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A Multi-Year Professional Development Program to Advance Active Learning Pedagogical Practices for Engineering Faculty

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ABSTRACT

Active learning pedagogical practices are more effective than instructor-centered teaching in building students' knowledge, skills, and understanding of engineering content and concepts. As such, a large-scale professional development (PD) program was created to move faculty toward the use of active learning. The project aimed to engage faculty in active learning best practices through workshops and communities of practice to shift their attitudes, beliefs, and practices toward active learning strategies. This paper examines how and to what extent participation in a large-scale PD program shifts faculty awareness of, attitudes towards, and use of active learning. As such, this paper offers a model and evaluation framework for a large-scale PD program, which can be adapted to PD programs in engineering and across other STEM disciplines. In total, 82 faculty members from seven engineering disciplines participated in the PD program, comprising workshops and communities of practice sessions. Multiple assessments were utilized or created to measure the extent of faculty change using Roger's diffusion of innovation model for individual change and Coburn's cultural change model for organizational change. Faculty awareness, beliefs, and classroom practice shifted from instructor-centered teaching toward student-centered active learning. Instructors progressed moderately well through Rogers' five stages of individual innovation change and fulfilled the three tenets of Coburn's organizational change model. There were only minor shifts in student achievement, particularly for smaller classes, possibly due to insufficient time for instructors to fully implement active learning practices. The PD program influenced the initiation of a sustainable community of new and continuing active learning practitioners in the College of Engineering.

Keywords: professional development, faculty development, engineering education, evaluation, active learning

Active learning (AL), which emphasizes student-centered teaching, is an instructional practice where instructors directly engage students in the learning process through interactive strategies in the classroom (Brame 2016). In contrast, traditional teacher-centered instruction involves passively transmitting information from the teacher to the student via a lecture. In AL classrooms, instructor-centered time is limited, with a significant portion of the class time dedicated to activities, group work, student discussions, or self-guided reflection and learning. Over the past decades, evidence in the literature indicates the efficacy of AL in STEM (Freeman et al. 2014; Felder & Brent 1996; Felder, Brent, and Oakley 2016), especially for under-represented minority students (Burke et al. 2020; Lorenzo, Crouch, and Mazur 2006; Theobald et al. 2020).

Despite the research base, the primary form of teaching in undergraduate engineering courses remains lecture- or teacher-centered instruction. Possible reasons for the continued use of the lecture are faculty unawareness, beliefs in the benefits of the lecture, a significant amount of time required to implement AL, and the fact that faculty could be teaching as they were taught. Increasing faculty awareness of student-centered teaching strategies and practices is essential to developing and utilizing effective AL instructional strategies.

Creating change at the faculty level is a critical step in shifting the culture of a department, college, and university towards more sustainable, lasting use of active learning practices across the institution. Professional development (PD) programs are a promising approach to increasing awareness and using AL teaching strategies (Wei, Darling-Hammond, and Adamson 2010). In PD settings, participants can engage in ongoing, deep learning regarding the subject of the PD, such as teaching practices. PD programs have the potential to foster sustainable, continuous shifting in faculty beliefs and instructional practices. However, there is a growing body of research on PD programs across the science, technology, engineering, and mathematics (STEM) field, especially in recent years.

This study addresses this opportunity by focusing on a large-scale, multi-year PD program named Just-in-Time Teaching with Two-Way Formative Feedback for Disciplinary Faculty (JTFD), developed and implemented at a large college of engineering in the southwest United States. The JTFD program involved over 80 faculty participating in a multi-year program to promote AL instructional practices to engineering faculty across multiple disciplines. The National Science Foundation's Improvement of Undergraduate STEM Education (IUSE) initiative funded the project. This study proposes a model and evaluation framework for a large-scale PD program, which other engineering or STEM programs could adapt.

LITERATURE REVIEW

Efficacy of Active Learning

A substantial body of prior research demonstrated the efficacy of AL, which are practices that directly engage students (e.g., Brame 2016; Felder and Brent 1996; Freeman et al. 2014; Jungst, Licklider, and Wiersema 2003; Prince 2004). With increased attention to student achievement in STEM, research on instructional practices has grown substantially since 2000.

In his review of the literature on AL within the context of engineering education, Prince (2004) found a few challenges with interpreting the literature on active learning. First, researchers employ different outcomes to measure achievement, making accurate measurement difficult. Further, there is a broad range of what researchers identify as active learning. Nevertheless, Prince (2004) concluded that faculty should consider incorporating AL practices despite the difficulties.

According to Freeman and colleagues (2014), over 600 studies have examined the use of active learning in undergraduate classrooms, with significant variations in overall effects and results. Freeman et al. (2014) conducted a meta-analysis of 225 studies that examined various instructional practices in undergraduate STEM classes across the US. Results were highly favorable for the benefit of AL in the classroom. Students enrolled in AL classes performed 6% higher on learning inventories/exams than their non-AL counterparts. Further, the non-AL students were 1.5 times more likely to fail a course. Overall, the collective summary of the results from over 200 studies speaks to the benefit of active learning as a sound instructional practice in STEM classrooms.

Despite substantial evidence, the predominant instructional practice in engineering remains teacher-centered, where faculty share information via lecture (Stains et al. 2018). On the one hand, faculty face increasing pressure for higher student achievement and more effective teaching methods. On the other hand, transitioning from information-centered teaching through the lecture to more student-centered learning is challenging for many faculty (Felder and Brent 2016).

Professional Development Programs

PD programs are a standard method to help shift faculty instructional practices in higher education and are linked to higher student achievement (Garet et al. 2001). Many PD programs employ workshops as the primary PD method.

The quality and design of the PD program are critical to ongoing success. For instance, many current PD efforts in higher education are single-occurrence events or short-lived programs, which do not lead to a significant lasting change in faculty practices. Yoon et al. (2007) identified that PD programs become more successful if they incorporate at least 14 hours into the program administration. The program's intensity and duration are vital components of a successful PD (Weiss, Montgomery, Ridgway, and Bond 1998). An essential factor in the effectiveness of faculty transformation is the knowledge derived from workshops and the opportunity to practice and discuss classroom experiences (McKenna, Yalvac, and Light 2009).

