The Effect of Active Learning Professional Development Training on College Students' Academic Outcomes

Elizabeth S. Park
Di Xu

Working Paper #21-6

VERSION: April 2021

UCI Education Research Initiative

The Effect of Active Learning Professional Development Training on College Students' Academic Outcomes

Elizabeth S. Park*

Di Xu

University of California, Irvine

Author Note

Acknowledgements
We thank Brian Sato, Andrea Aebersold and Mayank Verma for helpful conversations and feedback. Ashley Harlow, and Sabrina Solanki have also provided helpful suggestions on the manuscript. All mistakes are our own.

Funding

This work was supported by the National Science Foundation under grant number 1612258 and 1565073.

* 3018 Anteater Instruction and Research Building. 35 E. Peltason Dr. Irvine, CA 92617. liz.park@uci.edu. @elizabethpark. Corresponding author.

Abstract

Extensive literature emphasizes the promise of active learning instruction in engaging students in college classrooms. Accordingly, faculty professional development (PD) programs on active learning have become increasingly popular in postsecondary institutions; yet, quantitative evidence on the effectiveness of these programs is limited. Using administrative data and an individual fixed effects approach, we estimate the causal effect of an active learning PD program at a large public institution. Findings indicate that the training improved course performance and subsequent persistence in the same field. Further analysis of classroom observation data identifies a positive association between training and active learning teaching practices. These findings suggest that active learning PD, when implemented with high fidelity, has the potential to improve teaching quality and student outcomes.

Keywords: active learning; student outcomes; classroom observation

The Effect of Active Learning Professional Development Training on College Students' Academic Outcomes

Between fall 2010 and fall 2018, undergraduate enrollment increased by approximately 3.4 million at four-year institutions, representing a 26% growth (National Center for Education Statistics, 2019). However, during the same period, the national retention rates of all full-time, first-year students attending four-year public institutions -- measured by the percentage of students who return to the same institution for their second year -- has been stagnant between 76% and 79% (National Student Clearinghouse, 2019). In response to the sizable number of students who withdraw from college within their first year, extensive literature has focused on the need to improve classroom pedagogy. Specifically, researchers and policymakers raise the concern that the traditional lecture-intensive instruction that dominates college classrooms emphasizes memorization over conceptual learning and is thus "disengaging" for students (e.g., Braxton, Milem, & Sullivan, 2000; Deslauriers et al., 2011; Gasiewski et al., 2012; Pike, Smart, & Ethington, 2012; President's Council of Advisors on Science and Technology, 2012).

The ongoing conversation about the pitfalls of lecturing in teaching undergraduate-level courses has led to growing enthusiasm surrounding active learning instruction as a way to better engage students in their learning process (Deslauriers et al., 2011; Gasiewski et al., 2012; Prince, 2004; Wiggins et al., 2017). In contrast to lectures where students passively receive information, active learning emphasizes students' active participation through intentionally designed activities such as discussions, questions asked by the instructor, targeted in-class instructor feedback, in-class clicker questions, and small group active learning tasks or activities (Braxton, Milem, & Sullivan, 2000; Deslauriers et al., 2011).

Indeed, extant studies on active learning have generally identified a positive association between active learning instruction and student engagement. For example, based on student

surveys administered across 15 four-year institutions, Gasiewski et al. (2012) found that students reported greater engagement when taught with active learning instruction than lecture-intensive instruction. Perhaps as a result of increased engagement, students taught in active learning classrooms also display better class attendance, retain course materials longer, and perform better on exams compared to students taught in lecture-intensive classrooms across a number of disciplines (Cherney, 2008; Desauriers et al., 2011; Knight & Wood, 2005).

Given the growing evidence that active learning approaches improve college student outcomes, faculty professional development (PD) programs on active learning instruction and practices have become increasingly popular at the postsecondary sector (Pfund et al., 2009). At the national level, the National Institute on Scientific Teaching offers multi-day workshops and various professional development opportunities for faculty to incorporate evidence-based teaching practices with support and guidance from expert facilitators. Moreover, institutions across the nation have teaching and learning centers that provide opportunities for faculty to participate in teaching institutes focused on active learning instruction strategies (i.e., University of Southern California's Faculty Teaching Institute, University of Georgia's Active Learning Summer Institute). Despite the rapid increase in training on active learning and the high hopes around it, there is a striking lack of empirical evidence on the effects of these PD programs on classroom instructional practices and on student academic outcomes.

This study addresses this research gap by examining the causal effect of an Active Learning Professional Development (ALPD) implemented during 2018-2020 at a large public institution. Specifically, we link ALPD instructor participation data with detailed student transcript data from all courses offered between fall 2016 and winter 2020 and estimate the effect of ALPD participation on students' current course performance as well as subsequent persistence

and performance in the same field of study. To address instructor self-selection into ALPD and possible baseline differences between ALPD participants and nonparticipants, we leverage rich panel data and use an individual fixed effects approach that compares average student outcomes before and after the participants received the training while using non-participants to control for general contextual changes over time that may affect student outcomes. We further combine this approach with course fixed effects, thus ruling out any between-course variations in course difficulty and student outcomes. To our knowledge, this is the first study that employs a quasi-experimental design to provide quantitative evidence on the benefits of active learning PD programs on student outcomes in the postsecondary setting.

