Impact of Evidence-Based Active Learning Faculty Development on Low-SES Engineering Students' Achievement

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Kara Hjelmstad has currently worked as a faculty associate and student teacher supervisor for Mary Lou Fulton Teachers College at Arizona State University. After earning a BA degree in elementary education and an M.Ed. degree in curriculum and instruction, she spent twelve years teaching K-5 and enrichment at the elementary level.

In 2010, Kara began teaching courses and supervising student teachers at ASU. Kara is TAP certified, an evaluation system designed to improve teaching effectiveness and student achievement. The TAP evaluation involves classroom observations, coaching, and feedback/reflection for professional growth. Kara has worked with 60+ student teachers in various subjects at the pre-K through 12th grade level, and conducted over 100 TAP classroom observations.

Since the fall of 2016, Kara has been working with the JTFD Project, an NSF grant working to improve active learning in engineering education. She has completed 300 RTOP classroom observations in ASU engineering courses (civil, environmental, construction, chemical, aero/mechanical, materials, transportation, and biomedical engineering). The RTOP or Reformed Teaching Observation Protocol, is a rubric designed to assess student centered instruction in math and science. Kara also provided instructional coaching for 37 engineering faculty grant participants, after their teaching observations.

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Introduction

Promoting academic achievement of low-socioeconomic status (SES) students has been a persistent challenge in higher education for decades. Engineering disciplines typify many of the observed disparities and despite a variety of national and programmatic changes aimed at improving outcomes for unrepresented groups, only marginal success has been achieved in the last decade [1, 2]. The notable absence of low-SES students majoring in engineering disciplines has resulted in a profession that lacks the representation and diversity of the actual US population and significantly impacts the career potential of low-SES students in the engineering fields [1]. Engineering faculty frequently recognize the problem, but often lack the formal training in instructional best practices necessary to help underrepresented students to persist and succeed in their courses. Instead faculty often revert to teaching the way they were taught, employing the long-venerated 'sage on a stage' lecture models which depress student engagement and subsequently result in lower academic achievement for the most at-risk students in their courses [1].

This paper investigates how NSF-funded faculty development workshops aimed at improving student-centered pedagogy, along with classroom observations and coaching, impacted the teaching practices and subsequent student achievement of low-SES engineering students. Two research questions were developed from this goal and guided the study and data analysis. First, did low-SES students experience higher grades and lower failure rates after their instructors completed active learning professional development? And second, when low-SES student data were compared to higher-SES student data, was the rate of change similar or different between the two demographic groups pre and post-instructor professional development?

Background and Purpose

The setting for this study is a large NSF-funded, multi-year professional development program, called JTFD. Over the course of two years, 80 engineering faculty from seven disciplines (aerospace, mechanical, civil, construction, materials, chemical, and biomedical) participated in the program at a large southwestern university. The JTFD professional development program was comprised 8 bi-weekly workshops (fall semester) and six biweekly implementation discussion sessions (spring semester). Faculty attendance for the workshops was very good and averaged 80% during the fall semester and 73% during the spring, with 100% of faculty in cohort one completing the year-long program. The aim of the project was to shift faculty instruction from instructor-centered, information transmission by lecture to more student- centered, conceptual change learning through active learning and engagement pedagogies. The evidence-based instructional strategies (EBIS) were divided into eight workshops during the fall semester and included the following topics:

1. Introduction to the Project
2. Learning Objectives and Bloom's taxonomy

3. Overview of Active Learning
4. Active learning in Lecture
5. Cooperative Learning
6. Student Motivation
7. Promoting Inclusive Teaching Practices
8. Classroom Innovation: Tech Tools and Formative Feedback

In the spring semester, participants attended six sessions that focused on discussion and support for implementation of the strategies covered in the workshops the previous semester. These sessions were organized around the following topics:

1. Issues in implementing Active Learning
2. Assessing Student-Centered Learning vs. Teacher-Centered Learning (RTOP)
3. Implementation of Tech Tools and Impact on Formative and Summative Assessment
4. Discussions of Observations of Active Learning in the Classroom
5. Implementation of Cooperative Learning and Motivation
6. Instructor Role in the Classroom and Value of Discussion with Peers

