Activity Achievement Emotions and Academic Performance: A Meta-analysis

Jesús Camacho-Morles[1] · Gavin R. Slemp[1] · Reinhard Pekrun[2,3,4] · Kristina Loderer[5] · Hanchao Hou[1] · Lindsay G. Oades[1]

Abstract
Achievement emotions are emotions linked to academic, work, or sports achievement activities (activity emotions) and their success and failure outcomes (outcome emotions). Recent evidence suggests that achievement emotions are linked to motivational, self-regulatory, and cognitive processes that are crucial for academic success. Despite the importance of these emotions, syntheses of empirical findings investigating their relation with student achievement are scarce. We broadly review the literature on achievement emotions with a focus on activity-related emotions including enjoyment, anger, frustration, and boredom, and their links to educational outcomes with two specific aims: to aggregate all studies and determine how strongly related those emotions are to academic performance, and to examine moderators of those effects. A meta-analytical review was conducted using a systematic database of 68 studies. The 68 studies included 57 independent samples for enjoyment ($N = 31{,}868$), 25 for anger ($N = 11{,}153$), 9 for frustration ($N = 1418$), and 66 for boredom ($N = 28{,}410$). Results indicated a positive relation between enjoyment of learning and academic performance ($\rho = .27$), whereas the relations were negative for both anger ($\rho = -.35$) and boredom ($\rho = -.25$). For frustration, the relation with performance was near zero ($\rho = -.02$). Moderator tests revealed that relations of activity emotions with academic performance are stronger when (a) students are in secondary school compared with both primary school and college, and (b) the emotions are measured by the Achievement Emotions Questionnaires – Mathematics (AEQ-M). Theoretical and practical implications are discussed.

Keywords Achievement emotions · Enjoyment · Anxiety · Boredom · Control-value theory · Academic achievement

Achievement emotions are emotions that are linked to academic, work, or sports achievement activities and their success and failure outcomes (Pekrun 2006). In education, these emotions are

✉ Jesús Camacho-Morles
info@analyticsforschools.com.au

experienced by students in different achievement situations such as studying, attending classes, completing assignments, or taking exams (Pekrun 2014). There is a growing body of literature that recognizes and demonstrates the influence of achievement emotions for educational outcomes at all academic levels (e.g., primary, secondary, and tertiary). For instance, research suggests that adolescents' achievement emotions play a critical role in their learning and performance in traditional subject domains such as literacy, maths, and sciences (e.g., Luo et al. 2014; Muis et al. 2015b; Pekrun et al. 2017a). More recently, achievement emotions have been also found to be critical factors associated with students' competence in the twenty-first-century skills of communication, collaboration, critical thinking, and creativity grouped within the important subject domain of collaborative problem-solving (Camacho-Morles et al. 2019a).

The achievement emotions framework, proposed by Pekrun and colleagues (Pekrun 2006; Pekrun et al. 2002), categorizes emotions based on three dimensions, namely valence (positive vs. negative), physiological arousal (high vs. low), and object focus (e.g., activity-related or outcome-related). This classification allows, for example, distinctions between positive high-arousal activity emotions such as enjoyment, and negative low-arousal outcome emotions like hopelessness. Finally, outcome-related emotions can be further grouped into retrospective or prospective emotions depending on their timeframe (e.g., retrospective shame after an unsuccessful outcome in an exam). (See Table 1 for a full description of the achievement emotions taxonomy).

In this study, we focus on activity-related emotions which are defined as emotional episodes associated with the perceived experience of ongoing achievement situations, where the outcome of such activities is not in focus per se (Pekrun et al. 2002). For example, a student may experience enjoyment when taking an exam because the test itself is perceived as a challenge that is enjoyable, regardless of whether a successful result is expected (Lumby 2011). This is contrary to outcome-related emotions, which are not connected with the achievement activity itself, but with expectation of success or avoidance of failure. Before taking a test, for instance, a student may experience anticipatory joy because a successful outcome is perceived as achievable, yet the activity of completing the test can be seen as negative or unpleasant. Based on frequency of investigation and existence of sufficient numbers of studies, we focus on four activity-related emotions, namely enjoyment, frustration, anger, and boredom. Other activity-related emotions such as relaxation were not included in our study because empirical evidence on their associations with academic performance is largely lacking (Pekrun et al. 2011). Finally, we use the term discrete emotions as denoting specific emotions such as enjoyment or anger, in contrast to the global constructs of positive and negative affect.

