Choi *et al.*
International Journal of STEM Education (2025) 12:4
https://doi.org/10.1186/s40594-025-00526-6

International Journal of STEM Education

RESEARCH

Open Access

Exploring how course social and cultural environmental features influence student engagement in STEM active learning courses: a control–value theory approach

Yoon Ha Choi[1], Elli Theobald[2], Vicente Velasco[2] and Sarah L. Eddy[3*]

Abstract

Background Active learning, on average, increases student performance in STEM courses. Yet, there is also large variation in the effectiveness of these implementations. A consistent goal of active learning is moving students towards becoming active constructors of their knowledge. This emphasis means student engagement is of central importance. Thus, variation in student engagement could help explain variation in outcomes from active learning. In this study, we employ Pekrun's Control–Value Theory to examine the impact of four aspects of course social and cultural environments on student engagement. This theory posits that social and cultural features of the course environment influence students' appraisals of their ability to control their academic outcomes from the course and the value they see in those outcomes. Control and value in turn influence the emotions students experience in the course and their behaviors. We selected four features of the course environment suggested in the literature to be important in active learning courses: course goal structure, relevance of course content, students' trust in their instructor, and perceived course competition.

Results We surveyed students in 13 introductory STEM courses. We used structural equation modeling to map how features of the course environment related to control, value, and academic emotions, as well as how control, value, and academic emotions influenced engagement. We found engagement was positively related to control and value as well as the emotion of curiosity. Engagement was negatively related to the emotion of boredom. Importantly, features of the course environment influenced these four variables. All features influenced control: goal structure, relevance, and instructor trust increased it, while competition decreased it. All features except competition were related positively to value. Relevance and instructor trust increased curiosity. Goal structure, relevance, and instructor trust all reduced boredom, while competition increased it.

Conclusion Overall, our study suggests that the way instructors structure the social and cultural environment in active learning courses can impact engagement. Building positive instructor–student relationships, reducing course competition, emphasizing mastery and the relevance of the course to students can all increase engagement in course activities.

Keywords Active learning, Control–value theory, Structural equation modeling, Introductory STEM, Goal structure, Relevance, Instructor–student relationship, Competition, Emotions, Engagement

*Correspondence:
Sarah L. Eddy
seddy@umn.edu
Full list of author information is available at the end of the article

Introduction

Large-scale meta-analyses of STEM education studies have demonstrated that, on average, active learning strategies increase student performance and decrease performance disparities between student groups (Freeman et al., 2014; Theobald et al., 2020). These analyses also highlight the large variation in the effectiveness of individual implementation of active learning. A consistent characteristic and goal of active learning is to move students away from being passive listeners into active constructors of their own knowledge (Bonwell & Eison, 1991; Cooper, 2016; Freeman et al., 2014; Prince, 2004). This makes student engagement of central importance and concern in STEM active learning classrooms. In the context of active learning, engagement can be broadly conceived as behaviors and attitudes students exhibit that are indicative of the quality of their investment in learning activities (Groccia, 2018). If and how students choose to engage in active learning is ultimately up to individual students. Thus, variation in student motivation to engage during course activities could help explain variation in outcomes from active learning implementations.

Student motivation to engage in course activities is not a stable characteristic of a student but rather, is influenced by features of the course environment. Some environmental features that have been shown to influence in-class engagement include design of activities (Sperling et al., 2024; Wiggins et al., 2017), instructor explanations of why active learning is important (Hernandez et al., 2021), aspects of the social climate (Cooper & Brownell, 2016), and physical classroom layout (Barlow & Brown, 2020). In addition to course environment features, student emotions can also motivate a suite of antecedents of learning, such as self-regulation, students' choice of learning strategies, and even performance itself (Isen & Reeve, 2005; Pekrun & Stephens, 2010; Pekrun et al., 2010). However, in active learning contexts, emotions have been mostly studied as outcomes, rather than as factors influencing student behaviors and performance outcomes from active learning (e.g., Cleveland et al., 2017; Kalinowski et al., 2013). The emotion whose influence on engagement has been most well-studied in active learning contexts is anxiety. Across multiple studies, anxiety has been shown to negatively influence students overall and their engagement in active learning, in particular (Cooper et al., 2018; Downing et al., 2020; Hood et al., 2021). Yet, there are many other course-related emotions that students may experience in active learning courses and these emotions' influence on engagement is less clear.

Pekrun's (2006) Control–Value Theory of Achievement Emotions offers a motivational framework that connects features of the course environment, student emotions, and academic engagement. In this study, we applied Pekrun's theory to the context of active learning STEM classrooms to understand how features of the classroom environment impact a range of student emotions, and through emotions, engagement.

Theoretical framework: control–value theory of achievement emotions

The Control–Value Theory of Achievement Emotions is an integrative framework focused on understanding classroom emotions that builds on expectancy-value approaches (Pekrun, 1992; Turner & Schallert, 2001), theories of perceived control (Perry, 1991), and attributional theories (Weiner, 1985) among others. Figure 1 introduces the components of this framework. We will start our discussion with achievement emotions and the evidence for their influence on engagement and then move upward through the model components.

Achievement emotions

The focus of Pekrun's (2006) theory are achievement emotions. These are emotions tied directly to experiences of course activities (e.g., studying, in-class groupwork, out-of-class assignments) and/or course outcomes that are judged according to some standard of quality (i.e., grades). These emotions influence achievement-related behaviors such as engagement in academic tasks (Pekrun

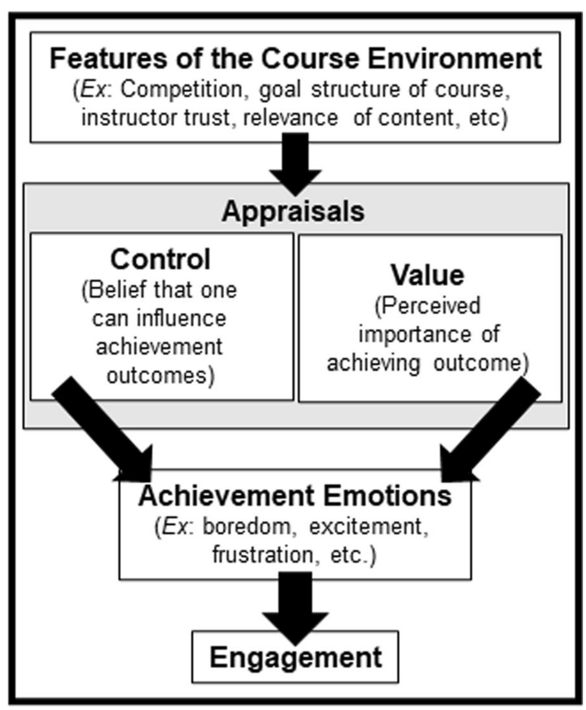

Fig. 1 A schematic of relevant elements of Pekrun's (2006) Control–Value Theory of academic emotions

& Linnenbrink-Garcia, 2012). Of particular importance to this study are *activity emotions*, which are emotions that occur while engaging in course activities. Examples of such emotions are boredom, relaxation, enjoyment, frustration, and anger. Activating positive emotions, such as enjoyment, is assumed to strengthen motivation and increase the use of flexible learning strategies and self-regulation, while negative emotions, such as anger, decrease these (Pekrun & Linnenbrink-Garcia, 2022). Multiple meta-analyses of activity emotions demonstrated that in most cases, these emotions can influence multiple academic outcomes, including performance, motivation, and study strategies (Camacho-Morles et al., 2021; Loderer et al., 2020; Tze et al., 2016). Interestingly, the influence of emotions seems to attenuate in tertiary educational settings like college courses (Camacho-Morles et al., 2021) suggesting the importance of further testing this framework in college courses.

Pekrun and Linnenbrink-Garcia (2022) outline multiple reasons to expect that emotions will influence engagement. For example, emotions can focus attention and cognitive resources on or off a task. Multiple studies have shown that negative emotions are associated with off-task thinking and positive emotions reduce that off-task thinking (Pekrun et al., 2010, 2011; Zeidner, 1998). In addition, positive emotions such as enjoyment increase effort and cognitive engagement, whereas hopelessness or boredom reduce effort (Buff et al., 2011; Linnenbrink, 2007; Pekrun et al., 2010, 2011). Finally, of particular interest for active learning, which often involves group work, positive emotions can support social engagement during learning by increasing group cohesion, active listening, and helping peers, while negative emotions decrease these while increasing social loafing (Linnenbrink-Garcia et al., 2011). Multiple studies at the college level explicitly explored the link between activity emotions and engagement although only one was in a STEM active learning classroom. In a study of in-class discussions, positive emotions supported engagement, while negative emotions elicited a more complex pattern (Do & Schallert, 2004). In a second study, boredom was positively correlated with attention problems and shallow information processing (Pekrun et al., 2010). Emotions have also been extensively studied in college level language learning classrooms (Dewaele & Li, 2020) and in these settings boredom has also been shown to reduce engagement (Derakhshan et al., 2022; Li, 2021), but classroom climate can also influence engagement (Derakhshan et al., 2022). Finally, one study in a flipped anatomy classroom explored the relationships between emotions and engagement (Ranellucci et al., 2021). Researchers found emotions like tired or irritated reduced attention to activities and emotions like excitement and happiness increased engagement and through engagement, achievement. Overall, we find strong evidence in the literature to support that engagement in class can be influenced by activity emotions, although the majority of this evidence comes from K-12 settings and little is known about undergraduate STEM active learning settings.

Appraisals

Student appraisals form another key component of Pekrun's model. A student's appraisal of their environment can influence the emotions they experience in that setting. Pekrun's model focuses on two appraisals: subjective control and subjective value. Control is a student's perception that they can influence their achievement actions and outcomes. Students feel a high sense of control when they believe all of the following are true: (a) actions are needed to achieve the outcomes they want, (b) they are able to perform the needed actions, and (c) the actions will produce a positive outcome or reduce the chance of a negative one (Pekrun, 2006). In an active learning classroom, perceived control could look like a student believing that being passive will not lead to achieving what they want, that they can successfully interact with and learn from other students in class during activities and/or completing any outside-of-class work, and that taking these actions will lead to the outcome they desire. Control is low when students believe they do not need to take action to achieve what they want (i.e., being passive in class is fine), they are not able to perform the actions needed (e.g., groupmates do not engage during activities so no matter what they do, they do not benefit from the activities), and/or taking action will not change the outcome (e.g., exams are unfairly written so no matter what effort they put in, they will not do well).

The second key appraisal in Pekrun's model is value, which is the students' perception regarding the importance of achieving the outcome. In combination, these two appraisals of control and value influence activity emotions (Pekrun, 2006). For example, if engaging in active learning and the outcomes from it are valued, and engaging in active learning feels controllable, then a student might feel enjoyment during active learning activities. If engagement in active learning is controllable but neither the active learning nor the outcomes from it are valued, then a student might feel anger at putting effort into something that they do not believe matters.

Multiple studies have now demonstrated the connection between the appraisals of control and value and the academic emotions students experience, although little of this work has occurred at the college level. For example, a study of 6th graders in Germany showed that when students' belief about their control over their learning and the value of their learning increased, their enjoyment of learning increased as well (Buff, 2014). Control and value were also seen to increase positive emotions in a population of German college students (Goetz et al., 2010). A recent longitudinal study following 5th and 6th graders in Portugal found perceived control and value at previous timepoints influenced the emotions students experienced in subsequent timepoints, and that these emotions, in turn, influenced achievement (Forsblom et al., 2022).

