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Some Believe, Not All Achieve: The Role of Active Learning Practices in Anxiety and Academic Self-Efficacy in First-Generation College Students†

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First-generation college students face a variety of barriers in higher education compared with their continuing-generation peers. Active learning practices in STEM classrooms can potentially narrow the achievement gap by increasing academic self-efficacy, or confidence in academic abilities. However, these practices can also provoke anxiety in students. Given that anxiety can impair cognitive performance, we sought to understand how first-generation students perceive active learning practices and whether these perceptions affect the anticipated benefits of active learning. As part of a larger study on pedagogical practices in anatomy and physiology courses at the community college level, we asked students to rate various active learning techniques on how much each provoked anxiety and how much each contributed to their learning. All students (*N* = 186) rated some techniques as more anxiety-provoking than others (e.g., cold calling); however, compared to continuing-generation students, first-generation students' ratings tended to be higher. First-generation students anticipated doing more poorly in a course and attained lower final grades. Notably, the use of active learning practices did not improve first-generation students' academic self-efficacy: by the end of term, academic self-efficacy decreased in non-white first-generation students whereas other students showed little change. When introducing active learning strategies, instructors may need to proactively address underrepresented minority students' emotional reactions and ensure that all students experience success with these practices early in a course as a way to bolster academic self-efficacy.

INTRODUCTION

Instructors have traditionally focused on the course content, ensuring that they provide lecture content that is accurate, topical, and, ideally, engaging. Yet, policy documents such as *Vision and Change* (1), as well as a growing body of literature, point to the critical role of *how* we teach as a means of increasing student retention and success in STEM disciplines. Importantly, the landmark meta-analysis by Freeman *et al.* (2) showed that student performance in STEM courses can be improved by implementing active learning practices (3). Through activities such as student response systems (e.g., clickers), guided inquiry, or conceptual problem assignments, active learning practices challenge students to reflect on what they do and do not know as a means of constructing their knowledge. Previous findings suggest that these practices in postsecondary STEM classrooms reduce failure rates, improve student performance on exams, and increase reported student enjoyment of learning (4, 5).

Active learning techniques have also been identified as a means of encouraging inclusivity and reducing the

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achievement gap faced by underrepresented demographics in STEM (6). Use of multiple active learning practices in first-year science courses, including frequent assessment (e.g., clicker questions or multiple smaller exams) and interactive instruction (e.g., group learning experiences, peer-led team learning) improved course grades and reduced failure rates, with underrepresented minority students exhibiting greater gains in grades than continuing-generation students (6–8). The reasons that active learning practices may disproportionately benefit certain demographics remain under investigation; however, findings suggest that they might afford greater opportunities for classroom participation from underrepresented students (9, 10); increase students' sense of belonging (11); mitigate an unfriendly or overly competitive atmosphere prevalent in large lecture classes (12); provide more opportunities for students to practice metacognitive skills instead of rote memorization (13); and enhance a sense of confidence in abilities to meet academic challenges, otherwise referred to as academic self-efficacy (8).

There is a recognized need to modify traditional STEM classroom practices to increase the retention and success of first-generation students in postsecondary institutions. First-generation students, who are more likely than continuing generation-students to be members of ethnic minorities and come from a financially disadvantaged background (14, 15), represent approximately 45% of enrollment at public American two-year colleges (16). As a group, first-generation students perform less well academically and are more likely to drop out than their continuing-generation peers (17). A reduced sense of belonging may contribute to this attrition; first-generation students' goals and expectations often differ substantially from other students' (18), and they often report difficulties integrating into college life (19, 20). First-generation students also report lower academic self-efficacy, greater fear of failing academically, and more uncertainty about their preparedness for college/university (14, 21). Perhaps consistent with this, first-generation students are more prone to use low-efficiency study strategies. The importance of academic self-efficacy to student success has received increasing attention, as evidence indicates that this psychological attribute predicts both sense of belonging to a postsecondary institution and actual academic outcomes (4, 22).

Some of the challenges faced by first-generation students could perhaps be ameliorated by incorporating active learning practices into teaching. In addition to supporting a more equitable classroom environment, active learning practices might help to decrease "imposter syndrome" by providing students opportunities to apply their skills and overcome meaningful, challenging problems (23). These "mastery experiences," when accompanied by clear instructions and opportunities to reflect on performance (24, 25), are considered the most powerful means to increase self-efficacy, and academic mastery experiences have improved ratings of academic self-efficacy in particular. For example, the meta-analysis of Talsma *et al.* (26) demonstrates that performance and self-efficacy are causally and reciprocally related; their data supported the validity of the statements "I believe therefore I achieve" (p. 136) as well as "I achieve therefore I believe" (p. 137). Other features of active learning practices can foster academic self-efficacy, such as opportunities to watch peers succeed at a learning task (27) and provision of feedback that highlights students' learning strategies and the causes of their successes and failures. However, feedback can be harmful if it does not increase understanding or if the student perceives a high level of threat to their self-esteem (28).