With increased focus on PD in higher education, there is a growing body of literature on effective programs. High-quality PD emphasizes content and how students learn/comprehend, active learning practices in the PD sessions and program design, extended duration, and collective participation (Desimone et al. 2002). In a comprehensive, large-scale study on professional development, Desimone and colleagues (2002) found that focusing on specific teaching practices increases teachers' use of these strategies. Further, they identified six best practices that are important for a PD program. Three of these are structural features: reform type, duration of PD, and collective participation. The others are content-based, including opportunities for active learning, coherence, and content focus (Desimone et al. 2002).

There is growing research on PD in higher education (Ebert May et al. 2011; Mundy, Kupczynski, Ellis, and Salgado 2012). Most PD program research focuses on K-12 education (e.g., Desimone et al. 2002; Huggins, Schuerich, and Morgan 2011). A decade ago, we had more limited research on the effectiveness of PD programs in higher education STEM, including engineering (Darling-Hammond et al. 2009). However, the research on STEM faculty development has grown considerably in recent years. Further, research suggests that discipline-specific faculty development effectively shifts faculty practices (Manduca et al. 2017).

Engineering Education Faculty Development

The field of engineering education has been active for over a century, with the establishment of the Society for the Promotion of Engineering Education in 1893, which was later named the American Society for Engineering Education (ASEE) in 1946 (ASEE 2022). Over the past two decades, ASEE has grown considerably, with a substantial increase in attention to engineering education. As a result, ASEE formally established the division of faculty development in 2017 (ASEE 2022).

Over the past five years, there has been an increase in research on faculty development within engineering education. Faculty PD programs can successfully advance the use of active learning in engineering classrooms (Favre, Bach, and Wheeler 2021). Felder & Brent (2003) described critical attributes of successful PD programs, including emphasizing disciplinary relevance, citing relevant research, and modeling from PD leaders on practices discussed. Khatri et al. (2017) highlight that successful PD programs often have funding and the ability to sustain long-term engagement in the PD program. Further, Soricinelli, Berg, Bond, and Watson (2017) also affirm the importance of using evidence-based practices within the PD program.

Further, these PLCs help mitigate faculty risk by providing a constructive space for group problem-solving. In these joint spaces, faculty can gain trust by working directly with their peers. Further, faculty groups can help contribute to an institutional, cultural shift critical to lasting change (Shadle, Marker, and Earl 2017). Ultimately, faculty development proves a promising practice to provide faculty space for enrichment experiences and can help improve instructional practices.

A key attribute of many successful PD programs is the establishment of faculty groups/cohorts. Strong, Kendall, Henderson, and Basalo (2016) found that establishing communities is critical in PD programs. Further, they highlight workshops as one means to help develop these communities. Strong, Chua, and Cutler (2019) also affirm the importance of establishing cross-group coalitions and communities. Finally, Pulford et al. (2015) discuss the importance of professional learning communities (PLCs) in faculty development. Their research highlights the importance of PLCs that translate educational research directly into practice.

Guiding Conceptual Frameworks

Two conceptual frameworks informed the development of the JTFD program to design a program that would lead to lasting change. First, to promote personal transformation, we utilized

Rogers' diffusion of innovation (2003). Second, we employed Coburn's (2003) model of sustainable innovation scaling to advance a cultural change throughout an organization.

Many researchers use the diffusion of innovation to examine PD in higher education. Rogers' conception of diffusion of innovation (2003) is a five-stage model through which individuals adopt an innovation. In the first stage, *awareness/knowledge*, an individual is exposed to an innovation or concept, and the individual is learning. In the second stage, *persuasion/interest,* an individual receives or seeks additional research, information, or resources on the topic. In the third stage, *evaluation/decision*, they will adopt or reject the innovation. If they opt to try the innovation, they advance to the fourth stage, *implementation/trial, in which the individual* attempts to implement the innovation in their context. Finally, in the fifth stage, *confirmation/adoption*, they will sustain long-term use of the innovation.

Individuals will often not advance through all the innovation stages (Rogers 2003), especially within the context of PD programs. Instead, they will typically progress through the first three stages, gaining interest in the phenomena before collecting more information. One potential explanation for the incomplete change is the lack of sustained support structure in PD programs to facilitate change. The approach or program alone does not help the participant progress through the later diffusion of innovation stages. Therefore, developing a PD program that supports the faculty member's learning and adopting an innovation through discussion and implementation is critical (Coburn 2003). In addition, positive attitudes towards a particular innovation are correlated with higher rates of adoption of the innovation.

Furthermore, modeling the use of the innovation in the PD program is a crucial way to help demonstrate and encourage the adoption of the innovation by program participants (Coburn 2003). In addition, sustained, ongoing PD programs are critical to fostering lasting change and adopting innovation (Yoon et al. 2007). Lastly, integrating opportunities for faculty to try the innovation in their classroom practices and then discuss what happened can also help individuals move through the adoption phase. Multiple researchers have employed the diffusion of innovation framework within the context of faculty development programs (e.g., Henderson, Dancy, and Niewiadomska-Bugaj 2012; Nelson, McKenna, Chavela Guerrera, and Pimmel 2016).

We also integrated Coburn's model of innovation scaling (2003) for cultural change of an organization into the development and planning of JTFD. We embraced three aspects of Coburn's (2003) model: depth, sustainability/spread, and shift of innovation. Depth is measured in the degree of change in faculty beliefs and practices. Our program focused on shifts in awareness of and attitudes toward student-centered teaching practices. By sustainability of spread, Coburn refers to the change in individual faculty beliefs beyond individuals to the organization, where multiple people adopt the practices and ideas across the organization rather than only one or two faculty. Lastly, "shift in ownership" is related to shifting ownership of the innovation (in this case, the PD program) from external facilitators to widespread cultural shifts across the organizational unit. Through this model, we sought to foster a change of culture to broad adoption of AL practices across the college of engineering.