Features of the course environment

Since student appraisals influence emotions and emotions can influence engagement, it is important to understand what influences student appraisals of control and value. Control–Value Theory assumes that features of the course environment (both social and cultural) provide information to students about their ability to control their success and the value of what they are being asked to do (Pekrun, 2006). Like control and value, these features of the course environment are also filtered through a student's perceptions and are sometimes termed "distal appraisals" in this theory (Pekrun & Stephens, 2010). We will refer to them as *environment features* to avoid confusion with appraisals of control and value. In a study of math classes in Hong Kong and England, the environment feature of instructor clarity increased students' sense of control and the value they saw in math and, through these, increased enjoyment (Chen & Lu, 2022). Thus, instructors can shape the course environment to influence activity emotions and behaviors (Linnenbrink-Garcia et al., 2016).

In the current study, we are interested in course environment features that instructors may be able to shape and through which they may influence engagement in active learning courses. Active learning courses are distinct from more traditional courses in their frequent use of formative assessment activities before (e.g., reading quizzes) and during class (e.g., clicker questions), as students are learning the material. For students to maximally benefit from these activities, they need to engage effortfully by trying hard, staying focused, and not giving up in the face of difficulty. This type of engagement is not always what students expect, particularly if they are used to being evaluated in a summative fashion only. This potential misalignment of student and course expectations can increase confusion and resistance, ultimately decreasing their motivation to engage. In addition, most active learning courses have social elements where students work together on in-class activities. This can raise concerns about "looking bad" in front of peers and lead to social comparison that may cause students to disengage (Canning et al., 2020; Elliott & Dweck, 1988). Given these unique characteristics of active learning courses, we focus on four features of the course environment that may be important to attend to in order to maximize student engagement: goal structure, relevance, instructor–student relationship, and competition. We present evidence that these features could operate through the dimensions of Pekrun's Control–Value Theory of Achievement Emotions to influence student engagement.

Goal structure. Instructors can establish goals for a course that influence students' personal goals (Fokkens-Bruinsma et al., 2020). Achievement Goal Theory provides one taxonomy for thinking about student goals relevant to active learning courses (Urdan & Kaplan, 2020). In this taxonomy, students can approach a course from a performance goal orientation (focusing on looking competent), a mastery goal orientation (focusing on developing competence), or both (Meece et al., 2006). There is evidence from the K-12 literature that students who hold performance goals as their primary goal will sacrifice opportunities to learn if those opportunities risk their ability to appear smart (Elliott & Dweck, 1988). This could manifest as reduced participation in small group conversations during active learning and reduced effort on activities. Mastery goal orientation, on the other hand, is associated with student persistence at challenging tasks and deep-level learning strategies that reflect effortful engagement (Greene et al., 2004; Wolters, 2004). A recent meta-analysis demonstrated that classroom goal structures promoting mastery increase students' adoption of mastery goals (Bardach et al., 2020).

Studies using Achievement Goal Theory have related a mastery focus to several dimensions found in Pekrun's theory. For example, a mastery focus is related to higher enjoyment of learning and lower anger and boredom compared to a performance focus (Daniels et al., 2008; Pekrun et al., 2009). Mastery goals may also promote a sense of control as a student measures their progress by personal growth rather than by a comparison to the performance of others (Linnenbrink, 2007; Linnenbrink & Pintrich, 2002; Linnenbrink-Garcia & Barger, 2014). Thus, classroom goal structure could influence engagement through activity emotions and control.

Relevance. Multiple studies have demonstrated that when students find a course to have relevance to them, their engagement increases (review in Priniski et al., 2018). In an active learning classroom, which may require students to engage in ways they may not be accustomed to, relevance may be a motivating factor for students to continue through difficult tasks. Relevance seems to work in multiple ways, but the most germane for our study is that it influences value. Specifically, relevance can influence utility value—helping students see something as useful to them—or attainment value—seeing something as related to the self (Eccles et al., 1983).

Pekrun's conception of value in Control–Value Theory captures both of these conceptions of interest. Instructors can influence relevance through course features such as making connections between content and real-world problems or relating the course to student identities (Linnenbrink-Garcia et al., 2016).

There are many different forms of relevance and in the current study, we focus on relevance of course content and skills for helping others. We focus on this because Generation Z, who is currently in college, is a prosocial generation, on average, and expresses being motivated by helping others and advocating for things they believe in (Seemiller & Grace, 2015). In addition, this form of relevance can relate both to utility value (i.e., how students might use what they are learning to help others) and attainment value (i.e., how learning this content might help students be the good person they strive to be).

Instructor–student relationship. Another important feature of classroom environments is the instructor–student relationship. Active learning often asks students to engage in challenging tasks and to engage in more coursework than a more passive course might ask of students. Students' belief that this extra work will benefit them has been shown to be important in active learning courses (Hernandez et al., 2021). One way this belief can develop is through the instructor–student relationship. Researchers have found that when students trust that the instructor cares about them and is competent to guide their learning, their engagement in active learning courses increases (Cavanagh et al., 2018; Reis et al., 2004).

The quality of instructor–student relationships has been widely demonstrated to influence student emotions in K-12 settings. For example, a supportive teaching style is positively correlated with feelings of enjoyment and pride, and negatively correlated with boredom and anxiety across multiple studies (Ahmed et al., 2010; Goetz et al., 2013; Lazarides & Buchholz, 2019). A better-quality relationship produced more positive emotions and weaker negative ones in 10th and 11th graders (Goetz et al., 2021). In addition, a study on the quality of instructor–student relationships, as measured through the ideas of closeness and conflict, found that greater closeness predicted more enjoyment and less boredom across multiple subject areas (Clem et al., 2021). Thus, the instructor–student relationship in active learning courses may matter for student engagement by influencing student emotions, although research has not demonstrated whether this is due to perceptions of control and/or value.

Competition. STEM courses, especially gateway courses, are often perceived as competitive courses. Competition can enhance social comparison concern in all students, and especially first-generation students (Canning et al., 2020). Fears about social comparison can lower student engagement and attendance (Canning et al., 2020). Such effects of competition are especially concerning in the context of active learning, since student learning hinges on their presence, participation, and interactions with peers. Course characteristics that may be under the instructor's purview can signal how competitive a course is. For example, curved grading inherently compares students' performances to each other (promoting competition), whereas criterion-based grading focuses on an individual student's ability to master a task (Covington & Omelich, 1984). Instructors can also signal the level of competition in a course through how they talk about course goals and aspects of course design (Canning et al., 2020).

Competition by its nature means there are winners and losers in the classroom which can reduce students' feelings of control (Frenzel et al., 2007). Competition in classrooms has been positively correlated with feelings of anxiety and anger (Baudoin & Galand, 2017; Frenzel et al., 2007), but also to a lesser degree, enjoyment and boredom (Frenzel et al., 2007). Thus, perceived competition can influence students' sense of control and their activity emotions.

In summary, the Control–Value Theory of Achievement Emotions suggests that features of the course environment have the potential to influence student engagement in active learning courses through students' appraisals of their control over their learning and the value they see in that learning, and the emotions experienced during course activities. In this study, we examine how four features of the classroom environment influence control, value, activity emotions, and ultimately, student engagement in active learning. Although engagement can be measured in many ways (Groccia, 2018), we focused on cognitive engagement, a measure of the degree of psychological investment (Fredricks et al., 2004). Our specific research questions were:

1. How do course environment features (specifically, student perceptions of classroom goal structure, relevance of the course, instructor–student relationship, and perceived competition in the class) relate to students' appraisals of control and value in active learning courses?
2. How do course environment features and students' appraisals of control and value relate to activity emotions students experience in active learning courses?
3. How do students' appraisals of control and value, and the activity emotions they experience relate to students' engagement in active learning courses?

4. How do course environment features, mediated by appraisals and activity emotions, influence students' engagement in active learning courses?

Methods

Course selection, survey procedures, and participant demographics

We recruited a national sample of 13 instructors using active learning and invited their students to participate in the study. We identified instructors through a process that began with a review of existing literature regarding implementation of active learning approaches in introductory STEM courses (Theobald et al., 2020). This review included published and unpublished studies authored by introductory STEM course instructors, who investigated their own use of active learning strategies. We emailed these studies' authors inviting them to participate in our study. In cases where the authors we contacted were not available to participate, we asked them to recommend colleagues who use similar approaches as they do in teaching an introductory STEM course. Thus, we relied on instructor self-report of use of active learning practices and confirmed their use of these practices through conversation before we collected data in their courses. Instructors in our sample used a suite of different practices (including small group work in class, clickers, group quizzes, etc.) that all fell under our broad definition of active learning, which involves engaging students during class through activities designed to elicit their involvement (Freeman et al., 2014). The variation in practices found across participants is a strength of our study, as it demonstrates that the model we build is robust to the range of varied practices that fall under the umbrella of active learning.

After obtaining necessary institutional permissions, we surveyed the students enrolled in each instructor's in-person introductory STEM course during 2022 or 2023. Disciplinary areas of the courses included: biology (4 classes), calculus (2 classes), chemistry (3 classes), computer science (1 class), geology (1 class), and physics (2 classes). Instructors distributed an electronic link to students to complete the online survey for a small amount of course credit. The survey was distributed during the second half of the term in order to ensure that students had sufficient exposure to the course environment. This study was considered exempt under IRBs: Eastern Michigan University UHSRC-FY21-22-139, Florida International University IRB-20-0370-AM01, New Mexico State University 2206001150, University of Minnesota STUDY00020526, University of South Florida Study003772, University of Washington Study00010826, and Washington University in St. Louis 202112131.

All classes included in this study are from institutions of higher education in the United States. Across the 13 classes, 1,885 students responded to the survey. Response rates by class can be found in Supplemental Table 1. Of the survey respondents, 63% reported a race/ethnicity that is non-White and/or reported more than one race/ethnicity, while 34% of respondents reported their race/ethnicity as White. Nationally in the United States, 48% of undergraduate students enrolled in higher education institutions in fall 2021 reported a race/ethnicity that is non-White or more than one race/ethnicity, while 52% of students reported their race/ethnicity as White (U.S. Department of Education, 2023). In terms of gender, 63% of respondents in this study reported female and/or feminine and/or woman, 31% of respondents reported male and/or masculine and/or man, and 4% of respondents reported another gender in addition to or other than binary gender categories. Nationally in the United States, information on student gender identity is not available, but in terms of binary sex categories, 58% of undergraduate students enrolled in higher education institutions in fall 2021 reported female and 42% of students reported male (U.S. Department of Education, 2023). Thirty percent (30%) of respondents in this study were deemed first-generation college students based on the highest level of education of their parent or guardian as reported by the survey respondents. Nationally in the United States, 54% of undergraduate students identified as first-generation college students in 2020 (RTI International, 2023).

Survey instrument and measures

The survey instrument included measures of students' perceptions of course environment features, their appraisal of the course in terms of control and value, the emotions they experience in relation to in-class course activities, their level of cognitive engagement in the course, and demographic information. Each of the measures that were considered for analysis in this study are briefly described below. Survey scales analyzed for this study can be found in Supplemental Table 2.

