practices that are indicative of the changing roles of instructors.

Anticipating. When instructors predict how students respond to problems and analyze students' learning challenges for specific problems and topics, they empower problem-centered learning by applying knowledge in both discipline and pedagogy. Instructors understand not only content, but also methods in which content can be taught and learned effectively. They are building and managing classroom discourse.

Monitoring. When instructors are open to different points of view, they invite students to take ownership of their learning and share the authority for student learning. Instructors create contexts where students can openly express their own ideas about science and engineering. Probing how students respond to underlying concepts is a necessary task for instructors in developing an inclusive learning community where students are willing to express their views and listen to opinions of others. Participating in discussions allows both students and instructors to make contributions to the learning community, and essentially to students' learning.

Connecting and contrasting. After small groups report to the class, students' opinions are made available to all in the class. Connecting student viewpoints to and contrasting them with the discipline illustrate the instructor's interest in exploring student viewpoints and holds students accountable without undermining their authority over learning. Students learn how to be responsible to others and to discipline norms while instructors are by no means the sole authoritative figure in the classroom. In a learning environment where scientific views are clarified and reinforced, students are prepared to attend to cognitively challenging concepts and grasp new ideas. Instructors are in charge of navigating classroom discussions.

Contextualized lecturing. Lecturing by instructors in this context is pointed and meaningful. It is based not only on instructors' experiences and anticipations, but also on learning needs. After students participate in group discussions to explore explanations and solutions to problems, they expect interventions from instructors to ensure that their viewpoints are scientific. Unlike traditional lectures and some directed guidance methods discussed in the literature, [18] contextualized lecturing is authoritative yet interactive. It is not one-sided and is not dominated by instructors without considering student responses. The time spent on contextualized lecturing varies, depending upon the structure of the content, the nature of the problem, and classroom interactions. It can be shorter than few minutes or longer than a whole lecture period.

Table (IV) describes the different roles that instructors play in a non-traditional classroom. It displays multiple facets. Instructors create learning context, build and manage classroom discourse, and steer group discussions. They are authoritative figures who are in charge of learning activities in the classroom yet they share the authority with students during learning processes. Understanding the responsibilities that instructors assume within the Four-Practice Model has pedagogical implications. How instructors define their roles will influence how they establish and manage classroom interactions, specifically classroom communications. In the following, we focus on features of classroom interactions and classroom communications that help shape student learning.

"Communicative teaching" or dialogic teaching has emerged as an effective pedagogical tool in pre-college science education recently. It is grounded in sociocultural theory, and has shown impact on student learning in cognitively challenging content, predominantly in secondary classrooms. [14,16] Although classroom interactions and communications have been recognized as basic elements in active learning models in college engineering education [8], little research has

focused on examining how instructors can in fact organize classroom learning activities and turn classroom interactions and communications into pedagogical tools. We discuss pedagogical implications of classroom interactions and communications as well as their effect on students' learning.

Table (IV): Descriptions of instructor's roles in the Four-Practice Instructional Model

Practices	Practice description	Instructor's role description
Anticipating	Foresee students' responses to problematized content before class.	Organizing classroom activities; building classroom discourse.
Monitoring	Circle around and watch students' responses; engage in conversation with students; keep group discussions on track; determine when to shift discussion format.	Creating and contributing to learning community; steering group discussions.
Connecting & Contrasting	Collect students' work; display and make students' responses available to the whole class; make connections about or contrast students' views to the discipline.	Leading classroom communications.
Contextualized Lecturing	Present lecture based on students' responses available to the class; include questioning and answering activities.	Providing authoritative interventions to achieve common understanding of specific points of view.