Table 1 A three-dimensional taxonomy of achievement emotions

Object focus/ Timeframe	Positive (pleasant)		Negative (unpleasant)	
	High arousal	Low arousal	High arousal	Low arousal
Activity	Enjoyment*	Relaxation	Anger* Frustration*	Boredom*
Outcome/Prospective	Anticipatory joy Hope	Anticipatory relief	Anxiety	Hopelessness
Outcome/Retrospective	Joy Pride Gratitude	Contentment Relief	Shame Anger	Sadness Disappointment

*Emotions included in the current study. Adapted from Pekrun and Stephens (2010).

Although outcome-related emotions (e.g., test anxiety, pride, and shame) have been traditionally the most frequently investigated achievement emotions (Pekrun et al. 2002; Goetz and Hall 2013), the last two decades have seen a growing trend towards the study of activity-related emotions (see Fig. 1). As the number of studies focusing on activity-related emotions continues to increase substantially, one of the most significant challenges in the field is to summarize and synthesize the conflicting findings that have emerged. For instance, there is contradictory evidence on the relationship between enjoyment and academic performance. Despite many studies reporting a positive correlation between the two constructs (see Baek and Touati 2017), some studies have reported non-significant (e.g., Trevors et al. 2016), or even negative relations (e.g., Ellis et al. 1995). Similarly, existing evidence for frustration, anger, and boredom does not provide a clear direction of relations as findings include positive, neutral, and negative associations with academic performance. Therefore, it is unclear if positive activity-related emotions such as enjoyment are, in fact, beneficial for student outcomes, and whether negative activity-related emotions, such as frustration, anger, and boredom, are detrimental.

As most research on achievement emotions focuses on outcome emotions, the importance and added value of our study is that it provides integrative knowledge about the relations of activity-related emotions with academic performance. Addressing this gap is both relevant and important because activity-related and outcome-related emotions play different roles in academic performance. Due to their focus on activities, activity emotions entail a different focus of attention and different motivational consequences. Specifically, positive activity emotions such as enjoyment of learning facilitate on-task attention and intrinsic motivation. If an achievement activity (e.g., attending a class, or studying) is perceived as interesting and intrinsically rewarding, then positive activity emotions such as enjoyment are experienced. Enjoyment tends to facilitate the allocation of attentional and cognitive resources to the task at hand, promote sustained effort and motivation to interest-based, intrinsic motivation, which in turn, may benefit learning and performance (Pekrun 2006; Camacho-Morles et al. 2019a). In contrast, for outcome emotions such as pride, the focus is on achievement outcomes such as success, which may divert attention away from learning and subsequent tasks and promote extrinsic motivation (e.g., motivation to win an academic prize).

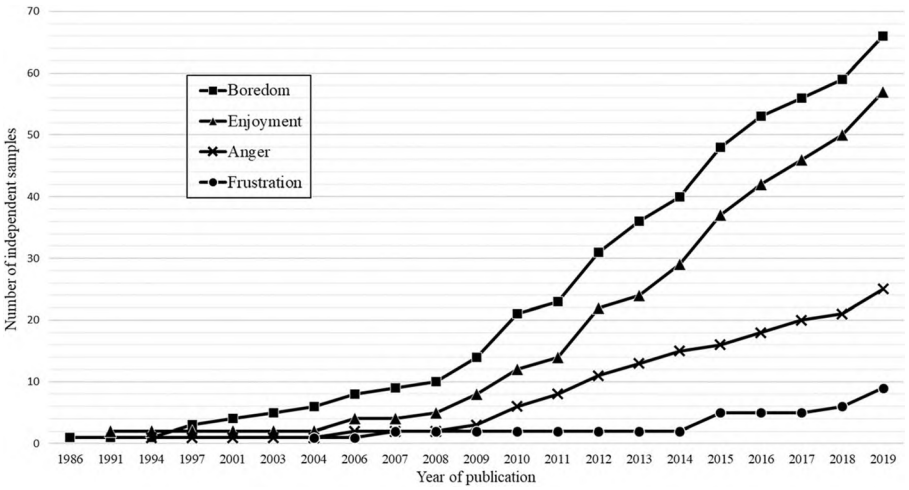

Fig. 1 Studies investigating the relation between activity emotions and academic performance (displayed are the numbers of independent samples)

Synthesizing available findings for activity-related achievement emotions, and their relations with students' achievement, provides cumulative evidence that can inform future research and facilitate evidence-based practice. Specifically, such evidence can be leveraged for designing emotionally sound classrooms that maximize beneficial, and minimize harmful emotions, and for designing programs that foster adaptive self-regulation of achievement emotions to promote academic success.

