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The relations between students' belongingness, self-efficacy, and response to active learning in science, math, and engineering classes

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ABSTRACT

Despite numerous benefits, students do not always respond positively and engage in active learning in STEM courses. Understanding the factors that influence how students' respond to active learning is important to devising interventions that support their learning, especially for students from historically underrepresented groups. This study examines the influence of students' belongingness and self-efficacy on their affective and behavioural response to active learning and the moderating influence of students' gender-identity. We surveyed 579 students from 25 Science, Engineering, and Computer Science courses across 14 universities. Using a latent indirect-effect model, we found that belongingness and self-efficacy independently predicted students' affective response to active learning and evaluation of the class. Belongingness also predicted students' self-reports of their behavioural participation in active learning. Using measurement invariance, we also found that, despite mean differences in value, positivity, and distraction, there were no gender differences in the strength of relations between variables. These findings suggest that belongingness and self-efficacy play an important role in how all students respond to active learning and that fostering an atmosphere that supports both may reduce student's resistance to engaging in active learning.

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KEYWORDS
Active learning; college; student response; belongingness; selfefficacy

In college STEM classrooms, active learning, a broad term used to categorise a variety of student-centered non-didactic classroom learning activities (Freeman et al., 2014), is more effective for student learning when compared to traditional lecturing instructional techniques (e.g. Arthurs & Kreager, 2017). However, students do not always respond positively to active learning (Eddy et al., 2015; Seidel & Tanner, 2013). This response to active learning (DeMonbrun et al., 2017; Henderson & Dancy, 2007), may influence

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students' willingness to participate in classroom activities and undercut their frequently cited benefits (Broeckelman-Post et al., 2016; Cooper et al., 2017). To address this concern, there is a need to better understand the nature and influences of students' response to active learning. Understanding these relations can highlight where targeted interventions can support students' participation in order to maximise the benefits of active learning (Cooper et al., 2017).

Researchers have often focused on the influence of active learning on students' sense of belongingness and on their self-efficacy (e.g. Ballen et al., 2017; Masika & Jones, 2016). However, when the focus of the research shifts from the activities themselves to considering students' response to these activities, a more complex model in which students' beliefs influence their response to active learning may be explored. Qualitative studies have demonstrated that students' who do not feel they belong in the class (e.g. Cooper & Brownell, 2016) or who lack self-efficacy for engaging in the academic tasks (e.g. Cooper et al., 2017) may be less willing to engage in classroom activities. These findings suggest that the students who may benefit the most may be the ones who are least likely to engage in active learning. Building on Control-Value Theory (CVT; Pekrun, 2006), we examine the influence of two key factors on students' response to active learning – their self-efficacy for learning (Pintrich et al., 1993) and course belongingness (Malone et al., 2012). Additionally, we examine the mediating role of students' affective response on the relation between these underlying factors and their behavioural responses. We present this theoretical model in Figure 1. Finally, we examine the degree to which students' gender-identity moderated these relations. This study is unique for

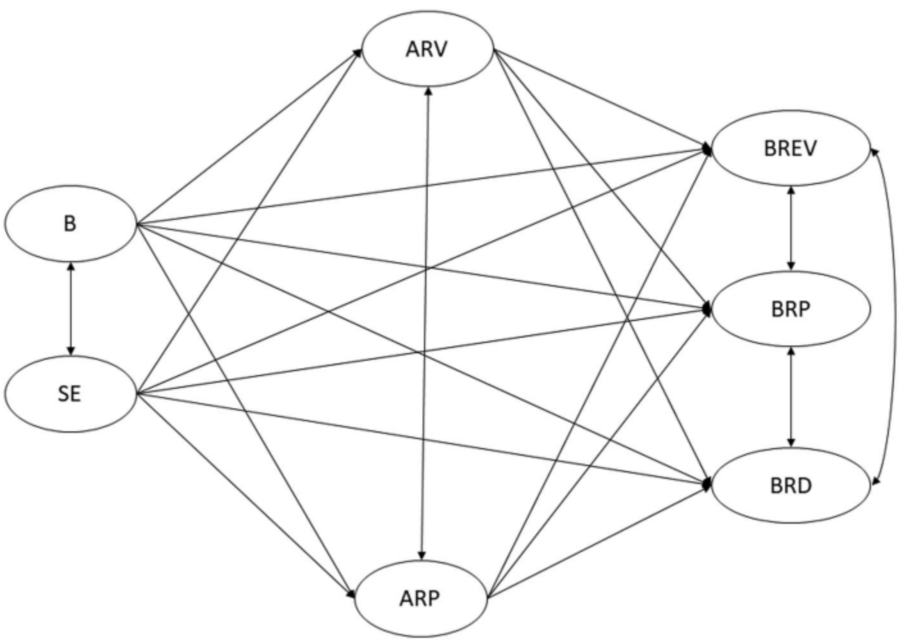

Figure 1. Tested Indirect Effect Model. B – belongingness, SE – self-efficacy for learning, ARV – affective response value, ARP – affective response positivity, BREV – behavioural response evaluation, BRP – behavioural response participation, BRD – behavioural response distraction. Manifest variables and factor loadings omitted for clarity.

examining the influence of the course-level factors of self-efficacy and belongingness on students' response to active learning, considering the moderating effect of students' gender-identity, and examining these relations across multiple courses across STEM disciplines and with a variety of different activities. Understanding these relations is an important step towards understanding how best to support students' participation active learning activities in their STEM course.

Student response to active learning

Significant effort has gone into supporting STEM faculty implement instructional techniques other than lecture in their university classrooms (e.g. Borda et al., 2020). We use the term 'active learning' to describe these instructional techniques that require students to actively construct rather than passively receive knowledge (Bonwell & Eison, 1991). Prior meta-analysis using a similar definition has found that while it may include a wide assortment of activities, ranging from embedding clicker questions to the use of problem-based learning, overall these techniques outperform traditional lecture instructional approaches (Freeman et al., 2014). Despite evidence that active learning has a positive effect on students' learning and persistence in STEM disciplines (e.g. Freeman et al., 2014; Stains et al., 2018; Stanberry & Payne, 2018), instructors are concerned about students' response to what might be perceived as novel teaching practices (Dancy & Henderson, 2012; Henderson & Dancy, 2007; Seidel & Tanner, 2013). Building on frameworks for classroom engagement (e.g. Fredricks et al., 2004), productivity (e.g. Chasteen, 2014), and resistance (e.g. Weimer, 2002), DeMonbrun et al. (2017) developed the Student Response to Instructional Practice (StRIP) framework in order to provide a nuanced understanding student response to active learning. This framework consists of two key aspects; (1) affective and (2) behavioural responses.

Student affective response includes two factors; (1) their value for the activity and (2) their feelings of positivity for the activity (DeMonbrun et al., 2017). Building on Fredricks et al. (2004) model of engagement, value is theorised as an element of emotional engagement corresponding with the degree to which students see the activity as worthwhile. Additionally, students' positive feelings such as their enjoyment about classroom activities has been found to be an important aspect of their response to active learning (Heaslip et al., 2014; Lumpkin et al., 2015). Inclusion of both value and emotions as motivators for students to engage in active learning is consistent with CVT (Pekrun, 2006).

Students' behavioural response includes three factors; (1) participation, (2) distraction, and (3) evaluation (DeMonbrun et al., 2017). Participation refers to students' active participation, or lack thereof, in learning activities. Distraction corresponds with the degree to which students distract their classmates or themselves. Lastly, given the importance of instructor evaluations as a tool for students to redress their dissatisfaction with learning activities within the classroom, in addition to the importance of course evaluations for promotion and tenure, the framework also considers students' evaluation of the course (DeMonbrun et al., 2017).

The StRIP framework and corresponding scales, including both students' affective and behavioural response to active learning, has been applied to a variety of contexts. Prior research has used the StRIP frame work to compare students' response to different type of learning activities (e.g. Du et al., 2020; Stanciulescu et al., 2022). It has been used to evaluate students' response to changes in instructional practice (e.g. Alkhoury et al., 2021; Chen & Yang, 2022; Clark et al., 2018) and changes in the classroom environment (e.g. Bork et al., 2018). It has been used to evaluate the effect of active learning on student persistence, particularly students from underrepresented groups (e.g. Kallemeyn et al., 2021). Additionally, the StRIP framework has been used to help develop instructional practices to support student participation in active learning (e.g. Chasteen, 2017).