Course environment features

Based on a review of the literature and in consultation with an advisory board of STEM education research experts, four constructs were selected to assess students' perceptions of their course environment. These constructs were measured by adapting existing scales: perceived classroom goal structure (Midgley et al., 2000), perceived relevance of the course for helping others (Jackson et al., 2016; Zambrano et al., 2020), students' trust in their instructor (Adams & Forsyth, 2009), and perceived sense of competition in the class (Arnold et al., 2009; Canning et al., 2020). In some cases, we combined items from two existing scales to measure one construct if we deemed that there were an insufficient number of items from one scale. We adapted the wording of some items if the original scales were written for K-12 or workplace contexts, rather than the undergraduate classroom context.

The scale measuring perceived classroom goal structure (henceforth referred to as "Mastery") consisted of 6 items (example item: "In this class, it's important to understand the work, not just memorize it"). Among the different ways to measure course relevance, we focused on relevance for helping others given that the current generation of college students are motivated by helping others and advocating for causes they believe in (Seemiller & Grace, 2015). The scale measuring perceived relevance of the course for helping others (henceforth referred to as "Relevance") consisted of 6 items (example item: "I think I can apply knowledge and skills I learn in this class to helping others"). Instructor–student relationship can be characterized and measured in many different ways. We chose to focus on students' trust in their instructor, since trust is considered a foundational component of instructor–student relationships (Addy et al., 2021; Artze-Vega et al., 2023). The scale measuring students' trust in their instructor (henceforth referred to as "Trust") consisted of 12 items (example item: "The professor of this class is always ready to help"). The scale measuring perceived sense of competition in the class (henceforth referred to as "Competition") consisted of 8 items (example item: "Everybody is concerned with finishing at the top of this class"). All items measuring the course environment features were asked on a six-point Likert scale (strongly disagree [1], disagree [2], somewhat disagree [3], somewhat agree [4], agree [5], strongly agree [6]).

Course appraisals

The two course appraisals of students' sense of control over their learning and their perceived value of the course were measured using existing scales (Perry et al., 2001; Pintrich et al., 1991, respectively). The scale measuring sense of control (henceforth referred to as "Control") consisted of eight items (example item: "I see myself as largely responsible for my performance in this course"). The scale measuring perceived value of the course (henceforth referred to as "Value") consisted of six items (example item: "I think I will be able to use what I learn in this course in other courses"). All items measuring the constructs of Control and Value were asked on a six-point Likert Scale (strongly disagree [1], disagree [2], somewhat disagree [3], somewhat agree [4], agree [5], strongly agree [6]).

Activity emotions

There are seven achievement-related activity emotions per Pekrun et al.'s (2017) short form of epistemic emotions scale. In the short form, each emotion is measured by a single item. Per the short form, students in this study were asked, "For each emotion, please mark how strongly you experience that emotion in a typical class day" and were provided with the following emotions: surprised, curious, excited, confused, anxious, frustrated, and bored. The scale for rating these emotions were: not at all (1), very little (2), moderate (3), strong (4), very strong (5).

Engagement

Students' level of engagement in the course was measured using Wang et al.'s (2016) math and science engagement scale. While Wang et al.'s (2016) full scale consists of items pertaining to cognitive, behavioral, emotional, and social engagement, we used eight items pertaining to cognitive engagement only. This was in order to keep the overall length of the survey reasonable and since some items pertaining to the other three types of engagement were deemed to overlap with items on other constructs being measured on the survey. For instance, there were items pertaining to behavioral engagement that were similar to items on the Mastery scale, items pertaining to emotional engagement that were similar to items on the Value scale, and items pertaining to social engagement that were similar to items on the Competition scale. Thus, for the purposes of this study, the eight items pertaining to cognitive engagement per Wang et al. (2016) constitute our Engagement scale. An example item on this scale was: "I try to understand my mistakes when I get something wrong." Items on this scale were asked on a six-point Likert scale (strongly disagree [1], disagree [2], somewhat disagree [3], somewhat agree [4], agree [5], strongly agree [6]).

Construct validity and reliability

Each construct was evaluated in terms of validity by seeking feedback from an expert panel of STEM education researchers and from examining the factor loadings through confirmatory factor analyses. Reliability was evaluated by assessing McDonald's omega coefficient for each of the scales included in the survey. Methodologists generally agree that McDonald's omega, rather than Cronbach's alpha, is the preferred measure of reliability given the former's general applicability, whereas the latter is only suitable under limited circumstances with assumptions that are usually unrealistic (Hayes & Coutts, 2020; Knekta et al., 2019; McNeish, 2018).

Data analysis

Descriptive statistics were examined to assess the normality of the measured variables and patterns of missingness. For items asked on a 6-point Likert scale (Mastery, Relevance, Trust, Competition, Control, Value, and Engagement) means ranged from 1.53 to 5.26, and standard deviations ranged from 0.80 to 1.65. For items asked on a 5-point Likert scale (activity emotions), means ranged from 2.42 to 3.41 and standard deviations ranged from 0.86 to 1.19. Univariate skewness ranged from 0.02 to 2.11 and kurtosis ranged from 0.01 to 5.24. Mardia's test of multivariate normality indicated a lack of multivariate normality, leading us to use maximum likelihood estimation with robust standard errors (MLR) in our confirmatory factor analyses (CFAs) and structural equation modeling (SEM) analyses. MLR is suitable for nonnormally distributed survey data with five or more response options that can be considered continuous (Knekta et al., 2019).

The individual survey item with the highest amount of missing data was missing at 0.80%. Based on Little's MCAR test, missing items were determined to be missing completely at random (MCAR) since the result was non-significant. This led us to apply full-information maximum likelihood (FIML) during the modeling phase of our analysis, which was conducted using the lavaan package in R.

Two-phase modeling approach

The first phase of the two-phase modeling approach was to examine measurement models using confirmatory factor analyses (CFAs). CFAs were chosen as appropriate for our purposes since we are testing (confirming) theoretical models using constructs with existing validity evidence based on prior studies that have been conducted in contexts similar to our study (Knekta et al., 2019). We used CFAs to examine how well the survey items reflected the latent variables of Mastery, Relevance, Trust, Competition, Control, Value, and Engagement. The measurement model for each construct was assessed individually, then as a unified model with all constructs included. Model fit indices, such as the comparative fit index (CFI), root-mean-square error of approximation (RMSEA), and standardized root-mean-square residual (SRMR) were used to assess model fit following Hu and Bentler's (1999) recommendations as rough guidelines (e.g., CFI > 0.95, SRMR < 0.08, and RMSEA < 0.06). In cases of clearly poor model fit we considered modifications such as the elimination of dysfunctional scale items and/or the addition of residual covariances between specific scale items, as long as these modifications were deemed theoretically sound after discussion and arriving at consensus among the authors.

Given satisfactory fit for measurement models in the first phase, we specified a unified structural model in the second phase of modeling, to assess the hypothesized paths between the predictor variables and the outcome of interest, student engagement, controlling for instructor, as shown in Fig. 2. Combined with the first phase, the two-phase approach constitutes structural equation modeling (SEM), which is an analytical method used to evaluate a priori theory-driven hypotheses regarding causal relationships among measured and/or latent variables, including relationships that are mediated by intermediary variables (Mueller & Hancock, 2019). During our second phase of SEM, we retained any measurement model modifications made in the first phase. We controlled for the hierarchical nature of the data (students nested within 13 classes) by making instructor a fixed effect variable and specifying it as covariates of the four course environment constructs and the two appraisal constructs. We selected an instructor at random to be the reference level. We did not hypothesize paths from the instructor variable to the seven activity emotions, since prior research on the effects of students' class environment perceptions on their emotional experiences concluded that the effects function primarily at the individual, rather than classroom, level (Frenzel et al., 2007). Similarly, we did not hypothesize paths from the instructor variable to Engagement since we deemed this construct to be more internally driven and less influenced by the nestedness of the data, as Urdan (2004) found in a study relating students' class environment perception to their goals and outcomes.

In terms of the relationships among constructs, course appraisals (Control, Value) were hypothesized to mediate the relation between the course environment features (Mastery, Relevance, Trust, Competition) and the seven activity emotions, as well as between the course environment features and Engagement. The seven activity emotions were also hypothesized to mediate the relations of the course appraisals with Engagement. In addition to the structural relations, we theorized that residuals with common blocks of endogenous variables would covary (i.e., between Control and Value; among all emotions), reflecting sources of relations other than their common causal antecedents within the model. The structural model was itself assessed for satisfactory fit using the three fit indices mentioned above. The full results combining the measurement and structural models can be found in the Supplements.

Results

Confirmatory factor analyses

During confirmatory factor analyses, we eliminated dysfunctional scale items and added residual covariances

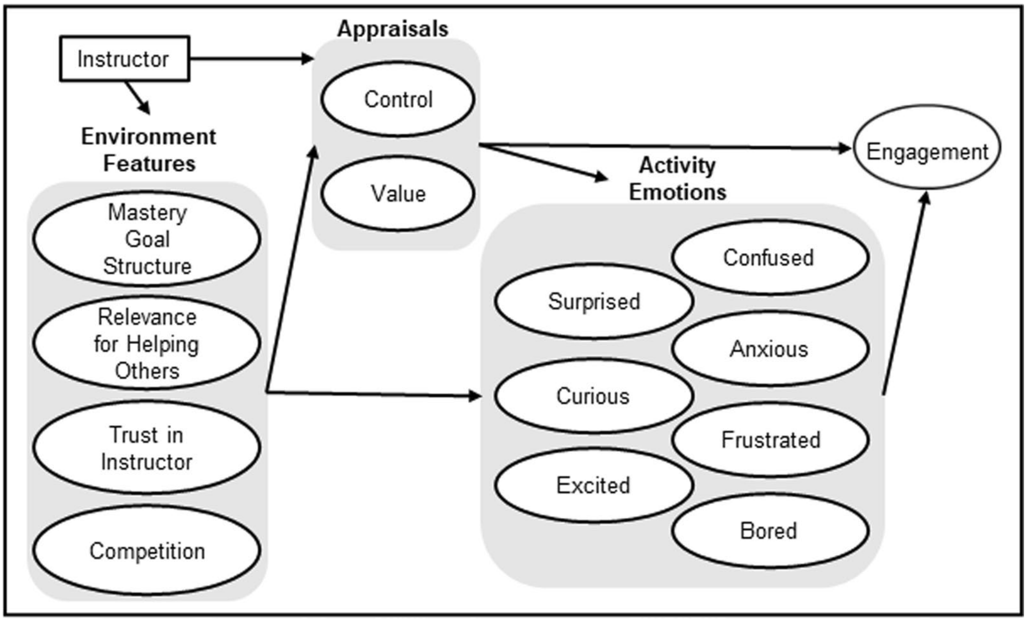

Fig. 2 Proposed SEM model. Each gray box includes multiple constructs. Arrows shown to and from the gray boxes are simplified representations of the diverse paths between each construct

between some scale items if the authors agreed these modifications were theoretically sound. Eliminated scale items included Trust 2 (initial CFA factor loading of 0.35), Engagement 5 (initial CFA factor loading of −0.33), Engagement 6 (initial CFA factor loading of −0.27), Engagement 7 (initial CFA factor loading of −0.40), and Engagement 8 (initial CFA factor loading of 0.32). All original survey items, including those eliminated during this phase of the analysis, can be found in Supplemental Table 2. Within the Control scale, residual covariances were added among Control 3, Control 5, Control 6, and Control 8, specifically to account for the fact that these items were negatively worded (i.e., they asked about lack of control) and all other items on the scale were positively worded. We added residual covariances between other scale items when the wording or the idea behind these items were similar in a way that led us to assume a relationship between the items beyond the fact that they are items within the same scale. These items were: Mastery 1 and Mastery 2, Mastery 1 and Mastery 6, Relevance 2 and Relevance 3, Trust 10 and Trust 11, Competition 1 and Competition 4, Competition 4 and Competition 5, Competition 6 and Competition 7, Value 2 and Value 6, Value 3 and Value 5. The residual covariances of these relations are reported in Supplemental Table 3.