This meta-analysis was carried out to identify an overall pattern and strength of the relation between discrete activity-related emotions and academic performance. In addition, building on the assumption that functional mechanisms of emotions, including relations between achievement emotions and performance outcomes (cognitive-motivational model and relative universality principle; Pekrun 2006, 2018; see section "The Control-Value Theory of Achievement Emotions"), we investigate how these relations may differ as a function of theory-relevant factors such as age and nationality of learners, the subject domain (e.g., literacy, maths, and sciences, among others), as well as the educational level (e.g., primary, secondary, or tertiary). Further, we explore whether the influence of activity emotions on performance varies systematically with methodological factors, namely the type of emotion measure (e.g., self-report questionnaires, thinking aloud protocols, etc.), type of performance measure (e.g., test scores, grades, combined measure), the function of the test score (institution-based compulsory tests vs tests created for research purposes), the type of learning setting (technology-enhanced or non-technology- enhanced learning environments), temporal specificity of emotions (e.g., trait or state emotions), and publication status (e.g., published or unpublished studies).

Concept of Activity Achievement Emotions

Activity-related emotions focus on the action during the achievement situation rather than the outcome of such activity (e.g., boredom). As emotions more generally, these emotions can be conceptualized as multi-component, coordinated processes of psychological subsystems including affective, cognitive, motivational, expressive, and peripheral physiological processes (Pekrun 2006; Scherer 2005).

Based on dimensions of valence and arousal, we can define specific activity-related achievement emotions as follows. Enjoyment is conceptualized as a positive (i.e., pleasant) and high-arousal emotion (Pekrun 2006), experienced by students when achievement situations are positively valued and sufficiently controllable (Buff 2014; Camacho-Morles et al. 2019b). Anger has been defined as a negatively valenced and high-arousal emotion that may arise when students perceive impasses or difficulties during achievement activities as being caused by other persons, such as teacher-defined task demands that are seen as unfair (Pekrun 2006). Frustration is also an unpleasant emotion, which typically is high in arousal (Pekrun and Stephens 2010). Students experience frustration in response to obstacles that hinder successful task completion, such as the inability to reach the desired solution when performing an achievement activity (Muis et al. 2015b). Finally, boredom is understood as an achievement emotion consisting of negatively valenced feelings, disinterest, lack of stimulation, and low physiological arousal (Pekrun et al. 2010; Vogel-Walcutt et al. 2012).

The Control-Value Theory of Achievement Emotions

The control-value theory of achievement emotions (CVT; Pekrun 2006, 2018, in press) integrates constructs and assumptions from diverse theoretical approaches to emotions in education and to achievement emotions more generally (Pekrun et al. 2007). In this section, we briefly describe this theory with a focus on two of its main propositions that are relevant for this study, namely the cognitive-motivational mediation model of emotion effects, and the relative universality principle of achievement emotions.

The central propositions of CVT relate to the arousal of achievement emotions. It is stated that achievement emotions are elicited by two distinct appraisals. These include (1) perceived control, concerning the individual's belief about external and personal factors (e.g., intellectual aptitude, educational experience) that may affect their performance in achievement situations (Perry et al. 2001), and (2) task value, referring to the importance or perceived value attributed by individuals to achievement activities and their success and failure outcomes (Eccles and Wigfield 1995; Pekrun 2006). In other words, the experience of different achievement emotions depends on how much control individuals feel they have over achievement activities that have importance or value to them. Further, the CVT proposes the multiplicative relations of control and value appraisals, suggesting that the intensity of positive emotions is a joint function of perceived control and value, whereas negative emotions are a joint function of lack of control and value (Pekrun et al. 2007; Putwain et al. 2018b; Shao et al. 2020).

Central to this study, CVT proposes a cognitive-motivational mediation model of emotion effects stating that achievement emotions influence academic engagement and achievement and that these effects are mediated by several cognitive, motivational, and self-regulatory processes that are critical for success in academic settings, such as interest, cognitive resources, effort regulation, and use of learning strategies (Pekrun 2006, 2018). We present a detailed review of the functions of activity-related emotions for academic performance in the following section.