The faculty participants were also observed six times over the course of the school year using the Reformed Teaching Observation Protocol (RTOP). RTOP is a 25-item rubric that measures student-centered vs. teacher-centered instruction in science, math and engineering disciplines [3, 4]. Fig. 1 shows a sample RTOP observation score sheet with the five main areas of observation and the 25 rubric items. At the conclusion of the faculty observations, faculty were provided coaching opportunities with an experienced instructional coach who reviewed their RTOP and provided guidance on how they could best use that information to improve their teaching practice. RTOP scores were analyzed to determine shifts in faculty implementation in the classroom, and positive gains were observed [5, 6]. Additional JTFD research also demonstrated significant increases in faculty use of active learning strategies in the classroom and positive shifts in attitudes toward active learning instructional methods as a result of program participation [5, 7].

Based on the observed increase in active learning from previous papers, we were curious to see how this shift in learning practices connects with student achievement.[1] This paper focuses on the impact participation in NSF-funded faculty development workshops aimed at improving student-centered pedagogy (implementation verified through RTOP classroom observation) has on low-SES engineering student achievement. Outcomes reported in this paper are from the first cohort of faculty who participated in the grant during the 2016-2017 academic year (n=49). Pre/before data were collected from archival courses from the 2015-2016 academic year (prior to faculty joining the project). Post data was then collected from courses that were taught after completion of the program (2017-2018 academic year). Low-SES students in this data set were identified using 'Pell grant eligibility' and student achievement was assessed through grade distribution reports as well as class withdrawal rates.

[1] It should be noted that while we did observe past shifts in RTOP, this paper does not consider individual shifts for faculty in our analysis on student achievement. The scope of this paper is not focused on connection between professional development and RTOP, or to observe how RTOP connects with shifts in active learning. This research will be done in the future.

Data were analyzed to determine if low-SES students experienced higher grades and lower failure rates after their instructors completed active learning professional development. Low-SES student data were compared to higher-SES student data to determine if the rate of change was similar or different between the two demographic groups after faculty completion of the professional development program.

Reformed Teaching Observational Protocol (RTOP)		
LESSON DESIGN AND IMPLEMENTATION		
1	The instructional strategies and activities respected students' prior knowledge and the preconceptions inherent therein.	0 1 2 3 4
2	The lesson was designed to engage students as members of a learning community.	0 1 2 3 4
3	In this lesson, student exploration preceded formal presentation.	0 1 2 3 4
4	This lesson encouraged students to seek and value alternative modes of investigation or of problem solving.	0 1 2 3 4
5	The focus and direction of the lesson was often determined by ideas originating with students.	0 1 2 3 4
CONTENT— Propositional knowledge		
6	The lesson involved fundamental concepts of the subject.	0 1 2 3 4
7	The lesson promoted strongly coherent conceptual understanding.	0 1 2 3 4
8	The teacher had a solid grasp of the subject matter content inherent in the lesson.	0 1 2 3 4
9	Elements of abstraction (i.e., symbolic representations, theory building) were encouraged when it was important to do so.	0 1 2 3 4
10	Connections with other content disciplines and/or real world phenomena were explored and valued.	0 1 2 3 4
CONTENT—Procedural Knowledge		
11	Students used a variety of means (models, drawings, graphs, concrete materials, manipulatives, etc.) to represent phenomena.	0 1 2 3 4
12	Students made predictions, estimations and/or hypotheses and devised means for testing them.	0 1 2 3 4
13	Students were actively engaged in thought-provoking activity that often involved the critical assessment of procedures.	0 1 2 3 4
14	Students were reflective about their learning.	0 1 2 3 4
15	Intellectual rigor, constructive criticism, and the challenging of ideas were valued.	0 1 2 3 4
CLASSROOM CULTURE—Communicative Interactions		
16	Students were involved in the communication of their ideas to others using a variety of means and media.	0 1 2 3 4
17	The teacher's questions triggered divergent modes of thinking.	0 1 2 3 4
18	There was a high proportion of student talk and a significant amount of it occurred between and among students.	0 1 2 3 4
19	Student questions and comments often determined the focus and direction of classroom discourse.	0 1 2 3 4
20	There was a climate of respect for what others had to say.	0 1 2 3 4
CLASSROOM CULTURE— Student/Teacher Relationships		
21	Active participation of students was encouraged and valued.	0 1 2 3 4
22	Students were encouraged to generate conjectures, alternative solution strategies, and ways of interpreting evidence.	0 1 2 3 4
23	In general the teacher was patient with students.	0 1 2 3 4
24	The teacher acted as a resource person, working to support and enhance student investigations.	0 1 2 3 4
25	The metaphor "teacher as listener" was very characteristic of this classroom.	0 1 2 3 4

