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Abstract

While active learning and group work are effective at engaging students in their learning process, studies report that students' perceptions of active learning approaches are not always positive. We collected classroom observation data to empirically categorize courses as active learning or lecture-based and surveyed 4,257 college students across 25 STEM classrooms during two academic terms at a research-intensive university to assess their perceptions of learning, task value, and effective instructor facilitation. We first examined the relationship between active learning on perceptions of learning or task value and similar to previously published work, found a negative relationship between active learning and these measures for both racially minoritized students and represented students. Next, we assessed whether students' perceptions of instructor effectiveness in facilitating group activities mediate these negative relationships. We found that, on average, students of all races were more likely to positively perceive instructor facilitation in active learning classes relative to lectures. In turn, the positive perceptions of instructor facilitation partially suppressed the negative relationship between active learning and perceptions of learning and task value. These results demonstrate that effective instructor facilitation can influence both students' self-assessment of learning and perceived utility of the learning activities, and underscores the importance of developing pedagogical competence among college instructors.

Keywords: active learning | opportunity gaps | undergraduate education | evidence-based teaching

Significance Statement

Studies have demonstrated students' resistance to active learning, despite evidence illustrating that their learning is improved relative to students in lectures. Here, we estimate students' perceptions of effective instructor facilitation as the mediator in the relationship between active learning and perceptions of learning and perceived utility for class activities (task value), and also examine differences by racial identification. Students of all races in active learning classrooms have decreased perceptions of learning, and this negative relationship is also true for their perceptions of task value. However, these relationships were partially suppressed when students' favorably perceived instructor facilitation, indicating that when instructors become more intentional in their facilitation, students may learn to embrace an active learning environment.

Introduction

Active learning instruction is characterized by increased student engagement, frequent assessment of conceptual learning, and group activities (1-3). In particular, these group activities are often a defining feature of active learning instruction (4) and are linked to deeper learning in higher education (5). Studies have found that active learning instruction better engages students in college STEM classrooms (6), improves learning outcomes (7-9), and may decrease academic performance differences between racially minoritized students[1] and represented students (10). Despite these collective benefits, active learning instruction has not been widely adopted in college settings (11,12). A contributing factor as to why faculty are hesitant to implement active learning is the perception that their students are resistant to active learning instruction (13,14) with variable findings regarding student receptiveness to active learning pedagogies (6, 15, 16). Furthermore, recent evidence found that students taught using active learning approaches reported lower perceptions of learning than their peers in lecture-based classrooms despite exhibiting greater learning in the course (17). Relatedly, while it has been shown that opportunity gaps decrease in active learning courses (10), we know less about whether racially-minoritized students perceptions of learning vary from that of their more represented peers. While all students in active learning classrooms face increased academic accountability, racially minoritized college students may face additional stress in an environment where their racial or college-going identit(ies) are less represented. If minoritized students are cued to feel out of place or feel uncomfortable as fewer students of similar racial backgrounds are present in class, they face an undue burden to fit in (18-20). In contrast, the opportunity gap between racially minoritized and represented students in active learning instruction relative to lecture-based

[1] Theobald et al. (2020) defines underrepresented racially-minoritized students as African-American, Latino/Latina, Native American, or Pacific Islander/Native Hawaiian. We also include underrepresented Asian students such as Southeast Asians as these students are typically excluded in the definition but are significantly less represented than East and South Asians.

instruction may decrease to the extent that they are given more feedback on their learning and are provided with scaffolded time on tasks (10).

Perceptions of learning are directly connected to student success, as students who hold accurate perceptions of learning in the course while also believing that the course material is useful and important are more likely to exert effort and persist in STEM fields. Prior research has documented that misperceptions about learning led STEM students to switch to non-STEM majors relative to students who held more accurate perceptions about the major (24). Similarly, college students' motivation to engage with the material and exert cognitive effort hinge on their perceptions of whether the activities are perceived as useful and important to their learning (25, 26). Yet, inaccurate perceptions become most pronounced when the context and tasks are unfamiliar or unstructured (27), which can include active learning practices as these pedagogies are exceptions rather than the norm (30). In active learning classrooms, therefore, instructor facilitation can shape students' perceptions of learning and whether they believe the in-class activity is useful to their educational progress.

Indeed, students' perceptions of learning may not be positive when instructors do not effectively facilitate group activities (21). Prior research has shown that without proper instructor facilitation, students do not equally contribute to group assignments and tend to not assume group roles in intended ways (22, 23). In turn, students may hold inaccurate perceptions of their learning progress and perceive that their learning tasks have lower value as they regard active learning as disjointed and lacking in flow relative to well-organized lecture-based instruction (17). In active learning environments, therefore, instructor facilitation can shape students' perceptions of learning and whether they believe the in-class activity is useful to their educational progress.

We begin our inquiry by asking three related questions: do students in active learning classrooms differ on perceptions of learning/task value than students in lecture-based classrooms, do these perceptions differ for racially minoritized students, and are these relationships mediated by students' perceptions of effective instructor facilitation? We conduct our examination using data collected across 25 introductory STEM classrooms offered during fall 2019 or winter 2020 at a large public, research-intensive institution (*SI Appendix Tables S1* and *S2*). We are able to characterize courses as active learning or lecture-based using rich classroom observation data obtained using the Classroom Observation Protocol for Undergraduate STEM (COPUS) protocol (29, 30). COPUS is a classroom observation protocol in which observers record instructor and student behavior during every two minutes of a class period (29, 30). We also collected student and faculty survey data across these 25 STEM classrooms. We asked students about their perceptions of instructor effectiveness in facilitating group activities, task value, and their perceptions of learning. Student survey response rate across the 25 courses ranged from 67% to 100% for a total sample size of 4,257 student respondents. After we completed survey data collection, we obtained administrative data that include students' demographic and achievement records. In all of our models, we hold constant a large number of potentially confounding factors such as departmental differences and term-by-term fluctuations, differences in the types of students in the course (i.e., demographic differences and prior achievement), and instructor differences (i.e., prior teaching experience, instructor rank etc.) (*Materials and Method*).

