After the Workshop: A Case Study of Post-Workshop Implementation of Active Learning in an Electrical Engineering Course

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***Abstract*—Engineering education research has empirically validated the effectiveness of active learning over traditional instructional methods. However, the dissemination of education research into instructional practice has been slow. Faculty workshops for current and future instructors offer a solution to promote the widespread adoption of active learning in engineering classrooms. However, most of the existing research has relied on faculty self-reporting to evaluate the success of engineering faculty workshops. Researchers have noted variations in self-reporting and the actual classroom implementation. In this paper, using classroom observations, faculty interviews, student surveys, and focus groups, the authors examine an engineering instructor's postworkshop implementation of active learning in an electrical engineering course. The findings demonstrate the influence of faculty conceptions of teaching in the selection and design of activities and the subsequent impact of these design choices on student engagement. The authors report the instructor's and students' responses to the active learning exercises and present recommendations for engineering faculty development.**

***Index Terms*—Active learning, engineering education, faculty development, student engagement.**

I. Introduction

RECENTLY, considerable attention in engineering education has been paid to active learning, i.e., instruction that engages students in learning through participation in meaningful activities during class time [1], [2]. In engineering education, existing research has empirically validated the effectiveness of active learning over traditional instructional methods; nonetheless, adoption of active learning in engineering classrooms has been slow [3], [4].

One way to improve engineering education is to "catalyze the widespread adoption of empirically validated teaching practices" [4]. Faculty members often lack awareness of evidence-based active learning methods, due to their lack of formal training in pedagogy [4]–[8]. Experts have recommended faculty professional development programs to provide training in active learning to current and future faculty [3], [4], [6], and faculty development programs have been initiated in engineering [9] and other STEM disciplines [10]. Researchers have suggested that faculty development programs positively influence pedagogical change in engineering classrooms [9], [11]. However, most of the existing engineering education research has relied on faculty self-reports to evaluate the success of faculty development programs, e.g., [9] and [11], which is a weakness acknowledged by the authors themselves [11], [12]. This paper responds to this gap in the literature, reporting the findings of a case study that is investigating an engineering instructor's post-workshop implementation of active learning.

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II. Literature Review

A. Faculty Development Programs

Faculty development programs promote the use of active learning by increasing the instructors' pedagogical knowledge among other things. Lattuca *et al.* [11] found a significant positive relationship between participation in professional development workshops and use of active learning-based instruction.

Faculty development workshops are more likely to have an impact if they are conducted by educational experts with the same disciplinary backgrounds as the participants [6]. One such faculty development workshop is the National Effective Teaching Institute (NETI), conducted every year in conjunction with the American Society for Engineering Education's annual conference. Since 1991, 1312 faculty members from 244 different institutions have participated in the workshop [13]. Faculty members who attended NETI have presented their experiences, challenges, and recommendations when implementing active learning in educational conferences including difficulty in selecting activities [14] or student resistance to the activities [15].

While researchers have highlighted that instructional choices and practices are considerably affected by the instructor's conceptions about teaching [16]–[18], student resistance has often been cited as a major barrier to the adoption of active learning [12], [19]–[22]. The authors argue that the influence of instructional choices and contextual factors, such as student resistance, often lead to variations in the implementation of active learning in the classroom. The conveners of the NETI workshop [9] and other researchers [12], [23] have acknowledged the existence of variations in implementation of various active learning types. In this paper, the authors focus on examining the influence of instructor conceptions of teaching and the student resistance on the implementation of active learning in engineering.

B. Implementation of Active Learning

Researchers have found that faculty self-reporting of pedagogical practices may differ significantly from classroom observation evidence [24]. Additionally, these self-reports primarily rely on instructors to report based on a prepopulated list of pedagogical types, e.g., in [11], [12], and [20], which constrains examination of various features and decisions that are part of teaching [25]. Thus, these self-reports often fail to capture variations in the way active learning is applied, such as the types of questions asked. Furthermore, such variations in practice are influenced by the instructors' conceptions of teaching, and researchers have emphasized the need to examine how instructors make decisions under the constraints of real classroom situations [26], [27], particularly through direct observations of teaching [28].