Lastly, we utilized Wenger's concept of communities of practice (1998) to inform the structure of the PD program. Communities of practice (CoPs) are groups of people who gather around a particular topic or practice. In this case, our communities of practice were faculty and staff members interested in expanding their use of AL practices in their engineering classrooms. CoPs also help facilitate learning through a situated experience for the participants. For example, in professional development programs, communities may be informal sessions where faculty members come together to discuss student-centered pedagogical strategies in the classroom and share tips and best practices with other group members.

Within the context of this project, we sought to extend the learning of individuals in the PD program into their departments to spread awareness of AL practices and facilitate a shift in the culture of instructional practices more broadly. Finally, PD participants served as "ambassadors" for AL amongst their peers, thus enabling a more systemic cultural change.

JTFD PROGRAM

The JTFD program was a multi-year initiative that engaged engineering faculty in a series of PD activities to increase the use of AL in the classroom. The JTFD program focused on expanding the use of AL instructional techniques in engineering classrooms and included seven disciplines within engineering: aerospace, biomedical, civil, chemical, construction, materials, and mechanical.

The JTFD program employed a "train-the-trainer" approach modeled after Pimmel and McKenna's (2014) work. First, project team led the PD training sessions for pairs of faculty members (one from each discipline), who was our disciplinary leader pairs (DLPs). In the following academic year, the DLPs then facilitated the PD sessions for a group of faculty members from their discipline in disciplinary faculty groups (DFGs). Each DFG comprised two DLPs and 6 to 20 other faculty members. Due to the high number of faculty participants (n=82) and disciplines (n=7), this process occurred over three years. See a visual representation of the PD structure in figure 1.

The official PD programming spanned one academic year for each of the two cohorts since prior research indicates that a longer duration is important to promote lasting change (e.g., Darling-Hammond, Meyer, and Gardner 2017; Yoon et al. 2007). During the program's first year, participants attended eight biweekly workshops in the fall semester. Workshop topics included: introduction to active learning, Bloom's taxonomy, three sessions on student engagement (making classes more

	Cohort 1 Tier 1 Disciplinary Leader Pairs (DLPs)	Cohort 1 Tier 2 Disciplinary Faculty Groups (DFGs)	Cohort 2 Tier 1 Disciplinary Leader Pairs (DLPs)	Cohort 2 Tier 2 Disciplinary Faculty Groups (DFGs)
Year 1 *Fall 2015 - Spring 2016*	Being trained by project leaders & classroom implementation			
Year 2 *Fall 2016 - Spring 2017*	Teach sessions to Tier 2 DFGs	Being trained by Cohort 1 Tier 1 DLPs	Being trained by project leaders & classroom implementation	
Year 3 *Fall 2017 - Spring 2018*	Facilitate CoPs Ongoing assessment	Ongoing assessment	Teach sessions to Cohort 2 Tier 2 DFGs	Being trained by Cohort 2 Tier 1 DLPs
Year 4 *Fall 2018 - Spring 2019*	Attend CCoPs Ongoing assessment	Attend CCoPs Ongoing assessment	Facilitate CoPs Ongoing assessment	Ongoing assessment
Year 5 *Fall 2019 - Spring 2020*	Ongoing assessment	Ongoing assessment	Attend CCoPs Ongoing assessment	Attend CCoPs Ongoing assessment

Figure 1. Program Structure and Timeline.

interactive, implementing active learning, and cooperative learning), motivation and learning, inclusive classroom practices, and muddiest points/other tech tools. One-hour workshops included a brief introduction to the topic and active learning activities, including discussions, think-pair-share, and other activities. We intentionally incorporated AL practices into our workshops since modeling has proven an effective pedagogical tool (Felder and Brent 2003).

Engineering education faculty development research highlights the significance of community-building (e.g., Pulford, Ruzycki, Finelli, Hahn, and Thorsen 2015; Strong, Kendall, Henderson, and Basalo 2016). Therefore, we intentionally created space for faculty to continue expanding their communities the following semester. In the spring semester, participants attended communities of practice (CoPs). CoPs were structured yet informal spaces for faculty to connect and discuss active learning and their experiences in the classroom, modeled after Wegner's (1998) ideas of CoPs. Each session comprised a brief refresher presentation on the topic and facilitated conversation. Faculty participants gave input on preferred issues to develop the final CoP schedule, which included Bloom's taxonomy, student- vs. teacher-centered instruction, technology, observing active learning classrooms, cooperative learning, and a final discussion. Due to high faculty interest, we extended the PD the following year with continuing communities of practice (CCoPs), an improvised program offering. CCoPs were completely voluntary and available to all participants in the years after the JTFD program officially ended. CCoPs met eight times across the academic year and were a continuation of CoPs, so faculty could continue to discuss their use of active learning in the classroom.

Program Participants

Department chairs and project team leaders sent out recruitment letters to faculty members. Participants received a $1,200 stipend for their participation across the academic year. This stipend was in exchange for their time attending eight 1-hour workshops in the fall semester and six 1-hour community of practice sessions in the spring semester. Additionally, for each workshop and CoP session, faculty were expected to complete readings and short homework assignments (of which the majority completed). In total, 82 of 370 eligible faculty members participated (see a breakdown of faculty participants in table 1).

Table 1. Faculty Participants.

Cohort	Discipline	Number of Faculty Participants
Cohort One (15–16)	Disciplinary Leader Pairs for cohort one	8
Cohort One (16–17)	Civil	13
	Construction	9
	Aerospace & Mechanical	13
	Disciplinary Leader Pairs for cohort two	6
Cohort Two (17–18)	Biomedical	18
	Chemical	7
	Materials	8

PROGRAM EVALUATION

We employed a multi-faceted program evaluation strategy to determine the effects of the JTFD program. Overall, the assessment focused on four primary areas: 1) faculty self-reporting of awareness of, attitudes towards, and use of AL strategies, 2) instructional practices in the classroom, 3) effectiveness and satisfaction of CoP sessions and the overall program, and 4) student achievement. Data sources included multiple surveys, classroom observations, and administrative student achievement data. We present a summary of our project evaluation methodology in Figure 2.