Results

Using the COPUS codes that measured instructor or student behaviors within two-minute intervals, we estimated k-means cluster analysis and grouped courses into active learning (i.e., instruction with high group activity) and lecture-based (i.e., instruction with low group activity). We first display the distribution of recorded instructor and student behaviors in courses categorized as active learning and courses categorized as lecture-based (Fig. 1). In active learning classes, instructors spent less time on lecturing and more time moving through class compared to low group activity courses. For example, in active learning classes, instructors spent, on average, 32% of the two-minute intervals lecturing and 34% moving through class and students spent 26% working in groups (blue bar, n=15). In lecture-based class, instructors spent, on average, 77% of the two-minute intervals lecturing and 2% moving through class and students spent 3% of the two-minute intervals working in groups (orange bar, n=10) (*SI Appendix, Fig. S1 for full COPUS codes*).

Student Perceptions of Learning and Task Value in Active Learning versus Lecture-Based Courses

To assess the relationship between active learning versus lecture-based on perceptions of learning, task value and instructor facilitation, we leverage student survey data. Students' perceptions of learning was assessed with the survey question, *I feel like I learned a great deal in the course* (17). Table 1 panel A indicates that students in active learning classrooms, on average, responded 9.5 percentage points lower ($p < 0.001$) on perceptions of learning than students in lecture-based classrooms. 77% of students in low group activity classrooms agreed or strongly agreed that they learned a great deal whereas 67.5% of students in high group activity classrooms felt like they learned a great deal in the course. In addition, task value was measured with six questions such as *It is important for me to learn the course material* (31; Cronbach's alpha=0.922), and these items together created a scale of good fit (Chi-sq/df = 949.427, $p < .001$; RMSEA=0.157; SRMR=0.055; CFI=0.995) (32). Similar to perceptions of learning (Table 1 panel A), panel B indicates that students in active learning classrooms were 0.16 SD units less likely to agree that the course material is useful or important to their learning than students in lecture-based classrooms ($p < 0.05$). These estimates show the association between active learning on outcomes accounting for all possible mediational pathways (i.e., total effect).

As previously discussed, the learning experience can be vastly different for students from minoritized populations. We were curious as to whether the above findings -- that both perceptions of learning and task value were more negative for students in active learning courses -- were more or less pronounced for racially minoritized students. Our analyses highlighted that minoritized students were just as likely to report decreased perceptions of learning and task value as represented students (*SI Appendix Table S4*).

To assess whether these negative relationships are driven by lower grades earned in active learning courses, we compare grade outcomes of students in active learning versus those in lecture-based instruction. We find that students received similar grades in the course irrespective of whether the course was lecture-based or active learning, confirming previous findings that students taught with active learning approaches tend to be inaccurate in their perceptions of learning relative to students taught with the more traditional lecture approach ($B = 0.006$; $p = 0.839$) (*SI Appendix Table S5*). Moreover, the relationship between students' perceptions and active learning were independent of grades earned in the course *(SI Appendix Table S6)*. It is important to highlight that we are comparing a variety of STEM courses across the 25 included in the sample, and not making direct comparisons of similar courses taught in active learning versus lecture formats.

Students' Perceptions of Effective Instructor Facilitation as a Mediating Variable

Next, we examine the extent to which students' perceptions of instructor effectiveness in facilitating group activities explain the negative relationship between active learning instruction and perceptions of learning and task value. Our mediating variable is a measure of students' perceptions of instructor effectiveness in facilitating group activities and was measured with five questions such as: *the instructor clearly explained the purpose of the activity* and *encouraged students to engage with the activity through their demeanor*. These items were drawn from the student buy-in survey on active learning strategies (33; Cronbach's alpha =0.879), and together created a scale of good fit (Chi-Sq(2) = 3.767, p = 0.152; SRMR = 0.006; RMSEA = 0.014; CFI = 1.00) (32) (*SI Appendix, Survey Items*). Students in active learning classrooms were 0.15 SD units more likely to perceive that the instructor was effective at facilitating group activities than students in lecture-based classrooms (Table 1 panel C). Controlling for students' perceptions of instructor effectiveness in facilitating group activities, the magnitude of the negative relationship on perceptions of learning increases from 9.5 to 12 percentage points. We interpret this estimate as the component of the total effect that does not occur through the perceptions of instructor effectiveness in facilitating group activities (i.e., holding constant students' perceptions of effective instructor facilitation). Similarly, the magnitude of the negative relationship between instruction type and task value increases from -0.16 SD to -0.22 SD. The indirect effects shown under Table 1 panels A and B are all positive, indicating that students' positive perceptions of instructors' facilitation associated with active learning suppressed the overall negative effect. For instance, the point estimate of 0.02 in panel B suggests that students' perceptions of learning in the course would have been about 2 percentage points more negative had students perceived instructor facilitation unfavorably in classrooms with high group activity ($p < 0.001$). Similarly, students' reported task value would have been more negative by 0.06 SD units had it not been for their positive perceptions of instructor facilitation in active learning classes ($p < 0.001$).

Moderated Mediation Analyses. We next examined whether the mediating influence differed depending on students' racial identification (Table 2). We find that the interaction between the mediator and the racially minoritized identification are statistically indistinguishable from zero. Column 1 indicates that racially minoritized students -- in active learning and lecture-based courses -- did not perceive instructor facilitation of group activities any differently from represented students. Furthermore, the non-significant interaction effects between active learning and racially minoritized students, shown in Column 2 panels A and B, suggest that the relationship between active learning and perceptions of learning or task value do not vary by students' racial identification. These findings indicate that the current mediational pathway is just as consequential for represented students as for racially minoritized students.

Triangulating Students' Perceptions of Effective Instructor Facilitation. Having observed the positive mediating effect of students' perceptions of instructor effectiveness in facilitating group activities, we triangulated whether students' perceptions of instructors' facilitation of group activities match that of the instructors'. If students and instructors are misaligned in what is occurring in the classroom, students may report decreased utility for in-class activities and perceive that they are learning less. Previous literature documented a misalignment between what the instructor believed had occurred in the classroom versus what the students believed happened (28, 48). Despite instructors' best intentions, students may express decreased perceptions of learning and task value when there exists a misalignment between what the instructor believed had occurred in the classroom versus the students.