III. Conceptual Framework

Light *et al.* [29] conceptualized the influence of faculty development on teaching approaches and presented an extended model of faculty development, teaching, and learning. The model identified instructors' conceptions of teaching, student presage factors, and faculty development experience as factors influencing instructional practices.

A. Conceptions of Teaching

Conceptions of teaching are "complex amalgams" of student experiences, department and disciplinary cultures, and classroom factors [30]. Several researchers have advocated the importance of considering instructors' conceptions of teaching for effective faculty development [18], [28], [30]–[32]. Kane *et al.* [33] reviewed research studies reporting the influence of college teachers' conceptions of teaching on their instructional practices and called for work that examines instructors' conceptions in conjunction with direct observations of their teaching practices.

In engineering education, Borrego *et al.* [32] found that engineering instructors' conceptions were aligned with existing educational research, namely, that students learn better when they solved practice problems in class. However, the instructors were reluctant to increase the amount of class time devoted in problem solving, due to social norms and difficulty in understanding how to implement group work. Froyd *et al.* [12] investigated the barriers to the adoption of various nontraditional instructional strategies for electrical and computer engineering courses and found that instructors' teaching conceptions were a more critical barrier than promotion and tenure.

B. Student Presage Factors

Student presage factors include predispositions that students bring into the classroom, including the preferred ways of learning [34]. Active learning techniques often receive resistance or a negative response from students because of a mismatch with their preferred ways of learning [35]–[40]. This student resistance has been identified as a critical barrier to instructional change [12], [19]–[22]. Weimer [38] categorized three types of student resistance: 1) passive, in which students do not engage in the activity; for instance, by not talking to their neighbors when asked to discuss a question; 2) partial compliance, in which students engage by giving minimal effort or by rushing through the activity; and 3) open resistance, in which students express complaints verbally to the instructor, peers, or other faculty members.

IV. Methodology

The authors choose a case study approach because this topic features several situations for which case studies are desirable, such as when investigating how and why questions [41], [42], developing new insights about a phenomenon or event [43]–[45], studying the application of an initiative to improve instruction [46], and studying a unique event that has not been researched in the past [41], [46]. Although faculty developers have conducted assessment of the workshops, minimal research has been done in investigating the case of post-workshop active learning use. Case studies are widely used in engineering education research that focuses on analytic deductions than generalizations, e.g., [47]–[51]. A single case study approach is usually acceptable [50] and can be followed when that case represents a unique event that has not been studied in the past [41].

A. Participants and Setting

This study was conducted in an undergraduate upper division electronic circuits course at a large public research university. The institutional climate focused on research rather than teaching, and active learning was not widely practiced. The instructor was a past NETI attendee. In addition to active learning, the instructor used Web-based polls to collect student feedback about the course in the third week of class. The class met two times a week for 90 min and had an enrollment of 65 third-year and fourth-year students. The classroom featured an auditorium-style seating arrangement; spaces between the semicircular rows allowed the instructor to move around the classroom and monitor the students' work.

B. Data Sources

One of the main advantages of a case study is the use of multiple data sources in a complementary manner to address rival explanations to establish trustworthiness [41] and triangulate findings to develop a convergent understanding of the event [43], [44].

1) Classroom Observations: The authors used the observation protocol developed by Shekhar *et al.* [52] to capture student engagement behaviors to active learning along with other contextual factors (i.e., type of active learning, instructor participation, etc.). Classroom observations were made in every class session of the semester and were used as the primary data source. The protocol identifies engagement as an observable participation in the activity measured. The approximate percentage of students engaged during the activity was classified as high (i.e., more than 90% of students engaged), medium (i.e., 50%–90% of students engaged), or low (i.e., less than 50% of students engaged). The type of student resistance demonstrated is categorized using Weimer's framework as partial compliance, passive, nonverbal resistance, and open resistance [38].