Our results indicate that ALPD improved students' current course grades, although the estimated effect is small and only marginally significant at the .10 level. In addition, ALPD improved the likelihood that a student persists into the next course within the same field by three percentage points, or a 5% increase. We do not observe any difference in student performance in the next course. We further complement these estimates with in-depth classroom observation data of a subsample of 392 classrooms to shed light into the relationship between ALPD on instructional practices. Our results suggest that the ALPD participation is associated with an increased likelihood of using active learning approaches instead of lecture-intensive instruction. These findings have implications for institutions seeking to scale up active learning instruction through institutionalized structures such as professional development.

Background

Studies conducted in a variety of disciplines document the benefits of active learning instruction on student engagement and performance relative to lecture-intensive instruction (e.g., Deslauriers et al., 2011; Deslauriers et al., 2019; Freeman et al., 2014; Gasiewiski et al., 2012;

Johnson, Johnson, & Smith, 1998; Loes et al., 2017; Prince, 2004; Ruiz-Primo et al., 2011; Theobald et al., 2020). For example, in their metaanalysis of 225 studies on the efficacy of active learning in STEM classrooms, Freeman et al. (2014) concluded that active learning increases course exam performance by approximately half of a letter grade (i.e., moving from a B to a B+) compared to lecture-intensive instruction. In addition, active learning has been associated with reduced equity gaps. For example, Theobald et al. (2020) conducted a meta-analysis of 15 studies across 51 STEM classrooms and found a 33% reduction in racial achievement gaps in student exam scores in active learning classrooms compared to lecture-intensive classrooms.

Despite the growing evidence for the promise of active learning instruction in engaging students, its implementation has yet to occur on a large scale in higher education (Stains et al., 2018). One of the reasons for instructors' suboptimal engagement in these practices is a lack of systematic pedagogical training that would enable faculty to apply these practices effectively to their own teaching (Brownell & Tanner, 2012; Mazur, 2009). In response, institutions and teaching institutes have begun to offer various training programs that provide space for cross-disciplinary faculty (and staff) to work together to discuss best practices and create a community of support within structured PD programs (Cox, 2004).

Yet, PD may not necessarily lead to alteration in instructional practices and improved student outcomes if the training is insufficient or if there is inadequate support and incentives for faculty to apply what they have learned to their own teaching. Indeed, the broad literature of teacher PD has increasingly emphasized the complex links between the design and implementation of PD and its effectiveness (Darling-Hammond et al., 2017; Garet et al., 2001; Fishman et al., 2003; Penuel et al., 2007). For instance, the duration of the training, the quality of learning materials and activities, and the presence of collective participation and community

support among PD participants can all influence the effect of a PD program (Birman et al., 2000; Desimone, 2009; Garet et al., 2001; Fishman et al., 2003).

Although PD on active learning pedagogies is increasingly popular in higher education, there is limited documentation of how these programs are designed, and even less is known about their impacts on instructional practices and student achievement. Among the handful of studies that describe such programs, there are substantial variations in the duration and community support across programs (Ebert-May et al., 2011; Pfund et al., 2009). We therefore document and rigorously evaluate an active learning PD program at a large, four-year public research university. We describe in detail how the program was designed and implemented, and also empirically assess the impact of the training on students' current course performance and subsequent outcomes. Finally, we also assess the association between the PD training and instructional practices to illuminate a mechanism through which the training may influence student outcomes.

Research Design and Data

Program Description: Active Learning Professional Development Training

The active learning professional development (ALPD) under study was implemented at a large public research institution and is open to faculty across all disciplines and ranks. The program introduces faculty to active learning instructional tools by involving participants in hands-on activities and apply evidence-based practices to the participants' own lesson designs. The ALPD was officially launched in fall 2018. At the beginning of each term, several campus-wide emails were sent out to solicit faculty's participation. Because there was limited space available for each session, the program was offered on a first-come, first-serve basis, and the

program was typically filled within one day. Since its inception until winter 2020, a total of 105 faculty have gone through the training.

ALPD includes eight 90 minutes weekly sessions, through which faculty worked to revamp their own instructional materials under the guidance of an expert facilitator from the Teaching and Learning Center on campus and in a supportive collegial atmosphere. Each session included a short lecture, assignments, and several readings related to topics in that session. Some of the key topics covered include the role of assessment, different forms of feedback, ways to increase inclusivity, linking course goals with assignments and activities, and leveraging technology. For each topic, faculty were first introduced to the general and discipline-specific literature underlying evidence-based practices in active learning, coupled with active learning strategies, instructional tools, and concrete examples that were specific to their discipline. The participants were then guided to apply evidence-based practices to their own course materials and lesson designs.