We assessed the level of alignment between instructors and students in their responses to identical survey questions related to effectiveness of facilitating group activities. We first conduct a simple correlation between instructor and students' responses to perceptions of instructor facilitation and find essentially no correlation (*SI Appendix Figure S2)*. In addition, this misalignment in perception of instructor effectiveness varied widely across disciplines (Fig 2). Whereas students were more positive about instructor facilitation in Biological Sciences and Mathematics/Physics than instructors themselves, instructors were more positive about their facilitation than students in Chemistry, Engineering/Computer Science, Public Policy, Psychology, and Social Ecology. These results indicate that there exists a misalignment in perceptions of effective instructor facilitation between instructors and students, and that the directionality of these misalignments differ depending on the discipline. These findings suggest that instructors may generally be unaware of when students perceive that their facilitation was effective or ineffective.

We also verify that students' survey responses regarding the occurrence of classroom activities align with independent observations of classroom practices (COPUS). We corroborate students' responses to questions regarding *frequency of lecturing* and *frequency of group activities* to our COPUS results and found that students and independent observers were closely aligned with one another (*SI Appendix Table S7).* So while there is clear alignment between students' perceptions of classroom activities and the actual activities themselves (as measured by independent classroom observers), students' perceptions of instructor effectiveness do not align with faculty's self-rating of how effective they were in facilitating these same group activities.

Discussion

Over the past few decades, there has been heightened interest in increasing the use of active learning pedagogies in higher education settings (4, 34), yet wide-scale implementation has yet to occur (11, 12). This study found that students of all races in active learning classrooms perceived they learned less and rated the utility of the course activities lower than their peers in more lecture-based courses, despite earning similar grades. Our mediation analysis suggests that the relationship between active learning and perceptions of learning and task value would have been even more negative had it not been for students' positive perceptions of instructor facilitation in active learning classrooms. In subsequent analyses, we investigated whether the instructors and students were aligned in their assessment of effective instructor facilitation and found little alignment.

Our results suggest that effective instructor facilitation not only influences students' learning in the course (23) but also students' self-assessment of learning and perceived utility of the learning activities. As such, instructors should be systematic and intentional in facilitating group activities, particularly as there can exist a disconnect between what students and faculty perceive is happening in the classroom (28). Potential means through which instructors can accomplish improved facilitation fall under the umbrella of pedagogical competence, which includes giving clear and relevant group assignments, giving direct feedback to students, and facilitating group discussions (35). For example, instructors may want to discuss the broader purpose and expectations before every in-class group activity, walk around the classroom during the activities, and provide feedback and answer questions, as recommended by previous research on effective teaching and pedagogical competence (35). While this mediator was just as consequential for racially-minoritized students as for represented students, faculty should continue to interrogate existing practices and be mindful of different racial group dynamics when facilitating group activities, given prior literature that racially minoritized students may experience group activities differently compared to represented students (19, 20).

Without training on effective group facilitation, faculty may operate with the incorrect assumption that their in-class group facilitation is effective. Accordingly, it is important that faculty remain transparent in their pedagogical decisions and that students feel personally invested in the activities. To address this misalignment, institutions should consider offering faculty the opportunity to learn about these evidence-based instructional practices through active learning training (36, 50). The burden of clearly explaining the activities' purpose may decrease in an institutional environment where active learning becomes the norm. As more faculty are provided with institutionalized support to implement active learning, students may also shift their perceptions on active learning and gradually buy-in to these course activities.

Our study provides directions for future research. To better understand student perceptions of instructor effectiveness, it will be important to distinguish the specific types of group activities that instructors have facilitated across the 25 STEM classrooms and whether certain activities are more positively perceived than others by students. In some instances, group problem solving activities may be a significant fraction of a lecture period whereas other cases may leverage clicker questions as a brief means to summarize a lecture. Identifying student perceptions of their instructor's effectiveness at facilitating different activities may help us understand which contribute disproportionately to student feelings of learning or which should be emphasized during professional development programs.

It is important to note that instruction that incorporates high levels of group activities may be seen by students as more active, engaging, and *difficult*. Many college students erroneously associate easy and enjoyable tasks to mean that they are learning the material while associating effortful and difficult tasks as the lack thereof (37, 38). Yet, as students engage with a challenging learning process, they retain the material longer and understand the concept more deeply (38). Given that students, on average, tend to feel like they learned less in active learning classrooms, faculty should, as part of their role as facilitators, clarify to students throughout the course that effortful learning leads to greater mastery in the long-run and immediate fluency does not necessarily equate to mastery. And that when students learn to embrace a more active and engaging learning environment, they may come to realize that they have learned less superficially and have gained skills and social networks that contribute to thriving academically.

Materials and Methods

During fall 2019 and winter 2020 terms, classroom observations were conducted using the COPUS protocol (29) to identify different types of instructional practices implemented on campus. The Teaching and Learning Center at a large, four-year university selected these courses based on the following criteria: undergraduate lecture courses (excluding lab sections, discussions, and seminar courses) held in rooms with capacity for 60 students or greater. All instructors who participated in the classroom observations were also invited to distribute a student survey and participate in a faculty survey during the last two weeks of the term. There are a total of 4257 students across 25 STEM courses in our analytical sample. We grouped courses as instruction with high group activity (i.e, active learning) and instruction with low group activity (i.e., lecture-based) using the COPUS data and k-means cluster analysis.. The goal of the k-means cluster analysis is to decrease the number of within sums of squared errors of a cluster by minimizing the distance from the centroid while maximizing the distance between clusters (39, 40).

Empirical Analyses. We estimate a series of regression models to examine whether students taught with high or low group activities differ on perceptions of learning and task value and to estimate the mediating effect. We calculate the extent to which the mediator explains the relationship between instruction type and outcomes by comparing the direct effect to the total effect (41). If the total effect is reduced to zero once the mediator is included in the model, we conclude that full mediation has occurred. If the magnitude of the coefficient is reduced once we account for the mediator, we conclude that partial mediation has occurred. In contrast, if the magnitude of the coefficient becomes larger once we account for the mediator, we conclude that the mediator has suppressed the relationship (42).