2) Instructor Interview: In this paper, the instructor was interviewed to triangulate the classroom observation findings and investigate the reasoning behind the selection and implementation of active learning exercises. The authors used a semi-structured interview format, starting with a set of predetermined questions asking the instructor about his conceptions about active learning, prior teaching experiences, implementation challenges, and student reactions and proceeding to probing questions to triangulate and refine the observational data. The interview was conducted at the end of the semester and was audio recorded for future reference and analysis.

3) Student Focus Groups: Focus groups allow the gathering of multiple perspectives and comments about others' opinions, and identifying consensus or shared views about the topic under consideration [53]. In this paper, the student focus groups were used to validate the findings of classroom observations and learn students' opinions about the active learning implemented in the classroom. A total of eight students voluntarily participated in four separate focus group sessions held at the end of the semester. The questions focused on active learning and covered opinions of the activities, participation level, preferences, and feedback.

4) Student Survey: In this paper, an end-of-semester survey $(N = 57)$ was used to collect data about students' instructional preferences and response to active learning. The survey was developed as part of a larger study examining student response to active learning [54]. The survey asked students how they reacted to specific types of active learning and whether they preferred more or less of the activities.

C. Data Analysis

An important goal of case study research is to build explanations [41]. Explanation building is described as "the process of refining a set of ideas, in which an important aspect is, again, to entertain other plausible or rival explanations" [41]. In this paper, the classroom observation protocol attempted to document student engagement level for every observable instance of active learning. These observed student engagement levels were grouped together based on the type of active learning (i.e., group discussion and problem solving) to develop and test the working hypothesis about student engagement patterns. The focus groups were used for triangulation and gaining students' perspective about the active learning exercises and noted variations in engagement, and the instructor interview was used to understand the influence of instructor's conceptions of teaching, workshop experience, and classroom factors on classroom instruction. The surveys were used to supplement the observational, focus group, and interview findings.

V. Findings

The instructor used two types of active learning: primarily, group discussions and one problem-solving exercise in the last week of class. Participation in the activities was not graded. On the first day of class, the instructor announced his plans of using active learning, where he had received good feedback in the past semesters, and he expected students to participate. Both group discussions and problem-solving activities typically lasted less than 5 min.

The choice of discussion-based activities was influenced by the instructor's conceptions of active learning. He explained that active learning allows students to "contemplate the questions and topics being presented" and serves as an "avenue for [students] to have real time contemplation and narrative discussion." Accordingly, most of the group discussion activities involved a broad question.

A. Group Discussions

In the discussion activities, the instructor followed the format of "think–pair–share," which asks students to discuss the answer to a specific question in groups. At the end of an activity, the instructor called upon almost every group to report their answers.

1) Student Response to Group Discussions: In the focus groups, students gave an overall positive feedback about these discussions. However, they expressed concerns about the implementation. One student responded, "*I did like them. I felt certain questions were a lot better for discussion than others.*" Another student echoed:

> "*I like the idea of group collaboration. It stimulates thought. It forces people to put their mind on their material. But, I feel maybe like they were implemented somewhat poorly because, like, so often the exercise was done on a general broad topic but the lesson dives deep in. So, the usefulness of the group activity was lost. It was like, we talked about it, but why?*"

The use of questions and prompts allow instructors to highlight key points, clarify misconceptions, review the material, and provide students an opportunity to work on the course content [55]. Variations in student engagement were observed based on the type of questions posed during the discussion. Questions reported by students as not too broad and within students' current understanding of the content received an overall high participation of over 90% of the students. As one student mentioned, "*I remember one of the first questions he asked was what electricity is. That's like a freshman-level question but it's interesting, the misconception that the people have even at this late stage in their education.*" A few students demonstrated passive resistance when they did not join a group at the beginning of the activity. This problem was ameliorated by approaching these students and asking whether they were part of a group or not.