We collected data at points in time during the formal program (one academic year): pre, which was at the start of the academic year in the fall, just before program participation; mid, in between fall and spring semesters; and post, at the end of the spring semester. This paper discusses program evaluation results on pre- and post-comparisons via paired samples t-tests[1].

[1] Response rates ranged from n = 29 – 36, which varied due to fluctuating response rates and missing data. This paper focuses on highlighting program achievements to facilitate a discussion of lessons learned and for professional development programs. As such, more limited results are presented here (for a robust discussion of program evaluation results, see Ross et al. 2020).

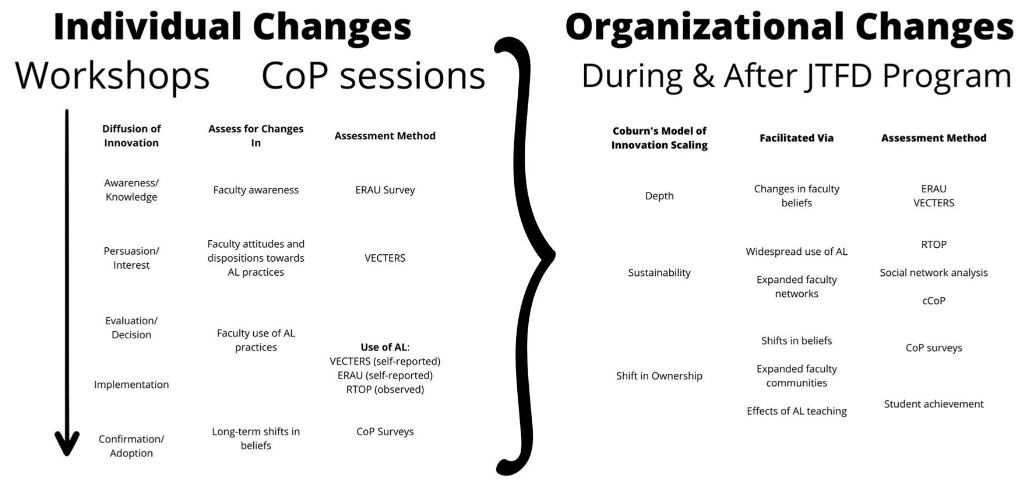

Figure 2. Program Evaluation Framework.

Education Research Awareness and Use Survey

The primary goal of the JTFD program was to increase awareness of instructional practices and research regarding student-centered teaching strategies. The project team designed the Education Research Awareness & Use (ERAU) survey to assess faculty awareness of various instructional practices related to AL teaching strategies. The items included: effective teaching, instructional design, how people learn, active learning, teams, student motivation, learning objectives, Bloom's taxonomy, and professional learning communities (PLCs). The survey measured awareness on a 4-point Likert scale from *very unfamiliar* to *very familiar*. The Shift in Awareness also asked about faculty members' use of four specific instructional practices: cooperative learning, AL, learning objectives, and Bloom's taxonomy. Faculty reported on their use before and after their participation in the program. Overall, the survey had strong internal reliability ($\propto = 0.91$).

Value, Expectancy, and Cost for Testing Educational Reforms Survey

We assessed faculty members' attitudes and motivations regarding student-centered teaching practices through the Value, Expectancy, & Cost for Testing Educational Reforms Survey (VECTERS) (Judson, Ross, Middleton, and Krause 2017). This self-reported instrument examines faculty motivation through expectancy-value theory. From the faculty perspective, expectancy-value theory frames the effort in instruction through the lens of costs, considered value, and expectation of success (Shah and Higgins 1997; Shu and Lam 2011). The expectation of success is defined as a function of value placed on attaining an end goal and cost (perceived effort and sacrifice). The more a faculty member values a particular strategy, expects the success of that practice, and sees lower cost/effort for implementation, the more likely they will integrate that instructional practice into their classroom.

VECTERS measures faculty members' a) dispositions towards and b) use of three specific student-centered teaching practices, which were the foundational components of an AL classroom (Judson, Ross, Middleton, and Krause 2017). The strategies are formative feedback, real-world applications, and instructor-facilitated student-to-student discussions. Formative feedback involves collecting ongoing feedback from students and using that information to adjust instruction throughout the academic term. The real-world application involves intentionally integrating relevant applications and problems into class examples to help students draw connections across industry and design. Finally, student-to-student discussions involve instructor-initiated discussions or activities during class time to help further students' conceptual and personal understanding of course material. The survey prompts faculty to assess their perceived expectation of success (10 items), value (11 items), and cost (5 items) for each strategy. VECTERS measures these dispositions on a 4-point Likert scale from *strongly disagree* to *strongly agree.* Faculty also reported current and anticipated future use of the teaching strategy. Cronbach's alpha for all constructs was above .7, indicating strong reliability.

Reformed Teaching Observational Protocol (RTOP)

Because self-reported data can be biased (Ebert May et al. 2011), we also conducted classroom observations to characterize instructional practices in the classroom accurately. As with the surveys, we conducted classroom observations three times: pre, mid, and post. At each time point, we observed two separate class sessions; two trained observers conducted each observation. To quantify student-centered teaching practices in the classroom, we employed the Reformed Teaching Observational Protocol (RTOP) (Sawada et al. 2002).[2] The RTOP rates faculty on 20 items on a 5-point scale, where a five indicates high use, for five dimensions:

- *Lesson design and implementation*: This construct focuses on the structure and delivery of the class materials. For example, one item assesses whether instructors engaged students' prior knowledge in learning.
- *Propositional knowledge (content):* These items examine how course material is presented in the class and is focused on the subject matter.
- *Procedural knowledge (content):* These items assess how students engage with the course subject, using multiple methods representing phenomena.
- *Communicative interactions (culture):* This construct examines the types of interactions that occur in the classroom. Specifically, it looks at whether the classroom culture was inclusive and the kinds of communication facilitated in the classroom.
- *Student/teacher relationships (culture):* The final construct examines the relationship between

[2] The authors acknowledge that multiple instruments are available to measure the extent of use of active learning practices in a classroom, such as the Teaching Dimensions Observational Protocol (Hora, Oleson, & Ferrare 2013) and the Classroom Observation Protocol for Undergraduate STEM (Smith, Jones, Gilbert, & Wieman 2013).

teachers and students in the classroom. For example, items might assess whether the teacher encouraged active participation in the class.