We first estimate the relationship between instruction type on the mediator, perceptions of instructor effectiveness in facilitating group activities. Next, we estimate the direct effect of the instruction type on student outcomes controlling for the mediator. To examine whether any patterns we observe vary by race, we estimate a moderated mediation analysis (43). The moderated mediation analysis was conducted to examine whether the strength and the direction of the mediation effect differ for racially-minoritized students. Specifically, we interact the previous models by race to tease out differential effects on the mediator and outcomes. To obtain our moderated mediation estimates, we estimate the moderation of the treatment effect on the mediator and multiplied that with the moderation of mediating effect on the outcome accounting for the treatment effect. We use R version 4.0.3 mediation package to conduct all of our mediation analyses (44). We estimate the standard errors and confidence interval of the mediation effect using bootstrap standard errors resampled 1000 times (44, 45) (*SI Appendix)*.

Several covariates were included in all of our mediation analyses because we observe nonrandom sorting of students across active learning instruction and lecture-based activity instruction (*SI Appendix, Table S3*). We include a number of carefully chosen covariates to account for the fact that we are comparing STEM courses from one another that may differ across a number of dimensions. To eliminate confounding variables such as student-level differences or instructor-level differences, we include student demographic characteristics such as students' major (STEM versus non-STEM), gender, race, low-income status, first-generation status, high school GPA, SAT math, SAT verbal, and whether students' transferred from another university. Furthermore, we model classroom-level characteristics because students' perceptions of group activities may be influenced by the peer composition of the class as well as by the instructor (46). We created various measures like the average high school achievement of students in the course and the proportion of racially-minoritized students in the class. In addition, we hold constant the size of the class because class size is a predictor of student engagement (47) as well as a binary variable to account for whether the course was offered in a building that is designed to encourage group activities and discussion on campus as the infrastructure may influence student perceptions (49). Because we administered faculty surveys, we also control for prior teaching experiences, instructor teaching self-efficacy, gender, and faculty rank (i.e., Lecturer, Assistant, Associate, etc.). Finally, we account for course-level grading differences to account for the possibility that instructors teaching a particular course tend to grade harder than other instructors teaching the same course. We create this indicator by pulling student-level administrative data of all of the courses in our analytic sample from 2016 and beyond. Then, we averaged students' performance of prior terms at the instructor-by-course level (i.e., determine course-specific average grade taught by a particular instructor). For instructors who taught the course for the first time within the timeframe of our data, we included their current class average performance.

In addition to a rich set of covariates, we include several fixed effects to account for any common group-level differences. For instance we include a time trend to account for when the students took the survey and for differences from term-to-term (e.g., common shock occurring at a particular term). We also include entry term fixed effects in order to compare students from the same entering cohort. Lastly we control for departmental differences by including department fixed effects to compare courses within the same department. We cluster the standard errors at the classroom-by-term level as there may be autocorrelation in student survey responses due to being in the same class during a particular term.

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Figures and Tables

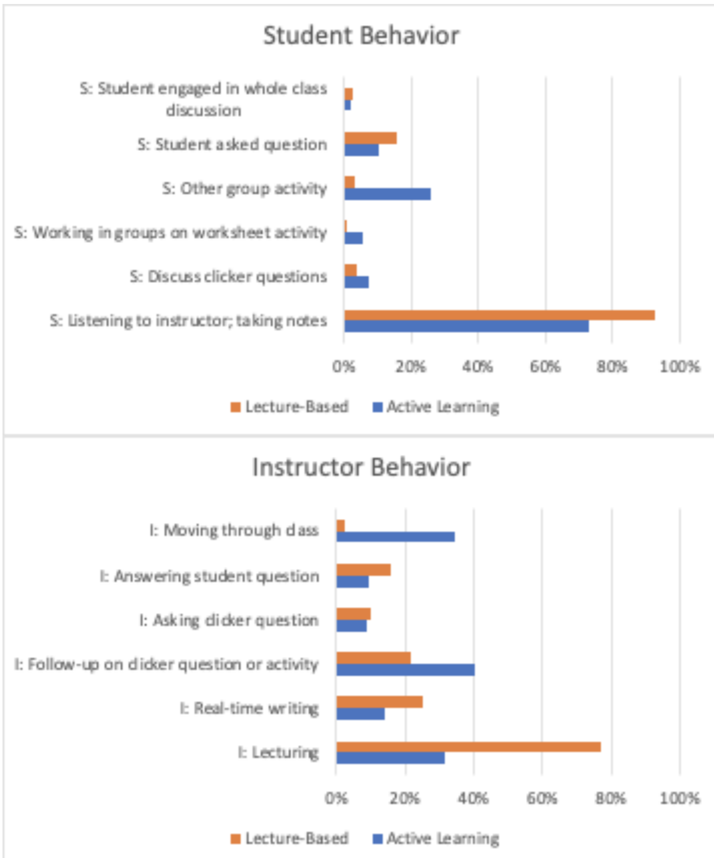

Figure 1. Distribution of Select Student and Instructor COPUS Codes in Active Learning and Lecture-Based Classrooms

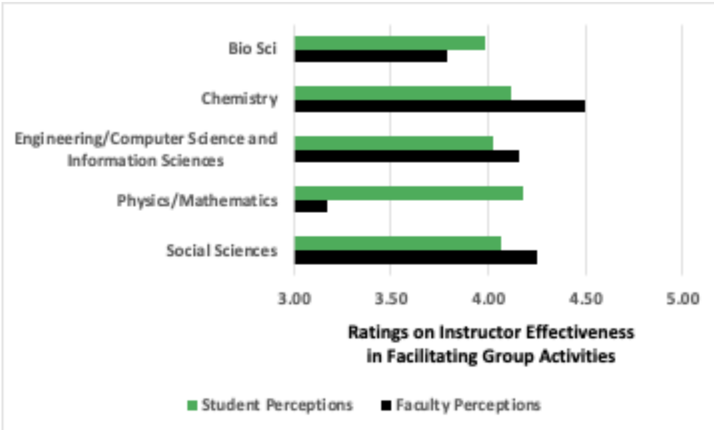

Figure 2. Alignment of Faculty and Student Perceptions across Disciplines. Social Science includes Public Policy/Social Ecology/Psychology.

