"I Like and Prefer to Work Alone": Social Anxiety, Academic Self-Efficacy, and Students' Perceptions of Active Learning

S. Hood,[†*] N. Barrickman,[‡*] N. Djerdjian,[§] M. Farr,[‡] S. Magner,[§] H. Roychowdhury,[‖] R. Gerrits,[¶] H. Lawford,[†] B. Ott,[#] K. Ross,[@] O. Paige,[†] S. Stowe,[†] M. Jensen,[**] and K. Hull[†]

[†]Bishop's University, Sherbrooke, QC J1M 1Z7, Canada; [‡]Department of Biology, Salt Lake City Community College, Salt Lake City, UT 84123; [§]Department of Biology, Anoka-Ramsey Community College, South Cambridge, MN 55008-5704; [‖]Science Department, Doña Ana Community College, Las Cruces, NM 88011; [¶]Department of Electrical Engineering and Computer Science, Milwaukee School of Engineering, Milwaukee, WI 53202-3109; [#]Department of Biology, Tyler Junior College, Tyler, TX 75711-9020; [@]Department of Biomedical Engineering, Georgia Tech and Emory University, Atlanta, GA 30332; and **College of Biological Sciences, University of Minnesota, Minneapolis, MN 55455

ABSTRACT

Although active learning improves student outcomes in science, technology, engineering, and mathematics (STEM) programs, it may provoke anxiety in some students. We examined whether two psychological variables, social anxiety (psychological distress relating to the fear of negative evaluation by others) and academic self-efficacy (confidence in one's ability to overcome academic challenges), interact with student perceptions of evidence-based instructional practices (EBIPs) and associate with their final grades in a STEM-related course. Human anatomy and physiology students in community college courses rated various EBIPs for their perceived educational value and their capacity to elicit anxiety (*N* = 227). In general, practices causing students the most anxiety (e.g., cold calling) were reported by students as having the least educational value. When controlling for students' self-reported grade point averages, socially anxious students rated several EBIPs as more anxiety inducing, whereas high-efficacy students reported less anxiety surrounding other EBIPs. Furthermore, mediation analysis revealed that individual differences in academic self-efficacy at the beginning of the term explained some of the negative association between students' social anxiety levels and final grades in the course. Our results, obtained in a community college context, support a growing body of evidence that social anxiety and academic self-efficacy are linked with how students perceive and perform in an active-learning environment.

INTRODUCTION

Despite significant evidence that active learning improves outcomes for most students, increases retention in science, technology, engineering, and mathematics (STEM) programs (Prince, 2004; Freeman *et al.*, 2014; Honicke and Broadbent, 2016), and fosters a more inclusive and equitable learning environment (Snyder *et al.*, 2016; Harris *et al.*, 2020; Theobald *et al.*, 2020), lecture still predominates in STEM classrooms across North America (Stains *et al.*, 2018). A variety of factors are thought to contribute to the limited uptake of evidence-based instructional practices (EBIPs), including instructor beliefs about and familiarity with these practices; contextual variables, such as classroom layout and departmental norms (Henderson and Dancy, 2007; Hora and Anderson, 2012; Avargil *et al.*, 2013; Goffe and Kauper, 2014; Lund and Stains, 2015); and mixed reception of these practices by students (Smith and Cardaciotto, 2011; Cavanagh *et al.*, 2016; Nguyen *et al.*, 2017). Indeed, the prospect of negative student

Kimberly Tanner, *Monitoring Editor*

Submitted Dec 12, 2019; Revised Dec 9, 2020; Accepted Dec 11, 2020

CBE Life Sci Educ March 1, 2021 20:ar12

DOI:10.1187/cbe.19-12-0271

*Address correspondence to: Suzanne Hood (shood@ubishops.ca); N. Barrickman (nancy.barrickman@slcc.edu).

reactions to a change in teaching technique (and the consequent impact on instructor evaluations) has been identified as a source of instructors' hesitation in adopting active learning (Yadav *et al.*, 2011).

Student apprehension concerning active learning may be due in part to particular EBIPs causing anxiety (England *et al.*, 2017; Cooper *et al.*, 2018; Cohen *et al.*, 2019; Downing *et al.*, 2020). Student ratings suggest that EBIPs vary in the degree to which they trigger anxiety, and this variability may be attributable in part to the opportunity for social evaluation involved in the instructional practice. For instance, cold calling (selecting a student to answer a question rather than asking for volunteers) has been shown to be particularly anxiety provoking, whereas answering clicker questions is less so (England *et al.*, 2017). Thematic analysis of interviews with university students and community college students suggests that anxiety in response to certain EBIPs is linked to the risk of being judged unfavorably by others in the classroom (e.g., fear of a negative perception for not knowing the answer or a fear of public speaking; Broeckelman-Post *et al.*, 2016; Cooper *et al.*, 2018; Downing *et al.*, 2020). Importantly, this socially oriented anxiety linked to fear of negative judgment may negatively affect student engagement with EBIPs: for example, some students report refraining from answering questions or sharing ideas in group-work settings due to social evaluation concerns (Eddy *et al.*, 2015; Cooper *et al.*, 2018). Anxiety may also increase the likelihood that students avoid active-learning classrooms on non-exam days (Broeckelman-Post *et al.*, 2016).

Students' emotional responses are important to consider in the use of EBIPs, given that anxiety can impair learning and academic performance (as reviewed in El Baze *et al.*, 2018). Anxiety affects all stages of the learning–testing cycle (planning and executing learning tasks, completing evaluations, and reflecting on performance; Cassady, 2004; Bryant *et al.*, 2013). It can hinder the use of deep-level cognitive skills such as critical thinking and synthesis and impair students' abilities to articulate their questions and ideas about course material (Downing *et al.*, 2020). Highly anxious students experience more discomfort in the classroom (Cohen *et al.*, 2019), tend toward having lower grades and Scholastic Aptitude Test scores (Hembree, 1988), and are more likely to drop out of a STEM program (Cassady and Johnson, 2002; England *et al.*, 2019). The negative relation between academic performance and anxiety has been well documented for specific subtypes of anxiety, such as generalized anxiety disorder (de Lijster *et al.*, 2018), evaluation or test anxiety (Richardson *et al.*, 2012), and subject-specific anxiety (e.g., math; Beilock and Maloney, 2015), and some recent evidence also shows a similar relationship with social anxiety (Brook and Willoughby, 2015; Scanlon *et al.*, 2020). Several features of STEM classrooms themselves have also been identified as anxiogenic for students, including large class sizes (McKinney *et al.*, 1983); a heightened atmosphere of competition among students; instructors who appear to students to be unapproachable or unsupportive (Daempfle, 2003); and a lack of representation of visible minorities and women in educational leadership (Mallow, 2006; Johnson, 2007). Together, these findings suggest that students' emotional states within the complex social context of the classroom can influence how effective active-learning practices are in supporting student learning.

Other psychological attributes likely play important roles in how and why EBIPs work and for whom these pedagogies are effective. Academic self-efficacy, or confidence in one's ability to overcome academic challenges, has been identified as one such important attribute (Artino, 2012). Academic self-efficacy is positively associated with persistence in the face of challenging material; self-perception of academic performance; and actual indicators of performance, including grades (Honicke and Broadbent, 2016). Academic self-efficacy correlates negatively with anxiety levels in university students (Raufelder and Ringeisen, 2016), and some findings suggest that heightened concern for evaluation by others might undermine academic self-efficacy by provoking students to doubt their intellectual abilities (Cooper *et al.*, 2018; Downing *et al.*, 2020). EBIPs are thought to promote academic self-efficacy by creating opportunities for students to apply their skills and overcome meaningful, challenging problems (often referred to as "mastery experiences"; Bong and Skaalvik, 2003; Usher and Pajares, 2009). Importantly, the benefits of these practices for narrowing the achievement gap between majority and underrepresented communities in STEM may depend, at least in part, on students from underrepresented communities increasing their academic self-efficacy (Ballen *et al.*, 2017).

The degree to which students perceive EBIPs as anxiety provoking may be attributable in some part to an interaction of psychological attributes such as self-efficacy with the demands of particular instructional strategies in the classroom. For example, student comments suggest that lack of confidence in their ability to meet a classroom challenge contributes to apprehension about some EBIPs (e.g., "Do I have the right answer if the instructor cold calls me?"; England *et al.*, 2017; Cooper *et al.*, 2018; Cohen *et al.*, 2019). Similarly, semistructured interviews with students indicate that those who express a stronger sense of self-efficacy with regard to active-learning activities are also those who report feeling more comfortable participating more intensively in these activities (e.g., volunteering ideas, contributing to discussions of problems; Cooper *et al.*, 2017).

In the present study, we assessed students' reported experiences of anxiety in response to various instructional practices and their ratings of how much each practice contributes to their learning. We also examined whether these perceptions were related to social anxiety levels and academic self-efficacy. Participants were students enrolled in human anatomy and physiology courses at 2-year community colleges. Two-year community college student populations are typically more diverse in both demographic and socioeconomic backgrounds compared with 4-year postsecondary institutions. For example, compared with classrooms in 4-year institutions, community college classrooms have, on average, a larger proportion of students who are of color, older than their early 20s, working outside school, and the first in their families to pursue postsecondary education (Radwin *et al.*, 2018). Importantly, some evidence indicates that rates of student attrition from health sciences programs are higher in community colleges than 4-year institutions (Chen and Soldner, 2013). As such, the reported value of EBIPs for enhancing equity in the classroom and improving student retention could be particularly significant in the 2-year community college context (Ma and Baum, 2016).