Student perceptions are an important consideration in the judicious use of active learning, as some evidence shows that these practices may cause anxiety (29, 30). Students identified social anxiety, fear of negatively impacting their final grade, awkwardness, and finding others to work with as reasons that active learning processes caused them anxiety (29). Among common active learning practices, cold calling (calling on students to answer a question rather than asking for volunteers) is considered one of the most anxiety-inducing, stemming from fear of not knowing the answer, being judged negatively by peers and teachers, and fear of public speaking (30, 31). After cold calling, students often rate volunteering to answer a question, completing worksheets, and responding to clicker questions as most-to-least anxiety-inducing (29). The consequences of student anxiety should not be underestimated, given the substantial literature demonstrating that academic anxiety affects all stages of the learning–testing cycle: planning and executing learning tasks, completing evaluations, and reflecting on performance (32, 33). Anxiety can be particularly detrimental for performance on evaluations and assignments that require deep-level cognitive skills, such as critical thinking and synthesis, over rote learning. Consistent with this, anxiety stemming from fear of evaluation (test anxiety) correlates negatively with markers of academic success, including grades and SAT scores (34, 35). Furthermore, heightened anxiety is associated with greater discomfort in the classroom (36) and greater likelihood of dropping out of a STEM program (37).

This negative impact of high anxiety on learning may be particularly relevant to understanding the experiences of first-generation students. In addition to experiencing more stress and greater fear of failure, first-generation students report a stronger sense of pressure to succeed to improve the financial standing of their family and bring pride and honor to their families (14, 20). Given these conditions, it is important to know how first-generation students perceive the introduction of active learning practices into the classroom and whether their perceptions influence the anticipated benefits of active learning practices on academic self-efficacy and academic performance.

In this study, we asked first- and continuing-generation students to rate a variety of active learning techniques in terms of their capacity to invoke anxiety and their perceived educational value. Participants were students enrolled

in Human Anatomy and Physiology courses at two-year community colleges. During the semester, their instructors introduced an active learning practice. We assessed students' level of social anxiety (or psychological distress relating to the fear of negative evaluation by others) and academic self-efficacy at the beginning and end of the semester and examined how these psychological variables related to first- and continuing-generation students' anticipated and actual academic performance in their course.

METHOD

Participants

An initial pool of 330 student participants was drawn from five different Human Anatomy and Physiology classes taught at three separate community colleges. These colleges were located in western and Midwest states, and student populations at these institutions were majority white in ethnicity (60% to 70%, [The Institute for College Access & Success, https://college-insight.org/]). Class sizes ranged from 29 to 90 students.

The instructors of these classes were themselves participants in a larger study examining the adoption of active learning at the community college level (38). Each instructor had previously completed a one-credit graduate level course in Educational Research and implemented a new evidence-based teaching practice (think-pair-share, cooperative quizzing, or muddiest point) into their classroom during the semester. Before joining this larger study, instructors had not completed formal training in pedagogical theories underlying active learning. For all instructors, this was the first time that they had introduced an evidence-based teaching strategy with a formal, conscious intent to increase active learning in their classrooms and measure its impact. Throughout their participation in this larger study, instructors had virtual meetings with the other instructors and the study's primary investigators to discuss their experiences.

Student questionnaire

The complete questionnaire administered to students is available in the Supplemental materials (Appendix 1). Students completed the same questionnaire at the beginning and the end of the semester via online survey software (Qualtrics).

We asked students to evaluate several active learning practices in terms of how much anxiety they cause the student to feel, on a scale from 1 (no anxiety) to 5 (extreme anxiety). Students were also asked to evaluate the same practices in terms of how much they contribute to their learning, on a scale from 1 (very little) to 5 (significantly). These practices are listed in Appendix 1. A core set of these practices were included in all the questionnaires administered in the classes (lecture; student response system alone; student response system in a team; volunteering to answer a question; cold calling by instructor). In contrast, each of the remaining practices was included in each instructor's questionnaire only when the practice had been used in their classroom. As a result of this, the sample sizes reported in the analyses of these ratings data vary across the practices.

We evaluated students' self-reported academic self-efficacy using a 10-item scale developed by McIlroy and colleagues (39). Students indicated their level of agreement with statements such as "If I don't understand an academic problem, I persevere until I do" on a seven-point Likert scale. After reverse scoring items, a total efficacy score was calculated for each student by summing across the values for all responses with a maximum possible score of 70. Cronbach's α analyses indicated good internal reliability of this scale when administered at the beginning of term (α = 0.78) and at the end of term (α = 0.86).

Social anxiety, or psychological distress relating to the fear of negative evaluation by others, was assessed in students using the mini-social phobia inventory (mini-SPIN) (40). This three-item self-report scale evaluates how much an individual has been bothered in the past week by situations potentially involving social judgment. In response to statements such as "I avoid activities in which I am the center of attention," students selected their response between 0 (not at all) and 4 (extremely). Total social anxiety was computed by summing across responses to these three items with a maximum possible score of 12. Analyses demonstrated good internal reliability when administered at the beginning of term (Cronbach's α = 0.83) and at the end of term (α = 0.82).

Additionally, students were asked to report the following information: their anticipated final grade in the course; current GPA; demographic characteristics including whether they were the first in their family to attend college (first-generation status), their identified gender, and their ethnicity. With respect to gender, students were asked to select among the following options: male, female, transgendered man, transgendered woman, genderqueer, nonbinary, other, or prefer not to say. Identified ethnicity was assessed using the following categories: White, Black or African American, American Indian or Alaska Native, Asian, Native Hawaiian or Pacific Islander, other, or prefer not to say.

Questionnaires completed at the beginning and the end of the term were linked for each student using either names or date of birth, depending on the class. For the class using student names, one of the lead researchers on this project (who was not involved in the teaching of these students) was responsible for adding course grades to students' completed questionnaire data and then deleting student names prior to data analysis. Data analyses were carried out by a different member of the research team. Instructors did not see the questionnaire results until after all grades were submitted.