Overall, faculty receive a score ranging up to 100 points. Higher scores generally indicate higher AL practices in the undergraduate engineering classroom. Further, we were more interested in seeing shifts in practices rather than paying close attention to the score. The RTOP instrument is highly reliable and well-established in STEM contexts (Sawada et al. 2017). Further, a co-PI was involved in developing the RTOP instrument and therefore was intimately familiar with the instrument and training procedures. Observers were trained on the RTOP by a project team member and watched multiple practice lessons as part of their training. Interrater reliability was above 60% across all observations.

Student Achievement Data

Of central interest was the influence that the JTFD program might have on student achievement. A plethora of research indicates that AL results in higher student achievement and learning (e.g., Felder and Brent 2016; Freeman et al. 2014). As such, we hoped the JTFD program would also substantially increase student achievement. To examine potential effects on student achievement, we collected the final grades awarded to students in all classes taught by the faculty participants before and after participating in the program. For comparison, we also collected this same data for all undergraduate engineering faculty who did not participate in the program. To be included in the analysis, we only kept those courses taught by the same faculty member in both the “pre” and “post” periods. In total, we looked at 109 unique courses with an average of 150 students in each “pre” course and 120 students in each “post” course. Course enrollments ranged from 50 to 300 students.

We conducted multiple analyses to examine student achievement (for a complete discussion, see Mayled et al. 2019; Ross et al. 2019; Hoyt et al. 2020). First, we used descriptive statistics and Chi-square analyses to examine the percentage of students with an A, B, C, D, or E as final grades or those who withdrew (W) from the course. We then compared average student performance (measured via cumulative GPA) before and after faculty participation in the program.

FINDINGS

Shift in Awareness & Beliefs/Attitudes Regarding Active Learning

ERAU Survey. The results of the ERAU survey are shown in Table 2. Across all instructional constructs, there was a significant increase in familiarity with research on the different teaching strategies ($p < .05$). The largest gains in awareness were for student motivation, professional learning communities, and instructional design. Although even the smallest percentage point increase for learning objectives still marked a critical gain. Further, all practices were characterized by either medium

Table 2. Change in Faculty Awareness of Education Research, n = 36.

Construct	Pre	Post	t	Cohen's *d*	% Change
Effective Teaching	2.59 (0.93)	3.07 (0.65)	3.76***	0.60	23%
Instructional Design	2.28 (0.89)	2.76 (0.77)	4.15***	0.58	30%
How People Learn	2.50 (0.94)	2.91 (0.63)	3.37**	0.51	20%
Active Learning	2.63 (0.90)	3.24 (0.67)	4.13**	0.77	23%
Teams	2.89 (0.90)	3.43 (0.75)	3.84***	0.65	21%
Student Motivation	2.30 (0.81)	2.98 (0.72)	5.59***	0.89	37%
Learning Objectives	3.04 (0.73)	3.37 (0.53)	3.02**	0.52	13%
Bloom's Taxonomy	2.50 (1.11)	3.43 (0.72)	5.85***	0.99	23%
Professional Learning Communities	2.04 (0.88)	2.76 (0.68)	5.12***	0.92	34%

$^*p < .05$, $^{**}p < .01$, $^{***}p < .001$

or large gains (Cohen's d = 0.51 through 0.99) in familiarity, with the largest growth happening in awareness of research around student motivation, and then Bloom's taxonomy (Cohen's d = 0.99), followed closely by professional learning communities (Cohen's d = 0.92). These changes demonstrate that the program effectively increased faculty awareness of different teaching strategies to promote more student-centered practices in the classroom.

We observed significant increases in the average use of all four teaching practices ($p < .05$), except for learning objectives, as shown in Table 3. The largest gain was in the use of Bloom's taxonomy (Cohen's d = 0.88), which is not unexpected as we devoted an entire workshop to Bloom's taxonomy. In addition, there was a medium increase in cooperative and active learning (Cohen's d = 0.46 and

Table 3. Shifts in Use of Active Learning from Shifts in Awareness, n = 36.

Construct	Pre	Post	t	Cohen's *d*	Percent Change
Cooperative Learning	3.17 (0.85)	3.47 (0.51)	2.74	0.46	31%
Active Learning	3.36 (0.78)	3.67 (0.48)	2.77**	0.48	31%
Learning Objectives	3.43 (0.75)	3.50 (0.55)	0.62	0.10	8%
Bloom's Taxonomy	2.35 (1.00)	3.13 (0.76)	5.69***	0.88	78%

$^*p < .05$, $^{**}p < .01$, $^{***}p < .001$

0.48, respectively), which were major topics we focused on in the workshops. The lack of shift in learning objectives (Cohen's d = 0.1, p > .05) is likely because most faculty were required to report on learning objectives as part of their syllabi, even before participating in the JTFD program.

VECTERS. The VECTERS measured a faculty member's beliefs regarding the value, expectation of success, and cost associated with three active learning instructional practices. Results from the analysis are presented in Table 4, which displays the percentage change in average score by construct after participating in the PD program. Faculty had the largest gains in expectation of success for (12%; Cohen's d = 0.72, p < .001) and value of formative feedback (7%; Cohen's d = 0.03, p < .01), one of the main strategies emphasized throughout the JTFD program. However, the effect size for the value of formative feedback was quite small, indicating a negligible increase. There were also considerable gains in real-world applications, with increased value (7%, Cohen's d =0.66, p < .01) and decreased perceived cost (-11%, Cohen's d =0.46, p < .05). Real-world applications emphasize the value of material in class to future work, helping students connect what they learned in class to their future careers.

There was no shift in perceived costs for formative feedback and student-to-student discussions,

Table 4. Percent change in the Shift in Attitudes constructs from pre to post, n=29.