In the present study, participants' instructors introduced EBIPs during one semester. We administered surveys at the start

TABLE 1. Sample characteristics (N = 227)

Identified gender	Male % (n)	19.8% (45)
	Female % (n)	77.1% (175)
	Prefer not to answer % (n)	0.4% (1)
	Missing % (n)	2.6% (6)
Ethnicity	White % (n)	61.2% (139)
	Black % (n)	3.5% (8)
	Native or Alaskan Native % (n)	1.3% (3)
	Asian % (n)	9.3% (21)
	Native Hawaiian/Pacific Islander % (n)	1.3% (3)
	Other % (n)	19.8% (45)
	Prefer not to answer % (n)	0.9% (2)
	Missing % (n)	2.6% (6)
First-generation status	Yes % (n)	33.5% (76)
	No % (n)	46.7% (106)
	Unsure % (n)	1.8% (4)
	Prefer not to answer % (n)	0.4% (1)
	Missing % (n)	17.6% (40)

and end of the semester to assess students' levels of social anxiety and academic self-efficacy and then examined the relation of these psychological variables to students' perceptions of instructional practices and to their performances in a course. Specifically, we addressed the following questions: 1) How do students rate various instructional practices for the amount of anxiety each causes them and the degree to which each contributes to student learning? 2) When controlling for academic ability, do levels of social anxiety and academic self-efficacy predict students' ratings of instructional practices for how much anxiety each practice provokes? 3) When controlling for academic ability, do levels of social anxiety and academic self-efficacy predict students' ratings of instructional practices for how much each practice is perceived to contribute to student learning? 4) When controlling for academic ability, do students' levels of social anxiety and academic self-efficacy predict students' anticipated and actual academic performance in a course?

METHODS

Participants

An initial sample of 330 student participants was drawn from five different classes of human anatomy and physiology taught at three separate community colleges. Each of the five classes was taught by a different instructor. These colleges are located in western and midwestern states, and student populations are majority white in ethnicity (60–70%) (data retrieved from "College Insight: College Spotlight," Institute for College Access and Success, 2017–2018). Class size ranged from 29 to 90 students. Of this initial sample, 227 students completed ratings of the majority of the 12 teaching practices analyzed in the present study. The demographic makeup of this sample of 227 students is summarized in Table 1. Briefly, 77% of participants identified as female and 61% of the sample identified as being of white ethnicity. Students identifying as first in their families to pursue postsecondary education (first-generation students) constituted 34% of the sample. The demographic composition per class is presented in Supplemental Table 1.

Participants were recruited through the classrooms of five community college instructors (N.B., N.D., M.F., S.M., and H.R.) who were themselves participants in a larger study examining the adoption of active learning at the community college level (National Science Foundation Community College Anatomy and Physiology Education Research [CAPER] Award Abstract No. 1829157; https://nsf.gov/awardsearch/showAward?AWD_ID=1829157&HistoricalAwards=false). The objectives of this larger, ongoing study include introducing community college N.B., N.D., M.F., S.M., and H.R. to discipline-based educational research and evaluating the impact of EBIP adoption on perceptions, attitudes, and classrooms behaviors of both students and N.B., N.D., M.F., S.M., and H.R. For N.B., N.D., M.F., S.M., and H.R. this was the first time that they had adopted EBIPs with a formal, conscious intent to increase active learning in their classrooms and measure EBIP impact on students. N.B., N.D., M.F., S.M., and H.R. completed a 1-credit graduate-level course in educational research in the semester just before their adoption of EBIPs in their classrooms. Among topics reviewed in this graduate course, several EBIPs were highlighted for their impact in supporting student learning and their ease of implementation in the classroom, such as personal response systems, alone or in pairs; in-class quiz alone; and in-class quiz in a group. Throughout their participation in this larger study, N.B., N.D., M.F., S.M., and H.R. had virtual meetings with each other and the study's primary investigators to discuss their experiences.

To recruit student participants, N.B., N.D., M.F., S.M., and H.R. made an announcement in their respective classrooms at the beginning of the semester about the study, and students received a link by email to the online survey (Qualtrics). Participation was voluntary. An incentive of a small number of bonus points was offered to participants; however, students were also offered an alternative activity to receive the same amount of bonus points if they did not want to participate in the study. The Salt Lake Community College Institutional Review Board granted approval to M.F. (IRB# 00009566; FWA00021259) and to N.B (IRB00009566; FWA00021259). The Dona Ana Community College Institutional Review Board granted approval to H.R (IRB #17565). The Chair of the Anoka-Ramsey Community College Institutional Review Board deemed the research conducted by N.D and S.M. to be routine and, therefore, exempt from IRB review.

Each of the instructors implemented two to three EBIPs in their classrooms. Table 2 summarizes which EBIPs were adopted

(for additional information on how these EBIPs were implemented in each class, please see Supplemental Table 2).

Of the 103 participants who were not included in our analyzed sample, 46 were excluded due to a data-collection error that precluded linking start-of-term and end-of-term data. We were unable to assess whether these 46 participants differed in demographic attributes from the main sample, because these questions were not included in the end-of-term survey. Analyses of variance (ANOVA) of this subsample showed that mean ratings of teaching practices for anxiety caused and contribution to learning, mean social anxiety scores, and mean academic self-efficacy scores reported at the end of term by these participants did not differ significantly from the main sample. The remaining 57 participants who were not included in the main sample completed less than 10% of the questionnaire at the start of term. Among those who answered demographic questions, their characteristics resembled those of the main sample, although there were fewer participants identifying as white in ethnicity (36.8%) and more endorsing the "other" ethnicity category (28.1%) (Supplemental Table 3).

Measures

The complete questionnaire administered to students is available in the Supplemental Material. Students completed the same online questionnaire at the beginning and the end of the semester. At the beginning of the semester, the survey was administered within the first 2 weeks of class when instructors had just started to deploy their EBIPs in the classroom. We did not control for the amount of experience students had with EBIPs before administering the first survey.

Instructional Practices

We modified a Likert-type scale created by England *et al.* (2017) to ask students to evaluate several instructional practices in terms of how much anxiety they cause the students 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). The instructions asked students to evaluate the instructional practices without specifically directing them to think about the context of the current course. A core set of practices were included in the questionnaires administered in all of the classes (lecture, personal response system alone; personal response system in a group; volunteering to answer a question; cold calling by instructor; in-class quiz alone; in-class quiz in a group). These core practices were selected on the basis of having been reviewed by instructors in the context of completing their educational research graduate seminar (described earlier) or being practices commonly used in traditional classrooms (e.g., lecturing, cold calling). Other practices were included in each instructor's questionnaire only when the practice had been used in the instructor's classroom (think–pair–share, muddiest point, nongraded activity completed alone, nongraded activity completed in a group, quiz out of class). As a result of this, the sample sizes for these ratings vary across the practices. For statistical analysis, we treated these ratings as continuous and calculated mean ratings with standard deviations for each teaching practice (Norman, 2010). We assessed whether ratings for each instructional practice differed by class using ANOVAs with an alpha level corrected for multiple comparisons ($p < 0.001$), and we report mean ratings from each class from the start of term in Supplemental Tables 4 and 5.

Significant differences were found for the anxiety ratings of lecturing between the classes with the lowest and highest means (see Supplemental Table 4). Dropping these two classes from the data set did not alter the pattern of results we obtained using all data pooled across the classes; as such, we report data pooled across all five classes.

Academic Self-Efficacy

We evaluated students' self-reported academic self-efficacy using a 10-item scale developed by McIlroy and colleagues (2000). 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. The instructions asked students to respond to each statement without specifically directing them to think about the context of their current course. After reverse scoring some items, we calculated a total efficacy score for each student by summing across the values for all responses with a maximum possible score of 70. Cronbach's α analysis indicated good internal reliability of this scale when administered at the beginning of term ($\alpha = 0.77$) and at the end of term ($\alpha = 0.86$). No significant differences were found in academic self-efficacy levels across the five classes.

Social Anxiety

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; Connor *et al.*, 2001). 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 a 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 $\alpha = 0.84$) and at the end of term ($\alpha = 0.83$). No significant differences were found in social anxiety levels across the five classes.

Academic Performance Indicators

Additionally, students were asked to report at the start of the term their current grade point averages (GPAs) and their anticipated final grades in the course by choosing a letter grade ranging from "A+" to "E." Current GPA was coded using an inverted scale ranging from 1 to 22 (on which "1" indicated a 4.0 GPA, "2" indicated a 3.9, and so on; scale values continued to 22 indicating less than 2.0). Anticipated final grade was also coded using an inverted scale on which each letter grade was assigned a value ranging from 1 ("A+") to 12 ("E"). Final grades in the course were also collected in the data set. Anticipated and final grade data were available from three classes but were missing from two classes due to an error in data collection. Across these three classes, the mean anticipated final grade was between an "A–" and "B+," corresponding to a mean value of 2.4 ± 1.39 (95% CI [2.18, 2.61]), whereas the mean final grade received was $76.9\% \pm 19.3$ (95% CI [73.9, 78.4]). Data for each class are reported individually in Supplemental Table 6.

TABLE 2. Summary of EBIPs implemented in classes

EBIP	Features	Class(es) used
Group work	Students were assigned to work in small groups on assignments across the semester. Groups had discretion over how frequently they would meet. Students completed weekly reflections on their experience.	Class 5
In-class quiz: individual	Students answered timed multiple-choice questions individually.	Classes 1, 2, 3, 4
In-class quiz: group	Students discussed multiple-choice questions in a small group and submitted the group's answers upon reaching consensus.	Classes 1, 3, 4
Muddiest point	Individually, students identified the most confusing concept presented that day in class.	Class 1
Personal response system: individual	Students used a response system (e.g., clicker) to report an answer to a question. A histogram of student responses was shown to the class in real time.	Classes 1, 2, 3, 4
Personal response system: group	Students worked in groups to answer a question using a response system (e.g., clicker). A histogram of student responses was shown to the class in real time.	Classes 1, 3, 4
Think–pair–share	Students paired with a partner to discuss a timed conceptual question and submitted an answer using a personal response system.	Class 2

Questionnaires completed at the beginning and the end of the term were linked for each student using a personal identifier such as name or date of birth, depending on the class. 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.