The study was approved by the Institutional Review Board of each participating community college.

Data analyses

Analyses were conducted on data from 186 students who entered a response of either yes or no in response to the question regarding first-generation college student status. Of a total sample *N* = 330, 144 students did not enter any response to the "first generation" question, and 5 selected "unsure" or "I'd prefer not to answer." These 149 students were not included in the analyses reported in the Results section.

In this sample, only three participants selected a gender identity category other than male or female. Because of this, the original gender identity categories were collapsed into male and female gender binary categories for the analyses reported below. With respect to ethnicity, relatively few students selected the categories American Indian or Alaska Native, Asian, Native Hawaiian or Pacific Islander. For the purposes of statistical analysis, these categories were collapsed together with participants in the Black or African American category to create a single "non-white" ethnicity category. The distribution of first-generation college students versus continuing-generation on the basis of binary gender and binary ethnicity was then tested using chi-square analysis.

A series of independent sample *t*-tests was used to compare first- and continuing-generation college students' ratings of various teaching techniques for how much each caused anxiety and how much each contributed to students' learning. The resulting *t* statistics from these comparisons were evaluated against a Bonferroni-corrected α level of 0.005. This approach was taken instead of using a multivariate analysis of variance to maximize the number of ratings of each teaching technique available in the data set.

A factorial repeated measures analysis of variance (ANOVA) was used to compare social anxiety levels at the beginning and end of term with first-generation status and ethnicity (white vs. non-white) as between-subjects variables. Gender was not included as a between-subjects variable in these analyses because of very small numbers of male students in each of the first-generation status x gender and ethnicity x gender cells. A second factorial repeated measures ANOVA was carried out to evaluate change in academic self-efficacy from the beginning to the end of term, with first-generation status and ethnicity (white vs. non-white) as between-subjects variables.

Finally, multiple linear regressions were carried out to measure the predictive value of first-generation status, ethnicity (white versus non-white), and academic self-efficacy for the outcome variables of anticipated final grade and actual final grade received in the course. An α level of 0.05 was used for all statistical tests, except where noted to adjust for multiple comparisons.

RESULTS

Sample characteristics

Of the 330 student participants drawn from five different classes who initially consented to participate in the study, a sample of 186 respondents from three different classes (representing two different community colleges) answered yes or no regarding first-generation college status. Table 1 presents the demographic characteristics of this sample with respect to binary gender identity and ethnicity. As shown, the majority of the sample identified as female in both the first-generation (87%) and continuing-

TABLE 1.
Sample characteristics (*N* = 186).

	First Generation	Continuing Generation
Identified Gender, % (*n*)		
Male	13 (10)	25 (27)
Female	87 (68)	75 (81)
Ethnicity, % (*n*)		
White	47.4 (37)	80.6 (87)
Black	6.4 (5)	1.9 (2)
Native or Alaskan Native	2.6 (2)	0.9 (1)
Asian	15.4 (12)	8.3 (9)
Native Hawaiian/Pacific Islander	2.6 (2)	0.9 (1)
Other	25.6 (20)	6.5 (7)
Prefer Not to Say	0 (0)	0.9 (1)

generation (75%) groups. With respect to ethnicity, the majority of the overall sample identified as white (67%). After collapsing all ethnicity categories other than white into a single "non-white" category, chi-square analysis indicated that non-white students were significantly overrepresented in the first-generation students (53% non-white) compared with non-first-generation (19% non-white) (χ^2 (1) = 23.4, p < 0.001). For gender and ethnicity breakdowns for each of the three classes sampled, refer to Supplementary tables 1–3.

Ratings of active learning practices for anxiety provocation and contribution to learning

Figures 1 and 2 illustrate student ratings from the beginning of term of how anxiety-inducing and educationally-valuable active learning practices were, respectively. In general, teaching techniques varied in how anxiety-inducing they were perceived to be, with cold calling ranking among the most and lecturing among the least. First-generation

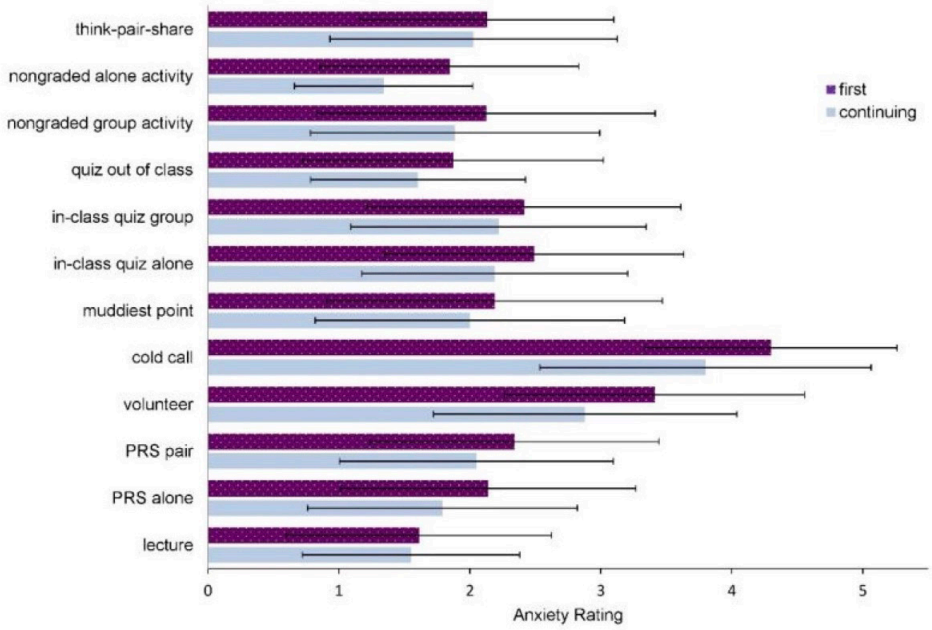

FIGURE 1. First- and continuing-generation students' ratings of the level of anxiety induced by various teaching strategies. Mean ratings (± SD) were taken at the beginning of the term.