Table 1. Total, Indirect (Mediation), and Direct Effect Estimates

	Estimate	
Panel A. Feelings of Learning		
Indirect Effect (Mediation)	0.021	***
Average Direct Effect	-0.116	***
Total Effect	-0.095	***
Panel B. Task Value		
Indirect Effect (Mediation)	0.059	***
Average Direct Effect	-0.217	**
Total Effect	-0.158	*
Panel C. Mediator		
Active Learning Instruction	0.15	*

All of the regression estimates presented in this table include covariates to account for baseline differences among students in high group activity classroom versus low group activity classroom. High group activity classroom is identified using COPUS observation data. Student-level covariates include the following: STEM major, gender, race, low-income status, first-generation status, transfer student status, weighted HS GPA, SAT math and verbal score, cumulative GPA in college prior to taking the course. Classroom composition covariates include the following: % low-income, % URM, % women, average HS GPA, average SAT math, average SAT verbal, building type. Instructor-level covariates include instructor experience, gender, rank, and teaching self-efficacy. Entry Term fixed effects accounts for between cohort differences due to entering college at a different time. Time trends account for potential differences from taking the class/survey in the fall versus winter quarter. Standard errors are clustered at the course-by-term level. N = 4257 students in 25 STEM classrooms. *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

Table 2. Moderated Mediation Results by RM versus non-RM students

	(1) On Mediator	(2) Total Effect	(3) Direct Effect
Panel A. Perceptions of Learning			
Active Learning	0.161*	-0.090***	-0.117***
	(0.059)	(0.017)	(0.018)
RM	0.031	0.036*	0.136+
	(0.052)	(0.015)	(0.067)
Active Learning x RM	-0.021	-0.008	0.001
	(0.062)	(0.028)	(0.029)
Perceptions of Instructor Facilitation			0.151***
			(0.026)
Perceptions of Instructor Facilitation x RM			-0.027
			(0.016)
Rsq	0.108	0.064	0.150
N	4257	4257	4257
Panel B. Task Value			
Active Learning		-0.101	-0.164*
		(0.060)	(0.062)
RM		0.064	0.266*
		(0.055)	(0.128)
Active Learning x RM		-0.070	-0.049
		(0.069)	(0.061)

Perceptions of Instructor Facilitation			0.359***
			(0.055)
Perceptions of Instructor Facilitation x RM			-0.054+
			(0.030)
Rsq		0.143	0.270
N		4257	4257

Each panel in columns 2 and 3 represent different regression results. Column 1 estimates the estimated differential effect on the mediator by race. Column 2 estimates moderation of the overall treatment effect. Column 3 estimates the moderation of the treatment effect by race accounting for differential effect on the mediator.

Same covariates as Table 1 were also included in this model.

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

Supplementary Information for

Instructor Facilitation Mediates Students' Negative Perceptions of Active Learning Instruction

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Supplementary Information Text

In this appendix, we detail the research design and our empirical strategy. There are three overarching goals of the appendix: 1) to provide an overview of the courses included in our analyses, and the sample generalizability; 2), to list the survey questions fielded to students and faculty; 3) to discuss the empirical methods in greater detail and 4) to present additional analyses pertaining to the results, with corresponding tables and figures.

I. Overview of the courses included in our analyses

Table S1. Distribution of Courses by Department and Active Learning versus Lecture-Based

Department Name	(1) Lecture-Based	(2) Active Learning
Biological Sciences	0	7
Chemistry	1	2
Engineering	2	2
Computer Science and Information Sciences	2	3
Physics/Math	2	1
Public Policy/Social Ecology/Psychology	3	0
Total	10	15

As shown in Table S2, compared to the broader student population enrolled at this large, selective institution, a greater proportion of students in our analytical sample were STEM majors (76% in our sample versus 47%). In addition, a greater proportion of students in our analytical sample are identified as racially-minoritized students relative to all students enrolled at this institution during fall 2019 (54% in our sample versus 29%). Despite these notable differences, we note similarities with regards to the representation of transfer students as well as the proportion of low-income or first-generation students.

Table S2. Generalizability Table

	Fall 2019 Undergraduate Enrollment		Analytic Sample		
	M	count	M or %	SD	count
STEM major	47%	30382	76%		4257
Women	52%	30382	57%		4257
Racially Minoritized	29%	30382	54%		4257
Transfer Student	22%	30382	20%		4257
Low-income	38%	30382	34%		4257
First Generation	47%	30382	50%		4257
High School GPA			3.91	0.45	4257
SAT Math			626.26	96.87	3629
SAT Verbal			583.26	92.42	3627

Table S3 indicates that students in active learning courses are more likely to be women and major in STEM, and have entered college with higher high school GPA than students in low group activity courses. Moreover, we see instructor level differences between those who used high group activity instructional approaches relative to instructors who used low group activities in that fewer first-time instructors tend to use active learning approaches. Specifically, close to 20% of instructors who taught using minimal group activity also reported having no prior experience teaching the course. In contrast, only 6% of instructors who taught using active learning approaches reported that this is their first time teaching the course. Regardless of prior experience, however, instructors in both instruction types rated themselves fairly highly on their teaching self-efficacy (5.64 on a 7-point scale). All of these covariates are included as control variables in all of the analyses.

Table S3. Student Characteristics and Class Composition

	Active Learning		Lecture-Based		-
Variable	M or %	n	M or %	n	p-value
Student Characteristics					
STEM major	88%	2355	62%	1902	0.000
Women	59%	2355	56%	1902	0.008
URM	54%	2355	55%	1902	0.751
Transfer Student	17%	2355	24%	1902	0.000
Low-income	33%	2355	35%	1902	0.704
First Generation	47%	2355	53%	1902	0.000
Weighted High School GPA	3.94	2355	3.88	1902	0.000
SAT Math	630.38	2069	620.81	1560	0.021
SAT Verbal	584.68	2068	581.39	1559	0.503
Class-Level Measures					
% URM	48.93	15	51.12	10	0.860

% Women	50.86	15	52.71	10	0.885
% Low-Income	30.39	15	32.80	10	0.831
Average SAT Math	563.49	15	532.39	10	0.526
Average SAT Verbal	513.71	15	491.73	10	0.634
Average HS GPA	3.92	15	3.85	10	0.226
Active Learning Building	80%	15	40%	10	0.105
Instructor Characteristics					
Women	67%	15	60%	10	0.799
Lecturer	7%	15	30%	10	0.285
Assistant	40%	15	40%	10	0.962
Associate	13%	15	10%	10	0.663
Full Professor	40%	15	20%	10	0.444
No prior experience	7%	15	20%	10	0.503
Prior experience teaching course	47%	15	60%	10	0.565
Prior experience teaching course in active learning infrastructure	47%	15	20%	10	0.234
Instructor self-efficacy	5.55	15	5.57	10	0.717