Figure 1. RTOP Rubric.

Literature Review

The continued gap in achievement between low-SES students and their higher-SES peers has been well documented throughout undergraduate engineering [8-10]. Research indicates the gap is already present at significant levels by eighth grade, when low-SES students score a full standard deviation below their higher-SES peers on measures of math and science achievement [10-12]. This trend continues through secondary and post-secondary institutions and results in lower graduation rates from both high school and college programs and perpetuates a cycle of underrepresentation in engineering majors and subsequent STEM career fields [13].

There are a variety of institutional and social-ecological factors that have been identified for the disparity of achievement between low- and high-SES students in engineering. In the school setting, Gutiérrez [14] explains that is important to understand the ways in which institutions and traditional teaching practices may perpetuate the underperformance of traditionally marginalized learners. Techniques that are frequently used in engineering classrooms across the country such as lecture delivery of content, traditional instructional material, and pedagogy that relies heavily on repetition and rote memorization have all been found to be particularly detrimental to the academic achievement of low-SES students [11, 15, 16].

In contrast, constructivist-based active learning instructional techniques have been shown to increase student interactions, engagement, retention, and academic performance while also lowering negative factors of isolation and dissatisfaction that often impact retention of low-SES engineering students [6, 17, 18]. Active learning instructional techniques ask students to construct their own comprehension of content through use of engaging instructional methods such as real-world problems, open-ended questions, student/audience participation, interactive problem-solving, group work and discussions, and formative feedback [19]. This model shifts the centeredness away from the teacher, to the students, and forces students to be more accountable for the learning process [6, 20, 21]. Active learning provides opportunities for students to be more emotionally and behaviorally engaged in the material [22] and improves student achievement through increased peer to peer interaction and formative feedback [18]. While particularly beneficial for underrepresented groups in engineering, active learning has been shown to increase examination scores and lower failure rates for all engineering undergraduates [6].

Finally, active learning delivery provides the opportunity to integrate a variety of instructional tools, including educational technology, into the classroom setting. This can include audience response systems, learning applications, collaborative and peer review platforms, or other class-specific tools used to encourage and facilitate interaction between students, and between the students and their instructor. When technology is leveraged to facilitate these active learning interactions, low-SES students demonstrate additional gains at a greater rate than their higher- SES peers [18, 23].

Professional development and active learning

Despite significant research indicating the successful effects of active learning teaching practices, the majority of engineering faculty still employ traditional teaching methods, which primarily include information transfer through lecture. Therefore, the persistent challenge in STEM disciplines remains finding ways to increase use of student-centered teaching practices at scale. One way to achieve this is through professional development programs that inform faculty on the effectiveness of active learning pedagogical practices, while also training faculty on how to incorporate student-centered teaching practices in the classroom.

Many researchers and practitioners have utilized Rogers' model of Diffusion of Innovation (DOI) when designing and assessing professional development programs [24]. The model articulates five stages through which people advance when learning about an innovation or new technique [25]:

1. Awareness or knowledge: an individual is exposed to an innovation
2. Persuasion or interest: interest in the subject grows and individuals seek out further information about the innovation
3. Evaluation & decision: individual either adopts or rejects the innovation
4. Implementation & trial: innovation is tested by an individual
5. Confirmation or adoption: individual continues and sustains the use of an innovation

Within Rogers' model (Figure 1), many people reach the first stage, where they become aware of a new innovation, technique, or concept. However, the majority of people fail to advance through the final stage of confirmation or adoption [25]. As such, in order to create sustainable and lasting changes in faculty teaching strategies, it is critical to create professional development programs that are supportive, provide contextual content, and allow room for faculty to have ongoing discussions regarding student-centered teaching strategies. Further, it is important that the materials presented in professional development programs model active learning pedagogical practices and foster learning environments where faculty can have both informal and targeted interactions and discussions about teaching innovations and ideas [26, 27]. Ultimately, professional development programs have great potential to bolster the use of active learning pedagogical practices in undergraduate engineering classrooms.