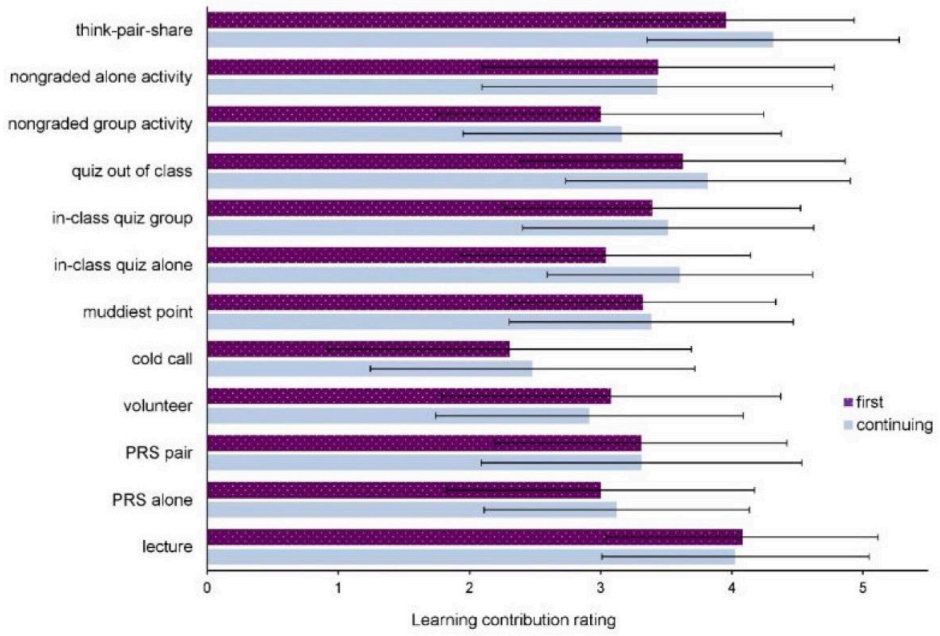

FIGURE 2. First- and continuing-generation students' ratings of various teaching strategies for how much each contributes to their learning. Mean ratings (± SD) were taken at the beginning of the term.

students tended to rate most techniques as more anxiety-provoking than did their continuing-generation peers, with cold calling (t (171) = 2.95, p = 0.004, Cohen's d = 0.445) and volunteering to answer a question (t (179) = 3.06, p = 0.003, d = 0.460) being rated as significantly more anxiety-provoking by first-generation students (Bonferroni-corrected threshold of 0.0045 for statistical significance). Ratings of techniques for learning contribution value did not differ significantly by generation status except for completing in-class quizzes independently, which first-generation students rated as contributing less to their learning compared with non-first generation students (t (178) = –3.54, p = 0.001, d = 0.529).

Social anxiety and academic self-efficacy in first- and continuing-generation students

We investigated whether the tendency for first-generation students to rate various teaching strategies as more anxiety-provoking was associated with particular psychological characteristics. We examined levels of social anxiety reported by participants, and Table 2 presents mean scores on these measures taken at the beginning and end of the semester (see Supplementary tables 6–8 for these scores in each of the classes). Social anxiety levels between these groups of students did not differ significantly. Social anxiety levels did not change significantly from the start to the end of the term, and this lack of change did not differ according to first-generation status or ethnicity.

We also examined reported academic self-efficacy at the beginning and end of the term. These scores are summarized in Table 3 (see Supplementary tables 9–11 for these scores in each of the classes). Students did not differ on this measure as a function of first-generation status or ethnicity at the beginning of term. By the end of term, however, academic self-efficacy scores had declined significantly in non-white students (F (1, 127) = 5.69, p = 0.02, partial eta^2 = 0.043), with the greatest decrease occurring in first-generation non-white students. These results are represented in Figure 3 as a change score in academic self-efficacy from the beginning to the end of term.

Relationship of academic self-efficacy to anticipated and actual academic performance

In view of previous findings that academic self-efficacy is a predictor of academic performance, we next examined whether reported academic self-efficacy showed any relationship with anticipated and actual final grade outcomes. In both first- and continuing-generation students, the academic self-efficacy score at the end of the term correlated positively with both anticipated grade [r (129) = 0.53, p < 0.001] and with final received grade in the course [r (129) = 0.70, p < 0.001]. Multiple linear regression modeling with first-generation status, ethnicity, and academic self-efficacy at the end of term as predictors indicated that the academic self-efficacy score significantly predicted students' anticipated final grade (Table 4; b −0.10 STE 0.02, 95% CI −0.07, −0.14; t = 6.73, p < 0.001, partial correlation = −0.51) and received final grade (b 0.79 STE 0.08, 95% CI 0.64, 0.94; t = 10.38, p < 0.001, partial correlation = 0.69) (Table 5). Ethnicity was also found to be a significant predictor of received final grade in the course whereby non-white ethnicity was associated with a lower grade (b −4.18 STE 1.80, 95% CI −7.74, −0.62; t = −2.33, p = 0.02, partial correlation = −0.21). In contrast, first-generation status alone was not a significant predictor of either outcome variable.