After making the above modifications, confirmatory factor analyses for each of the latent variables showed satisfactory fit to the data. McDonald's omega reliability coefficients for the seven scales ranged between 0.80 and 0.96, indicating acceptable reliability (Supplemental Table 2). Assessed under a unified measurement model, fit indices were: $\chi^2 = 4417$, $p < 0.001$; CFI (robust) = 0.94, RMSEA (robust) = 0.05; SRMR = 0.06. The standardized factor loadings for all items retained in the final model were highly significant ($p < 0.001$) and equal to or greater than 0.5 for all items, with the exception of Mastery 6 (factor loading of 0.46), Control 7 (factor loading of 0.49), and Control 8 (factor loading of 0.48). These three items were retained in the model since they were highly significant and since in the review of these items, there was no clear theoretical basis for removing them. Overall, these results indicated that the data fit the measurement model well.

Structural equation modeling

Fitting the data to the structural model indicated satisfactory fit: $\chi^2 = 7482$, $p < 0.001$; CFI (robust) = 0.92, RMSEA (robust) = 0.04; SRMR = 0.05. Full results of the structural model components can be found in Supplemental Table 4.

Direct effects of course environment features on course appraisals

Control was significantly influenced by all four course environment features ($p < 0.001$; $R^2 = 0.43$; Fig. 3). When Mastery (estimate and standard error: 0.40 ± 0.079; standardized coefficient: 0.21), Relevance (0.09 ± 0.023; 0.12), and Trust (0.44 ± 0.044; 0.35) increased, students'

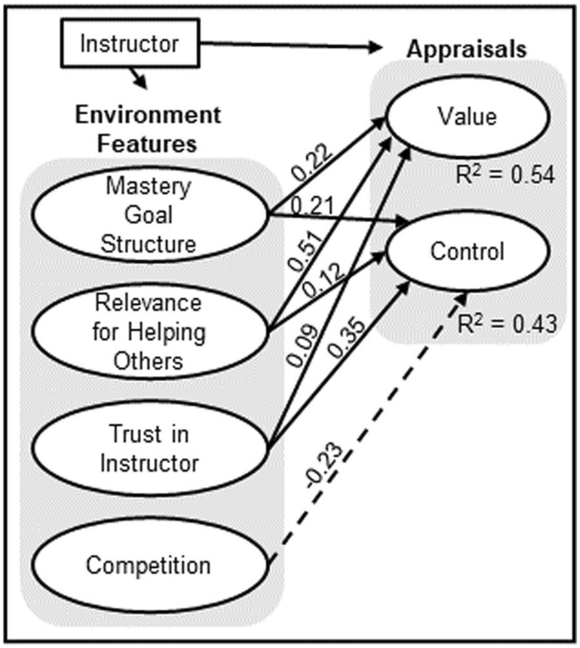

Fig. 3 Direct effects of course environment features on student appraisals of Control and Value, after accounting for instructor effects. Numbers shown above the paths are standardized coefficients with alpha values < 0.05. A solid black path is a positive relationship, and a dashed black path is a negative relationship. This figure is a subset of the full SEM model subdivided for clarity. See Figs. 4 and 5 for visuals of the rest of the structural model. See Supplemental Tables for full model results

sense of control also increased. As for Competition (−0.25 ± 0.036; −0.23), an increase in this course environment feature was associated with a decrease in students' sense of control. Of these four paths between the course environment features and Control, Trust had the strongest effect with a standardized coefficient of 0.35.

Value was significantly influenced by three of the four course environment features ($p < 0.001$; $R^2 = 0.54$; Fig. 3). Mastery (0.42 ± 0.068; 0.22), Relevance (0.38 ± 0.021; 0.51), and Trust (0.11 ± 0.033; 0.09) were found to increase students' perceived value of the course. Competition did not have a significant effect on Value. Relevance's influence on Value was found to have the largest effect with a standardized coefficient of 0.51.

We also saw variability among instructors in terms of students' perceptions of the four environment features, although the amount of variation explained at the instructor level was generally low ($R^2 = 0.07$–0.10) except for Competition ($R^2 = 0.25$). The variation in Control and Value explained by the instructor level was higher than for the environment features (R^2[control] = 0.43; R^2[value] = 0.54). See Supplemental Table 4 for full results.

Direct effects of course environment features and course appraisals on activity emotions

We found several course environment features and course appraisals significantly impacting the positive activity emotions of Surprise, Curiosity, and Excitement (Fig. 4). In terms of Surprise ($R^2 = 0.05$), there were significant positive direct paths from Relevance (estimate and standard error: 0.15 ± 0.029; $p < 0.001$; standardized coefficient: 0.18), Trust (0.12 ± 0.044; $p < 0.01$; 0.09), and Competition (0.15 ± 0.035; $p < 0.001$; 0.12). Among these predictors, Relevance had the largest effect with a standardized coefficient of 0.18. Mastery, Control, and Value were not found to be significant predictors of Surprise. For Curiosity ($R^2 = 0.32$), we found significant positive direct paths from Relevance (0.06 ± 0.029; $p < 0.05$; 0.08), Trust (0.15 ± 0.036; $p < 0.001$; 0.12), and Value (0.45 ± 0.051; $p < 0.001$; 0.45). Value was the strongest predictor of Curiosity with a standardized coefficient of 0.45. Mastery, Competition, and Control were not found to be significant predictors of Curiosity. In terms of Excitement ($R^2 = 0.30$), we found a significant negative direct path from Mastery (−0.17 ± 0.064; $p < 0.01$; −0.08) and positive direct paths from Relevance (0.16 ± 0.030; $p < 0.001$; 0.20), Trust (0.19 ± 0.039; $p < 0.001$; 0.14), Control (0.10 ± 0.036; $p < 0.01$; 0.09), and Value (0.34 ± 0.051; $p < 0.001$; 0.31). Value was the strongest predictor with a standardized coefficient of 0.31. There was no direct path between Competition and Excitement.

We also found several course environment features and course appraisals significantly impacting the negative activity emotions of Confusion ($R^2 = 0.26$), Anxiety ($R^2 = 0.26$), Frustration ($R^2 = 0.29$), and Boredom ($R^2 = 0.17$; Fig. 5). Mastery (0.73 ± 0.094; $p < 0.001$; 0.33) was a significant positive direct predictor of Confusion, while Trust (−0.12 ± 0.047; $p < 0.01$; −0.09), Control (−0.45 ± 0.043; $p < 0.001$; −0.40), and Value (−0.32 ± 0.046; $p < 0.001$; −0.28) were significant negative predictors of Confusion. Control had the largest effect on Confusion, with a standardized coefficient of—0.40. Relevance and Competition were not found to be significant predictors of Confusion. There were two significant positive direct predictors of Anxiety: Mastery (0.72 ± 0.104; $p < 0.001$; 0.27) and Competition (0.15 ± 0.043; $p < 0.001$; 0.10). There were also two significant negative direct predictors of Anxiety: Control (−0.64 ± 0.054; $p < 0.001$; −0.47), and Value (−0.24 ± 0.052; $p < 0.001$; −0.17). Control, with a standardized coefficient of −0.47 was the most influential predictor of Anxiety. There was no significant relationship between Relevance and Anxiety or Trust and Anxiety. As for Frustration, there was a significant positive direct path from Mastery (0.80 ± 0.105; $p < 0.001$; 0.32), and significant negative direct paths from Trust (−0.18 ± 0.055; $p < 0.001$; −0.11), Control (−0.60 ± 0.051;

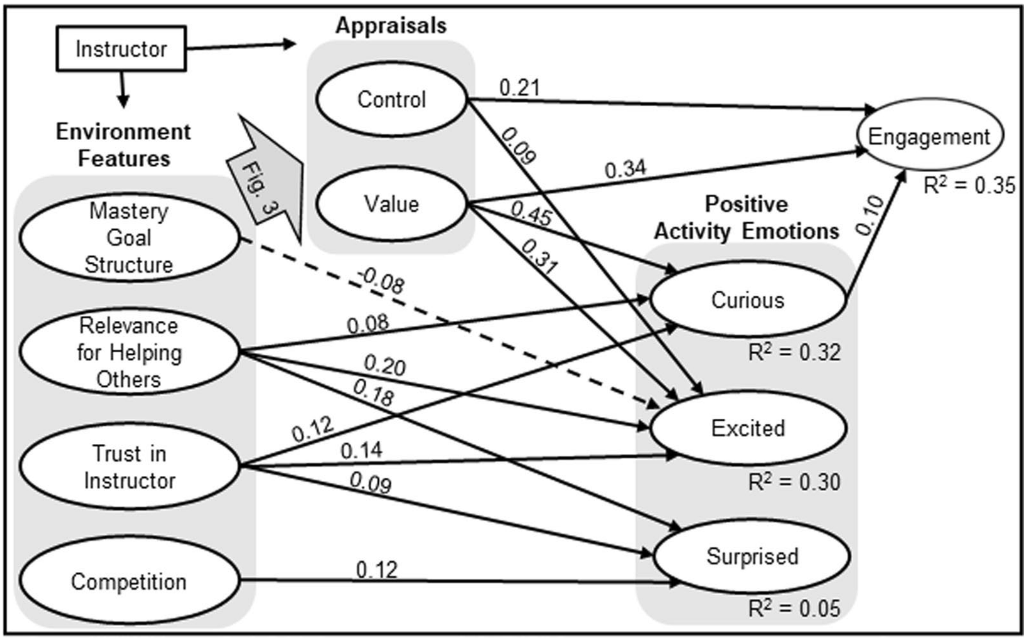

Fig. 4 Direct effects of course environment features and appraisals on positive activity emotions as well as the effects of these variables on engagement, after accounting for instructor effects on environment features and appraisals. This figure is a subset of the full SEM model subdivided for clarity. The direct effects of environment features on appraisals are illustrated in Fig. 3 and the relationships with negative activity emotions in Fig. 5. See Supplemental Tables for full model results