Control Value Theory (CVT; Pekrun, 2006) predicts that students' value, emotion, and behavioural responses are influenced by their self-efficacy. DeMonbrun et al. (2017) have found evidence for this relation in the context of active learning in engineering courses. This research suggests that students' affective response mediated the relation between self-beliefs and behavioural response. Although there is evidence that students' feelings of belongingness and inclusion can reduce their willingness to engage in active learning (e.g. Kahu & Nelson, 2018) the connection between belongingness, affective, and behavioural response to active learning is not frequently the focus of research.

Although both self-efficacy and belongingness are frequently listed as one of the positive outcomes of active learning (e.g. Ballen et al., 2017), it is possible that at the individual level, students who feel as if they do not belong are resisting engaging in the active learning and may be the very students who teachers are trying to reach. In other words, if belongingness and self-efficacy predict students' response to active learning, teachers may need direct support for students' self-efficacy and belongingness in addition to active learning. However, with the growing focus on the ways that students resist classroom activities, we argue that we need to think about the implications of these beliefs for students' response to active learning.

Self-efficacy & response to active learning

Self-efficacy refers to an individual's belief in their ability to execute the behaviours required to complete a task (Bandura, 1977, 1997). Decades of research has demonstrated the positive impact of self-efficacy on task participation (e.g. Pintrich, 2003; Schunk & Pajares, 2002), meaningful academic outcomes such as performance (e.g. Sawtelle et al., 2012; Skaalvik et al., 2015), and persistence within STEM disciplines (e.g. Concannon & Barrow, 2009; Sawtelle et al., 2012). For this reason, numerous interventions have been developed to support students' self-efficacy in undergraduate STEM courses (e.g. Cordero et al., 2010; Czocher et al., 2020; Rittmayer & Beier, 2009).

A substantial body of literature has established that course-level self-efficacy (e.g. Pintrich et al., 1993) can impact students' participation in classroom activities (e.g. Doo & Bonk, 2020; Ucar & Sungur, 2017). As a result, researchers have argued that response to active learning may be related to students' self-efficacy in that class (e.g. Ballen et al., 2017; Hood et al., 2021). However, this prior work examined students' willingness to participate in classroom activities and did not consider different aspects of this response. Building on prior research (e.g. Finelli et al., 2018) and grounded in CVT (Pekrun, 2006), we anticipate that students' self-efficacy will positively predict both students' sense of value and positivity for the activities as well as their participation and evaluation of the course, while negatively predicting distraction. Furthermore, we predict their affective responses, particularly their sense of value, will partially mediate the relation between students' self-efficacy and their behavioural responses.

Course belongingness & response to active learning

Baumeister and Leary (1995) posit that individuals must maintain a least a minimum number of significant interpersonal relations in order to fulfill a basic need for a sense of belongingness. Although there is a general need for a sense of belongingness, context-dependent belongingness is also important (Block, 2018; Stepick & Stepick, 2009). In academic settings, school belongingness (e.g. Goodenow & Grady, 1993) can play a significant role in important academic outcomes (Slaten et al., 2016) and student well-being (Arslan, 2021; Bernstein, 2016). A greater sense of belongingness has been associated with increases in participation (e.g. Zumbrunn et al., 2014) and performance (Anderman & Freeman, 2004).

Research on post-secondary students' feelings of belongingness has long history (e.g. Tinto, 1993, 2017). However, much of this work has primarily focused on students' feelings of belongingness at the institutional or disciplinary level. Recent research has begun to explore the importance of course-specific belongingness, or the feeling a student has about their social relationships within the course (e.g. Edwards et al., 2021; Won et al., 2018; Wilson et al., 2015). Higher levels of course-level belonging have been related to increases in student motivation and participation and associated with positive academic outcomes such as performance (e.g. Cwik & Singh, 2022; Edwards et al., 2021). These findings provide guidance for targeted interventions that instructors can implement in order to support students' participation, performance, and well-being (e.g. Wilton et al., 2019).

Studies of the impact of belongingness on learning in the classroom have focused on performance or engagement (e.g. Edwards et al., 2021; Wilton et al., 2019; Won et al., 2018), but less has been studied regarding the relation between course belongingness and response to active learning. Although we know that students' participation in the classroom in general is related to feelings of belongingness (e.g. Andrews et al., 2021), we do not have a clear picture of the relation between course belongingness in the class and their affective and behavioural responses. Building on this prior research and grounded in CVT (Pekrun, 2006), we anticipate that students' sense of belongingness will positively predict both their value and positivity for the activities and their participation and evaluation of the course, while negatively predicting their self-reported distraction. Furthermore, we predict their affective responses, particularly their sense of value, will partially mediate the relation between students' beliefs and their behavioural response to active learning.

Gendered differences in self-efficacy, belongingness, & participation

Gendered differences in STEM career participation post-graduation persist in many fields (Charlesworth & Banaji, 2019; Cheryan et al., 2017). Although active learning practices may support learning for students from historically underrepresented groups (e.g. Theobald et al., 2020), researchers have found it isn't a magic bullet. For these students, other classroom factors can create hurdles to participating in active learning (e.g. Aguillon et al., 2020). Research has found that students' self-efficacy and belongingness are key factors that differ between female- and male-identifying students and may lead to differences in STEM participation (Wang & Degol, 2017).

Despite narrowing of the gender gaps in STEM self-efficacy, female-identifying students still often report feeling less efficacious in many STEM courses (e.g. Dubrovskiy et al., 2022). Researchers have also found gender differences in students' sense of belongingness in STEM disciplines, departments, and courses (Leaper, 2015). These differences have been shown to relate with differences in student participation (e.g. Sankar et al., 2015) and persistence (e.g. Lewis et al., 2017) in STEM courses and careers. We may see differences in self-efficacy and belongingness between female identifying and male identifying students.

Prior studies indicate that here may also exist gender differences in the relations between self-efficacy, belongingness, and student participation (e.g. Lewis et al., 2017), where sense of belongingness may have a greater influence for female-identifying students than their male-identifying classmates.

The present study

In this study, we examined the relation between affective and behavioural response to active learning (DeMonbrun et al., 2017), the influence of course belongingness (Malone et al., 2012) and self-efficacy (Pintrich et al., 1993) on these responses, and the moderating influence of gender-identity. It is novel in examining the influence of both students' self-efficacy and course belongingness on their response to active learning. Understanding these relations may suggest where targeted interventions may be most effective at increasing students' participation in classroom activities. Specifically, we answer the following research questions:

> RQ1: Does students' self-efficacy and sense of belonging predict their affective and behavioral response to active learning? Building on previous research (e.g. Andrews et al., 2021), we hypothesize that both self-efficacy and belongingness will positively relate to positivity and value affective responses, positively relate to participation and evaluation, and negatively relate to distraction.

> RQ2: Does students' affective responses mediate the relation between students' self-efficacy and belonging and their behavioral responses? Grounded in CVT (Pekrun, 2006) and building on prior research (e.g. Finelli et al., 2018), we predict that value will at least partially mediate the relation between belongingness and self-efficacy on participation, distraction, and evaluation, but that positivity may only partially mediate the relation between belongingness and self-efficacy on evaluation.

> RQ3: Are the relations between belongingness, self-efficacy, affective responses and behavioral responses different for male- and female-identifying students? Building on previous research (e.g. Lewis et al., 2017), we hypothesize that the relations between belonging, affective, and behavioral response to active learning will be greater for female-identifying students.

Methods

Participants

Students were recruited from STEM classes taught by 25 instructors at 14 colleges and universities in the South Central and Pacific Northwest regions of the United States. Instructors were recruited as part of a larger project examining student response to active learning via an email sent from a contact within each department with approval from each institution. Institutions were selected for their proximity to the research institutions overseeing this study. Courses were in a variety of STEM disciplines, including science (e.g. biology, chemistry), engineering (e.g. statics, mechanical engineering), computer science, and math (e.g. calculus, non-linear algebra). We present demographic and discipline information for instructors in Table 1. Student participants ($n = 579$) were recruited from classes taught by instructors in these disciplines and ranged from 5 to 70 students in each class. We present demographic information for students in Table 2.