DISCUSSION

Taken together, our findings show that first-generation college students perceived certain active learning techniques as more anxiety-inducing than do continuing-generation students. We also observed that non-white first-generation students experienced a modest decline in academic self-efficacy by the end of term, whereas white students showed little change in this psychological state. Despite previous research indicating that active learning practices are especially beneficial to the academic performance of underrepresented minorities in STEM, our findings are consistent with some previous reports indicating that simply the introduction of

TABLE 2.
Total social anxiety score reported at the beginning and end of term (N = 131).

		First Generation		Continuing Generation	
		Total social anxiety ±SD	SE (95% CI)	Total social anxiety ±SD	SE (95% CI)
Beginning of term	White	5.77±3.42	0.56 (4.66, 6.88)	5.82±3.05	0.36 (5.11, 6.54)
	Non-white	6.75±3.48	0.52 (5.73, 7.78)	5.30±3.26	0.75 (3.83, 6.77)
End of term	White	5.33±3.42	0.74 (3.88, 6.79)	5.39±3.65	0.47 (4.46, 6.32)
	Non-white	7.09±3.44	0.64 (5.83, 8.36)	4.69±4.05	0.90 (2.90, 6.47)

SD = standard deviation; SE = standard error; CI = confidence interval.

TABLE 3.
Total academic self-efficacy score reported at the beginning and end of term (N = 131).

		First Generation		Continuing Generation	
		Total academic self-efficacy ±SD	SE (95% CI)	Total academic self-efficacy ±SD	SE (95% CI)
Beginning of term	White	47.67±7.59	1.78 (44.14, 51.20)	50.42±8.92	1.14 (48.17, 52.68)
	Non-white	50.13±9.02	1.55 (47.07, 53.18)	51.19±9.11	2.19 (46.86, 55.51)
End of term	White	49.67±9.93	2.15 (45.12, 53.92)	49.92±10.55	1.37 (47.20, 52.63)
	Non-white	45.47±10.16	1.55 (41.78, 49.15)	49.81±12.02	2.63 (44.60, 55.02)

SD = standard deviation; SE = standard error; CI = confidence interval.

these practices into a classroom is not sufficient to achieve this outcome (41). Additional factors may play an important role in determining how effectively active learning can support equity in the classroom.

The finding that first-generation students were more apprehensive about particular active learning practices is an important nuance to our knowledge not only of how students respond to these teaching strategies but also of how to incorporate these practices effectively into STEM teaching. Previous evidence has clearly shown that not all active learning techniques are welcomed equally by students, with practices such as cold calling rated as being especially anxiety-provoking by many. In our sample, this and some practices that involved a public or social interaction component (e.g., volunteering to answer a question; clicker question with another student) were rated as more anxiety-inducing by all students and more so by first-generation students. Importantly, this pattern also appeared to be tied to students' ethnic identity: in a class-by-class analysis, the difference between first- and continuing-generation students' anxiety ratings of teaching practices was greatest in the class with the largest proportion of non-white students (see Supplementary tables 1–3 and Supplementary figures 1–3).

Despite students' apprehension toward various teaching practices, the value of active learning for academic performance has been shown repeatedly (2). It is worth noting that, while much of the literature suggests that high anxiety has a negative influence on learning, anxiety is not always detrimental to student success. In fact, a moderate level of arousal can improve cognitive performance and academic outcomes (e.g., [42]). However, in our data, we observed that first-generation students tended to perform more poorly in their courses than their continuing-generation

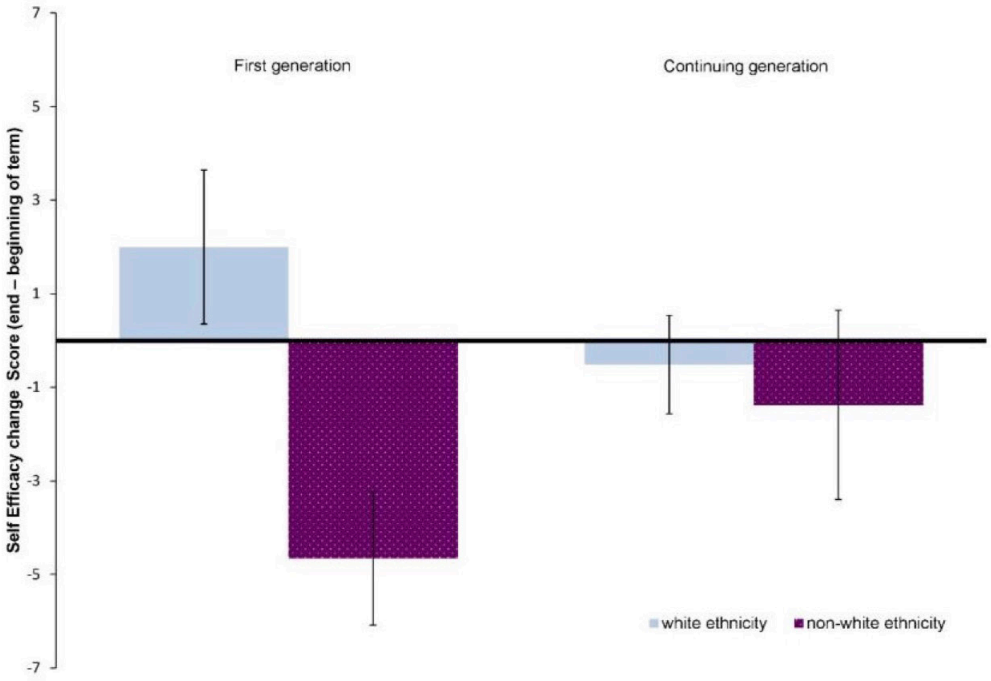

FIGURE 3. Mean change in academic self-efficacy score (± SD) from the beginning to end of term, shown for first- and continuing-generation students of white or non-white ethnicity.

