Examining Effects of an Evidence-Based Professional Development Program on Student Achievement

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Examining Effects of an Evidence-Based Professional Development Program on Student Achievement

Abstract

This is a complete research-based paper examining the effects of a professional development program on student achievement. Research indicates that student-centered, or active learning, teaching strategies promote greater student learning and achievement. However, teacher-centered, or lecture-based, pedagogical practices remain the dominant instructional practice in higher education engineering classrooms. Therefore, there is a strong need for professional development programs for faculty to learn more about active learning strategies and ways to implement student-centered teaching practices in the classroom.

The setting for this study is an NSF-funded professional development program at a large southwestern university. The program utilizes a “train-the-trainer” model to promote the use of active learning pedagogical practices to engineering faculty across multiple disciplines. This study examines the effects of the professional development program on changes in student achievement in the classes of participating faculty. This study utilized student grade data from the years 2015 – 2018, which serves as pre- and post-professional development data. Only those faculty participants’ courses that were the same during the fall and spring semester, respectively, from before and after the professional development program were included in the analysis.

Utilizing linear mixed effects models, pre- and post-data were analyzed to assess for effects on student achievement after the professional development program. Results indicate no significant differences in student achievement after participating in the professional development program. However, this analysis is only a subset of all program participants, so further research should be conducted. We conclude with a discussion of the results, areas for future research, and takeaways for other professional development programs.

Introduction

Active learning, or student-centered teaching practices, is a pedagogical technique where instructors engage students with course concepts, subjects, and materials through an interactive and adaptive manner. In classrooms with active learning, instructor-centered content (ie. a lecture) is limited, and much of the class time is dedicated to activities, group work, student discussions, or self-guided learning and participation.

Despite the research base and growing emphasis on active learning, the primary form of teaching in undergraduate engineering courses is the lecture/teacher-centered instruction [1, 2]. Therefore, it is important to shift faculty beliefs, and in turn, practices, regarding teaching strategies from primarily lectures to a more engaging, student-centered style classroom. One way to achieve this is through professional development programs. These programs have potential to increase faculty awareness of research regarding effective instructional techniques, while also providing space and opportunity for ongoing discussion around classroom innovations and active learning teaching practices. Professional development programs facilitate processes where faculty can engage in deep and ongoing learning and discussion around student-centered teaching practices. In turn, these professional development programs have the potential to foster sustainable, long-term change in faculty instructional techniques [3], [4].

The study presented in this paper is situated within the context of a large-scale professional development program in a large college of engineering at a university in the southwest United States. Funded through Improving Undergraduate Science Education (IUSE), this program promotes student-centered/active learning pedagogical practices to faculty across a diversity of engineering disciplines.

To understand the effects of the professional development program, a comprehensive and multi-faceted project evaluation was conducted. Data sources included surveys/assessments, classroom observations, and student-level data from courses. Faculty participants completed multiple surveys reporting their attitudes towards and use of student-centered teaching practices. Since self-reported measures can be biased, classroom observations were conducted in order to quantify the extent to which faculty implemented active learning strategies in the classroom. Lastly, to assess for shifts in student achievement, grade distribution data was pulled for faculty before and after the program.

In order to add to the growing body of literature focused on examining the effects of active learning on student achievement, this study focused on determining the effects of the professional development program on student achievement for the participating faculty,. To examine this, we pulled student-level grade data from all undergraduate engineering courses from Fall 2015 – Spring 2018 excluding Summer terms. By pulling across these years we are able to assess for changes over time for faculty before and after participating in the professional development program. This study was framed by the following research question:

> To what extent is student achievement effected in courses of faculty participating a the professional development program focused on student-centered, active learning pedagogy

Review of Related Research

Student Achievement and Active Learning

There is a plethora of research demonstrating the effectiveness of active learning for promoting greater student learning and achievement. This growing body of research demonstrates that student achievement is greater in classes with active learning environments than traditional lecture classes [5], [6], [2].