II. Survey Questions

List the survey questions fielded to students

Perceptions of instructor effectiveness in facilitating group work

Thinking about the group activities you have done in this class, please indicate how often your instructor did the following:

	Never (1)	Sometimes (2)	About half the	Most of the	Always (5)

			time (3)	time (4)	
Clearly explained the purpose of activities we did in class	O	O	O	O	O
Discussed how activities related to my learning	O	O	O	O	O
Clearly explained what I was expected to do for activities in class	O	O	O	O	O
Encouraged us to engage with activities through his/her demeanor	O	O	O	O	O

Perceptions of learning

Based on your experiences in this class, please indicate how much you agree or disagree with the following statements.

	Strongly disagree (1)				Strongly agree (5)
I feel like I learned a great deal from this course.	O	O	O	O	O

Task Value

Please indicate to what degree you feel the following statements are true:	Definitely false (1)	Probably false (2)	Neither true nor false (3)	Probably true (4)	Definitely true (5)
I will be able to use what I learn in this course in other courses.	O	O	O	O	O
It is important for me to learn the course material in this class.	O	O	O	O	O
I am very interested in the content area of this course.	O	O	O	O	O
I think the course material in this class is useful for me to learn.	O	O	O	O	O
I like the subject matter of this course.	O	O	O	O	O
Understanding the subject matter of this course is very important to me.	O	O	O	O	O

List the survey questions fielded to faculty

Thinking about the group activities you have facilitated in this class, please indicate how often you did the following:

	Never (1)	Sometimes (2)	About half the time (3)	Most of the time (4)	Always (5)
Clearly explained the purpose of activities we did in class	O	O	O	O	O
Discussed how this activity related to student learning	O	O	O	O	O
Clearly explained what students were expected to do for the activity	O	O	O	O	O
Encouraged students to engage with the activity	O	O	O	O	O

III. Empirical Method

Mediation Analysis. We obtain the magnitude of the mediating effect by obtaining the product of the coefficients of instruction type in equation (1) and in equation (2) $(\beta_1 * \gamma_1)$ or by subtracting the direct effect from the total effect (1, 2) Equation (1) estimates the direct effect and equation (2) estimates the effect on the mediator. The subscripts indicate the following: student *i* in class *c* taught by instructor *j* during term *t.*

$$Y_{icjt} = \gamma_0 + \gamma_1(activelearning_{cjt}) + \gamma_2(M_{icjt}) +$$
$$\gamma_{i,1}(predictor_i) + \ldots + \gamma_{i,n}(predictor_i) + \gamma_{c,1}(classlevelpredictor_{cjt}) +$$

$$\ldots + \gamma_{c,m}\,(classlevelpredictor_{cjt}) + \ \pi(prioraveragegrade_{jc}) + \alpha(term_{it}) \ + \theta(cohort_i) + \phi_d \ + e_{icjt} \quad (1)$$

$$M_{icjt} = \ \beta_0 \ + \ \beta_1(activelearning_{cjt}) + \beta_{i,1}\,(predictor_i) + \ldots + \beta_{i,n}\,(predictor_i) + \beta_{c,1}\,(classlevelpredictor_{cjt}) + .. + \beta_{c,m}\,(classlevelpredictor_{cjt}) + \pi(prioraveragegrade_{jc}) \ + \ \alpha(term_{it}) \ + \theta(cohort_i) + \phi_d \ + e_{icjt} \quad (2)$$

where Y_{icjt} refers to our three outcomes of interest: perceptions of learning, interest, and willingness to collaborate with peers. M_{icjt} refers to the mediator: perceptions of instructor effectiveness in facilitating group activities for student *i* in class *c* taught by instructor *j* during term t. $instructiontype_{cjt}$ refers to whether the course is flagged as instruction with high group activity or low group activity, based on COPUS cluster analysis results. β_1 estimates the relationship between active learning and the mediator while γ_1 estimates the relationship between instruction and the outcome controlling for the mediator. We use R version 4.0.3 mediation package to conduct all of our mediation analyses (3). We estimate the standard errors and confidence interval of the mediation effect using bootstrap standard errors resampled 1000 times (4).

Moderated Mediation Analysis. To examine whether any patterns we observe vary by race, we estimate a moderated mediation analysis (5) to examine whether the strength and the direction of the mediation effect differ for racially-minoritized students. Equations (3) and (4) provide the model that was estimated. Again, Equation (3) estimates the direct effect of the active learning interacted with racially minoritized indicator and equation (4) estimates the moderation of active learning by racially minoritized indicator on the mediator, students' perceptions of instructor effectiveness in facilitating group activities. For sake of simplicity, all covariates and fixed effects are identified as ***X***. Racially minoritized student indicator is a binary variable identified in the equation as RM_i.

$$Y_{icjt} = \gamma_0 + \gamma_1(activelearning_{cjt}) + \gamma_2(RM_i) + \gamma_3(RM_i * activelearning_{cjt}) + \gamma_4(M_{icjt}) + \gamma_5(M_{icjt} * RM_i) + X\varphi + e_{icjt} \quad (3)$$

$$M_{icjt} = \beta_0 + \beta_1(activelearning_{cjt}) + \beta_2(RM_i) + \beta_3(RM_i * activelearning_{cjt}) + X\tau + e_{icjt} \quad (4)$$

To identify the indirect effect via the mediator we do the following: $[\beta_1 + \beta_3(RM_i)] * [\gamma_4 + \gamma_5(RM_i)]$.

IV. Additional analyses pertaining to the results

Table S4. Interaction Effects by Racially Minoritized Students and Represented Students

	Perceptons of Learning	Task Value
Active Learning	-0.112***	-0.182*
	(0.018)	(0.074)
Racially Minoritized	0.032+	0.064
	(0.017)	(0.056)
Active Learning x Racially Minoritized	-0.005	-0.075
	(0.029)	(0.071)
Perception of Instructor Effectiveness in Facilitating Group Activities	0.136***	0.389***
	(0.025)	(0.064)
R-sq	0.150	0.269
N	4257	4257

In this analyses, we include student-level covariates, classroom-level covariates, instructor characteristics, entry term fixed effects, time trend, and department fixed effects. Standard errors are in parentheses.

+ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table S5. Relationship between Active Learning and Course Grades

	Grades
Active Learning vs. Lecture-Based	0.006
	(0.028)
Racially Minoritized	-0.053*
	(0.026)
Perception of Instructor Facilitation of Group Activities	0.023
	(0.022)
R-sq	0.484
N	4257

In this analyses, we include student-level covariates, classroom-level covariates, instructor characteristics, entry term fixed effects, time trend, and department fixed effects. Standard errors are in parentheses.

+ p < 0.10, * p < 0.05, ** p < 0.01, *** p < 0.001

Table S6. Relationship between Active Learning and Measures by Levels of Course Grades

	(1) Perceptions of Learning	(2) Perceptions of Learning x Grades	(3) Task Value	(4) Task Value x Grades
Active Learning	-0.115***	-0.045	-0.221**	-0.023
	(0.016)	(0.074)	(0.065)	(0.195)

Perception of Instructor Facilitation of Group Activities	0.135***	0.135***	0.385***	0.386***
	(0.024)	(0.024)	(0.060)	(0.061)
Course Grades	0.065***	0.074***	0.209***	0.236***
	(0.010)	(0.012)	(0.030)	(0.042)
Perception of Instructor Facilitation of Group Activities x Grades		-0.021		-0.060
		(0.022)		(0.059)
R-sq	0.160	0.160	0.288	0.289
N	4257	4257	4257	4257

In all four models, we include student-level covariates, classroom-level covariates, instructor characteristics, entry term fixed effects, time trend, and department fixed effects. Standard errors are in parentheses.

+ p < 0.10, * p < 0.05, ** p < 0.01, *** p < 0.001

Table S7. Alignment between COPUS Results and Student Survey Response

Student Survey Item	**Lecture-Based**	**Active Learning**
Spent most of time lecturing		
Never	1.1	9.9
Sometimes	2.7	16.2

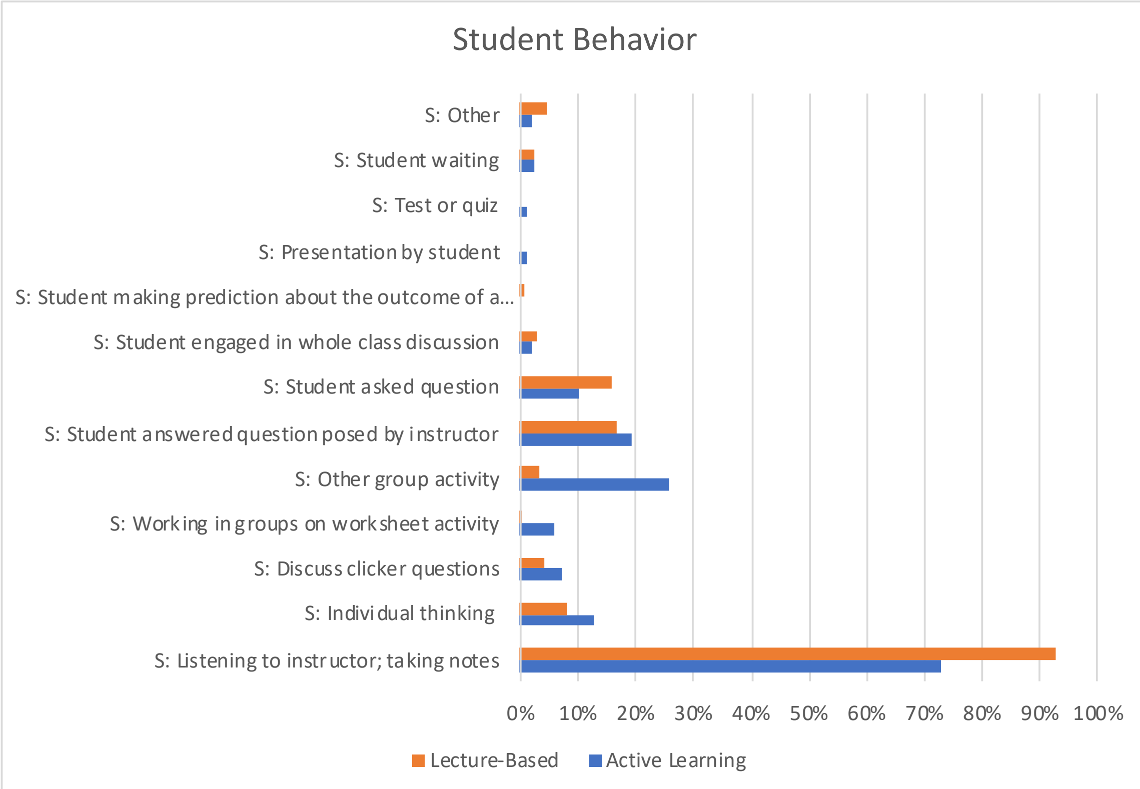
About half the time	7.7	13.9
Most of the time	35.3	30
Always	53.2	30.1
Total	1902	2355

Pearson chi2(4) = 507.9807, $p < 0.001$

Discuss with 2 or more an activity

Never	36.1	16.6
Sometimes	23.3	15.2
About half the time	12.6	14.3
Most of the time	11	23.9
Always	17	30.1
Total	1902	2355

Pearson chi2(4) = 369.1614, $p < 0.001$


Student Behavior
S: Other
S: Student waiting
S: Test or quiz
S: Presentation by student
S: Student making prediction about the outcome of a...
S: Student engaged in whole class discussion
S: Student asked question
S: Student answered question posed by instructor
S: Other group activity
S: Working in groups on worksheet activity
S: Discuss clicker questions
S: Individual thinking
S: Listening to instructor; taking notes
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Lecture-Based
Active Learning