Group discussion activities involving broad questions received lower engagement, with more than 50% of the students disengaged from the activities. Students primarily demonstrated partial compliance by completing the activity very quickly with minimal discussion, after which students sat idle or engaged in off-task discussions for the remaining time. Focus group responses confirmed the occurrence of short discussions and highlighted the broadness of the questions as the primary cause. One of the students explained, "*I think it definitely depended on the question that was asked*." Another student expressed that "*we usually discuss for like 10–20 s and then you kind of sit there a little bit and wait till he brings the class back together. Obviously, if the question is more relevant, we could answer it.*" In the survey, majority of the students reported

TABLE I
STUDENT RESPONSE TO ACTIVE LEARNING

How often did you react in the following ways?	Almost never (< 10% of the time)	Seldom (~30% of the time)	Some times (~50 % of the time)	Often (~70% of the time)	Very often (>90 % of the time)
I focused on doing specifically what the instructor asked, rather than on mastering the concepts.	9%	19%	30%	25%	17 %
I rushed through the activity, giving minimal effort	16 %	21 %	30 %	19%	14%

that they demonstrated partial compliance, i.e., 50% or more of the time. Specifically, 72% of the students reported that they focused on doing what the instructor asked, rather than on mastering concepts, and 63% reported that they rushed through the activity giving minimal effort, as shown in Table I.

In response to broad questions, students typically guessed or gave vague answers. For example, for an activity question asking students to identify a circuit in their cell phones where the concept of small-signal analysis will not be used, one student expressed, "*Some of the ones on basic concepts were actually good … and then you know we did not really know what we were doing so we kinda come up with half-assed answers.*" Another student echoed, "*And I think the whole point of a discussion is you have to be able to argue reasoned positions, so if we don't have enough knowledge, we just end up guessing.*" During class, one student prefaced his group's report with "*I don't know if this is a good enough of an answer…*"

In addition to partial compliance, students also demonstrated passive resistance by refusing to join a group. The instructor approached these students and insisted that they move closer to each other and start a discussion. For the broader questions, this was only marginally successful and typically resulted in the brief discussions followed by the off-task work characteristic of partial compliance.

Finally, the authors also observed that student attendance declined after the first exam and remained low, with nearly half of the students absent for most of the semester. The authors observed one instance in which a few of the students who were usually absent left the classroom immediately after the instructor introduced a discussion exercise. When asked about the reasons behind the decline in attendance, students reported that the primary cause was that most of the students received high grades on the first exam. Students also attributed it partly to the classroom discussions. The majority of the students felt that the discussions did not contribute to helping them learn the material: "*Yeah, I guess people feel like the class isn't adding anything, especially the discussions.*" Another student echoed, "*Personally, I did not think it helped with homework or exams so much but it did help give you a general background of microelectronics.*" One student attributed it more specifically to the disconnection between active learning exercises and exam questions, mentioning that "*It was more of the open-ended questions, and it didn't formulate on the test. You probably lost lot of people after the first test because of that.*"

2) Instructor Response to Group Discussions: The instructor's interview response emphasized interaction and student engagement as the primary advantages of active learning. The instructor reported that he has been using similar activities since attending a faculty workshop and felt confident based on previous course evaluations. The influence of faculty conceptions about active learning was evident in the design of discussion questions. Expressing the challenge he faced in designing the questions, the instructor explained:

> "*This is an engineering class, it is not like [a] political, you know, literature class where there is a wealth of questions one could discuss. In a very technical class like this, it's often right or wrong answers. That's really not the spirit of active learning. So I had to really think very deep and really go to kind of a more abstract level of exactly what this material is about, the subject matter, and not dwell too much on these very, very specific narrow issues. So by going to this more elevated abstract plane, then I can generate questions that have guided the development of the field that is still relevant today.*"

He believed that active learning is not associated with problems that have right or wrong answers, as well as designed abstract questions, which in his view would best facilitate discussion and engagement. This was evident in his statement: "*They are still very practical questions, but maybe questions that are not necessarily discussed in classrooms but you hear about them in popular media… it gives [students] a platform to voice their opinions and discussion among themselves.*"

In response to the survey results in Table I, the instructor initially identified group dynamics and classroom layout as probable reasons for student disengagement. Upon discussion of focus group results identifying overly broad questions as a reason, the instructor acknowledged their broad nature and reiterated the challenge he faced in designing suitable questions. The expectation of guessing was also evident in the instructions he gave in class, including to "identify plausible reasons or guess" the answer to the question.