Procedures

Following research procedures approved by the Internal Review Boards at the institutions overseeing this research project, instructors were asked to distribute anonymous online surveys to students immediately following a class period in which they indicated they had used active learning. Surveys included all required elements of informed consent consistent with the revised common rule (Protection of Human Subjects, 2005). Each instructor was provided a unique link in order to track the course from which students responded. Students completed the survey via an online survey platform (i.e. Qualtrics). Additionally, instructors completed a brief survey in which they described the active learning activities used during the class period. Faculty reported engaging students in activities ranging from the use of iclickers during class to asking students to complete problem sets in groups. All learning activities were coded independently by two members of the research team using the Interactive-Constructive-Active-Passive (ICAP) framework (Chi & Wylie, 2014) and found to be at least active with a high level (95.7%) of agreement, $KAlpha_{nominal} = .89$.

Measures

Measures included self-efficacy for learning (MSLQ; Pintrich et al., 1993), classroom belongingness (Malone et al., 2012) and affective and behavioural response to active learning (StRIP; DeMonbrun et al., 2017). All subscales from the StRIP questionnaire prompted participants to reflect on the class activities they were asked to engage in during a specific class period where the instructor provided additional information about the active learning activities students were asked to participate in class. Additionally, students self-reported their gender identity. We present descriptive statistics and correlations between measures for all students in and by students' gender identity in the supplemental materials.

Belongingness. Course belongingness was measured using six items adapted from the General Belongingness Scale (GBS; Malone et al., 2012). Items were adapted to ground

Table 1. Instructors demographic information.

	Race/Ethnicity Identity			Discipline				
Gender Identity	White Non-Hispanic	Hispanic	Asian	Science	Technology	Engineering	Math	Total
Male	5	1	2	3	1	4	0	8
Female	11	1	5	10	0	3	4	17
Total	16	2	7	13	1	7	4	25

Notes: Demographic data collected using open-ended responses.

Table 2. Student demographic information.

Gender Identity	White/ Caucasian	African/ African American/ Black	Asian	Latinx/ Hispanic	Mixed Race/ Multiracial	Pacific Islander	Other	Missing	Total
	Race/Ethnicity Identity								
Female	81	20	43	42	8	0	3	3	200
Male	136	14	37	39	13	2	8	4	253
Gender Non-conforming	2	1	0	0	0	0	1	0	4
Unsure	1	0	1	0	0	0	0	2	4
Other	0	0	0	0	0	0	1	1	2
Missing	1	1	2	0	0	0	2	110	116
Total	221	36	83	81	21	2	15	120	579

Notes: Demographic data collected using open-ended responses.

belongingness within the specific context of the classroom. The revised scale included three positively-worded items (e.g. 'I have a belongingness in this class.') and three reverse-coded negatively-worded items (e.g. 'I feel like an outsider in this class') measured on a 7-point Likert-type scale with values ranging from 1 (not at all true of me) to 7 (very true of me). Internal consistency for the six belongingness items was excellent; $\alpha = .88$.

Self-efficacy. Self-efficacy was measured using eight items from the Motivated Strategies for Learning Questionnaire (MSLQ; Pintrich et al., 1993). The MSLQ examines students' efficacy for learning, grounded in a specific class. The scale asks students to evaluate their performance expectations and their ability to master relevant course tasks (e.g. 'I'm certain I can master the skills being taught in this class.'). The eight items of the scale were measured on a 7-point Likert-type scale with values ranging from 1 (not at all true of me) to 7 (very true of me). Internal consistency was excellent for self-efficacy; $\alpha = .90$.

Positivity. Positivity for the active learning activities used in the specific class period was measured using three items from the StRIP instrument (DeMonbrun et al., 2017). These items ask students to evaluate the degree to which they felt positively towards the activities (e.g. 'I enjoyed the activities') and were measured on a 7-point Likert-type scale with values ranging from 1 (strongly disagree) to 7 (strongly agree). Internal consistency for our positivity measure was acceptable, $\alpha = .83$.

Value. Value for the active learning activities used in the specific class period was measured using three items from the StRIP instrument (DeMonbrun et al., 2017). These items ask students to evaluate the degree to which they found the activities to be of value (e.g. 'I saw the value of today's activities') and were measured on a 7-point Likert-type scale with values ranging from 1 (strongly disagree) to 7 (strongly agree). Internal consistency for our value measure was high, $\alpha = .92$.

Participation. Participation in the active learning activities used in the specific class period was measured using four items from the StRIP instrument (DeMonbrun et al., 2017). These items ask students to self-report the degree to which they actively participated in class activities (e.g. 'I participated actively in the activities') and were measured on a 7-point Likert-type scale with values ranging from 1 (strongly disagree) to 7 (strongly agree) Internal consistency for our participation measure was acceptable, $\alpha = .79$.

Distraction. Distraction during the active learning activities used in a specific class period was measured using four items from the StRIP instrument (DeMonbrun et al., 2017). These items ask students to self-report the degree to which they were distracted or distracted their classmates (e.g. 'I distracted my peers during the activities') and were measured on a 7-point Likert-type scale with values ranging from 1 (strongly disagree) to 7 (strongly agree). Internal consistency for our distraction measure was acceptable, $\alpha = .81$.

Evaluation. Anticipated evaluation of the course was measured using three items from the StRIP instrument (DeMonbrun et al., 2017). These items ask students to report how they will overall evaluate the course (e.g. 'Overall, this is an excellent course') and were measured on a 7-point Likert-type scale with values ranging from 1 (strongly disagree) to 7 (strongly agree). Internal consistency for our evaluation measure was high, $\alpha = .95$.

Gender Identity. Student self-reported demographic information, including their gender-identity, were captured using open-ended response prompts. Given their small *n* (< 2%), students who identified as 'Gender Non-conforming', 'Unsure', or 'Other' were excluded from the present analysis due to methodological limitations.

Analyses

All research questions were answered with latent indirect-effects structural equation models (SEM, Kline, 2015) using the *lavaan* package (Rosseel, 2012) in *R* open-source software (R Core Team, 2017). To answer our first research question, we fit a path model in which the relations between students' affective and behavioural responses and their self-efficacy and belongingness. Given the focus of the present study on the relation between students' sense of belonging and self-efficacy on students' response to active learning and not testing the relations between sense of belong and self-efficacy, we selected to all these two exogenous factors to covary, consistent with prior research (e.g. Lewis et al., 2017; Matthews et al., 2014). Additionally, given the lack of theorised direction (DeMonbrun et al., 2017), we allowed residual variance between the two affective factors (value and positivity) and three behavioural factors (participation, distraction, and evaluation) to covary, allowing for the possibility of additional exogenous common-cause factors outside the scope of the present study to influence shared residual variance in these factors. We present a diagram of this model in Figure 1. To answer our second research question, we used bootstrap standard errors (Bollen & Stine, 1990; Shrout & Bolger, 2002) to evaluate the indirect effect of students' affective response on the relation between their self-efficacy and belongingness on their behavioural response. To answer our third research question, we established measurement invariance in the structural model before constraining parameters of interest (i.e. regression and covariance of latent variables) to be invariant to test the moderating role of students' gender-identity (Putnick & Bornstein, 2016).

Results

To answer our first two research questions, we fit a latent variable indirect-effect SEM using bootstrap standard errors. This model achieved adequate fit (Hu & Bentler, 1999); $\chi^2(df) = 882.93(411)$, $p < .01$; CFI = .94; RMSEA [90% CI] = .06 [.05, .06]. We present unstandardised parameter estimates for this model in Table 3 and the path diagram with standardised parameter estimates in Figure 2. For this model, we found a strong correlation between belongingness and self-efficacy, $r = .38$ $p < .01$. Belongingness predicted both measures of affective response; positivity $\beta = .37$, $p < .01$ and value

Table 3. Unstandardised parameter estimates for baseline and best-fitting model.