Plan of Analysis

To address the first research question of how participants rate various instructional practices for anxiety caused by each and for their contribution to student learning, we calculated participants' average ratings of each instructional practice made at the beginning of the semester and at the end of the semester. To evaluate whether these ratings changed over the course of the semester, we used paired-sample *t* tests with a Bonferroni-corrected alpha level of 0.004 (0.05/12). This approach was used instead of a multivariate ANOVA to maximize the number of data points available for each instructional practice rating.

To address the second research question of whether social anxiety and academic self-efficacy predicted participants' mean ratings of instructional practices for anxiety caused, we conducted a series of linear regressions using mean social anxiety and academic self-efficacy levels reported at the beginning of the semester as predictors and an outcome of mean anxiety rating of each instructional practice made at the beginning of the semester. Given that anxiety typically correlates negatively with academic performance, we entered participants' self-reported GPAs at the beginning of the semester as a covariate in these analyses to control for differences in academic ability. Significance was evaluated using a Bonferroni-corrected alpha level of 0.004 (0.05/12).

A similar series of regressions was conducted to address the third research question of whether social anxiety and academic self-efficacy predicted participants' mean ratings of instructional practices for their contribution to student learning. For these analyses, the outcome variable was students' mean ratings of each practice's contribution to their learning, which was made at the beginning of the semester. Participants' self-reported GPAs at the beginning of the semester were entered as a covariate to control for differences in academic ability. Significance was evaluated using a Bonferroni-corrected alpha level of 0.004 (0.05/12).

To address the fourth question of whether social anxiety and academic self-efficacy predicted participants' anticipated and actual academic performance in a course, we conducted linear regressions using the predictors of social anxiety level and academic self-efficacy (as reported at the beginning of the semester) for the outcomes of anticipated grade (as reported at the beginning of the semester) and actual final grade (as reported by instructors at the end of the semester). Separate analyses were conducted for each of these outcomes. In all analyses, self-reported GPA at the beginning of the semester was entered as a covariate.

To test whether academic self-efficacy served as a mediator of the relation between social anxiety and the outcomes of anticipated grade and final received grade, we used the macro program PROCESS in SPSS (Hayes, 2017) to conduct a series of linear regressions as described by Baron and Kenny (1986), with bootstrapping to estimate 95% confidence intervals (5000 samples). Self-reported GPA at the beginning of the semester was entered as a covariate in this mediation analysis. As described in the *Results*, the direct effect of social anxiety on final course grade was not significant, which violates one of Baron and Kenny's (1986) original conditions for mediation testing. Despite this violation, we nonetheless pursued the mediation analysis to examine the indirect effect of social anxiety on grade through academic self-efficacy. This decision was made in view of previous literature establishing associations between these variables as well as evidence that it is not necessary to demonstrate a significant direct effect if a complete mediation is not anticipated (Shrout and Bolger, 2002).

RESULTS

Students Rate Instructional Practices with a Social Component as More Anxiety Provoking

We examined students' ratings of various instructional practices for the degree to which each caused students anxiety using a scale ranging from 1 (no anxiety) to 5 (extreme anxiety; Figure 1). At the start of the semester, students rated cold calling (3.99 ± 1.18, 95% CI [3.78, 4.20]) and volunteering to answer a question (3.16 ± 1.20, 95% CI [2.95, 3.37]) as the most anxiety-inducing practices, whereas nongraded activities completed alone (1.49 ± 0.79, 95% CI [1.28, 1.70]) were the least anxiety inducing. Lecturing was also rated as one of the least anxiety-inducing instructional practices (1.57 ± 0.92, 95% CI [1.42, 1.73]). Anxiety ratings of some instructional practices declined significantly by the end of term (personal response

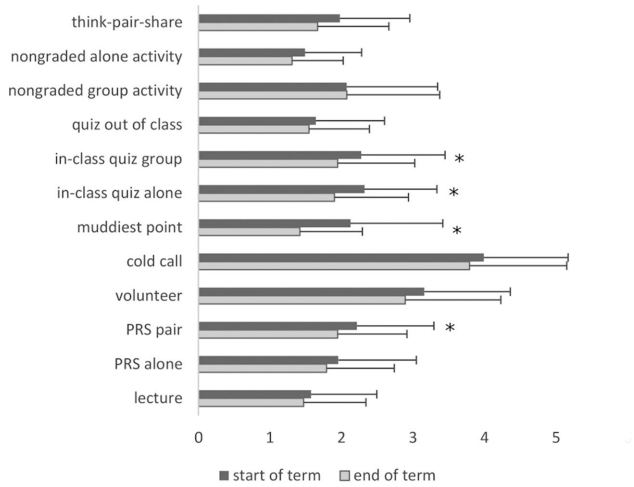

FIGURE 1. Ratings of teaching practices for anxiety (1 = no anxiety; 5 = extreme anxiety) made at the start of term and end of term. An asterisk (*) indicates a significant difference in anxiety rating between the start and end of term, $p < 0.004$. PRS, personal response system such as a clicker.

system in a group, muddiest point, in-class quiz alone, in-class quiz in a group), although these effect sizes were modest (data reported in Supplemental Table 7). Note that a Bonferroni-corrected alpha level of 0.004 (0.05/12) was used to assess significant changes in these ratings from the beginning to the end of term.

Given our interest in whether social anxiety influences students' perceptions of an active-learning classroom, we examined whether anxiety ratings of instructional practices differed based on whether the practice required a social component or allowed students to work individually. Using students' ratings from the beginning of the semester, we calculated a mean anxiety rating for "social" EBIPs (calculated by pooling ratings for personal response system in a group, think–pair–share, nongraded group activity, in-class quiz in a group, or speaking in front of a group by volunteering to answer a question or through instructor cold calling) and "non-social" EBIPs (personal response system alone; nongraded activity alone; in-class quiz alone; muddiest point; and out-of-class quiz alone). The mean anxiety rating of social EBIPs at the beginning of the semester was significantly higher (2.77 ± 0.96, 95% CI [2.59, 2.96]) compared with non-social EBIPs (2.07 ± 0.91, 95% CI [1.89, 2.24]) (paired-sample t test, t (105) = 8.15, $p < 0.001$, Cohen's $d = 0.79$).

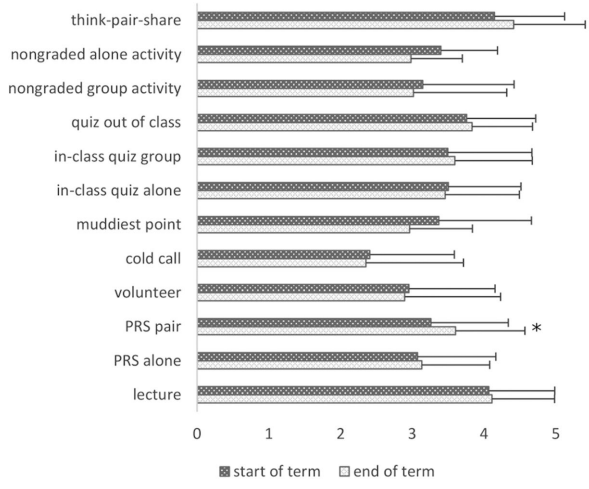

FIGURE 2. Ratings of teaching practices for how much each contributes to learning (1 = little contribution; 5 = significant contribution) made at the start of term and end of term. An asterisk (*) indicates a significant difference in rating between the start and end of term, $p < 0.004$. PRS, personal response system such as a clicker .

Students also rated instructional practices for how much they believed each contributed to their learning (Figure 2). At the start of term, lecturing (mean 4.07 ± 1.07, 95% CI [3.88, 4.25]) was considered to be one of the practices that contributed the most to learning relative to the majority of other practices. Among the EBIPs, think–pair–share (mean 4.15 ± 0.99, 95% CI [3.86, 4.43]) and quizzing out of class (mean 3.76 ± 1.18, 95% CI [3.44, 4.08]) were rated highly for contribution to learning, whereas cold calling was rated as having the least value (mean 2.41 ± 1.23, 95% CI [2.19, 2.63]). These ratings did not change significantly from the start to the end of term, except for personal response system in a group, which increased slightly (mean change 0.34 ± 1.28, 95% CI [0.13, 0.56], Cohen's $d = 0.27$) (Supplemental Table 8). Note that with a Bonferroni-corrected alpha level of 0.004 (0.05/12) was used to assess significant changes in these ratings from the beginning to the end of term.

Interestingly, we observed that students' ratings of instructional practices for their contribution to learning tended to vary inversely with the anxiety ratings of each practice. Using the mean ratings of each of the 11 EBIPs, we ranked these practices relative to one another for the amount of anxiety caused and for contribution to learning and compared these rankings (separate analyses were conducted using ratings made at the beginning of the semester and at the end of the semester). The instructional practices that ranked highest in contributing to learning (e.g., quizzing out of class) tended to be ranked low in causing anxiety, whereas highly anxiogenic practices such as cold calling and volunteering to answer a question ranked lowest in value for learning. Although this pattern was not significant using responses collected at the beginning of term (Kendall's tau-b (10) = –0.33, $p = 0.16$), it was in the end-of-term rankings (Kendall's tau-b (10) = –0.48, $p = 0.04$, $r^2 = 0.23$).