TABLE 4.
Multiple regression model, anticipated grade in the course.

	***b* (95% CI)**	**SE *b***	β	r_p
Constant	8.36 (6.43, 10.28)	0.97		
First or continuing generation	–0.14 (–0.83, 0.56)	0.35	–0.03	–0.03
Total academic self-efficacy at end of term	–0.10* (–0.14, –0.07)	0.02	–0.51	–0.51
Ethnicity	0.54 (–0.19, 1.26)	0.36	0.12	0.13

* $p < 0.001$
$R^2 = 0.30$, F (3, 127) = 17.88, $p < 0.001$
First or continuing generation coded as 0 = continuing, 1 = first. Ethnicity coded as 0 = white, 1 = non-white.
SE = standard error; CI = confidence interval.

peers. Given that first-generation students rated some active learning practices as more anxiety-inducing yet experienced generally poorer academic outcomes, it would seem that an additional degree of anxiety provoked by these practices did not benefit these students.

In addition to bearing on academic performance, first-generation students' anxiety towards various teaching practices may be important to consider in light of this demographic's greater risk of dropping out. Interestingly, we have observed that students tend to perceive less educational value from teaching practices that they rate as anxiety-provoking (manuscript under review). To the extent that a student's expectation of the educational value of a classroom activity predicts how much one is willing to engage in that activity, our data may suggest that first-generation students are at a greater risk of disengaging from active learning classrooms that incorporate practices that they perceive as particularly anxiogenic. Coupled with previous evidence that first-generation students report higher levels of stress during their studies (36), potential risks of using particular active learning practices could be an exacerbation of stress levels and a reduction in these students' commitment to their studies.

Given this, the effective introduction of active learning practices to a classroom may require some care on the part of the instructor. Consistent with this idea, anxiety levels of students in classrooms using active learning practices vary according to class and instructor (31). In the present study, instructors attempted their first formal use of active learning strategies in their classrooms, and it is likely that this newness of experience influenced how these instructors explained and implemented the strategy compared with how instructors with more active learning experience might have employed the same strategies (43). Instructor behaviors such as approachability, greater clarity in teaching style, and stronger communication skills have also been found to play important roles in improving students' emotional responses to a classroom (44). Greater emphasis on practicing these types of behaviors may thus help to reduce students' perceptions of certain teaching practices as anxiety-inducing and, in turn, foster a more equitable classroom environment (45–47).

In addition to finding generation differences in students' perceptions of classroom activities, notable differences emerged between students in their academic self-efficacy across time. Indeed, whereas white students did not differ in academic self-efficacy from the beginning to the end of term, non-white first-generation students decreased in academic self-efficacy. This pattern appeared in each of the three classes when examined individually (Supplementary tables 7–9). This finding was striking given that each classroom had implemented at least one active learning practice during the term, thereby providing more opportunities for mastery experiences to bolster self-efficacy. Indeed, the results of Ballen and colleagues (8) suggest that the beneficial effect of active learning in closing the achievement gap for underrepresented minorities is due to an increase in academic self-efficacy.

Taken together with previous research, our results imply that particular conditions may need to be in place for active learning practices to benefit the academic self-efficacy and academic performance of underrepresented minorities in STEM. For example, the "dosing" of active learning may be an influential variable: some studies that have reported a reduction of the achievement gap were done with the use of multiple, frequent, and highly structured active learning practices in the classroom (7, 8). Furthermore, the ways in which these practices are carried out may be critical. Best practices may include ensuring that all students' early experiences with active learning are scaffolded to promote success and incorporate vicarious learning experiences (watching others work on problems) with peer models who the observer perceives as similar in characteristics to them. This latter point speaks to previous findings in the literature that allowing students to self-select working partners rather than assigning partnerships is an important component of supporting underrepresented minorities in active learning STEM classrooms (48, 49).

TABLE 5.
Multiple regression model, final grade in the course.

	***b* (95% CI)**	**SE *b***	β	r_p
Constant	42.5 (32.87, 52.23)	4.89		
First or continuing generation	1.81 (–1.63, 5.25)	1.74	0.07	0.10
Total academic self-efficacy at end of term	0.79** (0.64, 0.94)	0.08	0.67	0.69
Ethnicity	–4.18* (–7.74, –0.62)	1.80	–0.16	–0.21

* $p < 0.05$
** $p < 0.001$
$R^2 = 0.52$, F (3, 118) = 43.17, $p < 0.001$
First or continuing generation coded as 0 = continuing, 1 = first. Ethnicity coded as 0 = white, 1 = non-white.
SE = standard error; CI = confidence interval.

Limitations

A primary limitation is the amount of attrition from our sample: although a total of 330 students consented to participate in our study, only 186 students reported whether they were first- or continuing-generation students and were included in the analyses reported here. Inspection of the data from students who did not report their generation status indicates that these students with unknown generation status reported higher levels of social anxiety and lower academic self-efficacy than participants who disclosed being a first-generation student (see Supplementary table 10). As our questionnaire included the answer option of "I prefer not to say," it is difficult to interpret why some students did not answer this question. Although this attrition may limit the robustness of our results, we note that the pattern of findings we report here is largely consistent with previous literature (18, 21).