Parameter Estimate (SE)	Baseline Model	Best Fitting Model: Female	Best Fitting Model: Male
Regressions			
Belonging → Positivity	0.42** (0.09)	0.37** (0.10)	
Belonging → Value	0.44** (0.09)	0.40** (0.10)	
Belonging → Participation	0.35** (0.11)	0.32** (0.11)	
Belonging → Distraction	−0.25 (0.17)	−0.18 (0.16)	
Belonging → Evaluation	−0.05 (0.08)	−0.03 (0.08)	
Self-efficacy → Positivity	0.38** (0.08)	0.39** (0.08)	
Self-efficacy → Value	0.21* (0.08)	0.21** (0.08)	
Self-efficacy → Participation	−0.03 (0.06)	−0.03 (0.07)	
Self-efficacy → Distraction	−0.02 (0.08)	−0.04 (0.09)	
Self-efficacy → Evaluation	0.10 (0.07)	0.12 (0.13)	
Positivity → Participation	0.11 (0.17)	0.21 (0.21)	
Positivity → Distraction	0.14 (0.18)	0.01 (0.19)	
Positivity → Evaluation	0.82** (0.21)	0.68 (0.57)	
Value → Participation	0.15 (0.15)	0.05 (0.16)	
Value → Distraction	−0.31 (0.19)	−0.15 (0.17)	
Value → Evaluation	0.12 (0.19)	0.24 (0.49)	
Indirect Effects			
Belonging → Positivity → Participation	0.04 (0.07)	0.08 (0.08)	
Belonging → Positivity → Distraction	0.06 (0.08)	<0.01 (0.07)	
Belonging → Positivity → Evaluation	0.34** (0.11)	0.25 (0.24)	
Belonging → Value → Participation	0.07 (0.06)	0.02 (0.07)	
Belonging → Value → Distraction	−0.14 (0.09)	−0.06 (0.07)	
Belonging → Value → Evaluation	0.05 (0.09)	0.10 (0.23)	
Self-efficacy → Positivity → Participation	0.04 (0.07)	0.08 (0.08)	
Self-efficacy → Positivity → Distraction	0.05 (0.08)	<0.01 (0.08)	
Self-efficacy → Positivity → Evaluation	0.31* (0.12)	0.26 (0.19)	
Self-efficacy → Value → Participation	0.03 (0.04)	0.01 (0.03)	
Self-efficacy → Value → Distraction	−0.06 (0.05)	−0.03 (0.04)	
Self-efficacy → Value → Evaluation	0.03 (0.05)	0.05 (0.08)	
Total Effect			
Belonging → … → Participation	0.46** (0.11)	0.42** (0.12)	
Belonging → … → Distraction	−0.33** (0.17)	−0.24 (0.15)	
Belonging → … → Evaluation	0.34** (0.10)	0.32** (0.10)	
Self-efficacy → … → Participation	0.04 (0.07)	0.07 (0.07)	
Self-efficacy → … → Distraction	−0.03 (0.08)	−0.07 (0.08)	
Self-efficacy → … → Evaluation	0.43** (0.10)	0.43** (0.10)	
Covariances			
Belonging ↔ Self-efficacy	0.37** (0.09)	0.38** (0.09)	
Positivity ↔ Value	0.74** (0.11)	0.73** (0.12)	
Participation ↔ Distraction	−0.51** (0.08)	−0.46** (0.07)	
Participation ↔ Evaluation	−0.03 (0.05)	−0.02 (0.05)	
Distraction ↔ Evaluation	0.02 (0.06)	0.03 (0.05)	
Means			
Belonging	–	0	−0.11 (0.08)
Self-efficacy	–	0	0.01 (0.10)
Value	–	0	−0.25** (0.09)
Positivity	–	0	−0.38** (0.09)
Participation	–	0	−0.14^{T} (0.08)
Distraction	–	0	0.26* (0.12)
Evaluation	–	0	−0.09 (0.13)

Notes: * $p < .05$ ** $p < .01$. Indirect and total effect significance test conducted using bootstrap standard errors (Bollen & Stine, 1990).

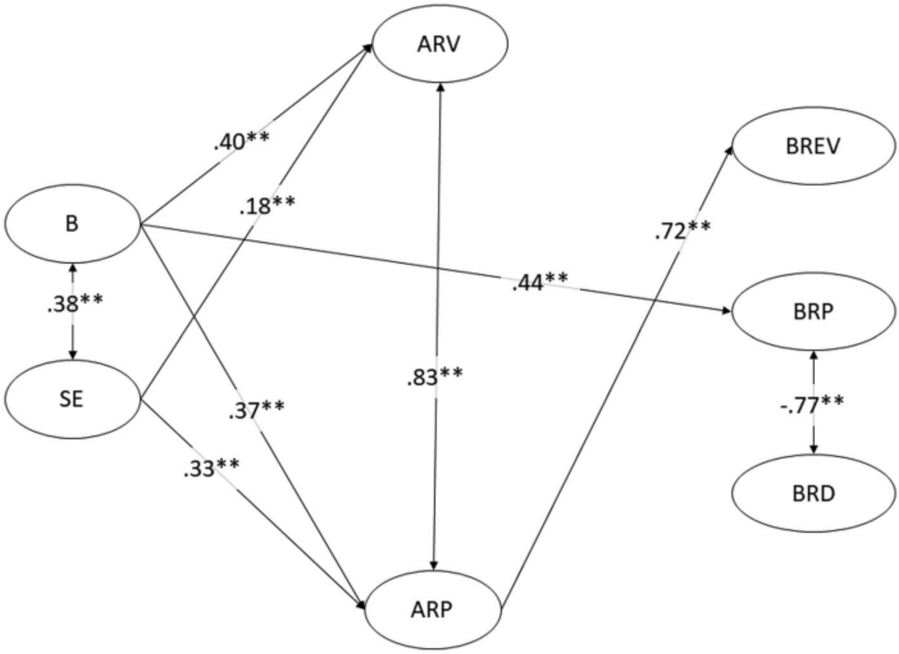

Figure 2. Structural model results for best fitting indirect effect analysis moderated by gender identity with standardised parameter estimates. B – belongingness, SE – self-efficacy for learning, ARV – affective response value, ARP – affective response positivity, BREV – behavioural response evaluation, BRP – behavioural response participation, BRD – behavioural response distraction. Non-significant parameter estimates, manifest variables, and factor loadings omitted for clarity. Variation in standardised parameter estimates constrained to be invariant across groups due to group differences in parameter variance.

$\beta = .40$, $p < .01$. Additionally, belongingness also predicted participation, $\beta = .44$, $p < .01$. However, belongingness did not directly predict either distraction, $\beta = -.22$, $p = .13$, or evaluation, $\beta = -.04$, $p = .49$. Self-efficacy predicted both measures of affective response, positivity $\beta = .33$, $p < .01$ and value $\beta = .18$, $p < .05$. However, we did not observe a relation between self-efficacy and participation, $\beta = -.04$, $p = .59$, distraction, $\beta = -.02$, $p = .80$, or evaluation, $\beta = .08$, $p = .17$. Value was related to positivity, $r = .83$, $p < .01$, but did not relate to any of the three measures of behavioural response; participation $\beta = .20$, $p = .31$, distraction $\beta = -.29$, $p = .10$, or evaluation, $\beta = .10$, $p = .53$. Positivity was related to evaluation, $\beta = .72$, $p < .01$ but was unrelated to either participation, $\beta = .15$, $p = .54$, or distraction, $\beta = .13$, $p = .46$. Participation correlated with distraction, $r = -.77$ $p < .01$, but was unrelated to with evaluation, $r = -.07$ $p = .52$. Distraction did not correlate with their evaluation, $r = .02$, $p = .75$.

To answer our second research questions, we examined the indirect effects of belongingness and self-efficacy on behavioural response to active learning through affective response. We found that the relation between belongingness and evaluation was mediated by positivity, $\beta = .27$, $p < .01$. We also found that the relation between self-efficacy and evaluation was similarly mediated by positivity, $\beta = .23$, $p < .05$. When examining the totality of influence of belongingness and self-efficacy on behavioural responses, we found that the total effect of belongingness on all three factors was significant;

participation $\beta = .58$, $p < .01$, distraction $\beta = -.29$, $p < .01$, and evaluation $\beta = .26$, $p < .01$. However, we found that only the total effect of self-efficacy on evaluation was significant, $\beta = .33$, $p < .01$.

To answer our third research question, we fit separate models for female- and male-identifying students and systematically constrained parameters to be invariant across groups. We present fit statistics for our measurement invariance testing in Table 4. We were able to establish weak invariance for our model after constraining factor loadings to be invariant for male- and female-identifying students, but were unable to establish strict invariance by constraining the latent variable means to be invariant across both groups. However, we did not find significant differences in the latent variable covariances or regression parameters when compared to the strong invariant model. Therefore, we present the strong invariant model with the latent variable covariance and regression parameters constrained to be invariant as our best fitting model. We present unstandardised parameter estimates for this model in Table 4 and a path diagram with standardised parameter estimates in Figure 3.