In a meta-analysis of 225 studies examining active learning and undergraduate STEM education, Freeman et al., found compelling evidence that supports active learning [7]. First, students enrolled in classes where instructors utilized active learning had 6% greater performance on concept inventories suggesting greater student learning in student-centered classrooms. Further, students who were enrolled in instructor-centered classes were 1.5 times more likely to fail than students enrolled in active learning courses. In a separate review the literature on active learning, Prince concluded that there was compelling evidence suggesting student-centered teaching promotes greater student learning [8]. As such, Prince urges engineering faculty to consider incorporating student-centered instructional practices in their courses.

The current literature base provides compelling evidence in favor of active learning teaching practices in undergraduate STEM classes, especially within the discipline of engineering. Ultimately, the current literature demonstrates that active learning teaching strategies have merit and should be utilized to promote greater achievement and comprehension for students, especially within undergraduate engineering.

Professional Development

Many researchers and practitioners have examined change processes for faculty within professional development programs. When people learn about new techniques, models, innovations, or ideas, they undergo a change process [3]. This change process is closely related to Rogers' model of diffusion of innovation, which articulates a five-stage model through which people adopt new innovations [9].

In the first stage of *awareness* or *knowledge*, an individual is exposed to a new innovation or idea. This can be through formal or informal means. After an individual becomes aware of the innovation, they advance to the second stage of *persuasion* or *interest.* In this stage, interest in the subject grows and individuals seek out additional information, resources, or experts on the innovation. Next, individuals advance to the *evaluation* and *decision* stage. In this stage, the individual chooses to either adopt or reject the innovation based on the evaluation of the information they gathered during the second stage. If an individual chooses to adopt the innovation, they advance to the fourth stage: *implementation* and *trial.* In this fourth stage, an individual attempts to implement the innovation and tests out how the innovation works. In the final stage, *confirmation* or *adoption*, the individual either chooses to sustain the use of the innovation for the long-term or ceases to employ the innovation.

This model, articulated by Rogers', has frequently been used by researchers when examining faculty professional development programs in higher education. Faculty frequently progress through the first two stages of the model, where they gain *awareness of* and *interest in* an innovation, especially related to teaching practices; however, faculty rarely advance all the way through the last two stages where they implement and sustain their use of the innovation [3].

Therefore, researchers have identified several important traits of successful professional development programs. First, it is critical to provide support and context for faculty to have opportunities to advance beyond the first three stages of Rogers' model for diffusion of innovation [10], [11]. Additionally, the program needs to be flexible and meet the needs of the participants, such as adapting discussions or content as needed. Next, the innovation being covered in the professional development needs to be implemented into the program [11]. So, for programs that are promoting active learning, it is essential to utilize activities, group discussions, and other facilitated exercises in the professional development sessions to model effective pedagogical practices. Through informal and targeted interactions, faculty can gain greater understanding of the innovation being discussed [12]. Lastly, it is important to facilitate an environment or program where faculty can see how to implement the innovation in the classroom, which will help faculty move into the *adoption* stage of the model [11].

Methods

Sample

In order to investigate the effects of an evidence-based professional development program on student achievement, course-level data were compiled for undergraduate engineering classes at a large southwestern university from the academic years of 2012-2013 through 2017-2018. Faculty participants were from engineering disciplines including aerospace, biomedical, chemical, civil, construction, materials, and mechanical engineering. Participation in the professional development program was voluntary. The program took place over the course of three years utilizing a "train-the-trainer" model in which select faculty were trained to be facilitators for their respective disciplines' professional development the following year. The first year consisted of training leaders from the engineering disciplines of civil, construction, and mechanical and aerospace. In the second year, 22 faculty within these three disciplines participated in a yearlong professional development program focused on active engagement strategies and other pedagogical practices linked to student achievement.