It is also important to acknowledge that our results are derived from only one semester of data collection. This feature of our study design limits the strength of our conclusions because it is unclear whether the present findings are replicable. As the data reported here were collected from the first year of an ongoing multi-year study, we plan to address this issue following completion of data collection from different classes. As a potential mitigation of the concern for replicability in the present results, we note that the current data set comprises results from three classes in two community colleges that were located in different geographic areas.

Within the sample of participants reporting their generation status, another limitation is the demographic make-up of our sample: students were primarily white in ethnicity and female across the three classes sampled, which limited both our statistical power to evaluate patterns in non-white students (and precluded gender-related analyses) and the generalizability of our findings. With respect to generalizability, it would be of interest to determine whether the perceptions of first-generation students, particularly those of color, vary according to the demographic make-up of the larger classroom environment. That is, would non-white first-generation students rate various active learning practices as more anxiety-inducing if the class make-up was majority non-white? An examination of a subset of our data from the class with the greatest ethnic diversity (41% non-white) would suggest no. However, it would be of interest to determine whether the patterns described here also persist in a larger and more diverse sample. We plan to collect more data from additional community colleges in the coming year to allow us to undertake these analyses.

Additional limitations of our design include the variation between classes in the types of active learning practices implemented and consequent inter-instructor differences in how active learning practices were introduced in their classrooms. We did not collect comprehensive data to evaluate how active learning practices were applied in the classroom (e.g., whether all students participated in the activities). As such, it is not possible to draw strong conclusions from our dataset regarding the conditions in which active learning practices may or may not influence academic self-efficacy.

CONCLUSIONS

Our findings indicate that underrepresented minorities in STEM may view some active learning techniques as more threatening than do other student demographics, and that use of active learning strategies does not by default increase academic self-efficacy in STEM classrooms. These results highlight the need for additional research into the contextual variables that allow for active learning practices to help close the achievement gap.

SUPPLEMENTAL MATERIALS

Appendix 1: Student questionnaire
Appendix 2: Supplementary tables
Appendix 3: Supplementary figures

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REFERENCES

1. American Association for the Advancement of Science. 2011. Vision and change in undergraduate biology education: a call to action: a summary of recommendations made at a national conference organized by the American Association for the Advancement of Science, July 15–17, 2009. Washington, DC.
2. Freeman S, Eddy SL, McDonough M, Smith MK, Okoroafor N, Jordt H, Wenderoth MP. 2014. Active learning increases student performance in science, engineering, and mathematics. Proc Natl Acad Sci 111:8410.
3. Bonwell CC, Eison JA. 1991. Active learning: creating excitement in the classroom. 1991 ASHE-ERIC higher education reports. ERIC Clearinghouse on Higher Education, The George Washington University, Washington, DC.
4. Honicke T, Broadbent J. 2016. The influence of academic self-efficacy on academic performance: a systematic review. Educ Res Rev 17:63–84.
5. Prince M. 2004. Does active learning work? A review of the research. J Eng Educ 93:223–231.
6. Snyder JJ, Sloane JD, Dunk RDP, Wiles JR. 2016. Peer-led team learning helps minority students succeed. PLOS Biol 14:e1002398.
7. Haak DC, HilleRisLambers J, Pitre E, Freeman S. 2011. Increased structure and active learning reduce the achievement gap in introductory biology. Science 332:1213–1216.
8. Ballen CJ, Wieman C, Salehi S, Searle JB, Zamudio KR. 2017. Enhancing diversity in undergraduate science: self-efficacy drives performance gains with active learning. CBE Life Sci Educ 16:ar56.
9. Ballen CJ, Aguillon SM, Awwad A, Bjune AE, Challou D, Drake AG, Driessen M, Ellozy A, Ferry VE, Goldberg EE, Harcombe W, Jensen S, Jørgensen C, Koth Z, McGaugh S, Mitry C, Mosher B, Mostafa H, Petipas RH, Soneral PAG. 2019. Smaller classes promote equitable student participation in STEM. BioScience 69:669–680.
10. Lorenzo M, Crouch CH, Mazur E. 2006. Reducing the gender gap in the physics classroom. Am J Phys 74:118–122.
11. Rainey K, Dancy M, Mickelson R, Stearns E, Moller S. 2019. A descriptive study of race and gender differences in how instructional style and perceived professor care influence decisions to major in STEM. Int J STEM Educ 6:6.
12. Cabrera AF, Colbeck CL, Terenzini PT. 2001. Developing performance indicators for assessing classroom teaching practices and student learning. Res High Educ 42:327–352.
13. Crouch CH, Mazur E. 2001. Peer instruction: ten years of experience and results. Am J Phys 69:970–977.
14. Bui KVT. 2002. First-generation college students at a four-year university: background characteristics, reasons for pursuing higher education, and first-year experiences. Coll Stud J 36:10.
15. Nunez A, Cuccaro-Alamin S. 1998. First-generation students: undergraduates whose parents never enrolled in postsecondary education. (Report number NCES 98-082.) US Department of Education, National Center for Education Statistics, Washington, DC.
16. Nomi T. 2005. Faces of the future: a portrait of first-generation community college students. American Association of Community Colleges.
17. Sirin SR. 2005. Socioeconomic status and academic achievement: a meta-analytic review of research. Rev Educ Res 75:417–453.
18. Stebleton MJ, Soria KM, Huesman RL. 2014. First-generation students' sense of belonging, mental health, and use of counseling services at public research universities. J Coll Couns 17:6–20.
19. Katrevich AV, Aruguete MS. 2017. Recognizing challenges and predicting success in first-generation university students. J STEM Educ Innov Res 18(2):40–44.
20. Pascarella ET, Pierson CT, Wolniak GC, Terenzini PT. 2004. First-generation college students: additional evidence on college experiences and outcomes. J High Educ 75:249–284.
21. Ramos-Sánchez L, Nichols L. 2007. Self-efficacy of first-generation and non-first-generation college students: the relationship with academic performance and college adjustment. J Coll Couns 10:6–18.
22. Wiederkehr V, Darnon C, Chazal S, Guimond S, Martinot D. 2015. From social class to self-efficacy: internalization of low social status pupils' school performance. Soc Psychol Educ 18:769–784.
23. Pajares F. 1996. Self-efficacy beliefs in academic settings. Rev Educ Res 66:543–578.
24. Bong M, Skaalvik EM. 2003. Academic self-concept and self-efficacy: how different are they really? Educ Psychol Rev 15:40.
25. Usher EL, Pajares F. 2008. Sources of self-efficacy in school: critical review of the literature and future directions. Rev Educ Res 78:751–796.
26. Talsma K, Schüz B, Schwarzer R, Norris K. 2018. I believe, therefore I achieve (and vice versa): a meta-analytic cross-lagged panel analysis of self-efficacy and academic performance. Learn Individ Differ 61:136–150.
27. Usher EL, Pajares F. 2009. Sources of self-efficacy in mathematics: a validation study. Contemp Educ Psychol 34:89–101.
28. Hattie J, Timperley H. 2007. The power of feedback. Rev Educ Res 77:81–112.
29. England BJ, Brigati JR, Schussler EE. 2017. Student anxiety in introductory biology classrooms: perceptions about