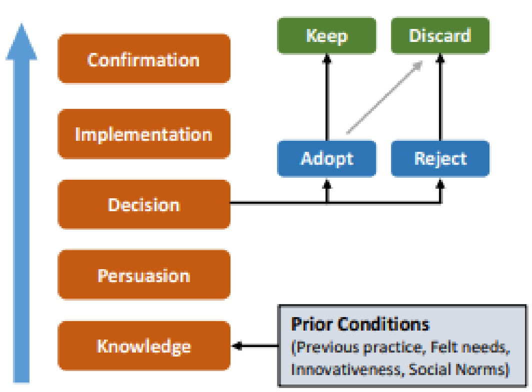

Figure 1. Innovation Stages of Rogers' Model of Diffusion [24]

Methodology

Overview and Schedule

This study continued the work presented in the literature review regarding active learning with low-SES students and addresses some of the gaps in research surrounding the effects of a professional development program (JTFD) on the achievement of low-SES students. Beginning in the 2016-2017 academic year, 80 engineering faculty from seven disciplines participated in 8 bi- weekly workshops (fall semester) and six biweekly implementation discussion sessions (spring semester). Workshops spanned a variety of evidence-based engineering instructional best practices and included several topics identified by literature to support low-SES student achievement. These topics included an overview of active learning, active learning in lecture, cooperative learning, student motivation, promoting inclusive teaching practices, and classroom innovation: tech tools and formative feedback.

Previous research showed that participating faculty implemented the new strategies into their courses and adopted more student-centered practices in the classroom [5]. This research provided confidence in the overall progression of faculty through Rogers' Diffusion of Innovation (DOI) model and led to the more targeted research on student outcomes as a result of faculty participation. Specifically, how did participation in NSF-funded faculty development workshops, aimed at improving student-centered pedagogy (implementation verified through RTOP classroom observation), impact the student achievement of low-SES engineering students? Did low-SES students experience higher grades and lower failure rates after their instructors completed active learning professional development? When low-SES student data were compared to higher-SES student data, was the rate of change similar or different between the two demographic groups pre and post-instructor professional development?

Data Sample and Sources

Data were collected from all undergraduate engineering courses during the 2015-2018 time period. This timeframe spanned both before and after the professional development program. Pre-data used in this paper included courses from the 2015-2016 academic year. Post-data included courses that were taught in the 2017-2018 academic year. A total of 80 faculty participated in the overall JTFD professional development program; however, analysis for this paper focused on the program participants from the 2016-2017 academic year (n=49). To improve reliability, we only included course data if the faculty member taught the same course in the fall semester (pre- and post-) or the spring semester (pre- and post-). Due to controlling for same course taught, teaching schedules, and missing data, the final numbers presented for the JTFD faculty participants are not 49, but a little below that for the pre- and post-periods. Moving forward faculty will be described as JTFD (if they participated in the professional development program) or Non-JTFD (all engineering faculty who did not participate in the professional development program). Also, faculty who were enrolled in later years of the JTFD program, but not during the 2016-2017 academic year were excluded from analysis.

Low-SES students were identified in this data set using 'Pell grant eligibility.' Student achievement was evaluated using final letter grade awarded to students in the class. Data were analyzed to determine the effects of the professional development program on low-SES students' student achievement when enrolled in classes taught by faculty in the professional development program. Further, low-SES student data were compared to higher-SES student data to determine if the rate of change was similar or different between the two groups pre- and post-instructor professional development. For each course, the percentage of low- and high-SES students receiving different final grades (A, B, C, or DEW) were calculated.