Socially Anxious Students Rate Several Instructional Practices as More Anxiety Provoking Than Do Non–socially Anxious Students

We next examined whether students' levels of self-reported social anxiety and academic self-efficacy predicted their anxiety ratings of instructional practices at the beginning of the semester. Within the sample, social anxiety as assessed using the mini-SPIN ranged from the minimum (0) to the maximum (12) levels possible (mean social anxiety score at the beginning of term = 6.21 ± 0.23, 95% CI [5.76, 6.66]). Academic self-efficacy scores at the beginning of term ranged from a minimum of 28 to a maximum of 70 (mean academic self-efficacy score at the beginning of term = 48.81 ± 0.59, 95% CI [47.64, 49.98]). Table 3 shows that students' social anxiety score correlated negatively, albeit modestly,

TABLE 3. Pearson correlations between social anxiety, academic self-efficacy, and self-reported GPA assessed at the beginning of term

	Social anxiety (*n*)	Academic self-efficacy (*n*)	Self-reported GPA (*n*)[a]
Social anxiety (*n*)	—		
Academic self-efficacy (*n*)	–0.29** (223)	—	
Self-reported GPA (*n*)	0.21** (214)	–0.25** (213)	—

[a]Self-reported GPA was scored according to a reverse scale.
**$p < 0.01$.

TABLE 4. Linear regressions using social anxiety and academic self-efficacy to predict anxiety ratings of instructional practices at the start of term

Practice (*n*)		*b* (95% CI)	SE *b*	ß	r_p
Lecturing (212)	Constant	2.366 (1.46, 3.28)	0.46		
	Self-reported GPA[a]	0.04 (0.01, 0.07)	0.01	0.17	0.17
	Social anxiety	0.03 (–0.01, 0.07)	0.02	0.11	0.11
	Academic self-efficacy	–0.02 (–0.04, –0.01)*	0.01	–0.20	–0.20
	$R^2 = 0.12$, $F(3, 208) = 9.56$, $p < 0.001$. *$p = 0.004$.				
PRS alone (213)	Constant	3.60 (2.54, 4.67)	0.54		
	Self-reported GPA	0.01 (–0.03, 0.04)	0.02	0.03	0.03
	Social anxiety	0.01 (–0.04, 0.05)	0.02	0.02	0.02
	Academic self-efficacy	–0.03 (–0.05, –0.02)*	0.01	–0.27	–0.25
	$R^2 = 0.08$, $F(3, 209) = 5.99$, $p = 0.01$. *$p < 0.001$.				
PRS group (213)	Constant	2.20 (1.25, 3.15)	0.48		
	Self-reported GPA	0.02 (–0.01, 0.05)	0.02	0.08	0.09
	Social anxiety	0.11 (0.07, 0.15)*	0.02	0.34	0.34
	Academic self-efficacy	–0.02 (–0.03, 0.00)	0.01	–0.13	–0.26
	$R^2 = 0.19$, $F(3, 209) = 16.29$, $p < 0.001$. $p < 0.001$.				
Volunteering (212)	Constant	2.63 (1.67, 3.60)	0.49		
	Self-reported GPA	0.01 (–0.02, 0.04)	0.02	0.04	0.04
	Social anxiety	0.19 (0.14, 0.23)*	0.02	0.52	0.51
	Academic self-efficacy	–0.01 (–0.03, 0.00)	0.01	–0.10	–0.11
	$R^2 = 0.33$, $F(3, 208) = 34.07$, $p < 0.001$. *$p < 0.001$.				
Cold calling (203)	Constant	3.85 (2.91, 4.80)	0.48		
	Self-reported GPA	–0.02 (–0.05, 0.01)	0.02	–0.07	–0.08
	Social anxiety	0.19 (0.15, 0.23)*	0.02	0.54	0.53
	Academic self-efficacy	–0.02 (–0.03, 0.00)	0.01	–0.13	–0.15
	$R^2 = 0.34$, $F(3, 199) = 34.18$, $p < 0.001$. *$p < 0.001$.				
Muddiest point (104)	Constant	1.25 (–0.38, 2.89)	0.82		
	Self-reported GPA	0.02 (–0.04, 0.08)	0.03	0.08	0.08
	Social anxiety	0.15 (0.08, 0.22)*	0.04	0.44	0.40
	Academic self-efficacy	0.00 (–0.03, 0.02)	0.01	–0.02	–0.02
	$R^2 = 0.22$, $F(3, 100) = 9.57$, $p < 0.001$. *$p < 0.001$.				
In-class quiz alone (213)	Constant	3.63 (–0.06, 0.00)	0.53		
	Self-reported GPA	–0.03 (–0.06, 0.00)	0.02	–0.12	–0.12
	Social anxiety	0.05 (0.01, 0.10)	0.02	0.16	0.15
	Academic self-efficacy	–0.03 (–0.05, –0.01)*	0.01	–0.23	–0.22
	$R^2 = 0.10$, $F(3, 209) = 7.27$, $p < 0.001$. *$p < 0.001$.				

(Continues)

TABLE 4. Continued

Practice (*n*)		*b* (95% CI)	SE *b*	ß	r_p
In-class quiz group (211)	Constant	1.78 (0.69, 2.86)	0.55		
	Self-reported GPA	0.04 (0.01, 0.07)	0.02	0.15	0.15
	Social anxiety	0.10 (0.05, 0.15)*	0.03	0.28	0.27
	Academic self-efficacy	–0.01 (–0.03, 0.01)	0.01	–0.05	–0.05
	$R^2 = 0.13$, $F(3, 207) = 10.71$, $p < 0.001$. *$p < 0.001$.				
Quiz out of class (74)	Constant	2.27 (0.79, 1.63)	0.80		
	Self-reported GPA	0.04 (–0.02, 0.09)	0.03	0.17	0.16
	Social anxiety	0.05 (–0.03, 0.12)	0.04	0.16	0.15
	Academic self-efficacy	–0.02 (–0.05, 0.00)	0.01	–0.21	–0.20
	$R^2 = 0.18$, $F(3, 70) = 5.09$, $p = 0.003$.				
Nongraded group activity (77)	Constant	1.29 (–0.75, 3.34)	1.03		
	Self-reported GPA	0.02 (–0.05, 0.09)	0.03	0.07	0.06
	Social anxiety	0.12 (0.03, 0.21)	0.05	0.33	0.30
	Academic self-efficacy	0.0 (–0.04, 0.03)	0.02	–0.02	–0.02
	$R^2 = 0.14$, $F(3, 73) = 3.96$, $p = 0.011$.				
Nongraded alone activity (76)	Constant	2.59 (1.12, 4.06)	0.74		
	Self-reported GPA	0.02 (–0.03, 0.07)	0.02	0.09	0.08
	Social anxiety	0.01 (–0.06, 0.08)	0.03	0.04	0.04
	Academic self-efficacy	–0.03 (–0.05, 0.00)	0.01	–0.27	–0.24
	$R^2 = 0.11$, $F(3, 72) = 3.13$, $p = 0.03$.				
Think–pair–share (60)	Constant	4.64 (2.54, 6.75)	1.05		
	Self-reported GPA	–0.04 (–0.15, 0.06)	0.05	–0.11	–0.11
	Social anxiety	0.03 (–0.06, 0.11)	0.04	0.08	0.08
	Academic self-efficacy	–0.05 (–0.09, –0.02)†	0.02	–0.40	–0.37
	$R^2 = 0.17$, $F(3, 56) = 3.69$, $p = 0.02$. †$p = 0.005$.				

[a]The variable GPA was scored on a reverse scale.

with reported academic self-efficacy and with prior academic achievement (assessed using self-reported GPA), whereas academic self-efficacy correlated positively with reported GPA at the beginning of the semester.

A Bonferroni-corrected alpha level of 0.004 (0.05/12) was used to assess the significance of social anxiety and academic self-efficacy in predicting students' anxiety rating of each instructional practice. When controlling for reported GPA, participants' social anxiety significantly predicted mean anxiety ratings of several instructional practices made at the beginning of the semester. However, these effect sizes were modest (see Table 4). Specifically, these practices were personal response system in a group, volunteering to answer a question, cold calling, muddiest point, and in-class quiz in a group. We note that four of these five practices involve a social component.

Within the same regression models, we found that academic self-efficacy significantly predicted anxiety ratings of some instructional practices, such that high-efficacy students rated these practices as causing less anxiety. However, these effect sizes were modest. Specifically, these practices were lecture, personal response system alone, and in-class quiz alone. There was a near-significant trend for think–pair–share ($p = 0.005$). Interestingly, these practices did not overlap with those predicted by social anxiety levels. We also note that three of these four practices involve students working independently.

Students with Higher Academic Self-Efficacy Rate Some Instructional Practices as Contributing More to Learning Than Do Students with Low Academic Self-Efficacy

We next examined whether students' levels of social anxiety and academic self-efficacy predicted beginning-of-semester ratings of instructional practices for their contribution to learning. Consistent with the analyses performed using anxiety rating as the outcome variable, the significance of social anxiety and academic self-efficacy in predicting students' ratings of contribution to learning was assessed against a Bonferroni-corrected alpha level of 0.004 (0.05/12). These results are shown in Table 5. When controlling for GPA, students' social anxiety levels did not predict these ratings for any instructional practice. In contrast, academic self-efficacy positively predicted ratings of some instructional practices for their contribution to learning, specifically personal response system alone, in-class quiz alone, in-class quiz in a group, and cold calling. Effect sizes were modest, however.