Table (V) shows a two-dimensional model, interactive/non-interactive and dialogic/authoritative for classroom communications within the Four-Practice Model. [19] We apply this analytical model to demonstrate ways that classroom communications function as a pedagogical tool. Table (VI) describes characteristics of classroom communications in the Four-Practice Model. Classroom interactions and communications do not spontaneously function as pedagogical tools if classroom activities are not organized and managed purposefully. Instructors play a central role in enabling interactions and communications and turning them into a meaningful sequence. During the practices of Monitoring, Connecting and Contrasting, and Contextualized Lecturing, instructors explicitly seek attention and engagement in sharing and exchanging ideas among the class. Instructors steer and support discussions and communications to connect and chain individual teacher-student and student-student exchanges, leading to a deep understanding of the content under study. Instructors' belief in their changing roles in non-traditional classrooms will help them organize classroom activities to empower these interactions. Instructors' pedagogical assumptions will shape classroom communications to be in line with teaching and learning objectives of the curriculum. We have observed that when students were encouraged to participate in both small and big group discussions to construct ways of representing answers to problems, they practiced to either accept or reject claims from their classmates and teacher. They

learned to adequately present evidence and justify solutions to support their own conclusions and beliefs. These discussions also prompted need for authoritative interventions. We have observed that when the instructor successfully engaged students in classroom communications, contextualized learning did not terminate the ongoing classroom discussions. Instead, it initiated new cycles of questioning, answering, and discussions, as stated in the previous section. [19]

Table (V): Two-dimensional model for classroom communications [20]

Interactive/Dialogic	Instructor and students consider a range of ideas.
Non-interactive/Dialogic	Instructor reviews different points of view.
Interactive/authoritative	Instructor focuses on one specific point of view and leads students through a question and answer routine to establish and consolidate that point of view.
Non-interactive/authoritative	Instructor presents a specific point of view.

Table (VI): Characteristics of classroom communications in the Four-Practice Model

	Interactive	**Non-interactive**
Dialogic	Monitoring	Connecting & Contrasting
Authoritative	Contextualized Lecturing	Problematizing content; Lecturing

Final comments

We have introduced a Four-Practice Model that is situated in a framework supporting productive disciplinary engagement in classroom learning. The instructional model allows us to redefine instructors' roles in non-traditional classrooms. It provides us with accounts of effective pedagogical strategies. Classroom dialogue explicitly seeks to make attention and engagement mandatory and to chain exchanges into a meaningful sequence.[19] Classroom interactions and communications are designed to achieve common understanding through structured, cumulative discussions. Our current study shows that the newly developed instructional model has propelled the alignment of refined roles of the instructor and the curriculum, helping the instructor develop and preserve efficacious beliefs in engineering teaching. To enact and sustain the new instructional model, it is important that we understand that developing instructors' efficacy beliefs is consistent with refining their roles in non-traditional classrooms. Our study also illustrates that students embrace changes in instructional approaches. Students' comments, shown in the following, reflect their learning gains in areas of cognitive understanding, contents, and meta-cognition.

- ... The problem solving was getting boring and not very helpful until we were grouped into 'states' and put in competition against each other. Class was enjoyable again and it helps with understanding.

- I enjoyed this class and starting the understanding the concept behind motor design and uses. This class did offer good tools to learn and did help me with my understanding more. I feel I could have been a little more prepared before lecture each day and would have understood the concepts even more.
- Good class. Very beneficial teaching style. Definitely feel like I actually learned which can't always be said.
- I enjoyed every class that i (*I*) had attended. Even though i (*I*) had learnt this in my under grad i (I) happen to learn lot of new things from prof (*xxx's*) classes. Also prof (*xxx*)'s book for this subject is excellent, explaining complex concepts in simple words.
- I really enjoyed the class and I felt that professor (*xxx*) really wanted me to learn in the class! I like the new approach and I hope you can find ways to apply it to more courses here at the U(*university*)….
- (*The*) instructor can and did seem to gauge progress and shorten up problem solving time when students did not appear to be making progress.
- It is great and new way of learning style.

Our next task is to establish methods to assess student learning outcomes. We will develop models that can be combined with student self-reports so that we are able to measure if students learn better under this new approach. We will continue to provide students with a learning environment where they can explore and express new ideas openly and freely. We will employ classroom interactions and communications to help students advance their abilities specifically in arbitrating competing claims and generalizing conceptual knowledge and skills of the discipline.

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