For our best fitting model, we found that male-identifying students were 0.35 *sd* below female-identifying students in positivity and 0.22 *sd* below female-identifying students in value. Additionally, male-identifying students were .22 *sd* higher than female-identifying students in distraction. No differences were observed between male- and female-identifying students' self-efficacy, belongingness, participation, or evaluation. Similar to our initial model, for both female- and male-identifying belongingness and self-efficacy each independently predicted both positivity and value; female belongingness on positivity $\beta = .34$, $p < .01$, belongingness on value $\beta = .41$, $p < .01$, self-efficacy on positivity $\beta = .33$, $p < .01$, positivity on value $\beta = .20$, $p < .01$, male belongingness on positivity $\beta = .34$, $p < .01$, belongingness on value $\beta = .36$, $p < .01$, self-efficacy on positivity $\beta = .36$, $p < .01$, self-efficacy on value $\beta = .19$, $p < .01$. Belongingness also predicted participation, female $\beta = .42$, $p < .01$ and male $\beta = .43$, $p < .01$, The total effect of belongingness on both participation, female $\beta = .55$, $p < .01$ male $\beta = .56$, $p < .01$, and evaluation, female $\beta = .26$, $p < .05$ male $\beta = .25$, $p < .01$, were significant, as was the total effect of self-efficacy on evaluation, female $\beta = .34$, $p < .01$ male $\beta = .33$, $p < .01$.

Discussion

In this study, we examined the relation between students' belongingness (Malone et al., 2012) and self-efficacy (Pintrich et al., 1993) on their affective and behavioural response

Table 4. Model fit indices and model comparison for multiple group analysis by gender.

Model	χ^2 (*df*)	$\Delta\chi^2$ (Δdf)	CFI	ΔCFI	BIC	ΔBIC
Baseline	1564.73** (822)		.90		38,278.51	
Weak Invariance	1579.85** (846)	15.12 (24)	.90	<.01	38,183.25	−95.26
Strong Invariance	1616.71** (868)	36.86* (22)	.90	<.01	38,090.35	−92.90
Strict Invariance[a]	1642.21** (877)	25.50** (9)	.90	<.01	38,060.67	−29.68
LV Covariance	1616.70** (873)	−0.01 (5)	.90	<.01	38,065.99	−24.36
Regression	1639.59** (889)	22.89 (16)	.90	<.01	38,005.76	−60.23

Notes: * $p < .05$ ** $p < .01$. CFI – comparative fit index. BIC – Bayesian Information Criterion. [a]model significantly worse than comparison, constraints not retained in subsequent model (LV Covariance model comparison to Strong Invariance model). Non-robust fit statistics reported in order to compare nested models.

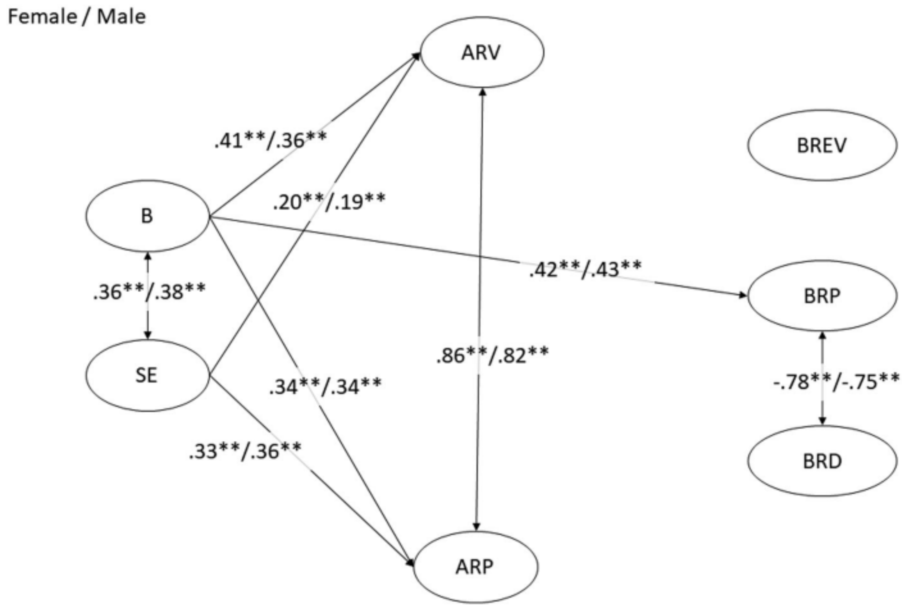

Figure 3. Structural model for indirect effect for all students with standardised parameter estimates. B – belongingness, SE – self-efficacy for learning, ARV – affective response value, ARP – affective response positivity, BREV – behavioural response evaluation, BRP – behavioural response participation, BRD – behavioural response distraction. Non-significant parameter estimates, manifest variables, and factor loadings omitted for clarity.

to active learning (DeMonbrun et al., 2017), the mediating role of their affective response, and the moderating influence of students' gender-identity.

In answering our first research question, we found evidence to partially support our hypotheses. We found that students' sense of belongingness did predict their value, positivity, and behavioural response towards active learning. These findings indicate that classroom structures which allow students to feel accepted and connected may support students' response to active learning. Although self-efficacy also predicted students' value and positivity, we found that it did not directly relate to students' behavioural response. This finding suggests that students' sense of belongingness may have a greater direct impact on their behaviour in the classroom. As a result, classroom practice may wish to focus on supporting both students' belongingness and self-efficacy. Answering our second research question, we found evidence to partially support our hypothesis that students' affective response would mediate the relation between students' belongingness and self-efficacy and their behavioural response. As we predicted and congruent with CVT (Pekrun, 2006), students' self-efficacy and belongingness predicted students' affective response. However, despite previous research suggesting students' valuing of the active learning activity relates to participation (e.g. Garn et al., 2017), we found that value only predicted students' evaluation of the course. We did observe that students' affective response did mediate the relation between their sense of belongingness and their self-reported participation in the activities. However, students' affective response, particularly positivity, more strongly predicted students' behavioural response than value. These results differ from the observed correlations of the mean scores presented in the supplemental material for several reasons. Factors that contributed to these differences include the use of item-level rather than scale-level correlations in our model, meaning the latent variables accounted for the different strength of relations between manifest variables measuring the same construct, leading to different relations between factors. Additionally, we handled missing data in the model using maximum likelihood estimation, unlike the correlation of the scale scores which used pairwise deletion. Finally, the differences in overlapping variance between self-efficacy, belonging, value, positivity, and our outcome variables attenuated the estimated strength of the parameters. These findings would suggest that whether or not students find an activity enjoyable may be more important than if they find it useful.

In answering our third research question, we found little evidence to support our hypothesis that relations between belongingness, self-efficacy, and students' affective and behavioural response to active learning would be different for female-identifying students. In fact, we found that the only statistically significant differences between male- and female-identifying students was that male-identifying students were lower in their sense of positivity and value regarding the activities in class and higher in distraction than their female-identifying classmates. This finding echoes other research which has suggested that, at least in some STEM disciplines, the 'confidence gap' and 'belongingness gap' may be closing (e.g. Britner & Pajares, 2006; Chen & Zimmerman, 2007; Kay & Knaack, 2008; Rittmayer & Beier, 2009). Findings also reiterate that belongingness and self-efficacy are important factors for all students.

There were several limitations to our study. First, we did not model the hierarchical structure of our data (i.e. students nested within classes). We selected not to as our top-most *n* would have been small for the complexity of the analysis. Future research with a large sample size should examine the influence of these nested data structures. Second, in this study, we only looked at differences between male- and female-identifying students. We understand that gender is not dichotomous, but a spectrum (e.g. Monro, 2005). Unfortunately, we did not have a sufficient sample size to examine if and how the relation between these factors differ for students who did not identify as either male or female. Future research with large sample size or different research methodology should examine the experience of these students to ensure equitable access to STEM career opportunities. Finally, we did not examine the moderating influence of students' race and ethnicity or the influence of intersecting identities. Future research with a more diverse sample should examine if and how these patterns of relations change across different identities.

Implication for research

These findings have significant implications for research. We found that students' affective response did not mediate the relation between students' self-beliefs and their behavioural response to active learning activities. As a result, there is a need for additional research examining other factors that might predict how and why students behave in class. Understanding these factors would allow instructors to adopt targeted interventions that would best support students' participation in class. We also found that students' sense of belongingness was a better predictor of their behavioural response than their self-efficacy. This finding is somewhat novel as often self-efficacy is one of the most influential factors predicting student participation, performance, and persistence in STEM disciplines (e.g. Wang & Degol, 2017). Future research should confirm these findings and further explore the importance of students' belongingness as a key factor predicting academic experiences. Finally, we did not find a gendered difference in the pattern of relation between students' affective and behavioural response to active learning and their self-efficacy and belonging. Given the uneven findings regarding if and when gender is salient in STEM courses, future research is needed to understand the course-level factors which predict differences in male- and female-identifying students' experiences.