Community building was an important part of ALPD. To ensure collaborative participation, all ALPD applicants were required to commit to attending at least six sessions of the eight-session program. In addition, at each session, participants were assigned into small groups of four. The facilitator intentionally assigned participants into different groups for the first few weeks until participants have met everyone and could start selecting their own groups. Each session started with small group discussion, where participants shared their own personal teaching experiences. Finally, assignments were intentionally designed to facilitate collaboration. For example, one assignment required participants to redesign a class period and present their work to the group, where all group members would provide feedback to the presenter.

At the end of the eight-week training, faculty received a certificate of completion if they were observed by independent classroom observers using the Classroom Observation Protocol of Undergraduate STEM (COPUS) (Smith et al., 2013).[1] Using the COPUS protocol, observers recorded both the instructor's and students' behaviors in each two-minute interval of a class session. Specifically, trained observers identified what the instructor did using 12 instructor behavioral codes (i.e., lecturing, answering student questions) and what the students did using 13 student behavioral codes (i.e., listening, asking questions) in each two-minute interval.[2] ALPD trained instructors were awarded a certificate of completion if the observer confirmed that the instructor lectured less than 50% of the class period and incorporated instructor-student interactions as well as student-student interactions. Some of the incentives for receiving the certificate include priority scheduling at the technology-enabled active learning classrooms, using the certificate as a second piece of evidence of instruction quality for tenure/promotion review, and the opportunity to help facilitate future ALPD. 42% of the 105 trained faculty in our data were certified.

Data, Student Outcomes, and Sample Description

We leverage two data sources to examine the effect of active learning professional development training on current and subsequent student outcomes. The first source of information comes from detailed administrative data on all students enrolled in each course-section that was offered from fall 2016 to winter 2020 (n=697,715). We exclude summer terms partly because fewer courses are offered during the summer and partly because summer courses follow different lengths and possibly different structure than courses offered in the fall, winter,

[1] Although the COPUS protocol was initially developed to observe STEM classroom instructions, it has also been used in observing non-STEM classrooms (Denaro et al., 2021).
[2] For example if the observer tallies 13 times that the instructor lectured during a 50-minute course, we would say that the instructor lectured 52% of class time (13/25).

and spring terms. In addition, given the goal of this study, we exclude courses that are not instruction focused, such as independent study, undergraduate research courses, and lab sessions. The data include the name of the course, term-year in which it was offered, class size, the class location, and the primary instructor of record, as well as student demographic characteristics and prior academic achievement profiles. We further merge the administrative data with ALPD participation data which include a list of instructors who participated in the training and the term when each participant completed the training as well as their certification date if the instructor pursued a certification.

Student Outcomes

In assessing the effectiveness of ALPD, we consider both current and subsequent student academic outcomes in the same field of study. Specifically, we begin our inquiry with student contemporaneous course performance, as measured by course grade on a 1 to 4 grading scale. Yet, current course grades alone may not be sufficient in fully capturing the impact of ALPD for two reasons. First, current grades may not be a reliable measure of actual learning due to instructor grading leniency. Indeed, existing studies on teacher effectiveness indicate that students tend to receive lower grades in introductory coursework from instructors who are most effective in preparing students for subsequent advanced courses (Carrell & West, 2010). In the context of the current study, if ALPD also influences instructors' grading practices, a change in average student grades may not necessarily reflect actual improvement (or deterioration) of teaching quality.

In addition, the effects of ALPD may unfold in different ways and some of them may not show in immediate course performance. In particular, existing studies have advocated for the promise of active learning in promoting student interest in a subject area (e.g. Gasiewski et al.,

2012), which arguably can be better captured through subsequent individual choices such as enrolling in another course in the same field of study than immediate performance outcomes.

Therefore, we build on the existing literature on teaching effectiveness (e.g., Carrell & West, 2010; Figlio et al., 2015; Xu, 2019; Xu & Solanki, 2020), and further include subsequent outcomes to provide a more comprehensive understanding of the impact of ALPD. Specifically, we use subsequent field persistence — whether a student took another course in the same field of study in the immediate next term — to measure student interests in a subject. In addition, we also examine students' performance in the next course to capture possible lasting impacts of ALPD on learning and engagement in the same field of study.[3]

Sample Description

Table 1 shows the summary statistics of the average outcome measures (panel A), characteristics of students (panel B), and characteristics of course-sections (panel C) taught by three groups of instructors: 1) instructors who never participated in the ALPD ("ALPD Non-participants" in column 1-3); 2) ALPD participants during the terms prior to the training ("ALPD Participants: Pre-Training" in column 4-6); and 3) ALPD participants during the terms after the training ("ALPD Participants: Post-Training" in column 7-9). Results presented in panel A reveal several baseline differences between ALPD participants and non-participants prior to the training, where the ALPD participants seem to be associated with consistently better student outcomes. This highlights the importance to account for the baseline differences between the ALPD participants and nonparticipants in estimating the impact of ALPD on student outcomes. Raw comparisons between the pre- and post-training periods among ALPD participants suggests

[3] To construct subsequent course achievement measures, we first looked at the entire course-taking records of each student and identified the next course within the same field for every course taken between 2016 to 2020 excluding summer terms. Repeat courses were excluded from next course persistence and performance.

that students' average grades in subsequent courses are higher in courses taught by ALPD participants during the post-training terms. Yet, these differences may be partly due to different courses taught by each group and the characteristics of students enrolled in those courses.