The first semester of the program included a series of eight bi-weekly workshops which covered active learning instructional practices and other pedagogical topics. In the spring semester, participants attended six communities of practice (CoPs), which were discussion oriented sessions focused on implementation of learned strategies into the classroom environment. During the second year, five leaders for three additional engineering disciplines including biomedical, chemical, and materials were trained. The third year of the program consisted of 34 participants from these engineering disciplines. The structure of the professional development program was consistent between years. Participants were offered opportunities of continued support through participation in continuing communities of practice as well as coaching and observations of their classes. A summary of the professional development program schedule and activities are presented in table 1.

Table 1

Project Overview and Schedule

	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*	Ongoing assessment	Ongoing assessment	Facilitate CoPs Ongoing assessment	Ongoing assessment

For this study, our analysis focused on faculty who participated in the professional development program for the 2016-2017 academic year. This includes individuals from all six disciplines because of the train-the-trainer model, in which the leaders for the 2017-2018 academic year were participants in 2016-2017. The data set is limited to individuals within this subgroup who taught the same class both before and after their involvement within the program. The academic years of focus for the data set include 2015-2016 and 2017-2018. The resulting sample included 38 individual classes taught by faculty across six disciplines in the college of engineering.

Data Treatment

For the purpose of this analysis, queries were created to compile information across several electronic archives of institutional data housed within the university repository. Archives accessed included both student- and class-level institutional data. Class-level data included discipline, course number, and lead instructor. Student-level data included final grade awarded and demographic information, including gender, ethnicity, and SES. In order to get a clear picture of pre- and post-data around the professional development program and lag time of implementation, longitudinal data spanning the academic years of 2012-2013 until 2017-2018 were compiled [3]. Within each academic year, data retrieved were limited to the discipline codes taught by the participants of the program. From this raw data, pivot tables were created including grade distributions and student demographics. Raw as well as pivot table data were exported and cleaned.

The cleaning process included the removal of any non-undergraduate level courses. Within the college of engineering, some courses were cross listed but were still taught by a single lead instructor. In order to get a more accurate picture of grade distributions, grade distribution data were merged for cross listed courses if discipline, course number, lead instructor, and course name were aligned. Once this merging was complete, all courses with less than five students were removed from the data. Within the remaining course data, grade distributions varied across courses in that some instructors used the +/- scale of letter grades and others did not. In order to limit variation, plus and minus grades were removed by compiling them into their respective letter grades. For instance, the number of students receiving A+, A, and A- would be summed and labeled as students receiving an A for the class. The grade distribution scale includes A, B, C, D, E, and W. Additionally, in order to control for the diversity of class size across the data set, the percentage of students receiving each final letter grade (i.e. A) were calculated. Lastly, the data set was limited to those participants who taught the same discipline and course number in the terms before and after the professional development program (2015-2016 and 2017-2018). As such, we had 38 classes from both pre- and post-time periods to analyze to assess for differences in student achievement after the professional development program.

Data Analysis & Results

Data analysis followed a two-step approach. First, we conducted descriptive statistics in SPSS to determine the average percentage of students awarded final grades of A, B, C, D, E, or W before and after the professional development program. Since performance could be influenced by academic term (fall or spring), descriptive statistics were compared holding academic term constant. Next, multiple linear mixed effects models were conducted in R to assess for differences in percentages of students awarded final grades of A, B, C, D, E, or W.

Descriptive Statistics

The results of the descriptive statistics are presented in table 2. Across both fall and spring terms, there was a decrease in the percentage of students receiving an A for a final grade after the professional development program. There was an increase in the percentage of students receiving final grades of B and C for both academic terms after the professional development program. However, the increase on the percentage of students receiving B's was much greater than those receiving a C. The percentage of students receiving a final grade of D or E increased slightly after the professional development program. The percentage of students receiving a W decreased for the fall courses, but increased for courses taking place in the spring semester.