Data Analysis and Results

Our main interest in this paper was to determine if participating in the professional development program had any effect on achievement of low-income students. Student achievement was measured through final letter grade awarded in each class (A, B, C, or DEW). The data was categorized into two student groups: low-SES and high-SES. The data were assessed in two ways: (a) comparing changes in student achievement of low- and high-income students between JTFD faculty and non-JTFD faculty; and (b) comparing student achievement of low- and high-income students in JTFD faculty members' classes before and after participating in the program.

Comparison of JTFD Faculty v. Non-JTFD Faculty

We first computed descriptive statistics to determine the average percentage of students receiving each final letter grade, by low- and high-income students for program participants and non-participating faculty before and after the professional development program. Then, to assess if there were differences in these averages, we conducted independent samples t-tests comparing the average percentage of students receiving each letter grade pre- and post- by faculty program participants v. those faculty that did not participate in the professional development program. A summary of the descriptive statistics and the results of the t-tests are presented in Table 1, below.

As expected, there were no significant differences in average percentage of both low- and high- income students in each letter grade group between program participants faculty and non-participants during the pre-time point before the JTFD professional development program ($p > .05$). However, there were significant differences in average percentage of students that received different letter grades during the post period after the professional development program. These differences were only significant among the percentage of students receiving various final grades for the high-SES students. Non-JTFD faculty had higher average percentages of students who received an A as a final grade ($p < .05$). Whereas, JTFD faculty had higher average percentages of students receiving a C or DEW as a final grade ($p < .05$). There were no significant differences in the percentages of low-SES students receiving an A, B, C, or DEW in the post-time point. These results were somewhat surprising, as we would have expected some variation based on prior research in the literature. However, this analysis did not account for starting points of students or various class/faculty effects.

Table 1. *Comparison of Average Percentages of Grade Distributions, by Low- and High-SES.*

Letter Grade	**SES Status**	**Mean (SD)**					
		Pre			**Post**		
		JTFD (n=40)	*Non-JTFD (n=173)*	*t*	*JTFD (n=41)*	*Non-JTFD (n=188)*	*t*
A	*Low*	45.02 (21.78)	48.90 (27.87)	0.96	43.93 (24.82)	53.15 (28.59)	1.91
	High	50.77 (21.39)	57.83 (22.20)	0.06	46.08 (24.24)	55.95 (24.28)	2.37*
B	*Low*	29.00 (12.67)	28.33 (20.55)	0.24	28.95 (13.85)	26.93 (19.52)	0.78
	High	27.68 (12.60)	25.35 (15.13)	0.92	27.18 (11.40)	25.46 (14.23)	0.47
C	*Low*	14.77 (11.33)	11.36 (14.44)	1.40	13.98 (11.10)	10.37 (13.00)	1.65
	High	10.81 (8.42)	8.24 (8.11)	1.83	13.54 (9.26)	9.27 (9.50)	2.62**
DEW	*Low*	11.24 (10.30)	11.41 (14.58)	0.07	13.15 (12.51)	9.55 (13.47)	1.56
	High	10.74 (7.89)	8.58 (8.86)	1.45	13.20 (11.95)	9.32 (10.47)	2.11*

*$p < .05$, **$p < .01$

To further explore these differences, we then computed a variable to measure the average change of percentage of low- and high-income students in each grade group before and after the professional development program. The change variable was calculated by subtracting the average percentage of students in "X" grade group in the pre-time point from the average percentage of students in "X" grade group from the post-time point. It should be noted that these figures do not add up exactly to the changes expressed in table 1, this is due to different complete cases for comparison in the independent samples t-test. We then compared the average change variable between program participants and non-participating faculty to see if there were any significant differences. The descriptive statistics and results of the independent samples t-tests for the average change variable is presented in Table 2, below.

The results of this analysis indicated that across all letter grades, with the exception of high-income students receiving a C grade, there were no significant shifts in the average percentage of students in each grade group before or after the program for low- and high-SES students. This was another surprising finding since previous research the literature indicates that active learning has positive effects on student achievement.