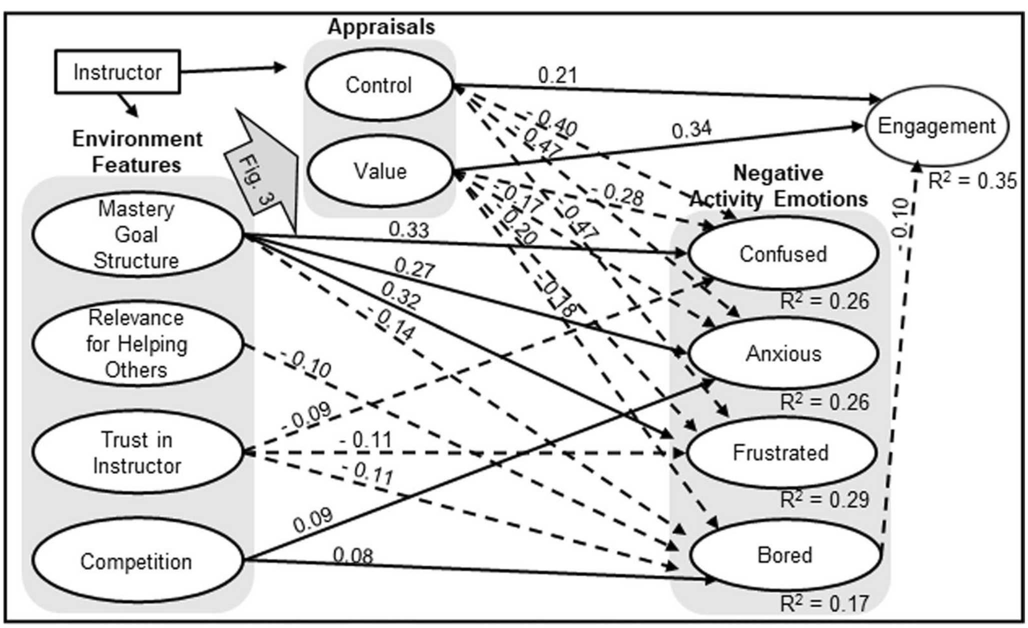

Fig. 5 Direct effects of course environment features and appraisals on negative activity emotions as well as the effects of these variables on engagement, after accounting for instructor effects on environment features and appraisals. This figure is a subset of the full SEM model subdivided for clarity. The direct effects of environment features on appraisals are illustrated in Fig. 3 and the relationships with positive activity emotions in Fig. 4. See Supplemental Tables for full model results

$p < 0.001$; −0.47), and Value (−0.26 ± 0.053; $p < 0.001$; −0.20). The largest effect was seen in the relationship between Control and Frustration, which had a standardized coefficient of −0.47. Relevance and Competition were not found to be significant predictors of Frustration. Finally for Boredom, significant negative direct predictors included Mastery (−0.29 ± 0.075; $p < 0.001$; −0.14), Relevance (−0.08 ± 0.029; $p < 0.01$; −0.10), Trust (−0.15 ± 0.044; $p < 0.001$; −0.11), and Value (−0.20 ± 0.046; $p < 0.001$; −0.18). Competition (0.10 ± 0.032; $p < 0.01$; 0.08) was a significant positive direct predictor of Boredom. Among these variables, Value had the largest effect on Boredom with a standardized coefficient of −0.18. Control was not a significant predictor of Boredom.

Direct effects of course appraisals and activity emotions on engagement

Of the potential direct predictors of Engagement ($R^2 = 0.35$), Control (estimate and standard error: 0.16 ± 0.031; $p < 0.001$; standardized coefficient: 0.21), Value (0.27 ± 0.030; $p < 0.001$; 0.34), Curiosity (0.08 ± 0.027; $p < 0.01$; 0.10), and Boredom (−0.07 ± 0.019; $p < 0.001$; −0.10) were found to be significant (Figs. 4 and 5). Of these predictors, Boredom was the only one that had a negative relationship with Engagement. Value had the largest direct effect on Engagement with a standardized coefficient of 0.34. The activity emotions of Surprise, Excitement, Confusion, Anxiety, and Frustration were not found to be significant predictors of Engagement.

Total effects of course environment features on engagement

Our study aimed to understand whether and how student perceptions of course environment features influence students' engagement through the mediated paths posited by Control–Value Theory. Our hypothesis is that since instructors can influence how they shape their course environment it is worth paying attention to how these course environment features are ultimately impacting student engagement. The caveat, of course, is that engagement is likely a complicated construct that students arrive at through various paths. To capture a global understanding of how course features impact engagement, we calculated the total effects of these variables inclusive of all their direct and indirect paths to engagement (this includes non-significant paths) based on the results of our structural equation modeling. As seen in Supplemental Table 5, Mastery (estimate and standard error: 0.23 ± 0.038; standardized coefficient: 0.15), Relevance (0.16 ± 0.012; 0.26), and Trust (0.13 ± 0.020; 0.13) had significant ($p < 0.001$) positive total effects on Engagement. Competition (−0.03 ± 0.014; −0.04) had a significant ($p < 0.05$) negative total effect on Engagement. Among these predictors, Relevance had the largest total effect with a standardized coefficient of 0.26. This total effect (and similarly, each of the total effects of the other course environment features on Engagement) was computed by summing up the effects of Relevance on Engagement mediated by Control and Value, then combining it with the effects of Relevance on Engagement mediated by each of the seven emotions. Examination of total effects is insightful since it quantifies how Engagement is influenced by the four course environment features, which, among all variables examined in this study, are arguably the most amenable to change as a direct result of specific instructor practices.

Discussion

We found that four course environment features (classroom goal structure, relevance for helping others, trust in instructor, and competition) all influenced student engagement in active learning course activities through students' appraisals of control and value and through the activity emotions of curiosity and boredom. Thus, Pekrun's Control–Value Theory of Achievement Emotions can be useful for considering student engagement in active learning courses, particularly in light of the relationships between environment features and the appraisals of control and value, as well as the relationships between these appraisals and student engagement. At the same time, there were several hypothesized paths that were not found to be significant, such as those between some activity emotions and student engagement. Results from this study point to both helpful insights regarding the applicability of Pekrun's theory in understanding student engagement in active learning courses as well as directions for further study.

Course environment features and their relationships to control, value, activity emotions, and engagement

The Control–Value Theory of Achievement Emotions posits that course environment features can influence achievement behaviors through their influence on student appraisals of control and value, and then through the influence of control and value on activity emotions. Our study generally confirmed this prediction: the four environment feature variables had stronger direct effects on control and value than direct effects on emotions (except for classroom goal structure which had similar sized direct effects on some emotions). Below we describe the patterns generated by each environment feature variable.

Goal structure

Classroom goal structure contributed equally to perceived control and value. This result is in line with literature demonstrating that a focus on mastery can enhance students' sense of control since students' metric for measuring their own success shifts to one focused on personal growth rather than comparison to others (Linnenbrink, 2007; Linnenbrink & Pintrich, 2002; Linnenbrink-Garcia & Barger, 2014). In addition, instructors who endorse mastery goals tend to explicitly tell their students why a deep understanding of the content matters and connect the content to students' interests (Meece, 1991). Both of these features of a mastery classroom can influence value, since students find the material personally meaningful when they are able to see how it relates to them (reviewed in Priniski et al., 2018).

Despite having positive relationships with control and value, a classroom goal structure focused on mastery was found to increase multiple negative emotions (confusion, anxiety, frustration) while it had no effect or decreased (in the case of excitement) positive emotions. This pattern was unexpected since a mastery goal structure should encourage the adoption of mastery goals, which are usually positively correlated with positive emotions and negatively correlated with negative emotions (see meta-analysis Huang, 2011). However, the complex relationship between a mastery goal structure and emotions is also reasonable if considering what a mastery-focused classroom might entail. Often when instructors emphasize a mastery goal structure in their class, students are asked to move towards more open-ended, complex activities (Belenky & Nokes-Malach, 2013), which students may find more difficult, especially if they are not well scaffolded (Whiteman & Ochakovskaya, 2017). More open-ended and difficult tasks could elevate experiences of confusion, anxiety, and frustration as we observed. Further studies of the activities occurring in classrooms with mastery goal structures are warranted to test this hypothesis. At the same time, it is important to note that in our study, the three negative emotions that were correlated with goal structure were not significantly related to engagement. As for the emotions that did have significant relationships with engagement, curiosity was not impacted by a mastery goal structure while boredom was reduced by a mastery goal structure.

On the whole, a more mastery-focused goal structure increased engagement, and it was found to have the second strongest positive overall impact on engagement among the four course environment features. Some examples of instructor practices that influence students' perceptions of course goal structure and promote a mastery focus in students include: structuring opportunities for iteration and feedback on assignments, providing varied and challenging activities, and engaging in appropriate pacing (Ames, 1992; Fokkens-Bruinsma et al., 2020; Pintrich & De Groot, 1990).

Relevance for helping others

Relevance for helping others had the largest positive effect on perceived value among all classroom environment features, smaller positive effects on control and positive emotions, and a small negative effect on boredom. Multiple studies have found that highlighting the relevance of course material can make the material personally meaningful (reviewed in Priniski et al., 2018) and, thus, increase its perceived value to students. Relevance that focuses on how the content can have a positive impact on the world has been called "self-transcendent purpose" and it works through increasing the salience of this goal in the classroom with the assumption that this goal matters to students (Yeager & Bundick, 2009; Yeager et al., 2014). Studies have found that students persisted longer at boring tasks (Eccles, 2009; Yeager et al., 2014) and engaged in deeper learning behaviors with those tasks (Yeager et al., 2014) when the tasks were framed with a prosocial purpose. When a topic becomes something of interest because of personal relevance it is also associated with positive emotions (Deci & Ryan, 1985; Hidi & Renninger, 2006). This explains the relationship between students' perceived relevance of the course for helping others and their positive emotions. The small relationship to control is less readily explained by existing literature. It is possible that relevance encourages students to put more effort into a course and, thus, makes positive outcomes seem more possible.

Of the four course environment features examined in this study, relevance had the strongest positive overall impact on engagement. Instructors can help students see the relevance of content for helping others through the use of short interventions (Yeager & Bundick, 2009; Yeager et al., 2014) and through explicitly teaching that connection as part of the course content.

Instructor–student trust

Students' trust in their instructor exhibited a larger positive influence on control than on value. It also had small positive impacts on positive emotions and small negative impacts on negative emotions (except anxiety, where it had no impact). These results align with the literature, which demonstrate that a better-quality relationship with instructors elicits positive emotions (Ahmed et al., 2010; Goetz et al., 2013, 2021; Lazarides & Buchholz, 2019). The literature also supports the relationship between instructor trust and students' appraisal of control. An instructor that is trustworthy likely exhibits characteristics such as competence, reliability, and care. In the literature, these characteristics are found to increase students' sense that an instructor is fair and empowers learners (Chory, 2007; Schrodt et al., 2009). A fair and empowering classroom environment allows students to feel that they are in control of their success and failure. It is important to note that students' trust in the instructor is one aspect of how students perceive the instructor's role or relationship to them. If we had measured other ways that students perceive their instructor, we may have seen more influence on value. For example, instructor enthusiasm has been correlated with student interest (as measured by value and affect; Kim & Schallert, 2014).

In this study, instructor–student relationship, as measured by trust, was the third most influential feature of the course environment in terms of its overall impact on engagement. The framework of trust we used has five facets: openness, benevolence, competence, honesty, and reliability (Adams & Forsyth, 2009) and these suggest areas for instructors to focus on to build trust. For example, openness is demonstrated when instructors share all relevant and important information with students (Hoy & Tarter, 2004). In an active learning setting, this could look like sharing why the instructor is using active learning (Hernandez et al., 2021). Another example of how to build trust involves leveraging benevolence. Benevolence is perceived when instructors engage in actions that show care for student wellbeing, such as flexibility with deadlines when a student is experiencing stressors in their life (Adams & Forsyth, 2009).