Academic Self-Efficacy Predicts Final Course Grade and Explains Some of the Association between Social Anxiety and Final Course Grade

Given that anxiety can negatively impact academic performance, we investigated whether students' social anxiety at the beginning of term was related to their anticipated and actual

TABLE 5. Linear regressions using social anxiety and academic self-efficacy to predict ratings of instructional practices' contribution to learning at the start of term

Practice (*n*)		*b* (95% CI)	SE *b*	ß	r_p
Lecturing (213)	Constant	3.09 (2.06, 4.13)	0.52		
	Self-reported GPA[a]	0.00 (–0.03, 0.03)	0.02	0.00	0.00
	Social anxiety	0.01 (–0.04, 0.06)	0.02	0.03	0.03
	Academic self-efficacy	0.02 (0.00, 0.04)	0.01	0.15	0.14
	$R^2 = 0.02$, $F(3, 209) = 1.36$, $p = 0.26$.				
PRS alone (213)	Constant	1.61 (0.53, 2.68)	0.55		
	Self-reported GPA	0.02 (–0.01, 0.06)	0.02	0.01	0.09
	Social anxiety	0.02 (–0.03, 0.07)	0.02	0.07	0.06
	Academic self-efficacy	0.03 (0.01, 0.04)*	0.01	0.20	0.18
	$R^2 = 0.04$, $F(3, 209) = 2.70$, $p = 0.05$. *$p = 0.007$.				
PRS group (213)	Constant	3.64 (2.46, 4.81)	0.60		
	Self-reported GPA	–0.03 (–0.07, 0.01)	0.02	–0.12	–0.12
	Social anxiety	0.00 (–0.05, 0.05)	0.03	0.01	0.01
	Academic self-efficacy	0.00 (–0.02, 0.02)	0.01	–0.02	–0.02
	$R^2 = 0.01$, $F(3, 209) = 0.99$, $p = 0.40$.				
Volunteering (213)	Constant	2.44 (1.27, 3.61)	0.59		
	Self-reported GPA	–0.01 (–0.05, 0.03)	0.02	–0.04	–0.04
	Social anxiety	–0.04 (–0.09, 0.23)	0.03	–0.10	–0.09
	Academic self-efficacy	0.02 (0.00, 0.04)	0.01	0.12	0.11
	$R^2 = 0.04$, $F(3, 209) = 2.65$, $p = 0.05$.				
Cold calling (212)	Constant	0.59 (–0.62, 1.81)	0.62		
	Self-reported GPA	0.02 (–0.02, 0.05)	0.02	0.05	0.06
	Social anxiety	–0.04 (–0.09, 0.02)	0.03	–0.10	–0.10
	Academic self-efficacy	0.04 (0.02, 0.06)*	0.01	0.28	0.26
	$R^2 = 0.10$, $F(3, 208) = 7.42$, $p < 0.001$ *$p < 0.001$.				
Muddiest point (102)	Constant	2.41 (0.75, 4.06)	0.83		
	Self-reported GPA	–0.02 (–0.08, 0.04)	0.03	–0.06	–0.05
	Social anxiety	0.02 (–0.05, 0.09)	0.04	0.07	0.06
	Academic self-efficacy	0.02 (–0.01, 0.04)	0.01	0.13	0.12
	$R^2 = 0.02$, $F(3, 98) = 0.74$, $p = 0.53$.				
In-class quiz alone (212)	Constant	1.35 (0.32, 2.39)	0.52		
	Self-reported GPA	0.02 (–0.01, 0.06)	0.02	0.10	0.10
	Social anxiety	0.00 (–0.04, 0.05)	0.02	0.00	0.00
	Academic self-efficacy	0.04 (0.02, 0.06)*	0.01	0.31	0.29
	$R^2 = 0.09$, $F(3, 208) = 6.65$, $p < 0.001$. *$p < 0.001$.				
In-class quiz group (211)	Constant	2.10 (0.98, 3.22)	0.57		
	Self-reported GPA	–0.01 (–0.05, 0.02)	0.02	–0.06	–0.05
	Social anxiety	0.01 (–0.04, 0.06)	0.03	0.04	0.04
	Academic self-efficacy	0.03 (0.01, 0.05)*	0.01	0.21	0.20
	$R^2 = 0.05$, $F(3, 207) = 3.43$, $p = 0.02$. *$p = 0.005$.				
Quiz out of class (77)	Constant	1.15 (–0.81, 3.10)	0.98		
	Self-reported GPA	0.02 (–0.05, 0.08)	0.03	0.07	0.06
	Social anxiety	0.07 (–0.02, 0.16)	0.04	0.21	0.19
	Academic self-efficacy	0.04 (0.01, 0.07)	0.02	0.33	0.29
	$R^2 = 0.10$, $F(3, 73) = 2.64$, $p = 0.06$.				

(Continues)

TABLE 5. Continued

Practice (*n*)		*b* (95% CI)	SE *b*	ß	r_p
Nongraded group activity (76)	Constant	2.47 (0.23, 4.70)	1.12		
	Self-reported GPA	0.02 (–0.06, 0.09)	0.04	0.06	0.05
	Social anxiety	–0.09 (–0.19, 0.01)	0.05	–0.23	–0.20
	Academic self-efficacy	0.02 (–0.02, 0.06)	0.02	0.14	0.13
	$R^2 = 0.09$, $F(3, 72) = 2.24$, $p = 0.09$.				
Nongraded alone activity (77)	Constant	1.55 (–0.79, 3.90)	1.18		
	Self-reported GPA	–0.04 (–0.11, 0.04)	0.04	–0.12	–0.11
	Social anxiety	0.06 (–0.05, 0.16)	0.05	0.14	0.13
	Academic self-efficacy	0.04 (–0.01, 0.08)	0.02	0.25	0.22
	$R^2 = 0.08$, $F(3, 73) = 2.21$, $p = 0.10$.				
Think–pair–share (60)	Constant	4.51 (2.48, 6.53)	1.01		
	Self-reported GPA	–0.13 (–0.23, –0.03)	0.05	–0.35	–0.32
	Social anxiety	–0.01 (–0.09, 0.08)	0.04	–0.03	–0.03
	Academic self-efficacy	0.00 (–0.03, 0.04)	0.02	0.02	0.02
	$R^2 = 0.13$, $F(3, 56) = 2.77$, $p = 0.05$.				

[a]The variable GPA was scored on a reverse scale.

academic performance in the course. When controlling for GPA, neither social anxiety nor academic self-efficacy levels reported at the start of term significantly predicted anticipated grade in the course. For actual final grade received in the course, level of academic self-efficacy was a significant predictor, whereas social anxiety at the beginning of term was not when controlling for GPA (Table 6).

Previous findings (Hull *et al.*, 2019) indicate that there may be a mediating relation between academic self-efficacy and anxiety in predicting academic performance; that is, anxiety level may predict subsequent academic performance because it is associated in part with the amount of confidence one has in one's ability to meet academic challenges. We undertook a mediation analysis to test this relation in our data, and these results are summarized in Figure 3. When controlling for prior GPA, the direct effect of social anxiety level on final course grade was not significant ($b = –0.64$, $p = 0.15$). Social anxiety score negatively predicted academic self-efficacy at the beginning of term, when controlling for GPA ($b = –0.73$, 95% CI [–1.12, –0.34]). Academic self-efficacy score at the beginning of term also predicted actual received final grade when controlling for GPA and social anxiety level ($b = 0.48$, 95% CI [0.13, 0.82]). We then tested in our data set whether the association of social anxiety with final grade in the course was significantly mediated by academic self-efficacy when controlling for students' self-reported GPA. As shown in Figure 3, there was a significant indirect effect of academic self-efficacy in accounting for the relation between social anxiety and final grade in the course ($b = –0.35$, bootstrapped 95% CI [–0.69, –0.08]). However, the size of this mediation effect was small (standardized indirect effect = –0.06, bootstrapped 95% CI [–0.12, –0.01]).

DISCUSSION

We report here that community college students experience varied levels of anxiety in response to several types of instructional practices and that individual differences in social anxiety and academic self-efficacy are associated with the amount of anxiety elicited by these practices. In our sample, students who were higher in social anxiety tended to perceive particular instructional practices as more anxiety inducing than did low-anxiety students, even when controlling for previous academic achievement. Students with high social anxiety also tended to have lower levels of academic self-efficacy, and low-efficacy students tended to receive a lower final grade even when controlling for prior academic achievement. In the following sections, we discuss the main findings from this study, consider the impact of some limitations on our findings, and propose some practical implications derived from our results.

Students Perceive Some Instructional Practices as Particularly Anxiety Provoking and Some Practices as Having Limited Value for Learning

Consistent with previous reports, our participants confirmed that cold calling and volunteering to answer a question are

TABLE 6. Linear regression using social anxiety and academic self-efficacy levels at the beginning of term to predict actual grade received, with self-reported GPA entered as a covariate ($n = 158$).

	b (95% CI)	SE *b*	ß	r_p
Constant	64.08 (43.81, 84.81)	10.26		
Self-reported GPA[a]	–1.23 (–1.84, –0.62)*	0.31	–0.30	–0.31
Social anxiety	–0.64 (–1.51, 0.24)	0.44	–0.11	–0.12
Academic self-efficacy	0.48 (0.13, 0.82)*	0.17	0.21	0.22

[a]GPA was scored using a reverse scale.
$R^2 = 0.07$, $F(3, 154) = 13.81$, $p < 0.001$.
*$p < 0.001$.