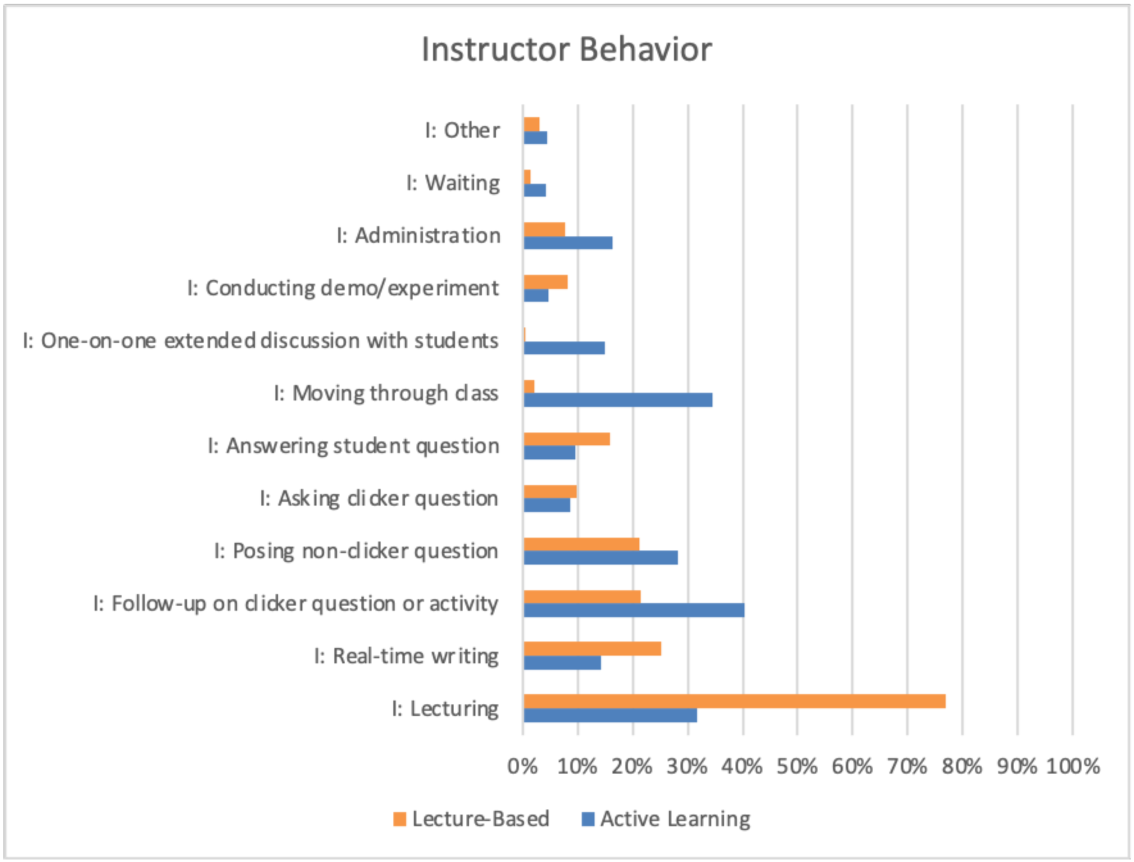


Fig. S1. Distribution of Full Student and Instructor COPUS Codes in Active Learning and Lecture-Based Classrooms

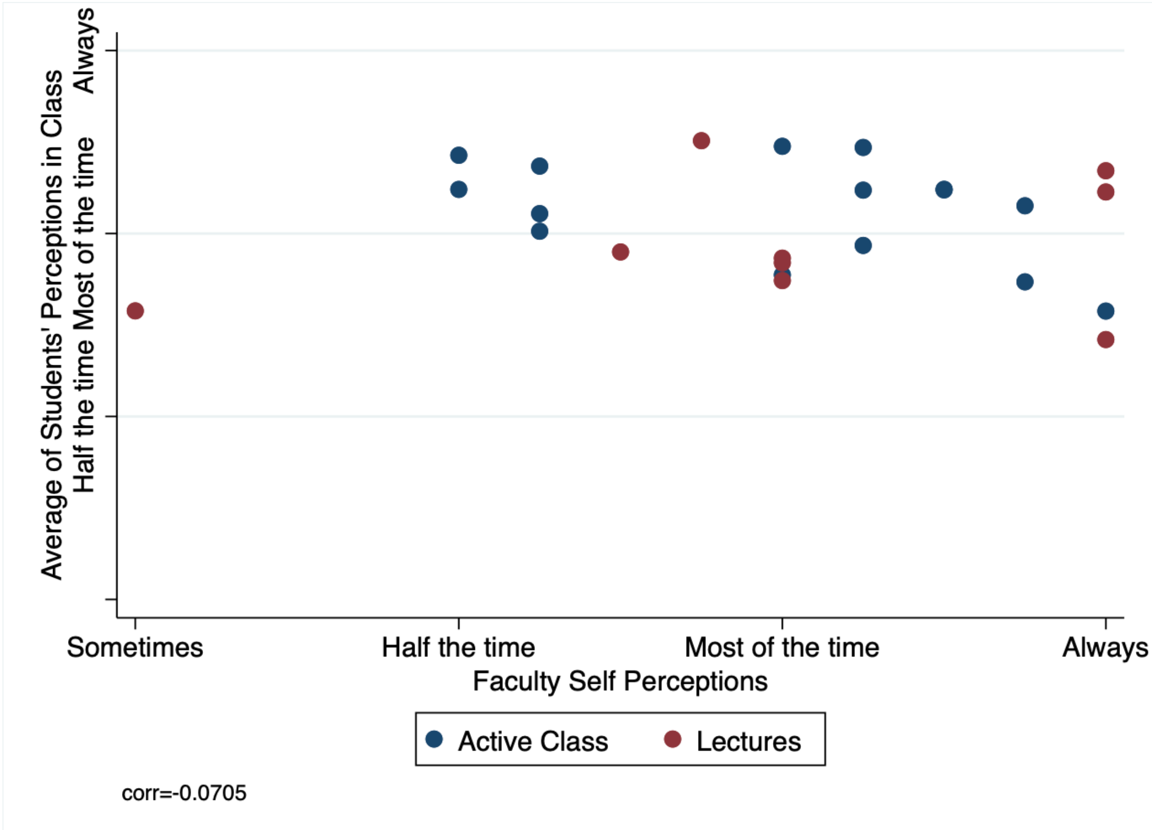


Fig S2. Scatterplot between Faculty and Student Perceptions of Instructor Facilitation of Group Activities

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