B. Problem-Solving Exercises

During the final week of the semester, instead of a discussion question, the instructor posed a problem for the entire class to solve. This single instance is presented separately to highlight two key findings. First, although the instructor provided minimal encouragement during the activity, this activity received high student engagement due to the clear relevance to homework and exam content. Second, the instructor attributed this activity to his prior teaching experience and not the workshop.

Unlike the discussion exercises that specified an allocated time and gave instructions to form a group, this problem was not presented as a formal active learning exercise. Nonetheless, students were highly engaged. Most of the students worked on the problem for the entire allotted time, and students volunteered to present their answers to the instructor by raising their hands as opposed to waiting for the instructor to call on discussion groups in turn. Focus group responses highlighted the choice of questions posed as a reason for high engagement in the problem-solving exercise. The questions were not broad (compared to the discussions) and were more relevant to homework or exam problems. In the survey, 53% of the students indicated that they would prefer more group problem solving, whereas only 3.5% of the students indicated that they wanted less. Similarly, 47% of the students wanted to do more individual problem solving in class, but only 10% wanted less. Students also expressed their concerns regarding the lack of computational problems in the lecture in the student feedback polls conducted by the instructor.

The instructor was in favor of problem-solving activities but struggled to design suitable problems. He explained, "*In principle that will be very good to do. But this kind of very higher level senior classes, I have to think about problems that are suitable within the boundaries of time in a group of two or three people.*" He also mentioned that student feedback requesting more problem solving is recurrent. He described this advanced undergraduate course as "very analytical," and that "*the nature of analytical classes wants you to do more problems ... Then, [instructors must consider] how to integrate actual analytical problems and concepts in active learning, I am not sure how one can do that successfully.*" He recommended that workshop facilitators should provide support in developing content-specific active learning questions, stating:

> "*You have to keep in mind that the [NETI] workshop is across all the engineering [fields]. So, it's only a subset of similar engineering faculty will be present. So, at least what they have used in the past is kind of generic things that are not content specific. But maybe if they had a handbook in which they said 'for this kind of engineering and that kind of engineering classes, [here are] some examples that have been very successful example questions'.*"

Initially, the instructor did not identify the problem as active learning. "*I did not decide [that problem-solving activity] as active learning. I have done that problem in class previously, and I felt the students really took great interest in this. It is something that they would need to use actually in their homework and exams.*" By the end of the interview, he recognized it as an example of the type of problem that he needs to increase for in-class activities.

C. Comparison of Discussions and Problem Solving

Table II summarizes the variations in student engagement based on the type and design of active learning in this study. Student responses highlighted the activities' lack of relevance to homework or exam problems, and the broadness of the questions posed, as the reasons behind student resistance.

Table III reports Pearson correlations between survey items, which demonstrate that students who wanted more problem solving self-reported greater resistance to the discussion activities throughout the semester. Students who wanted more group problem solving indicated that they focused on doing specifically what the instructor asked in the discussion, rather than mastering the concepts ($r = 0.332$). Similarly, students who wanted more individual problem solving reported that they rushed through the discussion activity, giving it minimal effort.

TABLE II
VARIATIONS IN STUDENT ENGAGEMENT

Type of Active Learning	**Type of questions**	**Student Engagement**	**Initial Student Resistance**	**Instructor Intervention**
Discussion	Broad and irrelevant to homework or exams	Low	Passive and partial compliance	Mitigates passive resistance but not partial compliance
Discussion	Not broad but irrelevant to homework or exams	High	Passive resistance	Mitigates passive resistance
Problem solving	Not broad and relevant to homework or exams	High	None	No resistance even though minimal intervention

TABLE III
INSTRUCTIONAL PREFERENCE

	Solve problems in a group during class	**Solve problems individually during class**
I focused on doing specifically what the instructor asked, rather than on mastering the concepts	0.332*	0.091
I rushed through the activity, giving minimal effort	0.189	0.299*
I pretended but did not actually participate	0.277*	0.253
I felt the effort it took to do the activity was worthwhile	-0.194	-0.314*
I felt the time used for the activity was beneficial	-0.275*	-.0279*

*Correlation is significant at the 0.05 level (2-tailed).