< Insert Table 1 >

Indeed, results presented in panels B and C revealed a number of differences in the type of courses taught and the characteristics of students between the ALPD participants and nonparticipants prior to the training, as well as between the pre-training and post-training terms among the ALPD participants. Specifically, compared with the nonparticipants, ALPD participants during the pre-training terms taught courses with a larger proportion of racially minoritized students, transfer students, first-generation students, students from low-income families, and students with lower high school GPA and SAT scores. The participants were also more likely to teach large classes (enrollment size>=60) than nonparticipants. The differences in student composition and class size may be partly driven by different fields of study between the participants and nonparticipants, where the participants seem to be more heavily concentrated in non-STEM disciplines.

Similarly, there are also noticeable differences in student characteristics between pre-training and post-training periods among the ALPD participants, where courses taught in the post-training terms had students with better pre-college academic performance and a smaller proportion of students from low-income families. In addition, courses taught in the post-training periods were more heavily concentrated in STEM fields than in the pre-training periods. These differences may be partly driven by general changes in student composition as well as course offering over time at this institution, which highlight the importance to account for between-

course and over-time variations in student outcomes in estimating the impact of the training on student outcomes.

Identification Strategy

To account for instructor self-selection into the PD training, we compare average student outcomes of ALPD participants after they completed the training to average outcomes of the same instructor before the training. This approach has been used widely in the education literature to address any time-invariant factors at the individual level such as ability in estimating the causal impact of educational investment (e.g., Cellini & Chaudhary, 2014; Jacobson, Lalonde, & Sullivan, 2005; Jepson, Troske, & Coomes, 2014, Xu & Trimble, 2016). In addition to individual fixed effects, we also include course fixed effects to compare average academic performance of students in different sections of the same course, as well as term fixed effects to account for general changes in student composition and outcomes over time. We estimate the following equation:

$$Y_{ijsct} = \alpha_j + \beta_1(ALPD_{jt}) + X_{ijsct}\beta + \theta_{sct}\pi + \gamma_c + \phi_t + \varepsilon_{ijsct}$$

where Y_{ijsct} is the outcome for student *i* taught by instructor *j* in section *s* of course *c* offered during term-year *t*. α_j refers to instructor fixed effects that control for all observed and unobserved instructor individual-level characteristics that are constant over time. $ALPD_{jt}$ captures whether an instructor has already received the ALPD training in a given term, which is identified as "0" during the terms leading up to when the instructor received the training and switches to "1" during the term after the instructor received the training and each term thereafter. X_{ijsct} includes student-level covariates such as students' race/ethnicity and high school GPA and θ_{sct} refers to section-level attributes such as enrollment size of a section. The equation also includes course fixed effects γ_c that control for any between-course variations in student

composition and performance, and quarter-year fixed effects φ_t that help address overall fluctuations in student composition and outcomes over time due to other contextual factors. Accordingly, β_1 can be interpreted as additional changes in student performance as a result of ALPD training aside from other changes that would have occurred in the absence of the ALPD training.

When estimating students' subsequent course grade in the same field of study, we draw on prior literature and further include next class fixed effects (e.g., Figlio, Schapiro, & Soter, 2015; Ran & Xu, 2019). By doing so, we are able to compare grades of students in the same next class with variations in taking a prior course with an instructor who had received ALPD versus an instructor who had not. This is to address the concern that learning experiences in a course may influence a student's subsequent course choice. For example, if a student had particularly inspiring experiences with an ALPD instructor, the student may intentionally opt into another course taught by the same instructor. In a similar vein, prior experiences may also influence the difficulty of the next class a student selects. By including next section fixed effects, we are able to account for selection biases that arise from students shopping across different next classes within a field by comparing student performance in exactly the same section.

Results

Impact of ALPD Training on Student Outcomes

Table 2 presents the estimated effect of participating in ALPD on three student outcome measures: current course grade (column 1), whether or not a student took another class in the same field in the immediate next term (column 2), and the grade received in that next class (column 3). The results indicate that students who took a course with an instructor who had

received ALPD on average had higher course grades by 0.006 grade points on a 0-4 grading scale, although this effect is marginally significant at the 0.1 level.