Implication for practice

In addition to implications for research, our findings also have implications for practice. In this study, we found that belongingness was a better predictor of students' behavioural response to active learning than their self-efficacy. Instructors can support students' course belongingness through deliberate evidence-based inclusive teaching practices which foster a supportive classroom climate focused on collaboration (e.g. Brame, 2019; Theobald et al., 2020; Walton & Cohen, 2011). These practices include incorporating increased structure (Eddy & Hogan, 2014; Wilton et al., 2019), guided peer-led team-based learning (Wamser, 2006), encouraging casual student-instructor interactions (Ballen et al., 2017), and promoting in-class near-peer student-student interactions (Stanich et al., 2018). Growing evidence indicates that targeting psychological and emotional supports for students through social-belonging interventions such as group writing activities, affirmation exercises, role-modelling interventions, and structured group discussions increase students' sense of belongingness in class (Jordt et al., 2017; Miyake et al., 2010; Theobald et al., 2020; Walton et al., 2015). Future research should continue to develop interventions like these aimed at developing relationships and classroom community and examine their effectiveness, particularly to increase student participation in high-impact instructional practices such as active learning.

Conclusion

We found that both students' sense of belonging and self-efficacy predicted their affective and behavioural response to active learning. In particular, we found that belonging predicted students' value, positivity, participation, distraction, and evaluation while self-efficacy predicted students' value, positivity, and evaluation. This suggests that while both student characteristics are important influences on their response to active learning, students' sense of belonging may be a better predictor of their behavioural response. Unlike previously theorised (e.g. DeMonbrun et al., 2017; Finelli et al., 2018) we did not find that students' affective response to active learning mediated the relation between belonging or self-efficacy and students' behavioural response to active learning. We also did not find differences in these patterns of relations between male- and female-identifying students. The results suggest that interventions that support students' sense of belonging or self-efficacy in STEM classes may be effective at supporting students' positive response to active learning for both male and female identifying students, and that interventions that support students' sense of belonging may be particularly effective for increasing students' participation in classroom activities.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Ethics statement

This research involved human subjects and was approved and conducted with oversight from the internal review boards at both the University of Texas – Austin and the University of Oregon.

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References

Aguillon, S. M., Siegmund, G. F., Petipas, R. H., Drake, A. G., Cotner, S., & Ballen, C. J. (2020). Gender differences in student participation in an active-learning classroom. *CBE—Life Sciences Education*, *19*(2), ar12. https://doi.org/10.1187/cbe.19-03-0048

Alkhoury, K., Edrees, A. Z., Sodhi, J., Borgaonkar, A. D., & Shekhar, P. (2021, July). Investigating Students' Expectations of Instruction in Engineering Laboratory Courses During the COVID-19 Pandemic. In 2021 *ASEE Virtual Annual Conference Content Access*.

Anderman, L. H., & Freeman, T. (2004). Students' sense of belonging in school. In M. L. Maehr, & P. R. Pintrich (Eds.), *Advances in motivation and achievement: Vol. 13. Motivating students, improving schools - The legacy of Carol Midgley* (pp. 27–63). Elsevier.

Andrews, M. E., Borrego, M., & Boklage, A. (2021). Self-efficacy and belonging: The impact of a university makerspace. *International Journal of STEM Education*, *8*(1), 1–18. https://doi.org/10.1186/s40594-020-00258-9

Arslan, G. (2021). School belongingness, well-being, and mental health among adolescents: Exploring the role of loneliness. *Australian Journal of Psychology*, *73*(1), 70–80. https://doi.org/10.1080/00049530.2021.1904499

Arthurs, L. A., & Kreager, B. Z. (2017). An integrative review of in-class activities that enable active learning in college science classroom settings. *International Journal of Science Education*, *39* (*15*), 2073–2091. http://dx.doi.org/10.1080/09500693.2017.1363925

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. https://doi.org/10.1187/cbe.16-12-0344

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review*, *84*(2), 191–215. https://doi.org/10.1037/0033-295X.84.2.191

Bandura, A. (1997). *Self-efficacy: The exercise of control.* W. H. Freeman.

Baumeister, R. F., & Leary, M. R. (1995). The need to belong: Desire for interpersonal attachments as a fundamental human motivation. *Psychological Bulletin*, *117*(3), 497–529. https://doi.org/10.1037/0033-2909.117.3.497

Bernstein, M. J. (2016). Research in social psychology: Consequences of short-and long-term social exclusion. In P. Riva & J Eck (Eds.), *Social exclusion: Psychological approaches to understanding and reducing its impact* (pp. 51–72). Springer.

Block, P. (2018). *Community: The structure of belonging*. Berrett-Koehler Publishers.
Bollen, K. A., & Stine, R. (1990). Direct and indirect effects: Classical and bootstrap estimates of variability. *Sociological Methodology*, *20*(1990), 115–140. https://doi.org/10.2307/271084.
Bonwell, C. C., & Eison, J. A. (1991). *Active learning: Creating excitement in the classroom*. Washington, DC: School of Education and Human Development, George Washington University.
Borda, E., Schumacher, E., Hanley, D., Geary, E., Warren, S., Ipsen, C., & Stredicke, L. (2020). Initial implementation of active learning strategies in large, lecture STEM courses: Lessons learned from a multi-institutional, interdisciplinary STEM faculty development program. *International Journal of STEM Education*, *7*(1), 1–18. https://doi.org/10.1186/s40594-020-0203-2
Bork, S. J., Wiwel, C. R., Blackburn, M. W., Johnson, A. W., & Finelli, C. J. (2018). Impact of flexible classroom spaces on instructor pedagogy and student behavior. In *ASEE Annual Conference proceedings*.
Brame, C. J. (2019). Inclusive teaching: Creating a welcoming, supportive classroom environment. In *Science teaching essentials: Short guides to good practice* (pp. 3–14). Elsevier.
Britner, S. L., & Pajares, F. (2006). Sources of science self-efficacy beliefs of middle school students. *Journal of Research in Science Teaching*, *43*(5), 485–499. https://doi.org/10.1002/tea.20131
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*, *045*(05). http://dx.doi.org/10.2505/4/jcst16_045_05_27
Charlesworth, T. E. S., & Banaji, M. R. (2019). Gender in science, technology, engineering, and mathematics: Issues, causes, solutions. *The Journal of Neuroscience*, *39*(37), 7228–7243. https://doi.org/10.1523/JNEUROSCI.0475-18.2019
Chasteen, S. (2014, November 4). *Measuring and improving students' engagement [Blog post]*. Retrieved January 9, 2016 from http://blog.sciencegeekgirl.com/2014/11/02/measuring-and-improving-students-engagement/
Chasteen, S. (2017). *How do I help students engage productively in active learning classrooms*. Posted to https://www. physport.org/recommendations/Entry.cfm
Chen, H., & Yang, M. (2022). Online student response systems and student engagement in large EFL classrooms. *Journal of Applied Learning and Teaching*, *5*(1), 60–70.
Chen, P., & Zimmerman, B. J. (2007). A cross-national comparison study on the accuracy of self-efficacy beliefs of middle-school mathematics students. *Journal of Experimental Education*, *75* (3), 221–244. https://doi.org/10.3200/JEXE.75.3.221-244
Cheryan, S., Ziegler, S. A., Montoya, A. K., & Jiang, L. (2017). Why are some STEM fields more gender balanced than others? *Psychological Bulletin*, *143*(1), 1–35. https://doi.org/10.1037/bul0000052
Chi, M. T., & Wylie, R. (2014). The ICAP framework: Linking cognitive engagement to active learning outcomes. *Educational Psychologist*, *49*(4), 219–243. https://doi.org/10.1080/00461520.2014.965823
Clark, R. M., Stabryla, L. M., & Gilbertson, L. M. (2018). Use of active learning and the design thinking process to drive creative sustainable engineering design solutions. In *2018 ASEE Annual Conference & Exposition*.
Concannon, J. P., & Barrow, L. H. (2009). A cross-sectional study of engineering students' self-efficacy by gender, ethnicity, year, and transfer status. *Journal of Science Education and Technology*, *18*(2), 163–172. https://doi.org/10.1007/s10956-008-9141-3
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), 18.12.20. https://doi.org/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. https://doi.org/10.1187/cbe.16-01-0074