Table 2

Descriptive Statistics, Pre and Post, by Term

	Average Percent					
Term	A	B	C	D	E	W
Fall						
Pre	54.32	24.61	10.82	2.07	2.75	5.38
Post	49.03	31.03	11.42	2.58	2.27	3.62
Spring						
Pre	50.91	27.01	11.49	1.94	1.92	0.00
Post	44.23	28.61	12.66	2.59	2.71	9.05

Linear Mixed Effects Models

To test if these shifts were significant, we utilized a multiple linear mixed effects model. We had 6 dependent variables of interest (percentage of students with a final grade of A, B, C, D, E, or W). We used two linear mixed effects models. Each model allowed us to control for different factors. In the first model, we only assessed for differences before and after the professional development program. In the second stage, we controlled for time (before and after), term, and the interaction between these two variables. A summary of the linear mixed effects models is reported in table 3, below.

Table 3

Linear Mixed Effects Model Summary

Model Number	Model Purpose	Independent Variables Included
1	Compared for differences of grades for faculty before and after program	Time: measured as pre and post
2	Same test from model 1, while also controlling for differences across term (fall/spring)	Time: measured as pre and post Term: fall and spring Interaction between time and term

Each model was run six times, once for each of the final grade categories of A, B, C, D, E, and W. The results for the six variations of model one are presented in table 4, below. For the first six variations of model one (with dependent variables of A, B, C, D, E, & W) there were no significant differences between the pre and post percentages of students within those grades ($p > .05$).

Table 4

Linear Mixed Effects Model Results for Model 1

	Dependent Variable					
	A	*B*	*C*	*D*	*E*	*W*
Time						
F	1.607	2.997	0.141	0.741	0.000	1.477
p-value	0.210	0.089	0.709	0.393	0.985	0.229
Intercept						
F	87.098	69.939	31.469	14.007	28.172	6.391
p-value	<.0001	<.0001	<.0001	<.01	<.0001	<.05

Next, model two assessed if there were differences in percentages of students in each grade group across time (pre- and post-professional development program), while holding the term constant. Within this model, we examined if there were differences within fall and within spring semesters. The results from these versions of model two are presented below, in table 5.

Table 5

Linear Mixed Effects Model Results for Model 2

	Dependent Variable					
	A	*B*	*C*	*D*	*E*	*W*
Time						
F	1.553	2.939	0.136	0.715	0.000	1.664
p-value	0.218	0.092	0.713	0.402	0.985	0.203
Term						
F	0.000	0.320	0.020	0.022	0.059	0.041
p-value	0.992	0.574	0.888	0.883	0.810	0.841
*Time*Term*						
F	0.028	0.346	0.016	0.012	0.576	11.885
p-value	0.869	0.559	0.899	0.914	0.451	< .01
Intercept						
F	86.674	68.877	30.971	13.983	27.782	0.883
p-value	<.0001	<.0001	<.0001	< .01	<.0001	0.0113

For the first five versions of model two, which tested for differences in A, B, C, D, & E grades, there were no significant coefficients for time (pre- and post-), term (fall and spring), and the interaction term for time and term. These results indicate that there were no significant differences in student achievement before or after the professional development program ($p < .05$). However, there were significant differences for the model with W grades. These results indicate that there was a significant change in students receiving a W before and after the professional development program ($p < .05$). There was a decrease in the percentage of students withdrawing for the fall semester, but an increase for the spring semester. A full discussion of the results is presented in the next section.

Discussion

This study is not without limitations. First, our measure of student achievement in this study is only the final grade each student received in the class. There are other measures of achievement that should be considered. Further, we did not incorporate a measure of the extent to which faculty shifted teaching practices to more student-centered. Future analysis will account for faculty teaching practices in the classroom, as measured through classroom observations.

The results of the analysis indicated surprising results. Based on previous research in the literature that supports a positive relationship between academic achievement and active learning, we expected to see an increase in the percentage of students in the A, B, and C grade group, and a decrease in the percentage of students in the D, E, and W groups. However, we did not observe any significant changes (either positive or negative) of distributions for faculty classes after participating in the professional development program. There were small shifts in the percentage of students withdrawing from the class; however, these shifts were offset by a positive change in the spring semester and a negative change in the fall semester. Otherwise, the results of the models demonstrate that there were no significant changes in the grade distributions for faculty after participating in the professional development program.