Table 2. *Independent Samples T-test for Average Change Variable.*

Letter Grade	**SES Status**	**Mean (SD)**		***t***
		JTFD	*Non-JTFD*	
A	*Low*	-0.62 (22.20)	7.04 (25.70)	1.70
	High	-4.69 (20.10)	1.48 (18.82)	1.81
B	*Low*	-0.33 (13.61)	-3.35 (18.38)	0.96
	High	-0.50 (11.09)	-1.27 (12.82)	0.35
C	*Low*	-0.87 (10.26)	-1.20 (12.76)	0.15
	High	2.72 (7.40)	0.03 (6.97)	2.14*
DEW	*Low*	1.82 (13.37)	-2.50 (18.77)	1.35
	High	2.46 (10.63)	-0.24 (8.05)	1.74

*$p < .05$, **$p < .01$

Pre- and Post-Comparison of JTFD Program Participants

To further explore the potential effects of the professional development on the academic achievement of low-income students, we then focused on examining shifts of student achievement only for the classes of the faculty participants in the professional development program. For this comparison, we restricted the analysis to JTFD faculty participants and then conducted paired-samples t-tests to compare achievement (measured through percentage of students in each letter grade) of low- and high-SES students before (pre) and after (post) the faculty participated in the professional development program. The descriptive statistics for the average percentage of students in each grade group, by low- and high-SES students before and after the professional development program is reported in Table 1. The results of the paired samples t-tests are presented below in table 3.

Table 3. *Paired Samples T-Test Results for JTFD Faculty Participants, by SES Status.*

Letter Grade	**SES Status**	***t***
A	*Low*	0.18
	High	1.50
B	*Low*	0.15
	High	0.29
C	*Low*	0.54
	High	2.36*
DEW	*Low*	0.86
	High	1.48

*$p < .05$, **$p < .01$

There were no significant differences in average percentage of low- and high-income students in each grade group from before and after the professional development program ($p > .05$). The only exception was that the average percentage of high-SES students receiving a C increased in faculty courses after they participated in the JTFD program ($p < .05$).

Summary and Discussion

Results are reported for courses taught by the first cohort of faculty who participated in the JTFD faculty development program during the 2016-2017 academic year (n=49). Their 'pre' data is from the 2015-2016 academic year (prior to participation) and their 'post' data is from the 2017-2018 academic year (after completing professional development). Limitations of this study were the relatively small sample size and somewhat narrow conclusions that can be drawn from this single snapshot of pre and post data. With these limitations in mind, the data were reviewed to answer two primary research questions. First, did low-SES students experience higher grades and lower failure rates after their instructors completed active learning professional development? And second, when low-SES student data were compared to higher-SES student data, was the rate of change similar or different between the two demographic groups pre and post-instructor professional development?

To address the first research question, we compared the average percentage of students receiving letter grades of A, B, C, or DEW for the JTFD faculty. After completing professional development, there was no significant change in the grades of low-SES students. This was a surprising result and not what was anticipated based on the available literature. Of note, the 'pre' values for low-income students reflect the underachievement explained in the literature and show that low- SES students receive fewer grades of A than their higher SES peers.

Next, we turned to how participating faculty compare against their non-participating colleagues. The data shows that there were no significant differences between JTFD and non-JTFD faculty for the pre-period (which is what we would expect). When reviewing the post-participation student grades for courses taught by participating faculty versus non-participating faculty, the non-participating faculty showed higher percentages of students in the A grades while JTFD faculty showed higher rates in the C and DEW grades. Again, these results were surprising and not in-line with anticipated outcomes.

Data presented in the literature review would suggest that all students, and particularly low-SES students, should improve after faculty participate in active learning training [6, 18]. Two factors may help to explain these results. First, the analysis did not control for cohort effects, starting points of students, classroom/instructor effects, or class type. Class type alone may be a large contributing factor for the grade discrepancies observed in the two subgroups of faculty. Secondly, the point-in-time analysis only looked at one academic year (pre) and one academic year (post). This may not provide enough data to draw a meaningful conclusion about low-SES academic achievement and indicates that a larger sample size may be needed to understand if this this snapshot data is representative of the overall shifts that took place as a result of participating in the professional development program.