The effect of the ALPD becomes more pronounced when we examine students' subsequent persistence in the same field. Specifically, students who took a course with an ALPD instructor in post-training terms were three percentage points more likely to persist within the field compared to students who took the same course with the same instructor in pre-training terms. Considering that the average next course persistence rate in our sample is 68%, a three percentage point increase would represent a 5% improvement. Finally, column 3 presents results on subsequent course performance conditional on enrolling in another course in the same field of study. The estimated impact of ALPD is small and not significantly different from zero. Taken together, our results suggest that ALPD is associated with marginal improvements in current course performance and modest boost in field persistence.[4]

<Insert Table 2>

Relationship between Training and Instructional Practices

In view of the positive effects of the ALPD on student outcomes, we explore whether such benefits are partly driven by altering instructor's teaching practices.[5] A total of 392 classes

[4] We also conducted analyses to see whether the effect of the training differs depending on the infrastructure (i.e., whether the course is offered in an active learning classroom), and the size of the class. Classroom layouts, for example, can allow for easier adoption of active learning techniques such as in-class group activities (Beicher & Saul, 2002; Dori & Belcher, 2005). As such, if the class is offered in a classroom designed to facilitate active learning, instructors may be more effective in raising student performance. In a similar vein, class size is an important consideration that determines whether active learning is adopted, with smaller class sizes being more conducive to implementing active learning (Carbone & Greenberg, 1998; Freeman et al., 2014; Heim & Holt, 2018). In both instances, we did not find that the impact of ALPD training is moderated by either the classroom infrastructure or class size. Yet, our sample size is small and we recognize that our findings may be due to a lack of power to deliver a precise estimate of any interaction effects.

[5] Starting in the 2018-2019 academic year, all undergraduate courses (i.e., excluding discussions, seminars, or labs) that enrolled at least 60 students at this institution were solicited to be observed using the COPUS protocol. A total of 250 classes between fall 2018 and winter 2020 were observed twice within the same term by independent observers affiliated with the Teaching and Learning Center and an additional 142 classes were observed once during this timeframe for a total of 392 classes. For classes that were observed twice, we averaged the classroom observation records.

across 289 unique instructors' courses were observed by independent classroom observers from fall 2018 through winter 2020. Among these instructors, 71 went through the ALPD training by the time of the observation while 218 instructors did not. We follow the criteria used for ALPD certification in defining active learning classes -- lecturing less than 50 percent of the class period and incorporating both instructor-student interactions and student-student interactions. Out of the 392 classes observed, 34 percent are classified as active learning.

< Insert Figure 1>

Figure 1 provides a snapshot of student behaviors in active learning instruction versus lecture-intensive instruction classrooms by showing the distribution of students' activities performed within each two-minutes interval of the observed class time. Appendix Figure A.1 shows the distribution of instructor activities performed during class time. The figure provides a visual contrast in student behaviors in lecture-intensive classes (figure on the left) versus active learning classes (figure on the right). Most notably, students in lecture-intensive classes spent 93 percent of two-minute intervals listening to the instructor whereas the corresponding percent is lower in the active learning classes (63%). In addition, students in active learning classes spent a quarter of the class time doing group work compared to only 5 percent in lecture-intensive classes. This behavioral breakdown aligns with prior literature on the characteristics of lecture-intensive versus active learning instruction (Braxton, Milem, & Sullivan, 2000; Deslauriers et al., 2011; Stains et al., 2018).

Table 3 presents the estimated correlation between ALPD training and the likelihood of using active learning instruction. Due to the small sample size of instructors with class observation data, we conduct a cross-section comparison between instructors who had received ALPD by the time of the classroom observation and instructors who had not on their likelihood

to implement active learning. Column 1 presents the raw comparison between the two groups while column 2 further includes available class-level covariations, such as student composition, enrollment size, field of study, and term-year fixed effects.

< insert Table 3 >

Our results indicate that ALPD trained instructors were 17 percentage points more likely to implement active learning instruction than non-ALPD trained instructors ($p < 0.001$) (column 1). Such relationship remains significant at the 0.1 level after we further control for all available covariates ($p = 0.053$) (column 2).[6] The positive estimates across models provide suggestive evidence that the ALPD training increased the likelihood of implementing active learning instruction.

Discussion

The growing evidence on the promise of active learning instruction in engaging students has spurred increasing interests in promoting active learning approaches in the college classroom (Freeman et al., 2014; McKeachie et al., 1990; Prince, 2004; Pfund et al., 2009; Ruiz-Primo et al., 2011; Theobald et al., 2020). Despite the expansion of professional development efforts on active learning and the high hopes surrounding them, there is limited knowledge about the impacts of these programs on teaching practices and student achievement outcomes (Ebert-May et al., 2011). To address this gap, we leverage detailed administrative data and program participation data and use a quasi-experimental design to estimate the impact of participating in

[6] Finally, we are concerned that ALPD participants and non-participants may differ in their instructional approaches even in the absence of the training. Accordingly, we further conduct a pre- versus post-training comparison among ALPD participants only and control for all available covariates. The estimated coefficient shown in column 3 is positive (coefficient=0.13, $p = 0.187$) and fairly comparable to the estimate shown in column 2 that is based on the cross-sectional comparison. However, since only 71 ALPD participants have classroom observation data, the sample size is too small to yield a precise estimate.

an Active Learning Professional Development (ALPD) on students' contemporaneous and subsequent outcomes.