Cordero, E. D., Porter, S. H., Israel, T., & Brown, M. T. (2010). Math and science pursuits: A self-efficacy intervention comparison study. *Journal of Career Assessment*, *18*(4), 362–375. https://doi.org/10.1177/1069072710374572
Cwik, S., & Singh, C. (2022). Students' sense of belonging in introductory physics course for bioscience majors predicts their grade. *Physical Review Physics Education Research*, *18*(1), 010139. https://doi.org/10.1103/PhysRevPhysEducRes.18.010139
Czocher, J. A., Melhuish, K., & Kandasamy, S. S. (2020). Building mathematics self-efficacy of STEM undergraduates through mathematical modelling. *International Journal of Mathematical Education in Science and Technology*, *51*(6), 807–834. https://doi.org/10.1080/0020739X.2019.1634223
Dancy, M. H., & Henderson, C. (2012). Experiences of new instructors implementing research based instructional strategies. In *Proceedings of the 2011 Physics Education Research Conference, Melville, NY.* http://homepages.wmich.edu/_chenders/Publications/2011DancyPERCPaper.pdf
DeMonbrun, M., Finelli, C. J., Prince, M., Borrego, M., Shekhar, P., Henderson, C., & Waters, C. (2017). Creating an instrument to measure student response to instructional practices. *Journal of Engineering Education*, *106*(2), 273–298. https://doi.org/10.1002/jee.20162
Doo, M. Y., & Bonk, C. J. (2020). The effects of self-efficacy, self-regulation and social presence on learning engagement in a large university class using flipped learning. *Journal of Computer Assisted Learning*, *36*(6), 997–1010. https://doi.org/10.1111/jcal.12455
Du, X., Chaaban, Y., Sabah, S., Al-Thani, A. M., & Wang, L. (2020). Active learning engagement in teacher preparation programmes-A comparative study from Qatar, Lebanon and China. *Asia Pacific Journal of Education*, *40*(3), 283–298. https://doi.org/10.1080/02188791.2020.1717436
Dubrovskiy, A., Broadway, S., Jang, B., Mamiya, B., Powell, C. B., Shelton, G. R., Walker, D. R., Williamson, V. M., & Mason, D. (2022). Is the STEM gender gap closing? *Journal of Research in Science Mathematics and Technology Education*, *5*(1), 47–67. https://doi.org/10.31756/jrsmte.512
Eddy, S. L., Converse, M., Wenderoth, M. P., & Schinske, J. (2015). PORTAAL: A classroom observation tool assessing evidence-based teaching practices for active learning in large Science, Technology, Engineering, and Mathematics Classes. *CBE—Life Sciences Education*, *14*(2), ar23. http://dx.doi.org/10.1187/cbe.14-06-0095
Eddy, S. L., & Hogan, K. A. (2014). Getting under the hood: How and for whom does increasing course structure work? *CBE—Life Sciences Education*, *13*(3), 453–468. https://doi.org/10.1187/cbe.14-03-0050
Edwards, J. D., Barthelemy, R. S., & Frey, R. F. (2021). Relationship between course-level social belonging (sense of belonging and belonging uncertainty) and academic performance in general chemistry 1. *Journal of Chemical Education*, *99*(1), 71–82. https://doi.org/10.1021/acs.jchemed.1c00405
Finelli, C. J., Nguyen, K., DeMonbrun, M., Borrego, M., Prince, M., Husman, J., Henderson, C., Shekhar, P., & Waters, C. K. (2018). Reducing student resistance to active learning: Strategies for instructors. *Journal of College Science Teaching*, *47*(5), 80–91https://doi.org/10.2505/4/jcst18_047_05_80.
Fredricks, J. A., Blumenfeld, P. C., & Paris, A. H. (2004). School engagement: Potential of the concept, state of the evidence. *Review of Educational Research*, *74*(1), 59–109. https://doi.org/10.3102/00346543074001059
Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences*, *111*(23), 8410–8415. https://doi.org/10.1073/pnas.1319030111
Garn, A. C., Simonton, K., Dasingert, T., & Simonton, A. (2017). Predicting changes in student engagement in university physical education: Application of control-value theory of achievement emotions. *Psychology of Sport and Exercise*, *29*, 93–102. https://doi.org/10.1016/j.psychsport.2016.12.005

Goodenow, C., & Grady, K. E. (1993). The relationship of school belonging and friends' values to academic motivation among urban adolescent students. *The Journal of Experimental Education*, *62*(1), 60–71. https://doi.org/10.1080/00220973.1993.9943831

Heaslip, G., Donovan, P., & Cullen, J. G. (2014). Student response systems and learner engagement in large classes. *Active Learning in Higher Education*, *15*(1), 11–24. https://doi.org/10.1177/1469787413514648

Henderson, C., & Dancy, M. (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), 020102-020101–020102-020114. https://doi.org/10.1103/PhysRevSTPER.3.020102

Hood, S., Barrickman, N., Djerdjian, N., Farr, M., Magner, S., Roychowdhury, H., Gerrits R., Lawford H., Ott B., Ross K., Paige O., Stowe S., Jensen M., & Hull, K. (2021). "I like and prefer to work alone": social anxiety, academic self-efficacy, and students'. *Perceptions of Active Learning. CBE—Life Sciences Education*, *20*(1), ar12. https://doi.org/10.1187/cbe.19-12-0271

Hu, L. T., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal*, *6*(1), 1–55. https://doi.org/10.1080/10705519909540118

Jordt, H., Eddy, S. L., Brazil, R., Lau, I., Mann, C., Brownell, S. E., King, K., & Freeman, S. (2017). Values affirmation intervention reduces achievement gap between underrepresented minority and white students in introductory biology classes. *CBE—Life Sciences Education*, *16*(3), 1–10. https://doi.org/10.1187/cbe.16-12-0351

Kahu, E. R., & Nelson, K. (2018). Student engagement in the educational interface: Understanding the mechanisms of student success. *Higher Education Research & Development*, *37*(1), 58–71. https://doi.org/10.1080/07294360.2017.1344197

Kallemeyn, L., Baura, G., Fils-Aime, F., Grabarek, J., & Livas, P. (2021). Engineering Curriculum Rooted in Active Learning: Does It Promote Engagement and Persistence for Women? In *2021 ASEE Virtual Annual Conference Content Access*.

Kay, R. H., & Knaack, L. (2008). A formative analysis of individual differences in the effectiveness of learning objects in secondary school. *Computers & Education*, *51*(3), 1304–1320. https://doi.org/10.1016/j.compedu.2008.01.001

Kline, R. B. (2015). *Principles and practice of structural equation modeling*. Guilford Publications.

Leaper, C. (2015). Do I belong?: Gender, peer groups, and STEM achievement. *International Journal of Gender, Science and Technology*, *7*(2), 166–179. https://genderandset.open.ac.uk/index.php/genderandset/article/view/405/672

Lewis, K. L., Stout, J. G., Finkelstein, N. D., Pollock, S. J., Miyake, A., Cohen, G. L., & Ito, T. A. (2017). Fitting in to move forward: Belonging, gender, and persistence in the physical sciences, technology, engineering, and mathematics (pSTEM). *Psychology of Women Quarterly*, *41*(4), 420–436. https://doi.org/10.1177/0361684317720186

Lumpkin, A., Achen, R. M., & Dodd, R. K. (2015). Student perceptions of active learning. *College Student Journal*, *49*(1), 121–133. https://www.ingentaconnect.com/contentone/prin/csj/2015/00000049/00000001/art00012

Malone, G. P., Pillow, D. R., & Osman, A. (2012). The general belongingness scale (GBS): assessing achieved belongingness. *Personality and Individual Differences*, *52*(3), 311–316. https://doi.org/10.1016/j.paid.2011.10.027

Masika, R., & Jones, J. (2016). Building student belonging and engagement: Insights into higher education students' experiences of participating and learning together. *Teaching in Higher Education*, *21*(2), 138–150. https://doi.org/10.1080/13562517.2015.1122585

Matthews, J. S., Banerjee, M., & Lauermann, F. (2014). Academic identity formation and motivation among ethnic minority adolescents: The role of the "self" between internal and external perceptions of identity. *Child Development*, *85*(6), 2355–2373. https://doi.org/10.1111/cdev.12318

Miyake, A., Kost-Smith, L. E., Finkelstein, N. D., Pollock, S. J., Cohen, G. L., & Ito, T. A. (2010). Reducing the gender achievement gap in college science: A classroom study of values affirmation. *Science*, *330*(6008), 1234–1237. https://doi.org/10.1126/science.1195996