In addition, students with group problem-solving preferences indicated that they only pretended to participate in the discussion exercises ($r = 0.277$). Two items about the value of the discussion activities were negatively correlated with students wanting more problem-solving exercises. Specifically, students who disagreed that the effort taken for discussion was worthwhile wanted more individual problem solving ($r = -0.314$), and students who felt that the time used for discussion was not beneficial wanted more individual ($r = -0.279$) and group ($r = -0.275$) problem solving in their ideal course.

VI. Discussion and Conclusion

The guiding framework used in this paper presented faculty conceptions of teaching, faculty development, and student presage as factors influencing classroom instruction [29]. The influence of instructors' conceptions is widely acknowledged as a critical factor in determining the effective implementation of research-based instructional practices [18], [28], [30]–[32], and instructors often choose to implement parts of these curricula based on their instructional and personal preferences [56]. The findings were in line with existing research; this paper has found that after attending the workshop, the instructor selected and used only discussion-based active learning. Due to lack of content-specific pedagogical training, this selection and design was informed by the instructor's conceptions about active learning, namely, that questions with right or wrong answers are not active learning. This led to his selection of discussion-based activities that were broad and disconnected from homework or exam problems, which are characteristics reported by students as the primary reason for decline in attendance and their disengagement in the classroom.

Researchers have suggested that teaching practices may not reflect the intentions of an instructional developer's strategy [12]. This instructor emphasized active learning as a means to increase classroom interaction, diverging from the definitions of active learning that place due emphasis on engaging in meaningful activities that enhance learning [1], [2]. One plausible explanation could be that instructors consider active learning more of a tool to increase classroom interaction than a technique to aid student learning. Faculty members are usually unfamiliar with educational research and its pedagogical implications [16]. Workshop participation may have limited results if "the underlying beliefs of the participants are inconsistent with the conceptual framework of the initiative" [30]. Thus, along with the dissemination of research-based instructional techniques, such as active learning, faculty development efforts should simultaneously educate instructors about their understanding of their pedagogical beliefs, epistemologies, and learning theories to facilitate effective adoption.

Student resistance is a major barrier to engineering instructors' adoption and continued use of active learning [19]. These results demonstrate that instructors can overcome resistance through specific strategies. Students were not resistant to the idea of active engagement, *per se*; rather, it was the choice of questions that hindered its effective implementation. Survey responses indicate that students who preferred more problem-solving activities responded negatively to discussions. Students often perceive that active learning does not contribute to their learning [57], [58]. The findings identify misalignment between activities and course components important to students (i.e., homework and exams) as one plausible reason behind student resistance, reiterating the need to assist instructors in the design of active learning exercises.

These findings point to specific recommendations for faculty development workshops. First, more effort might be focused on helping engineering instructors to translate complex quantitative problems into appropriate brief active learning exercises. Second, workshops might follow a more constructivist approach in allowing instructors to draw on their prior teaching successes to recognize when and how they may have already implemented active learning or other evidence-based teaching practices. Third, engineering faculty development initiatives might consider specializing more specifically within engineering disciplines such as electrical and computer engineering. Engineering education researchers have called for more targeted professional development efforts that bring together faculty in similar fields, rather than generic approaches [27]. In addition, engineering instructors are more likely to interact within their research-specific communities. Engagement with peers has been suggested as an enabling factor for increased adoption of active learning [12], [20]. Networking and community building facilitate the adoption of active learning [59]. Thus, the disciplinary content-specific pedagogical training will not only help instructors to design active learning exercises for their classrooms, but will also simultaneously foster a community of practitioners who can share their research as well as their teaching experiences.

This paper has examined the use of active learning by an engineering instructor after he had attended a faculty development workshop. It offers several implications for research focusing on the adoption of active learning in engineering classrooms, although the approach used limits the degree to which the findings can be generalized. The choice of case study methodology limits the direct applicability of findings to other contexts. Contextual factors such as the type of institution and level of students might influence the use of active learning. Replication of similar studies examining post-workshop use of active learning in other institutions, departments, and courses in the future will generate further understanding and identify strategies facilitating effective adoption.

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