Consistent with the existing literature on active learning, we find that ALPD is associated with an increase in concurrent course grade, although the estimated effect is relatively small in magnitude and is marginally significant at the 0.1 level. Yet, we also find that the ALPD is associated with a notable increase in subsequent persistence in the field-- a five percent improvement from the baseline persistence rate of 68%. Subsequent exploratory analyses reveal a positive association between ALPD training and active learning implementation, providing suggestive evidence that the impact on students' outcomes may be driven by instructors' increased use of active learning approaches. Indeed, our estimated magnitude on field persistence corresponds to other studies that examined the relationship between active learning opportunities and persistence outcomes. For example, Loes et al. (2017) found a five percentage point increase in second year college persistence when students are provided with more collaborative learning opportunities in the classroom. Similarly, Braxton et al. (2000) identified a five percentage points increase in students' intent to re-enroll in the following term when comparing classrooms with high in-class discussions with low in-class discussions. Our results are aligned with findings from this line of work and nominate professional development on active learning as a promising way to promote the use of active learning approaches in the classroom and increase students' persistence in the field. Accordingly, our results also highlight the importance of taking student subsequent outcomes into account when evaluating the effectiveness of any active learning PD training programs.

Our study also contributes to the broad literature on teacher PD by providing detailed description on how a successful active learning PD program was administered and implemented

at the college setting. From a theoretical perspective, there has been a growing consensus on several conditions under which PD programs might produce more favorable outcomes, including sustained duration, coherence, collective participation, active learning, and local supports (Darling-Hammond et al., 2017; Garet, Porter, Desimone, Birman, & Yoon, 2001). The ALPD in the current study combines several of these key features. For instance, the program involved highly committed and experienced program facilitators with a coherent training agenda, and rigorous requirement of continuous and active participation from all participants during an eight-week time span. In addition, a number of activities were also intentionally designed to facilitate community building, aligning with existing literature on the features of effective PD (Cox, 2001; Garet et al., 2001; Penuel et al., 2007). Therefore, our study complements the current literature that is primarily conducted at K-12 settings by lending support for incorporating these features in designing effective PD in higher education.

From a policy perspective, designing and implementing a resource-intensive program such as the ALPD may be associated with high personnel costs of staffing experienced program facilitators. Accordingly, the effects of such programs need to be considered relative to program costs. The field would benefit from additional analyses benchmarking the program cost the efficacy of the training. Relatedly, additional research is needed that explores the conditions for effective implementation of PD programs on active learning instruction at scale. For instance, an effective training program that is tailored to the specific needs of the program participants while also cognizant of the unique context of the institution may lose its effectiveness when taken at scale (e.g. Kraft et al., 2018). Future studies that are able to document and relate elements of the large-scale training with changes to instructor practice and student outcomes will further complement the findings of the study.

Finally, it is important to note that our study only focuses on short-term academic outcomes while theories of active learning have underscored several non-academic and long-term benefits that are not fully captured in the current study, such as students' stress-level, test anxiety, development of social skills, long-term college and field persistence, and graduation rates (Ballen et al., 2017; Johnson, Johnson, & Smith, 2014; Loes et al., 2017). These possible benefits are important considerations and warrant attention in future studies to fully understand the effects of active learning training on student outcomes.

In spite of these caveats, the findings from our study indicate that the professional development on active learning instruction can lead to better student performance and persistence outcomes through instructional improvement in the college classrooms. While additional research is still needed to illuminate specific conditions under which such PD programs may produce favorable outcomes, our study lends support to PD programs on active learning as a promising way to innovate college instruction and improve student outcomes. As more institutions seek to better engage students in their learning, institutional leaders should consider offering professional development as a way to institutionalize the use of active learning in higher education.

References

Ballen, C. J., Wieman, C., Salehi, S., Searle, J. B., & Zamudio, K. R. (2017). Enhancing diversity in undergraduate science: Self-efficacy drives performance gains with active learning. *CBE—Life Sciences Education, 16*(4), 1-6. https://doi.org/10.1187/cbe.16-12-0344

Birman, B., Desimone, Garet, M., & Porter, A. (2000). Designing professional development that works. *Educational Leadership, 57*(8), 28-33.

Braxton, J. M., Milem, J. F., & Sullivan, A. S. (2000). The influence of active learning on the college student departure process: Toward a revision of Tinto's theory. *The Journal of Higher Education*, *71*(5), 569-590. https://doi.org/10.2307/2649260

Brownell, S. E., & Tanner, K. D. (2012). Barriers to faculty pedagogical change: Lack of training, time, incentives, and… tensions with professional identity?. *CBE—Life Sciences Education*, *11*(4), 339-346.