Competition

Perceived classroom competition had a negative relationship with control and no significant relationships with value. The relationship between competition and control is expected since competitive classrooms encourage students to compare their performance to others, undermining control in two ways. First, students do not have control over other people's performance and second, a focus on comparison can cause students to doubt their own abilities (Sommet et al., 2013). Competition had small positive relationships with surprise, anxiety, and boredom. In the literature, competition in classrooms has been positively correlated with feelings of anxiety and boredom (Frenzel et al., 2007; Wigfield & Eccles, 1990), but the relationship to surprise is novel. However, surprise is the emotion we were least able to explain through the model ($R^2 = 0.05$), so the real-world relevance of this emotion and its connection to the different components of Control–Value Theory is potentially tenuous.

On the whole, in alignment with previous literature on this topic (Canning et al., 2020), perceived classroom competition had a small but negative overall impact on student engagement. Students are more likely to perceive a course as cooperative and less competitive when they spend more time working together in small groups rather than alone (Ghaith, 2003). Some research suggests these groups may see the most benefit if students are working towards a common goal but have independent tasks (Bertucci et al., 2016).

Control, value, and activity emotions and their relationships to engagement

Unlike the prediction of Control–Value Theory, we did not find that control and value influenced engagement strictly through emotions. Instead, we found moderate direct paths between the two appraisals and engagement. This could imply that there are other important emotions that we did not measure that are influencing these relationships. Alternatively, it could imply that control and value have influence on achievement behaviors beyond their influence on emotions. Further work is necessary to parse this out. Either way, our model suggests that perceived control and value are influential variables in active learning environments.

We measured seven emotions related to learning and found that not all of them were related to both control and value. For example, surprise was related to neither control nor value (and overall, our model did a poor job of capturing what influences feelings of surprise; $R^2 = 0.05$). Additionally, curiosity and boredom were influenced by value only, and not by control. Interestingly, these two emotions were the only activity emotions that significantly influenced engagement. Thus, value had an indirect impact through emotions on student engagement, but not control. The relationship of value increasing curiosity and decreasing boredom has been found before (Kögler & Göllner, 2018; Li, 2021; Pekrun et al., 2010, 2017). However, the lack of relationship with control differs from the literature for boredom (Kögler & Göllner, 2018; Li, 2021; Pekrun et al., 2010). We did not find literature relating curiosity to control.

Overall, this work suggests that variation in students' appraisals of control and value of active learning STEM courses could help explain the variation in outcomes we observe from active learning in these settings (Freeman et al., 2014; Theobald et al., 2020) by influencing student engagement. Instructors can leverage four course features examined in this study to influence these appraisals to varying degrees. Our model suggests that to increase students' subjective control in STEM active learning courses it is most effective to build trust with students. Reducing students' perception of competition in the course and focusing them on mastery goals were also found to increase student control. Instructors may be able to achieve changes in these course environment features by focusing on aspects of course design, implementation, and delivery. To increase students' subjective value, the most effective strategies according to our model were for instructors to help students see the relevance of the course for helping others and to focus students on mastery goals.

Limitations and further work

This study was conducted in 13 STEM classrooms with only 1,885 student survey respondents. Because of this small sample, we were not able to account for disciplinary differences that could impact environment features and students' appraisals of control and value. We also did not have sufficient sample size to look at patterns among students from different backgrounds. Students from different cultural background may be influenced differently by the same features of the course environment. For example, some studies have demonstrated that first-generation students have stronger prosocial goals than continuing-generation students (Stephens et al., 2014). This could mean that relevance for helping others would have a greater influence on them than their continuing-generation peers. A larger dataset could allow researchers to begin to parse out such differences.

Beyond limitations of sample size, this study also only focused on a few salient features of the classroom environment and on only one of many possible measures of engagement. Classrooms are a complex ecosystem (Guerrettaz & Johnston, 2013; van Lier, 2011) where many factors influence achievement behaviors and outcomes. Additional studies could explore the influence of additional measures of course features on control, value, and activity emotions. In addition, previous studies using Control–Value Theory have demonstrated that features of the activities themselves can influence control, value, and emotions (Chen & Lu, 2022; Dettmers et al., 2011). Activity features like working in groups and explaining reasoning behind answers are correlated with improved exam performance (Moon et al., 2021), which could be related to control and value. Exploring the interactions between activity design, course environment, and student course appraisals could be a powerful next step for understanding student engagement, and ultimately performance.

Finally, this work measured students' perceptions of the course environment, but did not clarify what specific elements of the course students were noticing to come to those perceptions. Pairing this quantitative investigation with interview studies could identify what led students to perceive a course as exhibiting the environment features we measured. For example, studies on mastery goal structures have found that the design of activities, rather than the instructor's verbal emphasis on mastery, is more salient to students (Belenky & Nokes-Malach, 2013). In addition, some work has begun to explore how students develop their perceptions of instructor fairness (which should be related to control) and their emotions (Rasooli et al., 2019). Expansion of this work into active learning classrooms will help guide instructor practice to optimize student engagement.

Conclusion

Student appraisals of control and value have an important, positive impact on engagement in active learning courses. These appraisals, in turn, are influenced by the environment features. Importantly, these features of the course environment are related to aspects of the course over which instructors have purview. Goal structures that focus on mastery, positive instructor–student relationships, and emphasizing the relevance of the course for helping others all have small to moderate influences on engagement. A sense that the course is competitive, on the other hand, has a small negative impact on engagement. Because we found variation between instructors, this study demonstrates that instructors have the ability to influence students' appraisals of control, value, and activity emotions through modifying different features of the active learning classroom. Ultimately, these classroom environment features matter for student engagement in course activities and could explain the variation in efficacy of active learning in promoting student learning and retention.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s40594-025-00526-6.

Supplementary material 1.

Acknowledgements

We appreciate the time and effort the instructors and students involved in this study put in which made this project possible. We also thank Melissa Aikens, Scott Freeman, and Mary Pat Wenderoth for feedback on early versions of this manuscript.

Author contributions

YHC organized data collection, analyzed data and was a major contributor in writing the manuscript. ET helped conceive the study, assisted with data collection, and substantially revised the work. VV assisted with data collection and preparing data for analysis. SLE designed the study, assisted with data collection, and was a major contributor in writing the manuscript. All authors read and approved the final manuscript.

Funding

This material is based upon work supported by the National Science Foundation under Grant No. 2012792 and 2420369.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Competing interests
The authors declare that they have no competing interests.

Author details
[1]Digital Promise, 1001 Connecticut Avenue NW, Suite 935, Washington, D.C. 20036, USA. [2]Department of Biology, University of Washington, Box 351800, Seattle, WA 98195-1800, USA. [3]Biology Teaching and Learning, University of Minnesota, 5-220 Moos Tower, 515 Delaware Street SE, Minneapolis, MN 55455, USA.

Received: 19 April 2024 Accepted: 3 January 2025
Published online: 22 January 2025

References

Adams, C. M., & Forsyth, P. B. (2009). Conceptualizing and validating a measure of student trust. In W. K. Hoy & M. DiPaola (Eds.), *Studies in school improvement* (pp. 263–279). Information Age Publishing Inc.

Addy, T. M., Dube, D., Mitchell, K. A., & SoRelle, M. (2021). *What inclusive instructors do: Principles and practices for excellence in college teaching*. Stylus Publishing LLC.

Ahmed, W., Minnaert, A., van der Werf, G., & Kuyper, H. (2010). Perceived social support and early adolescents' achievement: The mediational roles of motivational beliefs and emotions. *Journal of Youth and Adolescence, 39*(1), 36–46. https://doi.org/10.1007/s10964-008-9367-7

Ames, C. (1992). Classrooms: Goals, structures, and student motivation. *Journal of Educational Psychology, 84*(3), 261–271. https://doi.org/10.1037/0022-0663.84.3.261

Arnold, T., Flaherty, K. E., Voss, K. E., & Mowen, J. C. (2009). Role stressors and retail performance: The role of perceived competitive climate. *Journal of Retailing, 85*(2), 194–205. https://doi.org/10.1016/j.jretai.2009.02.002

Artze-Vega, I., Darby, F., Dewsbury, B., & Imad, M. (2023). *The Norton guide to equity-minded teaching*. W. W. Norton & Company.

Bardach, L., Oczlon, S., Pietschnig, J., & Lüftenegger, M. (2020). Has achievement goal theory been right? A meta-analysis of the relation between goal structures and personal achievement goals. *Journal of Educational Psychology, 112*(6), 1197–1220. https://doi.org/10.1037/edu0000419

Barlow, A., & Brown, S. (2020). Correlations between modes of student cognitive engagement and instructional practices in undergraduate STEM courses. *International Journal of STEM Education, 7*(1), 18. https://doi.org/10.1186/s40594-020-00214-7

Baudoin, N., & Galand, B. (2017). Effects of classroom goal structures on student emotions at school. *International Journal of Educational Research, 86*, 13–22. https://doi.org/10.1016/j.ijer.2017.08.010

Belenky, D. M., & Nokes-Malach, T. J. (2013). Mastery-approach goals and knowledge transfer: An investigation into the effects of task structure and framing instructions. *Learning and Individual Differences, 25*, 21–34. https://doi.org/10.1016/j.lindif.2013.02.004

Bertucci, A., Johnson, D. W., Johnson, R. T., & Conte, S. (2016). Effect of task and goal interdependence on achievement, cooperation, and support among elementary school students. *International Journal of Educational Research, 79*, 97–105. https://doi.org/10.1016/j.ijer.2016.06.011

Bonwell, C. C., & Eison, J. A. (1991). *Active learning: creating excitement in the classroom*. George Washington University.

Buff, A. (2014). Enjoyment of learning and its personal antecedents: Testing the change–change assumption of the control-value theory of achievement emotions. *Learning and Individual Differences, 31*, 21–29. https://doi.org/10.1016/j.lindif.2013.12.007

Buff, A., Reusser, K., Rakoczy, K., & Pauli, C. (2011). Activating positive affective experiences in the classroom: "Nice to have" or something more? *Learning and Instruction, 21*(3), 452–466. https://doi.org/10.1016/j.learninstruc.2010.07.008

Camacho-Morles, J., Slemp, G. R., Pekrun, R., Loderer, K., Hou, H., & Oades, L. G. (2021). Activity achievement emotions and academic performance: A Meta-analysis. *Educational Psychology Review, 33*(3), 1051–1095. https://doi.org/10.1007/s10648-020-09585-3

Canning, E. A., LaCosse, J., Kroeper, K. M., & Murphy, M. C. (2020). Feeling like an imposter: The effect of perceived classroom competition on the daily psychological experiences of first-generation college students. *Social Psychological and Personality Science, 11*(5), 647–657. https://doi.org/10.1177/1948550619882032

Cavanagh, A. J., Chen, X., Bathgate, M., Frederick, J., Hanauer, D. I., & Graham, M. J. (2018). Trust, growth mindset, and student commitment to active learning in a college science course. *CBE—Life Sciences Education, 17*(1), ar10. https://doi.org/10.1187/cbe.17-06-0107

Chen, X., & Lu, L. (2022). How classroom management and instructional clarity relate to students' academic emotions in Hong Kong and England: A multi-group analysis based on the control-value theory. *Learning and Individual Differences, 98*, 102183. https://doi.org/10.1016/j.lindif.2022.102183

Chory, R. M. (2007). Enhancing student perceptions of fairness: The relationship between instructor credibility and classroom justice. *Communication Education, 56*(1), 89–105. https://doi.org/10.1080/03634520600994300

Clem, A.-L., Rudasill, K. M., Hirvonen, R., Aunola, K., & Kiuru, N. (2021). The roles of teacher–student relationship quality and self-concept of ability in adolescents' achievement emotions: Temperament as a moderator. *European Journal of Psychology of Education, 36*(2), 263–286. https://doi.org/10.1007/s10212-020-00473-6

Cleveland, L. M., Olimpo, J. T., & DeChenne-Peters, S. E. (2017). Investigating the relationship between instructors' use of active-learning strategies and students' conceptual understanding and affective changes in introductory biology: A comparison of two active-learning environments. *CBE—Life Sciences Education, 16*(2), ar19. https://doi.org/10.1187/cbe.16-06-0181

Cooper, M. M. (2016). It is time to say what we mean. *Journal of Chemical Education, 93*(5), 799–800. https://doi.org/10.1021/acs.jchemed.6b00227

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

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. https://doi.org/10.1186/s40594-018-0123-6

Covington, M. V., & Omelich, C. L. (1984). Task-oriented versus competitive learning structures: Motivational and performance consequences. *Journal of Educational Psychology, 76*(6), 1038–1050.