Finally, and also relevant for the current study, CVT states that the functional mechanisms of achievement emotions are universal, meaning that the arousal process of emotions depends on both control and value appraisals regardless of academic domain, gender, or cultural background of learners (Pekrun 2009). However, specific contents and parameters of emotions (i.e., frequency and intensity) may differ among individuals as a function of gender, age, culture, content-domain, etc. (see Pekrun 2018, for a summary of supporting evidence). Our study is grounded in this theoretical assumption; therefore, we investigate how the relation between activity-related emotions and academic performance may differ as a function of the age, educational level, and nationality of learners as well as subject domain.

Functions of Activity Emotions for Academic Performance

We understand academic performance as the extent to which students reach or achieve their education goals as a result of ongoing classroom tasks, exams, or standardized tests (Ward et al. 1996). In the literature on achievement emotions, the relative importance of enjoyment for academic achievement and performance has been subject to considerable discussion. While the vast majority of studies report a moderate positive correlation between enjoyment and achievement, as it facilitates the use of flexible learning strategies and increases motivation and effort (see Ahmed et al. 2010; Baek and Touati 2017; Goetz et al. 2010; Pekrun et al. 2017a), there is also a significant amount of research evidence suggesting no correlation or even negative relations (e.g., Beck 2011; Pekrun et al. 2006; Ranellucci et al. 2015). One argument for observed negative relationships between enjoyment and performance is

that the processing of emotionally arousing events of either valence, negative as well as positive, may compete with task-related processing resources (Meinhardt and Pekrun 2003). Also, from a mood-as-information approach, the experience of positive affect (e.g., enjoyment) during ongoing achievement activities may negatively influence motivation to invest effort and attention (Carver and Scheier 2001). For example, when progress towards successful completion of a task is above expectations, positive emotions arise, signaling that everything is going well, and the activity, therefore, is no longer perceived as a high priority. This "reordering of priorities," in turn, may lead individuals to think that effort is no longer needed, and the attention to the task at hand is shifted, allocating cognitive resources to fulfilling other needs, compromising task performance, and achievement (Carver 2003).

The mechanisms underpinning the relationship between anger and academic performance are also complex. According to Pekrun et al. (2006), anger can be detrimental to academic achievement as it reduces intrinsic motivation and promotes the use of rigid learning strategies. This is reflected in the existing evidence that shows, in most cases, a negative association between anger and achievement (Peixoto et al. 2017; Pekrun et al. 2009; Villavicencio and Bernardo 2013). Given there are also studies reporting zero correlation between these two constructs (see Beck 2011; Kirwan 2018; Pekrun et al. 2006), there is an ongoing debate on whether the experience of anger during academic activities reduces academic performance or if there is no association between them.

Although the evidence for frustration is comparably more limited, existing findings show very weak (close to zero) correlation coefficients with academic performance (see Graesser et al. 2007; Novak et al. 2018). Although the relationship between frustration and academic achievement can be usually assumed as unfavorable, there are authors who argue it may be beneficial for task performance. Carver and Scheier (1999), for instance, proposed that making unsatisfactory progress (e.g., a signal of falling behind) in achievement activities elicits negative emotions (e.g., frustration), which in turn increases effort towards task completion.

One of the most prolific current discussions in the academic emotion literature is the influence of boredom on academic performance. On the one hand, a substantial body of literature has shown the adverse effects of boredom on student outcomes as it undermines attention, effort, motivation, and engagement during achievement activities as well as resulting task performance (Camacho-Morles et al. 2019a; Craig et al. 2004; Haager et al. 2018; Pekrun et al. 2010; Pekrun et al. 2017a; Perry et al. 2001; Putwain et al. 2018a; Tze et al. 2016). On the other hand, there is evidence suggesting potential benefits of boredom for academic performance as it can lead students to initiate creative processes and greater self-reflection (Mann and Cadman 2014; Seib and Vodanovich 1998) and can also create an urge to make changes to the current achievement situation as it may be perceived as demotivating (Bench and Lench 2013).

Taken together, different theoretical perspectives on causal mechanisms linking enjoyment, anger, frustration, and boredom with academic achievement, as well as extant evidence on these relations, suggest potential variation in effects of activity emotions on achievement outcomes. Relatedly, the degree to which experienced emotions impact motivation, learning behaviors, and resulting achievement outcomes may depend on students' efforts and abilities to up-/down-regulate emotions during achievement activities (see, e.g., Harley et al. 2019), and activities themselves may differ in the degree to which they leave room for emotion regulation in the first place (e.g., time available for completion; task complexity; see, e.g., Aldao et al. (2015), for a discussion of person- and situation-specificity of emotion regulation).