Monro, S. (2005). Beyond male and female: Poststructuralism and the spectrum of gender. *International Journal of Transgenderism*, *8*(1), 3–22. https://doi.org/10.1300/J485v08n01_02
Pekrun, R. (2006). The control-value theory of achievement emotions: Assumptions, corollaries, and implications for educational research and practice. *Educational Psychology Review*, *18*(4), 315–341. https://doi.org/10.1007/s10648-006-9029-9
Pintrich, P. R. (2003). A motivational science perspective on the role of student motivation in learning and teaching contexts. *Journal of Educational Psychology*, *95*(4), 667–686. https://doi.org/10.1037/0022-0663.95.4.667
Pintrich, P. R., Smith, D. A., Garcia, T., & McKeachie, W. J. (1993). Reliability and predictive validity of the motivated strategies for learning questionnaire (MSLQ). *Educational and Psychological Measurement*, *53*(3), 801–813. https://doi.org/10.1177/0013164493053003024
Putnick, D. L., & Bornstein, M. H. (2016). Measurement invariance conventions and reporting: The state of the art and future directions for psychological research. *Developmental Review*, *41*, 71–90. https://doi.org/10.1016/j.dr.2016.06.004
R Core Team. (2017). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing. https://www.R-project.org/
Rittmayer, M. A., & Beier, M. E. (2009). Self-Efficacy in STEM. In B. Bogue, & E. Cady (Eds.), *Applying research to practice (ARP) resources* (pp. 1–12). Rice University. http://www.engr.psu.edu/AWE/ARPresources.aspx
Rosseel, Y. (2012). Lavaan: An R package for structural equation modeling and more. Version 0.5–12 (BETA). *Journal of Statistical Software*, *48*(2), 1–36. https://doi.org/10.18637/jss.v048.i02
Sankar, P., Gilmartin, J., & Sobel, M. (2015). An examination of belongingness and confidence among female computer science students. *Acm Sigcas Computers and Society*, *45*(2), 7–10. https://doi.org/10.1145/2809957.2809960
Sawtelle, V., Brewe, E., & Kramer, L. H. (2012). Exploring the relationship between self-efficacy and retention in introductory physics. *Journal of Research in Science Teaching*, *49*(9), 1096–1121. https://doi.org/10.1002/tea.21050
Schunk, D. H., & Pajares, F. (2002). The development of academic self-efficacy. In A. Wigfield, & J. S. Eccles (Eds.), *Development of achievement motivation: A volume in the educational psychology series* (pp. 15–31). Academic Press.
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. https://doi.org/10.1187/cbe-13-09-0190
Shrout, P. E., & Bolger, N. (2002). Mediation in experimental and nonexperimental studies: New procedures and recommendations. *Psychological Methods*, *7*(4), 422. https://doi.org/10.1037/1082-989X.7.4.422
Skaalvik, E. M., Federici, R. A., & Klassen, R. M. (2015). Mathematics achievement and self-efficacy: Relations with motivation for mathematics. *International Journal of Educational Research*, *72*, 129–136. https://doi.org/10.1016/j.ijer.2015.06.008
Slaten, C. D., Ferguson, J. K., Allen, K. A., Brodrick, D. V., & Waters, L. (2016). School belonging: A review of the history, current trends, and future directions. *The Educational and Developmental Psychologist*, *33*(1), 1–15. https://doi.org/10.1017/edp.2016.6
Stains, M., Harshman, J., Barker, M. K., Chasteen, S. V., Cole, R., DeChenne-Peters, S. E., Eagan M. K., Esson J. M., Knight J. K., Laski F. A., Levis-Fitzgerald M., Lee C. J., Lo S. M., McDonnell L. M., McKay T. A., Michelotti N., Musgrove A., Palmer M. S., Plank K. M., Rodela T. M., Sanders E. R., Schimpf N. G., Schulte P. M., Smith M. K., Stetzer M., Van Valkenburgh B., Vinson E., Weir L. K., Wendel P. J., Wheeler L. B., & Young, A. M. (2018). Anatomy of STEM teaching in North American universities. *Science*, *359*(6383), 1468–1470. https://doi.org/10.1126/science.aap8892
Stanberry, M. L., & Payne, W. R.. (2018). Active learning in undergraduate STEM education: A review of research. In M. Shelly & S. A. Kiray (Eds.), *Research Highlights in STEM Education* (pp. 147–164). ISRES.

Stanciulescu, A., Castronovo, F., & Oliver, J. (2022). Assessing the impact of visualization media on engagement in an active learning environment. *International Journal of Mathematical Education in Science and Technology*, 1–21. https://doi.org/10.1080/0020739X.2022.2044530

Stanich, C. A., Pelch, M. J., Theobald, E., & Freeman, S. (2018). A new approach to supplementary instruction narrows achievement and affect gaps for underrepresented minorities, first-generation students, and women. *Chemistry Education Research and Practice*, *19*(3), 846–866. https://doi.org/10.1039/C8RP00044A

Stepick, A., & Stepick, C. D. (2009). Diverse contexts of reception and feelings of belonging. In *Forum Qualitative Sozialforschung/Forum: Qualitative Social Research* (Vol. 10, No. 3).

Theobald, E. J., Hill, M. J., Tran, E., Agrawal, S., Arroyo, E. N., Behling, S., Chambwe, N., Cintrón, D. L., Cooper, J. D., Dunster, G., & Grummer, J. A. (2020). Active learning narrows achievement gaps for underrepresented students in undergraduate science, technology, engineering, and math. *Proceedings of the National Academy of Sciences of the United States of America*, *117*(12), 6476–6483. https://doi.org/10.1073/pnas.1916903117

Tinto, V. (2017). Reflections on student persistence. *Student Success*, *8*(2), 1–9. https://doi.org/10.5204/ssj.v8i2.376

Tinto, V., Goodsell Love, A, & Russo, P (1993). Building community. *Liberal Education*, *79*(4), 16–21.

Ucar, F. M., & Sungur, S. (2017). The role of perceived classroom goal structures, self-efficacy, and engagement in student science achievement. *Research in Science & Technological Education*, *35*(2), 149–168. https://doi.org/10.1080/02635143.2017.1278684

Walton, G. M., & Cohen, G. L. (2011). A brief social-belonging intervention improves academic and health outcomes of minority students. *Science*, *331*(6023), 1447–1451. https://doi.org/10.1126/science.1198364

Walton, G. M., Peach, J. M., Logel, C., Spencer, S. J., & Zanna, M. P. (2015). Two brief interventions to mitigate a "chilly climate" transform women's experience, relationships, and achievement in engineering. *Journal of Educational Psychology*, *107*(2), 468–485. https://doi.org/10.1037/a0037461

Wamser, C. C. (2006). Peer-led team learning in organic chemistry: Effects on student performance, success, and persistence in the course. *Journal of Chemical Education*, *83*(10), 1562. https://doi.org/10.1021/ed083p1562

Wang, M. T., & Degol, J. L. (2017). Gender gap in science, technology, engineering, and mathematics (STEM): current knowledge, implications for practice, policy, and future directions. *Educational Psychology Review*, *29*(1), 119–140. https://doi.org/10.1007/s10648-015-9355-x

Weimer, M. (2002). *Learner-centered teaching: Five key changes to practice*. Jossey-Bass.

Wilson, D., Jones, D., Bocell, F., Crawford, J., Kim, M. J., Veilleux, N., Floyd-Smith, T., Bates, R., & Plett, M. (2015). Belonging and academic engagement among undergraduate STEM students: A multi-institutional study. *Research in Higher Education*, *56*(7), 750–776. https://doi.org/10.1007/s11162-015-9367-x

Wilton, M., Gonzalez-Niño, E., McPartlan, P., Terner, Z., Christoffersen, R. E., & Rothman, J. H. (2019). Improving academic performance, belonging, and retention through increasing structure of an introductory biology course. *CBE—Life Sciences Education*, *18*(4), ar53. https://doi.org/10.1187/cbe.18-08-0155

Won, S., Wolters, C. A., & Mueller, S. A. (2018). Sense of belonging and self-regulated learning: Testing achievement goals as mediators. *The Journal of Experimental Education*, *86*(3), 402–418. https://doi.org/10.1080/00220973.2016.1277337

Zumbrunn, S., McKim, C., Buhs, E., & Hawley, L. R. (2014). Support, belonging, motivation, and engagement in the college classroom: A mixed method study. *Instructional Science*, 42(5), 661-684. https://doi.org/10.1007/s11251-014-9310-0