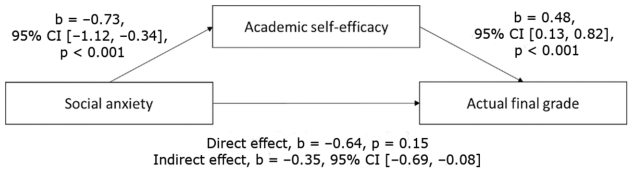

FIGURE 3. Model of academic self-efficacy as a mediator of the association between social anxiety and final grade received in the course when controlling for self-reported GPA. Unstandardized regression coefficients are shown. The indirect effect of social anxiety on final grade received via academic self-efficacy was significant.

intimidating activities (England *et al.*, 2017; Cooper *et al.*, 2018). This study also revealed that practices involving social interaction such as group quizzes, think–pair–share, and nongraded group activities also ranked as slightly more anxiety provoking compared with individual activities such as using a personal response system alone. This pattern may lend support to the view that active learning may induce anxiety when it creates opportunities for social judgment.

It is worth noting that experiencing low levels of anxiety can actually facilitate focused attention and learning in some individuals, particularly when completing activities that are familiar or relatively simple (Yerkes and Dodson, 1908; Keeley *et al.*, 2008). Furthermore, mild anxiety is not necessarily perceived by students as a bad thing in the classroom (Cooper *et al.*, 2018). However, students in our sample did not appear to equate anxiety with benefit to their learning; rather, EBIPs that were rated as the most anxiogenic also tended to be those rated as having the least educational value, and vice versa. This inverse relationship may reflect students' experience with the known impairing effects of heightened anxiety on cognitive functions such as working memory and goal-focused attention, which are needed to successfully complete classroom activities (Beilock *et al.*, 2004; Mowbray, 2012).

With the exception of cold calling, students rated all teaching practices on average as contributing at least moderately to their learning. Interestingly, their ratings revealed a preference for lecturing as one of the most valued pedagogical tools. Ratings of teaching practices also changed very little over the term, despite the fact that instructors integrated more than one new EBIP into their course (i.e., increased familiarity with new teaching practices did not markedly change students' sense of what works in the classroom by the end of the semester). These results could suggest that student beliefs contribute to the inertia against adopting EBIPs: instructors may be reluctant to move away from lecturing, a traditional teaching method, because not only they but also their students perceive it to be effective. This interpretation is in line with recent findings that students perceive themselves as learning more in lecture-based classrooms despite assessments indicating that content mastery is better in an active-learning environment (Deslauriers *et al.*, 2019). Student ratings of lecturing may also be influenced by greater familiarity with this teaching practice. Given that lecturing is the most widely practiced teaching technique, students' sense of what pedagogies work best may be confounded with established expectations of what "should" be done in the classroom.

Social Anxiety and Academic Self-Efficacy Predict Students' Perceptions of Some Instructional Practices

We also report here that the psychological attributes of social anxiety and academic self-efficacy play a role in how students perceive instructional practices. In our sample, social anxiety levels tended to correlate negatively with academic self-efficacy and academic performance, patterns consistent with existing literature. Interestingly, even when controlling for students' academic ability using self-reported GPA, socially anxious students gave higher anxiety ratings to several instructional practices at the beginning of the semester, and particularly to those having a social component, whereas students high in academic self-efficacy tended to give lower anxiety ratings. This pattern suggests that socially anxious students not only begin the term as more apprehensive of the classroom, but also that they may be more reluctant to engage in evidence-based instructional activities.

Students' reported levels of academic self-efficacy also positively predicted the perceived value of several instructional practices for contribution to learning. That is, after controlling for academic ability, students with greater confidence in their ability to meet academic challenges rated some instructional practices as having more educational value compared with ratings made by low-efficacy students. We note that three of these four practices (cold calling, personal response system alone, in-class quiz alone, in-class quiz in a group) involved working independently on an activity that would receive feedback in class (and, potentially, feedback that could be seen by others in the class). This result may relate to findings that academic self-efficacy is associated with greater persistence in the classroom and with students' reported openness to active-learning practices (Cooper *et al.*, 2017); that is, perhaps students with greater academic self-efficacy are more comfortable engaging in classroom activities that may reveal gaps in one's knowledge in real time. In turn, deeper engagement in these activities through, for example, more participation in discussions and volunteering answers to questions may increase the likelihood that students experience firsthand the benefits of these activities for their learning. Taken together, our findings would appear to support a larger body of literature that both academic self-efficacy and social anxiety play important roles in influencing students' perceptions of an active-learning classroom and that these factors may affect students' degree of engagement with an active-learning environment.

Academic Self-Efficacy Predicts Academic Performance in a Course

The present findings also show that students' levels of academic self-efficacy at the beginning of the semester are associated with their actual grades received in a course, even when controlling for prior academic achievement. In contrast to previous findings (Brook and Willoughby, 2015), however, social anxiety was not a significant predictor of final grade in our sample. Despite the lack of a significant direct effect between social anxiety and grade in this instance, the mediation model demonstrated that academic self-efficacy can account for a significant portion of the shared variance between social anxiety and academic outcome. This pattern would seem to be generally consistent with existing literature on the relationships between anxiety, academic self-efficacy, and academic performance

measures (Seipp, 1991; Raufelder and Ringeisen, 2016; Hull *et al.*, 2019) and poses some considerations for practical takeaways from this study, is as described in *Practical Implications*.

The design of the present study does not allow for any causal inferences to be drawn about the relationships of these psychological variables with student performance. However, previous literature indicates that students with more anxiety report being less able to engage deeply with active-learning activities (whether in terms of the amount of students' contributions to classroom activities with peers or in their abilities to reflect critically). As such, one might speculate that targeted actions within the classroom could prove useful in increasing low-efficacy students' engagement with an active-learning classroom and could support actual academic performance. Such interventions could include activities designed to improve students' beliefs in their own academic abilities, including the use of low-stakes, mastery-focused assignments with clear and constructive feedback (Usher and Pajares, 2009; Tanner, 2013). To the extent that reducing social anxiety in students may facilitate the development of academic self-efficacy, actions undertaken to mitigate classroom features that may exacerbate anxiety in students may also prove beneficial (e.g., decreasing overly competitive classroom climates, increasing representation of minority groups in classroom instructors, increasing instructor transparency in the rationale behind instructional practices, supporting greater instructor availability and approachability).

Limitations

A number of limitations impact the nature and strength of the conclusions that can be drawn from this study. Among these, we note that some features of the design and administration of our survey may have introduced confounds in our data. For example, in contrast to other studies examining the relationship between active learning and student anxiety, the wording of our survey did not direct participants to reflect on and answer questions in reference to a specific context such as the current anatomy and physiology class, all science classes in general, or within their programs. We also did not validate in advance the wording of the Likert-type scales used by students to rate instructional practices before we deployed the survey. As a result, it is possible that there may have been some differences across participants in how they interpreted and answered the questions. Order effects in the presentation of demographic questions and answer options may have also played a role in how participants subsequently answered questions related to social anxiety and academic self-efficacy. For example, asking students to begin the surveys by identifying personal attributes like gender and ethnicity and listing answer options that presented "majority" STEM community attributes first, such as male gender and Caucasian ethnicity, may have inadvertently primed stereotypes in participants. Subconscious stereotype threat in individuals identifying as nonmajority community members could have systematically biased responses about anxiety and academic self-efficacy levels as well as anticipated grade (Steele, 1997).

Furthermore, we did not include any mechanisms to assess and control for participants' degree of experience with various instructional practices at the time of completing the surveys. In particular, we did not specifically control for the amount of instructors' use of their EBIPs in the classroom before the first round of the survey was administered. We also did not ask participants about their degree of familiarity with various EBIPs from previous classes. Given that students' familiarity with EBIPs may influence their reported sense of self-efficacy with respect to these practices (Cooper *et al.*, 2017), our inability to control for students' prior EBIP exposure may have played a role in how participants responded on the surveys. With respect to the beginning-of-term survey, this limitation may have introduced some ambiguity in the interpretation of participants' ratings of instructional practices; that is, it is possible that some participants' ratings of a practice reflected a "fear of the unknown" compared with ratings made by other participants who had some prior experience with that practice. However, we note here that ratings of the instructional practices in the overall sample did not change substantively from the beginning to the end of the semester. This lack of change over time may suggest that increased familiarity with several types of EBIPs did not markedly alter the aggregate response pattern of students in our sample.

Additional limitations of our design include inter-instructor variation in the types of EBIPs selected for implementation and the methods used to employ each practice in a classroom. As shown in Supplemental Table 2, the implementation of some practices varied across instructors; for example, in the use of personal response systems for individual students, some instructors restricted time for these questions and graded answers for accuracy, whereas others did not. This may have consequently introduced variability in students' ratings of practices, because previous evidence shows that the specific characteristics of use of an EBIP can influence how anxiogenic it is perceived to be (Cooper *et al.*, 2018). We did not collect comprehensive data to evaluate how instructors presented their EBIPs nor how much students engaged in these practices. Prior evidence suggests that instructor-associated variables such as their openness and availability to students as well as their efforts to explain the rationale underlying the use of EBIPs are positively associated with student perceptions of active learning.

Finally, some features of our sample limit the generalizability of our results. Our data set was collected over only a single semester (albeit from three different institutions separated geographically). Furthermore, there was significant attrition from the pool of participants who initially consented to the project, and the makeup of the final sample was predominantly white and female. Importantly, social anxiety levels have been found to vary according to some demographic characteristics such as gender, whereby women tend to report higher levels of social anxiety than men (Faravelli *et al.*, 2013). Taken together, these limitations highlight the need for replication. As the present study was conducted within a larger, multiyear project, more data collection in the coming year will assist in evaluating the reliability of the patterns we report here.