Carrell, S. E., & West, J. E. (2010). Does professor quality matter? Evidence from random assignment of students to professors. *Journal of Political Economy*, *118*(3), 409-432. https://doi.org/10.1086/653808

Cellini, S. R., & Chaudhary, L. (2014). The labor market returns to a for-profit college education. *Economics of Education Review*, *43*, 125-140. https://doi.org/10.1016/j.econedurev.2014.10.001

Cherney, I. D. (2008). The effects of active learning on students' memories for course content. *Active learning in higher education*, *9*(2), 152-171. https://doi.org/10.1177/1469787408090841

Cox, M. D. (2004). Introduction to faculty learning communities. *New directions for teaching and learning*, *2004*(97), 5-23. https://doi.org/10.1002/tl.129

Denaro, K., Sato, B., Harlow, A., Aebersold, A., & Verma, M. (2021). Comparison of cluster analysis methodologies for characterization of Cassroom Observation Protocol for Undergraduate STEM (COPUS) Data. *CBE—Life Sciences Education*, *20*(1), 1-11. https://doi.org/10.1187/cbe.20-04-0077

Darling-Hammond, L., Hyler, M.E., & Gardner, M. (2017). *Effective teacher professional development.* Palo Alto, CA: Learning Policy Institute. Retrieved from: https://files.eric.ed.gov/fulltext/ED606743.pdf

Desimone, L. M. (2009). Improving impact studies of teachers' professional development: Toward better conceptualizations and measures. *Educational Researcher*, *38*(3), 181-199. https://doi.org/10.3102/0013189X08331140

Deslauriers, L., Schelew, E., & Wieman, C. (2011). Improved learning in a large-enrollment physics class. *Science*, 332(6031), 862-864. https://doi.org/10.1126/science.1201783

Deslauriers, L., McCarty, L. S., Miller, K., Callaghan, K., & Kestin, G. (2019). Measuring actual learning versus perceptions of learning in response to being actively engaged in the classroom. *Proceedings of the National Academy of Sciences, 116*(39), 19251-19257. https://doi.org/pnas.1821936116

Ebert-May, D., Derting, T. L., Hodder, J., Momsen, J. L., Long, T. M., & Jardeleza, S. E. (2011). What we say is not what we do: Effective evaluation of faculty professional development programs. *BioScience*, *61*(7), 550-558. https://doi.org/10.1525/bio.2011.61.7.9

Figlio, D. N., Schapiro, M. O., & Soter, K. B. (2015). Are tenure track professors better teachers?. *Review of Economics and Statistics*, *97*(4), 715-724.

Fishman, B. J., Marx, R. W., Best, S., & Tal, R. T. (2003). Linking teacher and student learning to improve professional development in systemic reform. *Teaching and Teacher Education*, *19*(6), 643-658.

Freeman, S., Eddy, S.L., McDonough, M., Smith, M.K., Okoroafor, N., Jordt, H., & Wenderoth, M.P. (2014). Active learning increases student performance in science, engineering and mathematics. *Proceedings of the National Academy of Sciences, 111* (23), 8410-8415. https://doi.org/pnas.1319030111

Garet, M. S., Porter, A. C., Desimone, L., Birman, B. F., & Yoon, K. S. (2001). What makes professional development effective? Results from a national sample of teachers. *American Educational Research Journal*, *38*(4), 915-945.

Gasiewski, J. A., Eagan, M. K., Garcia, G. A., Hurtado, S., & Chang, M. J. (2012). From gatekeeping to engagement: A multicontextual, mixed method study of student academic engagement in introductory STEM courses. *Research in Higher Education*, *53*(2), 229-261.

Jacobson, L., LaLonde, R. J., & Sullivan, D. (2005). The impact of community college retraining on older displaced workers: Should we teach old dogs new tricks?. *ILR Review*, *58*(3), 398-415. https://www.jstor.org/stable/30038595

Jepsen, C., Troske, K., & Coomes, P. (2014). The labor-market returns to community college degrees, diplomas, and certificates. *Journal of Labor Economics*, *32*(1), 95-121. https://doi.org/10.1086/671809

Johnson, D.W., Johnson, R.T., & Smith K. (1998). Cooperative learning returns to college: What evidence is there that it works?, *Change*, 27-35

Johnson, D. W., & Johnson, R. T. (2009). An educational psychology success story: Social interdependence theory and cooperative learning. *Educational Researcher*, *38*(5), 365-379. https://doi.org/10.3102/0013189X09339057

Knight, Jennifer K., and William B. Wood. "Teaching more by lecturing less." *Cell Biology Education* 2005(4), 298-310. https://doi.org/10.1187/05-06-0082

Kraft, M. A., Blazar, D., & Hogan, D. (2018). The effect of teacher coaching on instruction and achievement: A meta-analysis of the causal evidence. *Review of Educational Research, 88*(4), 547-588. https://doi.org/10.3102/0034654318759268

Loes, C. N., An, B. P., Saichaie, K., & Pascarella, E. T. (2017). Does collaborative learning influence persistence to the second year of college?. *The Journal of Higher Education*, *88*(1), 62-84. https://doi.org/10.1080/00221546.2016.1243942

Mazur, E. (2009). Farewell, lecture. *Science*, *323*(5910), 50-51.