Construct	Pre	Post	t	Cohen's d	% Change
Formative Feedback					
Expectation of success	2.95 (0.56)	3.31 (0.43)	4.09***	0.72	12%
Value	3.52 (0.36)	3.51 (0.38)	3.21**	0.03	7%
Cost	2.59 (0.72)	2.60 (0.62)	0.13	0.02	0%
Real-World Applications					
Expectation of success	3.52 (0.36)	3.51 (0.38)	0.12	-0.02	0%
Value	3.02 (0.20)	3.22 (0.38)	3.26**	0.66	7%
Cost	2.43 (0.62)	2.13 (0.68)	2.74*	0.46	–11%
Student-to-Student Discussions					
Expectation of success	3.13 (0.56)	3.15 (0.49)	0.11	0.02	2%
Value	2.93 (0.33)	3.05 (0.36)	1.60	0.30	5%
Cost	2.29 (0.62)	2.31 (0.58)	0.13	0.02	1%

*p < .05, **p < .01, ***p < .001

indicating that people still thought those two strategies were just as costly to implement at the end of the program as they did when they first started. We did observe an 11% average decrease in perceived costs of implementing real-world applications into lectures, which suggests that faculty found that strategy less time-consuming or resource-draining at the end of JTFD. The Shift in Attitudes survey demonstrates that faculty advanced from developing awareness, the first stage of Rogers' diffusion of innovation, to the third stage, where they tried to practice/implement AL in the classroom. Overall, participants made significant gains in dispositions towards AL strategies, particularly formative feedback and real-world applications.

We also examined the faculty's self-reported current and planned future use of the three teaching strategies from the survey: formative feedback, real-world applications, and student-to-student discussions (see Table 5). Current and planned future use were asked about at two time points (pre and post), so the beginning of the PD and the end of the first semester of the JTFD program. Overall, we did not find any significant shifts in the current use of any of the three strategies, except for a slight increase in the reported planned future use of formative feedback (Cohen's d= 0.39, p < .05). However, there was no shift in the planned future use of the other two strategies.

Adoption of Active Learning Practices in the Classroom

Next, we examined how faculty participants' classroom practices shifted after participating in the program. We then examined classroom practices as measured in observations via RTOP. The distribution of scores for RTOP is presented in Table 6. Shifts in RTOP scores demonstrate significant

Table 5. Percent change in use of the Shift in Attitudes constructs from pre to post, n=33.

Construct	Pre	Post	t	Cohen's *d*	% Change
Current Use					
Formative feedback	2.18 (0.92)	2.52 (0.76)	1.94	0.37	14%
Real-world applications	3.09 (0.81)	3.30 (0.77)	1.23	0.22	7%
Student-to-student discussions	2.61 (0.93)	2.79 (0.99)	0.93	–0.16	7%
Future Use					
Formative feedback	2.70 (0.85)	3.00 (0.66)	2.05*	0.36	11%
Real-world applications	3.36 (0.74)	3.64 (0.65)	1.60	0.28	8.3
Student-to-student discussions	3.06 (0.90)	3.09 (0.98)	0.16	0.03	1%

Table 6. Distribution of RTOP Scores, n=46.

	Pre	Mid	Post
Minimum	30.50	34.50	36.00
Lower Quartile	45.81	46.50	56.00
Mean (SD)	58.44 (16.87)	58.34 (15.65)	66.50 (15.13)
Upper Quartile	71.50	66.06	78.50
Maximum	92.00	95.00	97.50

advancement through the diffusion of innovation stages toward the fourth stage of implementation and the fifth stage of adoption.

We conducted a series of paired samples t-tests to assess the significance of these shifts from pre to mid, mid to post, and pre to post (see Table 7). There was a 1.51-point increase in average scores from the pre- to mid-period, which was not statistically significant (Cohen's $d = 0.09$, $p > .05$). However, we found a significant increase from both mid to post and pre to post (Cohen's $d = 0.53$ and 0.50, respectively; $p < .05$) with a 12 to 13% average increase in the use of active learning practices. The greatest gain was observed from mid- to post-period (Cohen's $d = 0.53$), indicating that the greatest shifts in instructional practices occurred during the spring semester. This shift in practices is likely because the faculty had time to consider implementing these changes during the fall semester.

Further, these shifts were moderate, indicating significant increases in the use of AL (Cohen's d=0.50). The larger change from mid to post suggests that participants could take the strategies presented in the first semester and modestly incorporate them into their practice in the second semester of participation. This further supports the concept that they were achieving movement of their practice to Roger's (2003) fourth stage of implementation and the fifth stage of adoption.

Table 7. Changes in Total RTOP Scores.

Time Period	Average Point Change	t	Cohen's *d*	% Change
Pre to Mid	1.51	0.60	0.09	3%
Mid to Post	7.36*	4.21***	0.53	12%
Pre to Post	7.50*	2.92***	0.50	13%

$^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$

Student Achievement

A central goal of the program was to improve student achievement through enhanced faculty practices. As such, we did collect student achievement data to examine how faculty participation (and resulting shifts in instructional practices) influenced student achievement. Overall, results indicated that there was generally little shift in student achievement for students enrolled in participating faculty members' courses after they participated in the program (Table 8). A series of Chi-square tests were used to compare distributions of students by grade type (i.e., A-F), as well as withdrawals and incompletes per instructor/course were evaluated across all course levels, across undergraduate courses only, and per grade level (100-, 200-, 300-, and 400-levels). As shown in Table 8, there were no significant changes in mean GPA. We did observe a slight decrease in the number of students receiving a C grade ($p < .01$); similarly, we saw a reduction in the average number of course withdrawals. We also found an increase in the percentage of students receiving a D or E grade ($p < .001$). Though not significant, we did see an increase in the rate of students receiving an A grade and a decrease in the percentage of students receiving a B grade ($p > .05$).

Table 8. Student Achievement Statistics.

	Percentage						
	A	**B**	**C**	**D**	**E**	**W**	**Average GPA**
Pre	41.84	37.12	15.25	3.07	2.71	5.57	3.12
Post	45.44	32.78	15.19	3.51	3.08	5.20	3.14
Change	3.60	–4.34	–0.06**	0.44*	0.37***	–0.37**	0.02

$^{**}p < .05$, $^{**}p < .01$, $^{***}p < .001$

DISCUSSION

Throughout the multi-year PD program, the PIs and project team could hone and develop a well-delivered, highly effective PD program. The program's success was due to a multi-faceted, diverse group of individuals that created a flexible and adaptable program to meet the participants' needs best. This section presents positive features and adaptations across the program in program design and evaluation/assessment.