Practical Implications

What practical implications do our findings have for using active-learning techniques in the classroom? First, these results highlight the importance of instructor awareness that their instructional strategy choices can impact students' emotional state and that this impact may be unpleasant for some. Findings to date would suggest that the method by which EBIPs, and particularly social EBIPs, are introduced and implemented has a

bearing on how much anxiety certain instructional strategies may provoke in a student. For example, previous reports indicate that design choices such as making activities low stakes or no stakes in terms of grading, providing ample time for activity completion, and allowing students to self-select working groups or partners may help to make particular EBIPs less intimidating (Cooper and Brownell, 2016; Freeman *et al.*, 2017; Cooper *et al.*, 2018). Instructor behaviors might also help to temper students' sensitivity to social judgment in the classroom (Pollock and Finkelstein, 2008; Andrews *et al.*, 2011; Bernstein, 2018): for example, students may benefit from a brief discussion about the evidence that learning happens through conversations and exchanges with others (Vygotsky, 1980; Freeman *et al.*, 2017). At a departmental or institution level, providing psychoeducation for students to learn strategies to manage anxiety may also be valuable (Ayres *et al.*, 2017). Instructor efforts to explain to students the pedagogical value of EBIPs at both the beginning of semester and periodically throughout a course have also been proposed as useful in decreasing student apprehension toward EBIPs (Seidel and Tanner, 2013).

A second implication of our findings is that efforts to promote academic self-efficacy early in a course may improve students' perceptions of an active-learning classroom and their likelihood of success in a course. Although the nature of the present study does not support inferring a causal link between academic self-efficacy, students' attitudes toward instructional practices, and academic achievement, the pattern of results that we report here would appear to be consistent with a growing body of literature suggesting that academic self-efficacy is an important component of student success. Because mastery experiences with clear, constructive feedback are among the most effective means of enhancing self-efficacy, instructors could attempt to structure their classroom activities so that students have opportunities from the beginning of a course to succeed in solving meaningful problems and to reflect on their thinking. Other interventions that promote academic self-efficacy include the use of peer models (e.g., teaching assistants, lab demonstrators), particularly those who reflect the demographic characteristics of observing students (Cooper and Brownell, 2016; Freeman *et al.*, 2017).

CONCLUSION

Taken together, our results add to the growing body of evidence that students do not experience an active-learning classroom in a uniform way. Rather, individual differences in students' psychological attributes appear to be a meaningful component of the recipe for using active learning successfully, a recipe that also includes influential contributions from variables such as instructor behaviors and larger environmental factors in the classroom (Johnson, 2007; Usher and Pajares, 2009; Seidel and Tanner, 2013). Considering how individual differences interact with other known ecological variables in the classroom will likely be an important part of any strategy to increase the widescale adoption of active learning in STEM.

ACKNOWLEDGMENTS

This study was funded by a grant from the National Science Foundation Community College Anatomy and Physiology Education Research (CAPER) Award Abstract No. 1829157.

REFERENCES

Andrews, T. M., Leonard, M. J., Colgrove, C. A., & Kalinowski, S. T. (2011). Active Learning Not Associated with Student Learning in a Random Sample of College Biology Courses. *CBE—Life Sciences Education*, *10*(4), 394–405. doi: 10.1187/cbe.11-07-0061

Artino, A. R. (2012). Academic self-efficacy: From educational theory to instructional practice. *Perspectives on Medical Education*, *1*(2), 76–85. doi: 10.1007/s40037-012-0012-5

Avargil, S., Herscovitz, O., & Dori, Y. J. (2013). Challenges in the transition to large-scale reform in chemical education. *Thinking Skills and Creativity*, *10*, 189–207. doi: 10.1016/j.tsc.2013.07.008

Ayres, I., Bankman, J., Fried, B., & Luce, K. (2017). Anxiety psychoeducation for law students: A pilot program. *Journal of Legal Education*, *67*, 118–132.

Ballen, C. J., Wieman, C., Salehi, S., Searle, J. B., & Zamudio, K. R. (2017). Enhancing diversity in undergraduate science: Self-efficacy drives performance gains with active learning. *CBE—Life Sciences Education*, *16*(4), ar56. doi: 10.1187/cbe.16-12-0344

Baron, R. M., & Kenny, D. A. (1986). The moderator-mediator variable distinction in social psychological research: conceptual, strategic, and statistical considerations. *Journal of personality and social psychology*, *51*(6), 1173–1182. https://doi.org/10.1037//0022-3514.51.6.1173

Beilock, S. L., Kulp, C. A., Holt, L. E., & Carr, T. H. (2004). More on the fragility of performance: Choking under pressure in mathematical problem solving. *Journal of Experimental Psychology: General*, *133*(4), 584–600. doi: 10.1037/0096-3445.133.4.584

Beilock, S. L., & Maloney, E. A. (2015). Math anxiety: A factor in math achievement not to be ignored. *Policy Insights from the Behavioral and Brain Sciences*, *2*(1), 4–12. doi: 10.1177/2372732215601438

Bernstein, D. A. (2018). Does active learning work? A good question, but not the right one. *Scholarship of Teaching and Learning in Psychology*, *4*(4), 290. doi: 10.1037/stl0000124

Bong, M., & Skaalvik, E. M. (2003). Academic self-concept and self-efficacy: How different are they really? *Educational Psychology Review*, *15*(1), 1–40. doi: 10.1023/A:1021302408382

Broeckelman-Post, M., Johnson, A., & Schwebach, J. R. (2016). Calling on students using notecards: Engagement and countering communication anxiety in large lecture. *Journal of College Science Teaching*, *45*(5), 27.

Brook, C. A., & Willoughby, T. (2015). The social ties that bind: Social anxiety and academic achievement across the university years. *Journal of Youth and Adolescence*, *44*(5), 1139–1152. doi: 10.1007/s10964-015-0262-8

Bryant, F. B., Kastrup, H., Udo, M., Hislop, N., Shefner, R., & Mallow, J. (2013). Science anxiety, science attitudes, and constructivism: A binational study. *Journal of Science Education and Technology, 22*(4), 432–448. doi: 10.1007/s10956-012-9404-x

Cassady, J., & Johnson, R. (2002). Cognitive test anxiety and academic performance. *Contemporary Educational Psychology*, *27*, 270–295. doi: 10.1006/ceps.2001.1094

Cassady, J. C. (2004). The influence of cognitive test anxiety across the learning–testing cycle. *Learning and Instruction*, *14*(6), 569–592. doi: hTtps://doi.org/10.1016/j.learninstruc.2004.09.002

Cavanagh, A. J., Aragón, O. R., Chen, X., Couch, B. A., Durham, M. F., Bobrownicki, A., ... & Graham, M. J. (2016). Student buy-in to active learning in a college science course. *CBE—Life Sciences Education, 15*(4), ar76.

Chen, X., & Soldner, M. (2013). *College students' paths into and out of STEM Fields (NCES 2014-001)*. Washington, DC: National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education.

Cohen, M., Buzinski, S. G., Armstrong-Carter, E., Clark, J., Buck, B., & Reuman, L. (2019). Think, pair, freeze: The association between social anxiety and student discomfort in the active learning environment. *Scholarship of Teaching and Learning in Psychology*, *5*(4), 265–277. doi: 10.1037/stl0000147

Connor, K. M., Kobak, K. A., Churchill, L. E., Katzelnick, D., & Davidson, J. R. T. (2001). Mini-SPIN: A brief screening assessment for generalized social anxiety disorder. *Depression and Anxiety*, *14*(2), 137–140. doi: 10.1002/da.1055

Cooper, K. M., Ashley, M., & Brownell, S. E. (2017). Using expectancy value theory as a framework to reduce student resistance to active learning: A proof of concept. *Journal of Microbiology & Biology Education*, *18*(2). doi: 10.1128/jmbe.v18i2.1289

Cooper, K. M., & Brownell, S. E. (2016). Coming out in class: Challenges and benefits of active learning in a biology classroom for LGBTQIA students. *CBE—Life Sciences Education, 15*(3), ar37. doi: 10.1187/cbe.16-01-0074

Cooper, K. M., Downing, V. R., & Brownell, S. E. (2018). The influence of active learning practices on student anxiety in large-enrollment college science classrooms. *International Journal of STEM Education*, *5*(1), 23. doi: 10.1186/s40594-018-0123-6

Daempfle, P. A. (2003). An analysis of the high attrition rates among first year college science, math, and engineering majors. *Journal of College Student Retention: Research, Theory & Practice*, *5*(1), 37–52. doi: 10.2190/DWQT-TYA4-T20W-RCWH

de Lijster, J. M., Dieleman, G. C., Utens, E. M. W. J., Dierckx, B., Wierenga, M., Verhulst, F. C., & Legerstee, J. S. (2018). Social and academic functioning in adolescents with anxiety disorders: A systematic review. *Journal of Affective Disorders*, *230*, 108–117. doi: https://doi.org/10.1016/j.jad.2018.01.008

Deslauriers, L., McCarty, L. S., Miller, K., Callaghan, K., & Kestin, G. (2019). Measuring actual learning versus feeling of learning in response to being actively engaged in the classroom. *Proceedings of the National Academy of Sciences USA*, *116*(39), 19251–19257. doi: 10.1073/pnas.1821936116

Downing, V. R., Cooper, K. M., Cala, J. M., Gin, L. E., & Brownell, S. E. (2020). Fear of negative evaluation and student anxiety in community college active-learning science courses. *CBE—Life Sciences Education*, *19*(2), ar20. doi: 10.1187/cbe.19-09-0186

Eddy, S. L., Brownell, S. E., Thummaphan, P., Lan, M.-C., & Wenderoth, M. P. (2015). Caution, student experience may vary: Social identities impact a student's experience in peer discussions. *CBE—Life Sciences Education, 14*(4), ar45. doi: 10.1187/cbe.15-05-0108