Turning to the second research question, data were also reviewed to determine if low- and high- SES student data changed at a similar rate before and after faculty participation in program participation. Separate from the first research question which only looked at low-SES students, this question aims to understand the change as a measure of differences between the two demographic groups. There are several individual grade shifts that were observed for both low- and high-SES students pre and post-participation that are interesting in regards to this question, however the key data comes from the comparison of the average change of percentage for both demographics.

This data shows that, other than the number of C grades earned by high-SES students, the average percentage of low- and high-SES students before and after the program remained unchanged. The second research question asks if the rate of change was similar or different between the two demographic groups pre and post-instructor professional development. This data suggests that no significant changes were observed for either group, so while the rates were similar, neither group improved significantly. As with the first research question, this is contrary to what was anticipated based on the literature surrounding active learning. As discussed above, some of the observed results may be due to the point-in-time nature of this analysis. A larger sample that looks at a broader number of classes both before and after intervention may provide more accurate data on the actual changes that took place for both demographics. The analysis of low-SES students suggests that there remains room for improvement, as low-SES students continue to underperform in comparison with their higher-SES peers and achieve fewer grades of A for all courses.

Rogers' Diffusion of Innovation (DOI), presented above, articulates five stages for adoption of innovation (such as active learning), and provides an interesting perspective for the results of this paper. Considering the progressive nature of the model, it is possible that despite participating in the project and receiving initially higher RTOP scores, faculty may have been unsuccessful in progressing through the final phases of 'confirmation or adoption' and subsequently failed to fully implement the innovation of active learning into their teaching practice after the conclusion of the professional development project. If they did not continue or sustain their implementation of the active learning strategies, this may explain some of the observed data in the post-participation grades. Additionally, developing successful teaching practices takes time, and thus there could be delayed effects of implementation on student achievement. This lag time, either in implementation of consistent active learning teaching practices or in quality of active learning teaching in the classroom, could be an explanation for the observed results. As such, we plan on continuing this analysis in the future to assess for potential changes over time.

As noted above, the project employed the RTOP classroom observations to provide a reliable and objective account of which faculty made substantial changes in their teaching practice. It may be helpful to repeat the RTOP observations to determine if the adoption of active learning strategies is still observable two years post-participation. Data from both the initial and future RTOP observations could be used as confirmation that faculty continue to implement what was learned in workshops. Grade data from faculty who continue to use the active learning strategies in their courses could then be reviewed and more targeted faculty analysis (of courses where sustained RTOP confirmation is available) could be completed. This filter may provide greater clarity on the program impact to low-SES students than participation status alone, as some participants may be more diligent with implementing active learning teaching practices in their classrooms. We will continue to evaluate the data from additional courses taught by the faculty participants to provide more robust and definitive answers to the research questions. This data combined with additional RTOP classroom observations will provide greater insights into the impact of the faculty development program on low-SES engineering students and will be presented at forthcoming ASEE conferences and through additional publications.

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References

1) Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderith, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *PNAS 11* (23), 8410-8415.
2) Salto, L. M., Riggs, M. L., Delgado De Leon, D., Casiano, C. A., & De Leon, M. (2014). Underrepresented minority high school and college students report STEM-pipeline sustaining gains after participating in the Loma Linda University summer health disparities research program. *Plos ONE, 9*(9), 1-13. doi:10.1371/journal.pone.0108497
3) R. Brent, & R. Felder, R., "Introduction to college teaching," Teaching and Learning STEM: A Practical Guide, Jossey-Bass: A Wiley Brand. 1-10, 2016. Knowledge Persuasion Confirmation Implementation Decision Adopt Reject Keep Discard Prior Conditions (Previous practice, Felt needs, Innovativeness, Social Norms)
4) D. Sawada, M. Piburn, E. Judson, J. Turley, K. Falconer, R. Benford, and I. Bloom. "Measuring reform practices in science and mathematics classrooms: The reformed teaching observation protocol." School Science and Mathematics, vol. 102, 245-253, 2002.
5) Authors, 2018.
6) Authors, 2017.
7) Authors, 2018.
8) Salto, L. M., Riggs, M. L., Delgado De Leon, D., Casiano, C. A., & De Leon, M. (2014). Underrepresented minority high school and college students report STEM-pipeline sustaining gains after participating in the Loma Linda University summer health disparities research program. *Plos ONE, 9*(9), 1-13. doi:10.1371/journal.pone.0108497
9) MacPhee, D., Farro, S., & Canetto, S. S. (2013). Academic self-efficacy and performance of underrepresented STEM majors: Gender, ethnic, and social class patterns. *Analyses of Social Issues & Public Policy, 13*(1), 347-369. doi:10.1111/asap.12033
10) Lyon, G. H., Jafri, J., & St. Louis, K. (2012). Beyond the pipeline: STEM pathways for youth development. *Afterschool Matters, 16,* 48-57.