This paper offers an in-depth analysis of a multi-year, multi-disciplinary, large-scale professional development program in undergraduate engineering. Through our research, we offer insight into the evaluation strategies employed and the results of our study. Though this study focuses specifically on undergraduate engineering faculty, the results of this study are generalizable to other contexts and programs. This study was focused specifically on undergraduate engineering faculty.

The findings from this study are particularly generalizable to PD programs focused on enhancing educational practices in engineering. However, many findings will apply to other professional development programs across disciplines. We conclude by discussing student achievement evaluation and suggestions for future PD programs.

Shift in Faculty Awareness & Beliefs

As Rogers (2003) and Coburn (2003) discussed, you must also shift beliefs and awareness to promote lasting change in practices. The primary goal of the JTFD program was to increase awareness of active learning practices while also improving attitudes and perceptions of these instructional practices.

To advance in the diffusion of innovation model, it is critical that faculty first learn about research and access information regarding the innovation (in this case, active learning). The ERAU survey demonstrated significant shifts in awareness of research on all eight areas we asked about, which aligns with Rogers' (2003) first stage of *knowledge/awareness.* JTFD was very successful in promoting information related to student-centered instructional practices.

Next, people advance into the *persuasion/interest* stage, where they have a growing interest in the innovation. We measured advancement to this stage through shifts in attitudes regarding active learning strategies via VECTERS. The results of the VECTERS analysis demonstrated significant gains in attitudes regarding active learning. However, these results were nuanced as we saw growth in value and expectation of success, despite no shift in perceived costs of implementing these practices in the classroom. These findings suggest the complicated relationships between value, the expectation of success, and cost related to actual attitude shifts. Nevertheless, the results are encouraging because we see growth in value and expectation of success, even though faculty still perceived high costs for implementing student-centered teaching practices in the classroom.

We were encouraged to see substantial gains in awareness of and attitudes toward active learning instructional practices. The evaluation of knowledge of and attitudes towards AL practices included a multi-faceted approach, which allowed us to gain a strong and holistic understanding of how faculty advanced through the *knowledge/awareness* and *persuasion/interest phases*.

Other programs seeking to expand their understanding of the effects of the PD program should consider incorporating the shifts in awareness and use surveys to measure the extent to which faculty have shifted in their understandings, attitudes, and self-reported use. This is particularly important to assess because awareness is a prerequisite for shifting attitudes, which can help influence use. Therefore, having clear measures of these are critical. Other programs should consider additional or alternative methods for measuring attitudes, including the shifts in attitudes survey.

Adoption of Active Learning Strategies

Next, we were interested in evaluating if the faculty advanced to the *evaluation* or the *implementation/trial phases*. In these phases, we expect to see actual implementation or *use* of student-centered teaching practices in the classroom. Therefore, we measured classroom practices in two ways. First, we collected self-report data from faculty on how much they implemented active learning practices. Nevertheless, since self-report data can be biased, we also conducted classroom observations to objectively measure how faculty implemented student-centered teaching practices in the classroom.

On both the ERAU survey & VECTERS, participants reported a significant growth in the use of active learning practices. In both surveys, faculty indicated using various strategies, including formative feedback, Bloom's taxonomy, general active learning practices, and cooperative learning. Through this use of strategies, faculty moved to the *implementation/trials phases* of diffusion of innovation. In this part of the program, we evaluated the faculty's initial use and attempted to integrate their active learning strategies into the classroom.

Through RTOP observations, we found that faculty increased their use of active learning in the practices. We found that, on average, faculty increased their use of active learning practices in the classroom by 13% in the semester following the JTFD program. This finding suggests that faculty remained in the *implementation/trial* phase or had moved into the *confirmation/adoption* phase. Interestingly, on the specific use strategies, faculty were less likely to indicate the planned increase in use. However, on the RTOP survey, we did observe greater use of active learning practices overall. This could be because faculty utilized other active learning strategies or because they used more active learning practices than originally intended. These results indicate that the faculty had advanced to the final innovation diffusion stages.

Student Achievement

As with much of the work in higher education, there is frequently a keen focus on student outcomes and experiences, including learning and achievement. Much of the literature on AL focuses on student learning outcomes and achievement (e.g., Freeman et al. 2014). Following this trend, the JTFD goal was to shift faculty attitudes and instructional practices to improve student comprehension and achievement in undergraduate engineering. Unfortunately, our analysis did not show substantial student achievement shifts as expected. Though not significant, we did see an increase in the percentage of students receiving an A grade. Also, we saw a decrease in the percentage of students withdrawing from the course, suggesting that there might have been improvements in course delivery or engagement. This could indicate that students had greater motivation or confidence in the course; however, we did not assess this, so we cannot explain why.

Overall though, the shifts in the achievement of final student grades were less than had been expected by the project team. However, they are still noteworthy because they suggest that fewer students were withdrawing from these classes, which translates into greater student persistence in engineering. While these results did not show expected gains, the project team still believes that student learning did improve based on faculty feedback and prior research that speaks to the efficacy of active learning (Freeman et al. 2014).

Further, it takes multiple semesters/years to successfully implement AL practices in a classroom, so a longitudinal analysis of the faculty participants' course grades might show different results. Numerous faculty members reported in CoP sessions that their students were more engaged and doing well in in-class activities, suggesting improved learning. While we did not focus on this for our evaluation, we need to understand better the effects of PD on other areas for students, including engagement, motivation, interest, and comprehension. Further, we need to expand our ideas and attitudes around program evaluation for PD programs, especially for those focused on instructional practices. This section first discusses possible explanations for the lack of a change. Next, we discuss ideas for expanded program evaluation for PD programs focused on teaching in higher education.