El Baze, J.-A., Stowe, S., Hood, S., Lawford, H., Jensen, M., & Hull, K. (2018). Academic anxiety in higher education: Causes, implications, and potential solutions. *HAPS Educator*, *22*, 208–219. doi: 10.21692/haps.2018.033

England, B., Brigati, J., Schussler, E., & Chen Musgrove, M. (2019). Student anxiety and perception of difficulty impact performance and persistence in introductory biology courses. *CBE—Life Sciences Education*, *18*, ar21. doi: 10.1187/cbe.17-12-0284

England, B. J., Brigati, J. R., & Schussler, E. E. (2017). Student anxiety in introductory biology classrooms: Perceptions about active learning and persistence in the major. *PLoS ONE*, *12*(8), e0182506-0182517. doi: 10.1371/journal.pone.018250610.1371/journal.pone.0182506citation-id:ENgland 2017modified-date:2018-01-3108:34:51-0500

Faravelli, C., Alessandra Scarpato, M., Castellini, G., & Lo Sauro, C. (2013). Gender differences in depression and anxiety: The role of age. *Psychiatry Research*, *210*(3), 1301–1303. doi: 10.1016/j.psychres.2013.09.027

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences USA*, *111*(23), 8410–8415. doi: 10.1073/pnas.1319030111

Freeman, S., Theobald, R., Crowe, A. J., & Wenderoth, M. P. (2017). Likes attract: Students self-sort in a classroom by gender, demography, and academic characteristics. *Active Learning in Higher Education*, *18*(2), 115–126. doi: 10.1177/1469787417707614

Goffe, W. L., & Kauper, D. (2014). A survey of principles instructors: Why lecture prevails. *Journal of Economic Education*, *45*(4), 360–375. doi: 10.1080/00220485.2014.946547

Harris, R. B., Mack, M. R., Bryant, J., Theobald, E. J., & Freeman, S. (2020). Reducing achievement gaps in undergraduate general chemistry could lift underrepresented students into a "hyperpersistent zone." *Science Advances*, *6*(24), eaaz5687. doi: 10.1126/sciadv.aaz5687

Hayes, A. F. (2017). *Introduction to mediation, moderation, and conditional process analysis: A regression-based approach* (2nd ed.). New York: Guilford.

Hembree, R. (1988). Correlates, causes, effects, and treatment of test anxiety. *Review of Educational Research*, *58*(1), 47–77. doi: 10.3102/00346543058001047

Henderson, C., & Dancy, M. H. (2007). Barriers to the use of research-based instructional strategies: The influence of both individual and situational characteristics. *Physical Review Special Topics—Physics Education Research*, *3*(2), 020102. doi: 10.1103/PhysRevSTPER.3.02010210.1103/PhysRevSTPER.3.020102citation-id: Henderson 2007modified-date: 2018-01-05 20:38:16-0500

Honicke, T., & Broadbent, J. (2016). The influence of academic self-efficacy on academic performance: A systematic review. *Educational Research Review*, *17*, 63–84. doi: 10.1016/j.edurev.2015.11.002

Hora, M. T., & Anderson, C. (2012). Perceived norms for interactive teaching and their relationship to instructional decision-making: A mixed methods study. *Higher Education*, *64*(4), 573–592. doi: 10.1007/s10734-012-9513-8

Hull, K., Lawford, H., Hood, S., Oliveira, V., Murray, M., Trempe, M., … & Jensen, M. (2019). Student anxiety and evaluation. *Collected Essays on Learning and Teaching*, *12*, 23–35. doi: 10.22329/celt.v12i0.5409

Institute for College Access and Success. (2017–2018). *College Insight: College Spotlight 2017*. Retrieved December 5, 2020, from https://college-insight.org/spotlight

Johnson, A. C. (2007). Unintended consequences: How science professors discourage women of color. *Science Education*, *91*(5), 805–821. doi: 10.1002/sce.20208

Keeley, J., Zayac, R., & Correia, C. (2008). Curvilinear relationships between statistics anxiety and performance among undergraduate students: Evidence for optimal anxiety. *Statistics Education Research Journal*, *7*(1), 4–15.

Lund, T. J., & Stains, M. (2015). The importance of context: An exploration of factors influencing the adoption of student-centered teaching among chemistry, biology, and physics faculty. *International Journal of STEM Education*, *2*(1), 13. doi: 10.1186/s40594-015-0026-8

Ma, J., & Baum, S. (2016). Trends in community colleges: Enrollment, prices, student debt, and completion. *College Board*, 1–23. https://research.collegeboard.org/pdf/trends-community-colleges-research-brief.pdf

Mallow, J. V. (2006). Science anxiety: Research and action. In Handbook of *college science teaching* (pp. 3–14). Arlington VA: National Science Teachers Association.

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. *British Journal of Educational Psychology*, *70*(Pt 1), 17–32.

McKinney, M. E., Gatchel, R. J., & Paulus, P. B. (1983). The effects of audience size on high and low speech-anxious subjects during an actual speaking task. *Basic and Applied Social Psychology*, *4*(1), 73–87. doi: 10.1207/s15324834basp0401_6

Mowbray, T. (2012). Working memory, test anxiety and effective interventions: A review. *Australian Educational and Developmental Psychologist, 29*(2), 141–156. https://nsf.gov/awardsearch/showAward?AWD_ID=1829157&Historical-Awards=false

Nguyen, K., Husman, J., Waters, C., Henderson, C., Finelli, C. J., Demonbrun, M., … & Borrego, M. (2017). Students' expectations, types of instruction, and instructor strategies predicting student response to active learning. *International Journal of Engineering Education*, *33*(1), 2–18.

Norman, G. (2010). Likert scales, levels of measurement and the "laws" of statistics. *Advances in Health Sciences Education*, *15*(5), 625–632. doi: 10.1007/s10459-010-9222-y

Pollock, S. J., & Finkelstein, N. D. (2008). Sustaining educational reforms in introductory physics. *Physical Review Special Topics—Physics Education Research*, *4*(1), 010110. doi: 10.1103/PhysRevSTPER.4.010110

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

Radwin, D., Conzelmann, J. G., Nunnery, A., Lacy, T. A., Wu, J., Lew, S., … & Siegel, P. (2018). 2015–16 National Postsecondary Student Aid Study (NPSAS:16): Student *financial aid estimates* for 2015–16 (NCES 2018-466). Washington, DC: National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education. Retrieved March 1, 2020, from https://nces.ed.gov/pubs2018/2018466.pdf

Raufelder, D., & Ringeisen, T. (2016). Self-perceived competence and test anxiety. *Journal of Individual Differences*, *37*(3), 159–167. doi: 10.1027/1614-0001/a000202

Richardson, M., Abraham, C., & Bond, R. (2012). Psychological correlates of university students' academic performance: A systematic review and meta-analysis. *Psychological Bulletin*, *138*(2), 353–387. doi: 10.1037/a0026838

Scanlon, C. L., Del Toro, J., & Wang, M.-T. (2020). Socially anxious science achievers: The roles of peer social support and social engagement in the relation between adolescents' social anxiety and science achievement. *Journal of Youth and Adolescence*, *49*(5), 1005–1016. doi: 10.1007/s10964-020-01224-y

Seidel, S. B., & Tanner, K. D. (2013). "What if students revolt?"—Considering student resistance: Origins, options, and opportunities for investigation. *CBE—Life Sciences Education*, *12*(4), 586–595. doi: 10.1187/cbe-13-09-0190

Seipp, B. (1991). Anxiety and academic performance: A meta-analysis of findings. *Anxiety Research*, *4*(1), 27–41.

Shrout, P. E., & Bolger, N. (2002). Mediation in experimental and nonexperimental studies: New procedures and recommendations. *Psychological Methods*, *7*(4), 422–445. doi: 10.1037/1082-989x.7.4.422

Smith, C. V., & Cardaciotto, L. (2011). Is active learning like broccoli? Student perceptions of active learning in large lecture classes. *Journal of the Scholarship of Teaching and Learning*, *11*(1), 9.

Snyder, J. J., Sloane, J. D., Dunk, R. D. P., & Wiles, J. R. (2016). Peer-led team learning helps minority students succeed. *PLoS Biology*, *14*(3), e1002398. doi: 10.1371/journal.pbio.1002398

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

Steele, C. M. (1997). A threat in the air: How stereotypes shape intellectual identity and performance. *American Psychologist*, *52*(6), 613–629. doi: 10.1037/0003-066X.52.6.613

Tanner, K. D. (2013). Structure matters: Twenty-one teaching strategies to promote student engagement and cultivate classroom equity. *CBE—Life Sciences Education*, *12*(3), 322–331. doi: 10.1187/cbe.13-06-0115

Theobald, E. J., Hill, M. J., Tran, E., Agrawal, S., Arroyo, E. N., Behling, S., ... & Freeman, S. (2020). Active learning narrows achievement gaps for underrepresented students in undergraduate science, technology, engineering, and math. *Proceedings of the National Academy of Sciences USA*, *117*(12), 6476–6483. doi: 10.1073/pnas.1916903117

Usher, E. L., & Pajares, F. (2009). Sources of self-efficacy in mathematics: A validation study. *Contemporary Educational Psychology*, *34*(1), 89–101. doi: hTtps://doi.org/10.1016/j.cedpsych.2008.09.002

Vygotsky, L. S. (1980). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Yadav, A., Subedi, D., Lundeberg, M. A., & Bunting, C. F. (2011). Problem-based learning: Influence on students' learning in an electrical engineering course. *Journal of Engineering Education*, *100*(2), 253–280. doi: 10.1002/j.2168-9830.2011.tb00013.x

Yerkes, R., & Dodson, J. (1908). The relation of strength of stimulus to rapidity of habit formation. *Journal of Comparative Neurology*, *18*(5), 459–482.