McKeachie, W. J. (1990). Research on college teaching: The historical background. *Journal of Educational Psychology, 82*(2), 189–200. https://doi.org/10.1037/0022-0663.82.2.189

National Center for Education Statistics. (2019). *The condition of education.* Retrieved from: https://nces.ed.gov/programs/coe/indicator_cha.asp#:~:text=2000%20through%202029.-,See%20Digest%20of%20Education%20Statistics%202019%2C%20table%20303.70

National Student Clearinghouse. (2020). *Persistence & retention – 2019*. Retrieved from: https://nscresearchcenter.org/snapshotreport35-first-year-persistence-and-retention/

Penuel, W. R., Fishman, B. J., Yamaguchi, R., & Gallagher, L. P. (2007). What makes professional development effective? Strategies that foster curriculum implementation. *American Educational Research Journal*, *44*(4), 921-958.

Pfund, C., Miller, S., Brenner, K., Bruns, P., Chang, A., Ebert-May, D., ... & Handelsman, J. (2009). Summer institute to improve university science teaching. *Science*, *324*(5926), 470-471.

Ran, F. X., & Xu, D. (2019). Does contractual form matter? The impact of different types of non-tenure-track faculty on college students' academic outcomes. Journal of Human Resources, 54(4), 1081-1120. https://doi.org/10.3368/jhr.54.4.0117.8505R

Pike, G. R., Smart, J. C., & Ethington, C. A. (2012). The mediating effects of student engagement on the relationships between academic disciplines and learning outcomes: An extension of Holland's theory. *Research in Higher Education, 53*(5), 550–575. https://doi.org/10.1007/s11162-011-9239-y

President's Council of Advisors on Science and Technology. (2012). *Engage to excel: Producing one million additional college graduates with degrees in science, technology, engineering, and mathematics.* Retrieved from: https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/pcast-engage-to-excel-final_2-25-12.pdf

Prince, M. (2004). Does active learning work? A review of the research. *Journal of Engineering Education, 93*(3), 223-231. https://doi.org/10.1002/j.2168-9830.2004.tb00809.x

Ruiz-Primo, M. A., Briggs, D., Iverson, H., Talbot, R., & Shepard, L. A. (2011). Impact of undergraduate science course innovations on learning. *Science*, *331*(6022), 1269-1270. https://doi.org/10.1126/science.1198976

Smith, M. K., Jones, F. H., Gilbert, S. L., & Wieman, C. E. (2013). The Classroom Observation Protocol for Undergraduate STEM (COPUS): A new instrument to characterize

university STEM classroom practices. *CBE—Life Sciences Education, 12*(4), 618-627. https://doi.org/10.1187/lse.13.2.359

Stains, M., Harshman, J., Barker, M. K., Chasteen, S. V., Cole, R., DeChenne-Peters, S. E., ... & Levis-Fitzgerald, M. (2018). Anatomy of STEM teaching in North American universities. *Science*, *359*(6383), 1468-1470. https://doi.org/10.1126/science.aap8892

Theobald, E. J., Hill, M. J., Tran, E., Agrawal, S., Arroyo, E. N., Behling, S., ... & Grummer, J. A. (2020). Active learning narrows achievement gaps for underrepresented students in undergraduate science, technology, engineering, and math. *Proceedings of the National Academy of Sciences*, *117*(12), 6476-6483. https://doi.org/pnas.1916903117

Wiggins, B. L., Eddy, S. L., Wener-Fligner, L., Freisem, K., Grunspan, D. Z., Theobald, E. J., ... & Crowe, A. J. (2017). ASPECT: A survey to assess student perspective of engagement in an active-learning classroom. *CBE—Life Sciences Education*, *16*(2), 1-13.

Xu, D. (2019). Academic performance in community colleges: The influences of part-time and full-time instructors. American Educational Research Journal, 56(2), 368-406. https://doi.org/10.3102/0002831218796131

Xu, D., & Solanki, S. (2020). Tenure-track appointment for teaching-oriented faculty? The impact of teaching and research faculty on student outcomes. Educational Evaluation and Policy Analysis, 42(1), 66-86.https://doi.org/10.3102/0162373719882706

Xu, D., & Trimble, M. (2016). What about certificates? Evidence on the labor market returns to nondegree community college awards in two states. Educational Evaluation and Policy Analysis, 38(2), 272-292. https://doi.org/10.3102/0162373715617827