active learning and persistence in the major. PLOS One 12:e0182506-17.
30. Cooper KM, Downing VR, Brownell SE. 2018. The influence of active learning practices on student anxiety in large-enrollment college science classrooms. Int J STEM Educ 5:23.
31. Broeckelman-Post M, Johnson A, Reid Schwebach J. 2016. Calling on students using notecards: engagement and countering communication anxiety in large lecture. J Coll Sci Teach 45:27–33.
32. Cassady JC. 2004. The influence of cognitive test anxiety across the learning–testing cycle. Learn Instr 14:569–592.
33. Bryant FB, Kastrup H, Udo M, Hislop N, Shefner R, Mallow J. 2013. Science anxiety, science attitudes, and constructivism: a binational study. J Sci Educ Technol 22:432–448.
34. Ramirez G, Beilock SL. 2011. Writing about testing worries boosts exam performance in the classroom. Science 331:211–213.
35. Cassady JC, Johnson RE. 2002. Cognitive test anxiety and academic performance. Contemp Educ Psychol 27:270–295.
36. Cohen M. 2019. Think, pair, freeze: the association between social anxiety and student discomfort in the active learning environment. Scholarsh Teach Learn Psychol 5(4):265–277.
37. England BJ, Brigati JR, Schussler EE, Chen MM. 2019. Student anxiety and perception of difficulty impact performance and persistence in introductory biology courses. CBE Life Sci Educ 18:ar21.
38. Community College Anatomy and Physiology Education Research (CAPER). Award Abstract #1829157. NSF Award Search Community.
39. McIlroy D, Bunting B, Adamson G. 2000. An evaluation of the factor structure and predictive utility of a test anxiety scale with reference to students' past performance and personality indices. Br J Educ Psychol 70:17–32.
40. Connor KM, Kobak KA, Churchill LE, Katzelnick D, Davidson JR. 2001. Mini-SPIN: a brief screening assessment for generalized social anxiety disorder. Depress Anxiety 14:137–140.
41. Andrews TM, Leonard MJ, Colgrove CA, Kalinowski ST. 2011. Active learning not associated with student learning in a random sample of college biology courses. CBE Life Sci Educ 10:394–405.
42. Keeley J, Zayac R, Correia C. 2008. Curvilinear relationships between statistics anxiety and performance among undergraduate students: evidence for optimal anxiety. Stat Educ Res J 7(1):12.
43. Auerbach AJ, Higgins M, Brickman P, Andrews TC. 2018. Teacher knowledge for active-learning instruction: expert-novice comparison reveals differences. CBE Life Sci Educ 17:ar12.
44. Mazer JP, McKenna-Buchanan TP, Quinlan MM, Titsworth S. 2014. The dark side of emotion in the classroom: emotional processes as mediators of teacher communication behaviors and student negative emotions. Commun Educ 63:149–168.
45. Rocca KA. 2010. Student participation in the college classroom: an extended multidisciplinary literature review. Commun Educ 59:185–213.
46. Tanner KD. 2013. Structure matters: twenty-one teaching strategies to promote student engagement and cultivate classroom equity. CBE Life Sci Educ 12:322–331.
47. Mallow JV. 2006. Science anxiety: research and action. National Science Teachers Association.
48. Cooper KM, Brownell SE. 2016. Coming out in class: challenges and benefits of active learning in a biology classroom for LGBTQIA students. CBE Life Sci Educ 15:ar37.
49. Freeman S, Theobald R, Crowe AJ, Wenderoth MP. 2017. Likes attract: students self-sort in a classroom by gender, demography, and academic characteristics. Act Learn High Educ 18:115–126.