11) Baird, K. (2012). Class in the classroom: The relationship between school resources and math performance among low socioeconomic status students in 19 rich countries. *Education Economics, 20*(5), 484-509.
12) Salto, L. M., Riggs, M. L., Delgado De Leon, D., Casiano, C. A., & De Leon, M. (2014). Underrepresented minority high school and college students report STEM-pipeline sustaining gains after participating in the Loma Linda University summer health disparities research program. *Plos ONE, 9*(9), 1-13. doi:10.1371/journal.pone.0108497
13) DeArmond, M. Denice, P., Gross, B., Hernandez, J., Jochim, A., Lake, R. 2015. Measuring Up: Educational Improvement and Opportunity in 50 Cities. Center on Reinventing Public Education, Seattle, WA
14) Gutiérrez, R. (2013). Why (urban) mathematics teachers need political knowledge. *Journal of Urban Mathematics Education, 6*(2), 7-19.
15) Jorgensen Z., R. R., & Lowrie, T. T. (2015). What have we achieved in 50 years of equity in school mathematics? *International Journal for Mathematics Teaching & Learning*, 20.
16) Molina, R. R., Borror, J. J., & Desir, C. C. (2016). Supporting STEM success with elementary students of color in a low-income community. *Distance Learning, 13*(2), 19- 25.
17) Karimshah, A., Wyder, M., Henman, P., Tay, D., Capelin, E., & Short, P. (2013). Overcoming adversity among low SES students. A Study of strategies for retention. *Australian Universities' Review, 55*(2), 5-14.
18) Phillips, P., & Loch, B. (2011). Building lectures and building bridges with socio- economically disadvantaged students. *Journal of Educational Technology & Society, 14*(3), 240-251
19) Jacoby, J., Heugh, S., Bax, C., & Branford-White, C. (2014). Enhancing learning through formative assessment. *Innovations in Education & Teaching International, 51*(1), 72-83. doi:10.1080/14703297.2013.771970
20) Carbonneau, K., Marley, S., & Selig, J. (2013). A meta-analysis of the efficacy ofteaching mathematics with concrete manipulatives. *Journal of Educational Psychology, 105*(2), 380-400.
21) Semerci, Ç., & Batdi, V. (2015). A meta-analysis of constructivist learning approach on learners' academic achievements, retention and attitudes. *Journal of Education and Training Studies, 3*(2), 171-180.
22) Kahraman, N. N. (2014). Cross-grade comparison of relationship between students' engagement and TIMSS 2011 Science Achievement. *Education & Science,39*(172), 95- 107.
23) EŞGİ, N. n. (2013). Comparison of the effects of E-learning types designed according to the expository teaching method on student achievement. *Education & Science / Egitim Ve Bilim, 38*(170), 194-205.
24) Rogers, E. M. (2003). Diffusion of Innovations (5th ed.). New York: Free Press.
25) Borrego, M., Froyd, J. E., Hall, T. S. Diffusion of engineering education innovations: A survey of awareness and adoption rates in US engineering departments. *Journal of Engineering Education, 99*(3), 185-207.
26) Coburn, C.E. (2003). Rethinking scale: Moving beyond numbers to deep

and lasting change. *Educational Researcher, 32*(6), 3-12.

27) Brown, J. and Duguid, P. (1991). Organizational learning and communities of practice: Toward a unified view of working, learning, and innovation. *Organizational Science, 2*(1) 40-57.