Daniels, L. M., Haynes, T. L., Stupnisky, R. H., Perry, R. P., Newall, N. E., & Pekrun, R. (2008). Individual differences in achievement goals: A longitudinal study of cognitive, emotional, and achievement outcomes. *Contemporary Educational Psychology, 33*(4), 584–608. https://doi.org/10.1016/j.cedpsych.2007.08.002

Deci, E. L., & Ryan, R. M. (1985). Conceptualizations of intrinsic motivation and self-determination. In E. L. Deci & R. M. Ryan (Eds.), *Intrinsic motivation and self-determination in human behavior* (pp. 11–40). Springer.

Derakhshan, A., Fathi, J., Pawlak, M., & Kruk, M. (2022). Classroom social climate, growth language mindset, and student engagement: The mediating role of boredom in learning English as a foreign language. *Journal of Multilingual and Multicultural Development*. https://doi.org/10.1080/01434632.2022.2099407

Dettmers, S., Trautwein, U., Lüdtke, O., Goetz, T., Frenzel, A. C., & Pekrun, R. (2011). Students' emotions during homework in mathematics: Testing a theoretical model of antecedents and achievement outcomes. *Contemporary Educational Psychology, 36*(1), 25–35. https://doi.org/10.1016/j.cedpsych.2010.10.001

Dewaele, J.-M., & Li, C. (2020). Emotions in second language acquisition: A critical review and research agenda. *Foreign Language World, 196*(1), 1.

Do, S. L., & Schallert, D. L. (2004). Emotions and classroom talk: Toward a model of the role of affect in students' experiences of classroom discussions. *Journal of Educational Psychology, 96*(4), 619–634. https://doi.org/10.1037/0022-0663.96.4.619

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. https://doi.org/10.1187/cbe.19-09-0186

Eccles, J. (2009). Who am I and what am I going to do with my life? Personal and collective identities as motivators of action. *Educational Psychologist, 44*(2), 78–89. https://doi.org/10.1080/00461520902832368

Eccles, J. S., Adler, T. F., Futterman, R., Goff, S. B., Kaczala, C. M., Meece, J. L., & Midgley, C. (1983). Expectancies, values, and academic behaviors. In J. T. Spence (Ed.), *Achievement and achievement motivation* (pp. 75–146). W. H. Freeman.

Elliott, E. S., & Dweck, C. S. (1988). Goals: An approach to motivation and achievement. *Journal of Personality and Social Psychology, 54*(1), 5–12. https://doi.org/10.1037/0022-3514.54.1.5

Fokkens-Bruinsma, M., Van Rooij, E. C. M., & Canrinus, E. T. (2020). Perceived classroom goal structures as predictors of students' personal goals. *Teachers and Teaching, 26*(1), 88–102. https://doi.org/10.1080/13540602.2020.1740195

Forsblom, L., Pekrun, R., Loderer, K., & Peixoto, F. (2022). Cognitive appraisals, achievement emotions, and students' math achievement: A longitudinal analysis. *Journal of Educational Psychology, 114*(2), 346–367. https://doi.org/10.1037/edu0000671

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.

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

Frenzel, A. C., Pekrun, R., & Goetz, T. (2007). Perceived learning environment and students' emotional experiences: A multilevel analysis of mathematics classrooms. *Learning and Instruction, 17*(5), 478–493. https://doi.org/10.1016/j.learninstruc.2007.09.001

Ghaith, G. (2003). The relationship between forms of instruction, achievement and perceptions of classroom climate. *Educational Research, 45*(1), 83–93. https://doi.org/10.1080/0013188032000086145

Goetz, T., Bieleke, M., Gogol, K., van Tartwijk, J., Mainhard, T., Lipnevich, A. A., & Pekrun, R. (2021). Getting along and feeling good: Reciprocal associations between student–teacher relationship quality and students' emotions. *Learning and Instruction, 71*, 101349. https://doi.org/10.1016/j.learninstruc.2020.101349

Goetz, T., Frenzel, A. C., Stoeger, H., & Hall, N. C. (2010). Antecedents of everyday positive emotions: An experience sampling analysis. *Motivation and Emotion, 34*(1), 49–62. https://doi.org/10.1007/s11031-009-9152-2

Goetz, T., Lüdtke, O., Nett, U. E., Keller, M. M., & Lipnevich, A. A. (2013). Characteristics of teaching and students' emotions in the classroom: Investigating differences across domains. *Contemporary Educational Psychology, 38*(4), 383–394. https://doi.org/10.1016/j.cedpsych.2013.08.001

Greene, B. A., Miller, R. B., Crowson, H. M., Duke, B. L., & Akey, K. L. (2004). Predicting high school students' cognitive engagement and achievement: Contributions of classroom perceptions and motivation. *Contemporary Educational Psychology, 29*(4), 462–482. https://doi.org/10.1016/j.cedpsych.2004.01.006

Groccia, J. E. (2018). What is student engagement? *New Directions for Teaching and Learning, 2018*(154), 11–20. https://doi.org/10.1002/tl.20287

Guerrettaz, A. M., & Johnston, B. (2013). Materials in the classroom ecology. *The Modern Language Journal, 3*(97), 779–796. https://doi.org/10.1111/j.1540-4781.2013.12027.x

Hayes, A. F., & Coutts, J. J. (2020). Use omega rather than Cronbach's alpha for estimating reliability. But…. *Communication Methods and Measures, 14*(1), 1–24. https://doi.org/10.1080/19312458.2020.1718629

Hernandez, D., Jacomino, G., Swamy, U., Donis, K., & Eddy, S. L. (2021). Measuring supports from learning assistants that promote engagement in active learning: Evaluating a novel social support instrument. *International Journal of STEM Education, 8*(1), 22. https://doi.org/10.1186/s40594-021-00286-z

Hidi, S., & Renninger, K. A. (2006). The four-phase model of interest development. *Educational Psychologist, 41*(2), 111–127. https://doi.org/10.1207/s15326985ep4102_4

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

Hoy, W. K., & Tarter, C. J. (2004). Organizational justice in schools: No justice without trust. *International Journal of Educational Management, 18*(4), 250–259. https://doi.org/10.1108/09513540410538831

Hu, L., & 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

Huang, C. (2011). Achievement goals and achievement emotions: A meta-analysis. *Educational Psychology Review, 23*(3), 359–388. https://doi.org/10.1007/s10648-011-9155-x

Isen, A. M., & Reeve, J. (2005). The influence of positive affect on intrinsic and extrinsic motivation: Facilitating enjoyment of play, responsible work behavior, and self-control. *Motivation and Emotion, 29*(4), 295–323. https://doi.org/10.1007/s11031-006-9019-8

Jackson, M. C., Galvez, G., Landa, I., Buonora, P., & Thoman, D. B. (2016). Science that matters: The importance of a cultural connection in underrepresented students' science pursuit. *CBE—Life Sciences Education, 15*(3), ar42. https://doi.org/10.1187/cbe.16-01-0067

Kalinowski, S. T., Leonard, M. J., Andrews, T. M., & Litt, A. R. (2013). Six classroom exercises to teach natural selection to undergraduate biology students. *CBE—Life Sciences Education, 12*(3), 483–493. https://doi.org/10.1187/cbe-12-06-0070

Kim, T., & Schallert, D. L. (2014). Mediating effects of teacher enthusiasm and peer enthusiasm on students' interest in the college classroom. *Contemporary Educational Psychology, 39*(2), 134–144. https://doi.org/10.1016/j.cedpsych.2014.03.002

Knekta, E., Runyon, C., & Eddy, S. (2019). One size doesn't fit all: Using factor analysis to gather validity evidence when using surveys in your research. *CBE—Life Sciences Education, 18*(1), rm1. https://doi.org/10.1187/cbe.18-04-0064

Kögler, K., & Göllner, R. (2018). Control-value appraisals predicting students' boredom in accounting classes: A continuous-state-sampling approach. *Empirical Research in Vocational Education and Training, 10*(1), 4. https://doi.org/10.1186/s40461-018-0065-8

Lazarides, R., & Buchholz, J. (2019). Student-perceived teaching quality: How is it related to different achievement emotions in mathematics classrooms? *Learning and Instruction, 61*, 45–59. https://doi.org/10.1016/j.learninstruc.2019.01.001

Li, C. (2021). A control–value theory approach to boredom in English classes among university students in China. *The Modern Language Journal, 105*(1), 317–334. https://doi.org/10.1111/modl.12693

Linnenbrink, E. A. (2007). *The role of affect in student learning: A multi-dimensional approach to considering the interaction of affect, motivation, and engagement. In Emotion in education* (pp. 107–124). Elsevier Academic Press.

Linnenbrink, E. A., & Pintrich, P. R. (2002). Achievement goal theory and affect: An asymmetrical bidirectional model. *Educational Psychologist, 37*(2), 69–78. https://doi.org/10.1207/S15326985EP3702_2

Linnenbrink-Garcia, L., & Barger, M. M. (2014). Achievement goals and emotions. In R. Pekrun & L. Linnenbrink-Garcia (Eds.), *International handbook of emotions in education* (pp. 142–161). Routledge.

Linnenbrink-Garcia, L., Patall, E. A., & Pekrun, R. (2016). Adaptive motivation and emotion in education: Research and principles for instructional design. *Policy Insights from the Behavioral and Brain Sciences, 3*(2), 228–236. https://doi.org/10.1177/2372732216644450

Linnenbrink-Garcia, L., Rogat, T. K., & Koskey, K. L. K. (2011). Affect and engagement during small group instruction. *Contemporary Educational Psychology, 36*(1), 13–24. https://doi.org/10.1016/j.cedpsych.2010.09.001

Loderer, K., Pekrun, R., & Lester, J. C. (2020). Beyond cold technology: A systematic review and meta-analysis on emotions in technology-based learning environments. *Learning and Instruction, 70*, 101162. https://doi.org/10.1016/j.learninstruc.2018.08.002

McNeish, D. (2018). Thanks coefficient alpha, we'll take it from here. *Psychological Methods, 23*(3), 412–433. https://doi.org/10.1037/met0000144

Meece, J. L. (1991). The classroom context and children's motivational goals. In M. Maehr & P. Pintrich (Eds.), *Advances in achievement motivation research* (pp. 261–285). Academic.