Though a little surprising, there are a number of possible reasons for the lack of a change. First, effects on student achievement might be delayed. When faculty first implement a new teaching innovation, there might be a slight decrease in performance, due to challenges in incorporating new pedagogical practices. Over time, it is expected to observe positive increases in student achievement [e.g., 7, 8]. Further, based on Rogers' diffusion of innovation, faculty often advance slowly through the adoption phase, and therefore many of the participants might not have fully implemented the active learning pedagogical practices into their classrooms yet [3]. This analysis only looked at a one-year time period both before and after faculty participated in the professional development program. Therefore, with time, we will not only have more years to examine, but there will also be more opportunity for faculty to continue to implement and hone their pedagogical practices in the classroom, which could lead to shifts in student achievement in the future. In other studies that examined the impact of professional development on student achievement, gains were often observed after at least three-years [13].

Another possible reason to consider is complexities around grading. For instance, faculty may have preconceived ideas about student grade distributions. This professional development program did not address topics of grade distributions, so if faculty have these thoughts about grade distributions, student achievement measured through a final grade would likely not shift. Therefore, even if student learning improves, this might not be captured in final grade data. Assigning student grades, especially final course grades, is complex and is influenced by many factors [14], [15]. Lastly, policy changes at the institution could influence practices of academic advisors or the way that faculty can award final grades, such as a "W," so incorporating institutional analysis could also be illuminating about shifts/lack of changes in student grades. Future research should consider incorporating measurement of faculty attitudes towards grade distributions. Researchers should also consider additional measures of student learning and achievement, beyond just final grades assigned.

To further explore the effects of the professional development program on student achievement, there are a number of areas for future research. First, a longitudinal analysis should be conducted to determine if there are delayed effects on student achievement. This analysis could be conducted at the end of each academic year to assess for possible changes. Next, a linear mixed effects model looking at student-level shifts in grade distribution should be conducted, as this might allow for more variability in the data, so as to better observe actual differences. As previously mentioned, other measures of student achievement and learning should be examined to assess for shifts in learning in a different way. In this study, we only compared student achievement for faculty in the professional development program. However, comparing faculty in the professional development program to faculty teaching similar classes, but having not participated in the professional development program could provide more insight into the effects of the professional development program on student achievement. Further, we did not include measurement of shifts of faculty practices; in the future, we will incorporate quantified measurements of active learning practices in the classroom. Lastly, other areas for consideration include comparison by course level (ie. lower or upper), discipline, faculty gender, and student subgroups (ie. low income students).

Conclusion

There is a large, and growing, body of literature suggesting that active learning teaching practices positively influence student learning and academic achievement. This study focused on assessing the effects of a large-scale professional development program on student achievement, measured through final grades awarded. The linear mixed effects model indicated that there were no significant shifts in the percentages of students awarded A, B, C, D, E, or W, as a final grade in courses after faculty participated in the professional development program.

The lack of change could be due to delayed implementation time, complexities around faculty grading practices, as well as a number of other factors. Further, this study had a limited sample of faculty from only the first year of the professional development program. Future research will assess for changes across all participants of the program. With more time and data to examine, we anticipate the possibility of positive shifts in student achievement for faculty participants.

The findings from this study have important ramifications for researchers, administrators, and practitioners. First, when designing faculty professional development programs, it is important to consider possible attitudes towards student grading. Next, professional development programs should not solely be evaluated through student achievement measured through final grades, as they are complex and can be influenced by many factors. Longitudinal analysis and opportunity for conversation around faculty innovations should be incorporated into the program, as shifting faculty practices can take a long time. Lastly, many of the student attrition within engineering happens in the lower level (100 and 200 level classes). As such, to prevent attrition within engineering, faculty professional development programs should target those faculty/instructors teaching those entry-level engineering classes. Ultimately, though this point-in-time analysis indicates that there was not a shift in student achievement in courses taught by faculty in the professional development program, we anticipate positive shifts in future analysis, with more time for faculty to implement active learning practices, and with more than one year of post-data to analyze.

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