The lack of shift in student achievement could be due to several factors. First, we utilized only one measure of student achievement – final letter grade. However, a final letter grade may not be the best measure of student achievement. Another challenge with letter grades is the complexities around grading. Research indicates grading is complex (Love and Kotchen 2010; Walton et al. 2008). Assigning final grades is not always straightforward or directly linked to student learning. As such, the final letter grade may not be the best way to represent student learning. Many faculty members might have preconceived ideas about grading and grade distributions (Love and Kotchen 2010). Therefore, even if faculty improve their teaching, this could mean that they still assign grades in the same distribution as they did before the professional development program. So even shifts in learning would not be evident in final grades. We did not ask faculty about their grading philosophy in this PD program, so we cannot account for their beliefs in our student achievement analysis. Future studies should consider accounting for faculty's grading philosophy within their study design. PD programs should also consider incorporating discussions around grading into their programming to foster dialogue around equitable grading and evaluation practices.

Other measures of learning, including specific class assignments and individual exams, all measure student learning that should also be considered as data sources for student achievement, as they could better reflect student learning than a final grade. One area for future PD professionals to consider is to have faculty administer learning or concept inventories (e.g., class quizzes, homework assignments) in classes before and after participation in the PD program. However, this could be a considerable logistical challenge. In addition, if faculty utilize the same evaluation forms (e.g., quiz or exam) developed using a teacher-centered instructional approach, it might not align with the new AL classroom environment. Therefore, faculty might also consider shifting how they evaluate student learning. Integrating a discussion on evaluation and measuring student learning into future PD programs will be essential to faculty development.

Another possible explanation for the lack of shift in student achievement is the delayed student achievement effects. Rogers' (2003) diffusion of innovation model articulates the slow process of actual change and adoption of innovations. Even if implementing changes, it might take time for faculty to integrate AL practices into their classrooms fully, as found by other PD programs (Henderson, Dancy, and Niewiadomska-Bugaj 2012). Therefore, it might be that effects on student achievement are delayed by at least a few more years. Future PD programming could consider the delay in student achievement and incorporate a longitudinal analysis into their planning, allowing delayed effects to be better observed. With continued observation, we would likely see advancement through the fourth and fifth stages of Rogers' model, where faculty begin to develop ongoing use of the innovation and integrate it fully into their classroom practices.

Instead, we urge future PD programs and those evaluating them to focus on new and innovative ways to measure the success of PD programs aimed at teaching practices. First, PD programs should be directly assessed on those aspects within their control. For example, student achievement is outside our control, even with improved instructional practices. Faculty might have a better chance of influencing student motivation or self-efficacy, both of which are often linked to student achievement. So, instead of focusing mainly on student achievement, PD programs could incorporate measures of student motivation or self-efficacy into their evaluations. Further, it is possible that if we evaluate student achievement through the same methods as we did before shifting from teacher- to student-centered practices, then we might not see a change in student achievement. Research suggests that we should shift how we evaluate student achievement in active learning environments (Freeman et al. 2014; Wieman 2014). Therefore, future PD programs should also discuss alternative student learning methods.

Lastly, despite some compelling qualitative (e.g., Steen-Utheim and Foldnes 2018) and quantitative (e.g., Freeman et al. 2014) evidence that AL is a more effective strategy for student learning, there are still mixed results in the literature (e.g., Prince 2004). This could be because many of these studies compare active learning to lectures, which Freeman et al. (2014) argue that we should no longer do since they are not taught similarly and might require alternate ways of assessing student learning. Further, other researchers suggest incorporating comparison groups into our analyses of PD outcomes (Derting et al. 2016). We must look at new ways to evaluate active learning in undergraduate STEM classrooms (Wieman 2014), including more mixed-methods studies incorporating qualitative evidence. Research indicates that AL practices can help improve self-efficacy and student motivation, which can, in turn, influence student achievement (Corkin, Horn, and Pattison 2017).

Therefore, researchers should examine other forms of student learning/understanding, motivation, and interest in the subject as possible areas of influence from improved instructional practices. Ultimately, PD programs and researchers must consider more than final grades to measure student achievement.

CONCLUSION

The JTFD program can be a model to expand professional development programs in other contexts and disciplines (such as other STEM disciplines, business, humanities, and social sciences). First, this large-scale PD program engaged over 80 faculty members across four years. The program manager role was an essential component in the success of our project. Next, we developed a comprehensive assessment model and evaluation framework to measure the faculty's awareness of, attitudes towards, and use of active learning strategies. We also assessed classroom observations to measure the fidelity of implementing student-centered practices in the classroom. Lastly, we developed a program with carefully curated and designed workshop materials while maintaining an adaptable framework to maximize faculty participation and engagement.

Ultimately, the JTFD PD program engaged over 80 faculty members across seven engineering disciplines in a multi-year professional development program. Through workshops, communities of practice, and continuing communities of practice, the JTFD program engaged faculty in deep conversations about effective instructional practices in undergraduate engineering. The program created a space for faculty members to deeply ponder their classroom practices and determine ways to foster more meaningful learning environments for students. Furthermore, the college of engineering has sustainably initiated more effective teaching programs for new, incoming faculty and a program with unique teaching and learning topics for continuing faculty. Overall, faculty reported strong satisfaction with the program, nearly all indicating they would suggest program participation to a colleague (Ross et al. 2020).

The results of this study are generalizable and applicable to a broad range of professional development programs across various contexts and education levels. We hope the lessons shared in this paper can contribute to developing rigorous, successful future PD programs within and outside engineering education and instructional practices. This paper can inform the development of engineering PD programs by integrating an engineering-specific curriculum. We believe there is good potential for initiating similar programs in other engineering colleges. However, the structure and best practices could be extended to nearly any STEM discipline, promising more robust PD programs across higher education. Lastly, we encourage PD program administrators and evaluators to consider a broader range of outcomes, particularly affective/behavioral outcomes such as motivation and engagement.

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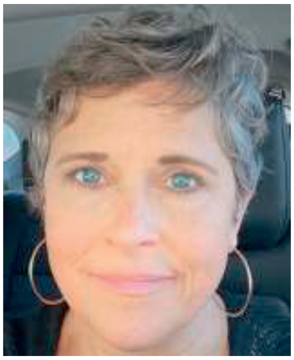

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