Meece, J. L., Anderman, E. M., & Anderman, L. H. (2006). Classroom goal structure, student motivation, and academic achievement. *Annual Review of*

Psychology, 57(1), 487–503. https://doi.org/10.1146/annurev.psych.56.091103.070258
Midgley, C., Maehr, M. L., Hruda, L. Z., Anderman, E., Anderman, L., Freeman, K. E., Gheen, M., Kaplan, A., Kumar, R., Middleton, M. J., Nelson, J., Roeser, R., & Urdan, T. (2000). Manual for the Patterns of Adaptive Learning Scales (PALS). *University of Michigan*. https://doi.org/10.1037/t19870-000
Moon, S., Jackson, M. A., Doherty, J. H., & Wenderoth, M. P. (2021). Evidence-based teaching practices correlate with increased exam performance in biology. *PloS One*, *16*(11), e0260789.
Mueller, R. O., & Hancock, G. R. (2019). Structural equation modeling. In G. R. Hancock, L. M. Stapleton, & R. O. Mueller (Eds.), *The reviewer's guide to quantitative methods in the social sciences* (2nd ed., pp. 445–466). Routledge.
Pekrun, R. (1992). The impact of emotions on learning and achievement: Towards a theory of cognitive/motivational mediators. *Applied Psychology, 41*(4), 359–376. https://doi.org/10.1111/j.1464-0597.1992.tb00712.x
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
Pekrun, R., Elliot, A. J., & Maier, M. A. (2009). Achievement goals and achievement emotions: Testing a model of their joint relations with academic performance. *Journal of Educational Psychology, 101*(1), 115–135. https://doi.org/10.1037/a0013383
Pekrun, R., Goetz, T., Daniels, L. M., Stupnisky, R. H., & Perry, R. P. (2010). Boredom in achievement settings: Exploring control–value antecedents and performance outcomes of a neglected emotion. *Journal of Educational Psychology, 102*(3), 531–549. https://doi.org/10.1037/a0019243
Pekrun, R., Goetz, T., Frenzel, A. C., Barchfeld, P., & Perry, R. P. (2011). Measuring emotions in students' learning and performance: The Achievement Emotions Questionnaire (AEQ). *Contemporary Educational Psychology, 36*(1), 36–48. https://doi.org/10.1016/j.cedpsych.2010.10.002
Pekrun, R., & Linnenbrink-Garcia, L. (2012). Academic emotions and student engagement. In S. L. Christenson, A. L. Reschly, & C. Wylie (Eds.), *Handbook of research on student engagement* (pp. 259–282). Springer.
Pekrun, R., & Linnenbrink-Garcia, L. (2022). Academic emotions and student engagement. In A. L. Reschly & S. L. Christenson (Eds.), *Handbook of research on student engagement* (pp. 109–132). Springer International Publishing.
Pekrun, R., & Stephens, E. J. (2010). Achievement emotions: A control-value approach. *Social and Personality Psychology Compass, 4*(4), 238–255. https://doi.org/10.1111/j.1751-9004.2010.00259.x
Pekrun, R., Vogl, E., Muis, K. R., & Sinatra, G. M. (2017). Measuring emotions during epistemic activities: The epistemically-related emotion scales. *Cognition and Emotion, 31*(6), 1268–1276. https://doi.org/10.1080/02699931.2016.1204989
Perry, R. P. (1991). Perceived control in college students: Implications for instruction in higher education. *Higher Education: Handbook of Theory and Research, 7*, 1–56.
Perry, R. P., Hladkyj, S., Pelletier, S. T., & Pekrun, R. H. (2001). Academic control and action control in the achievement of college students: A longitudinal field study. *Journal of Educational Psychology, 93*(4), 776–789.
Pintrich, P. R., Smith, D. A. F., Garcia, T., & McKeachie, W. J. (1991). A manual for the use of the Motivated Strategies for Learning Questionnaire (MSLQ). National Center for Research to Improve Postsecondary Teaching and Learning.
Pintrich, P. R., & De Groot, E. V. (1990). Motivational and self-regulated learning components of classroom academic performance. *Journal of Educational Psychology, 82*(1), 33–40. https://doi.org/10.1037/0022-0663.82.1.33
Prince, M. (2004). Does active learning work? A review of the research. *Journal of Engineering Education, 93*(3), 223–231. https://doi.org/10.1002/j.2168-9830.2004.tb00809.x
Priniski, S. J., Hecht, C. A., & Harackiewicz, J. M. (2018). Making learning personally meaningful: A new framework for relevance research. *The Journal of Experimental Education, 86*(1), 11–29. https://doi.org/10.1080/00220973.2017.1380589
Ranellucci, J., Robinson, K. A., Rosenberg, J. M., Lee, Y., Roseth, C. J., & Linnenbrink-Garcia, L. (2021). Comparing the roles and correlates of emotions in class and during online video lectures in a flipped anatomy classroom. *Contemporary Educational Psychology, 65*, 101966. https://doi.org/10.1016/j.cedpsych.2021.101966
Rasooli, A., DeLuca, C., Rasegh, A., & Fathi, S. (2019). Students' critical incidents of fairness in classroom assessment: An empirical study. *Social Psychology of Education, 22*(3), 701–722. https://doi.org/10.1007/s11218-019-09491-9
Reis, H. T., Clark, M. S., & Holmes, J. G. (2004). Perceived partner responsiveness as an organizing construct in the study of intimacy and closeness. In D. J. Mashek & A. P. Aron (Eds.), *Handbook of closeness and intimacy* (pp. 201–225). Psychology Press.
RTI International. (2023). First-generation college students in 2020: Demographic characteristics and postsecondary enrollment. https://firstgen.naspa.org/files/dmfile/15405_NASPA_FactSheet-01.pdf. Accessed 16 Sept 2024.
Schrodt, P., Witt, P. L., Turman, P. D., Myers, S. A., Barton, M. H., & Jernberg, K. A. (2009). Instructor credibility as a mediator of instructors' prosocial communication behaviors and students' learning outcomes. *Communication Education, 58*(3), 350–371. https://doi.org/10.1080/03634520902926851
Seemiller, C., & Grace, M. (2015). *Generation Z goes to college*. John Wiley & Sons.
Sommet, N., Pulfrey, C., & Butera, F. (2013). Did my M.D. really go to university to learn? Detrimental effects of numerus clausus on self-efficacy, mastery goals and learning. *PLOS ONE, 8*(12), e84178. https://doi.org/10.1371/journal.pone.0084178
Sperling, J., Mburi, M., Gray, M., Schmid, L., & Saterbak, A. (2024). Effects of a first-year undergraduate engineering design course: Survey study of implications for student self-efficacy and professional skills, with focus on gender/sex and race/ethnicity. *International Journal of STEM Education, 11*(1), 8. https://doi.org/10.1186/s40594-024-00467-6
Stephens, N. M., Hamedani, M. G., & Destin, M. (2014). Closing the social-class achievement gap: A difference-education intervention improves first-generation students' academic performance and all students' college transition. *Psychological Science, 25*(4), 943–953. https://doi.org/10.1177/0956797613518349
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., Hennessey, K., Hsiao, J., Iranon, N., Jones, L., Jordt, H., Keller, M., Lacey, M. E., Littlefield, C. E., & 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, 117*(12), 6476–6483. https://doi.org/10.1073/pnas.1916903117
Turner, J. E., & Schallert, D. L. (2001). Expectancy–value relationships of shame reactions and shame resiliency. *Journal of Educational Psychology, 93*(2), 320–329. https://doi.org/10.1037/0022-0663.93.2.320
Tze, V. M. C., Daniels, L. M., & Klassen, R. M. (2016). Evaluating the relationship between boredom and academic outcomes: A meta-analysis. *Educational Psychology Review, 28*(1), 119–144. https://doi.org/10.1007/s10648-015-9301-y
U.S. Department of Education, Institute of Education Science. (2023). Undergraduate enrollment. Condition of education. National Center for Education Statistics.
Urdan, T. (2004). Using multiple methods to assess students' perceptions of classroom goal structures. *European Psychologist, 9*(4), 222–231. https://doi.org/10.1027/1016-9040.9.4.222
Urdan, T., & Kaplan, A. (2020). The origins, evolution, and future directions of achievement goal theory. *Contemporary Educational Psychology, 61*, 101862. https://doi.org/10.1016/j.cedpsych.2020.101862
van Lier, L. (2011). Language learning: An ecological-semiotic approach. In E. Hinkel (Ed.), *Handbook of research in second language teaching and learning*. Routledge.
Wang, M.-T., Fredricks, J. A., Ye, F., Hofkens, T. L., & Linn, J. S. (2016). The math and science engagement scales: Scale development, validation, and psychometric properties. *Learning and Instruction, 43*, 16–26. https://doi.org/10.1016/j.learninstruc.2016.01.008
Weiner, B. (1985). Attribution theory. In B. Weiner (Ed.), *Human motivation* (pp. 275–326). Springer.
Whiteman, R., & Ochakovskaya, Y. (2017). Using a mastery goal structure in the classroom: Three actionable areas to motivate your students to learn. In R. Obeid, A. M. Schwartz, C. Shane-Simpson, & P. J. Brooks (Eds.), *How we teach now: The GSTA guide to student-centered teaching* (pp. 42–53). Society for the Teaching of Psychology.

Wigfield, A., & Eccles, J. S. (1990). Test anxiety in the school setting. In M. Lewis & S. M. Miller (Eds.), *Handbook of developmental psychopathology* (pp. 237–250). Springer.

Wiggins, B. L., Eddy, S. L., Grunspan, D. Z., & Crowe, A. J. (2017). The ICAP active learning framework predicts the learning gains observed in intensely active classroom experiences. *AERA Open, 3*(2), 2332858417708567. https://doi.org/10.1177/2332858417708567

Wolters, C. A. (2004). Advancing achievement goal theory: Using goal structures and goal orientations to predict students' motivation, cognition, and achievement. *Journal of Educational Psychology, 96*(2), 236–250. https://doi.org/10.1037/0022-0663.96.2.236

Yeager, D. S., & Bundick, M. J. (2009). The role of purposeful work goals in promoting meaning in life and in schoolwork during adolescence. *Journal of Adolescent Research, 24*(4), 423–452. https://doi.org/10.1177/0743558409336749

Yeager, D. S., Henderson, M. D., Paunesku, D., Walton, G. M., D'Mello, S., Spitzer, B. J., & Duckworth, A. L. (2014). Boring but important: A self-transcendent purpose for learning fosters academic self-regulation. *Journal of Personality and Social Psychology, 107*(4), 559–580. https://doi.org/10.1037/a0037637

Zambrano, J., Lee, G. A., Leal, C. C., & Thoman, D. B. (2020). Highlighting prosocial affordances of science in textbooks to promote science interest. *CBE—Life Sciences Education, 19*(3), ar24. https://doi.org/10.1187/cbe.19-09-0176

Zeidner, M. (1998). *Test anxiety: The state of the art*. Springer Science & Business Media.

Publisher's Note