It is thus possible that relations between activity emotions and academic performance vary as function of moderating factors. In this study, we examine ten possible moderators of effect sizes that warrant consideration. We generally group these moderators into (1) those that are

theory-relevant (i.e., CVT), namely age and nationality of learners, the subject domain (e.g., literacy, math, and sciences, among others), and the educational level (e.g., primary, secondary, or tertiary), and (2) those that pertain to methodological factors such as the type of emotion measure (e.g., self-report questionnaires, thinking aloud protocols, etc.), the type of performance measure (e.g., test scores, grades, or combined scores), the function of test scores (institution-based compulsory tests versus tests created for research purposes), the type of learning setting (technology-enhanced versus non-technology-enhanced learning environments), the temporal specificity of emotions (e.g., trait or state emotions), and publication status (e.g., published or unpublished studies). Such moderator analyses are thus pivotal for probing the generalizability of construct relations across different groups of learners, learning settings, and construct operationalizations and provide insight into potential boundary conditions of a theory (Aguinis et al. 2011; Pekrun 2009). Moreover, they can help identify possible sources of effect size heterogeneity which is essential for reconciling conflicting findings as observed in past research.

Within the methodological factors, we investigate the operationalization of achievement emotions. Several instruments have been used to measure achievement emotions, including the (original) Achievement Emotions Questionnaire (AEQ; Pekrun et al. 2011), as well as the corresponding version for pre-adolescents (AEQ-PA; Peixoto et al. 2015), among others. Because correlation magnitudes can be attenuated by factors such as imperfect construct validity in the measurement instruments, to the extent that some vary in construct validity, their correlations may correspondingly vary as a function of this.

It is also possible that effect sizes are moderated by the measure used to quantify performance in the study (e.g., test score, grades, or a combination of both). For example, cumulative grades that are based on multiple assessments of achievement and may include classroom participation or attendance could yield higher correlations with habitual emotions than test scores that are typically derived from one-shot assessments.

We are also interested in whether the strength of the relationship between activity emotions and academic performance varies according to the function of achievement tests. First, it is possible that emotions have a stronger effect on achievement tests that are relevant to students' academic success (e.g., compulsory standardized achievement tests), compared with achievement tests where success or failure is irrelevant (e.g., achievement tests administered to suit researchers' needs in a particular study), where the influence of emotions may be minor.

Given the transformational impact of technology on learning (OECD 2015; Griffin and Care 2014), we believe it is relevant to explore if the influence of activity emotions on performance differs between technology-enhanced learning environments and non-technology-enhanced forms of learning. We understand technology-enhanced learning settings as the learning of content that occurs online via all electronic technology (e.g., internet, intranets, video and audio conferencing, or computer-based instruction). These types of learning environments usually support independent learning and are characterized by giving the student the possibility to access several sources of information, work alone or in groups, at a flexible pace, and at any time and from any place. In non-technology-enhanced learning settings, on the other hand, learning of content usually occurs synchronously and in non-digital (e.g., face-to-face) settings, usually in a classroom environment with a teacher/instructor who regulates instruction (e.g., in terms of pacing or content covered in class). Evidence suggests that emotions can be triggered in different ways and by different objects (Wosnitza and Volet 2005), as emotions can be directed at technology devices (e.g., frustration towards a slow-processing computer; or anger elicited by a poor internet connection) or towards artificial

contexts (e.g., lab settings; Jarvenoja and Jarvela 2005). Therefore, the type of learning environment is a possible moderator we examine in the present study.

Furthermore, as researchers have studied both trait-oriented/habitual emotions as well as state emotions experienced momentarily, we investigate the moderating effect that the temporal specificity of emotions may have on the emotion-performance association. We argue that habitual activity-related emotions may have a stronger influence on students' cumulative and long-term performance, as compared with momentary state emotions. Therefore, we investigate if the temporal specificity of emotions (trait vs. state) moderates the relation between emotion and performance.

Finally, we examine the publication status of the included studies as a moderator of effects. If publication bias is present in a literature, it should be reflected in an upward bias in mean effect sizes due to inflated results in smaller studies. Similarly, it will also cause a downward bias in effect size variability due to "missing" and low-effect size studies (Schmidt and Hunter 2015). Thus, to explore this possibility in the present study, we examine publication status as a moderator of effects.

Previous Meta-Analytic Studies on Achievement Activity Emotions and Educational Outcomes

There are only two meta-analytic reviews investigating the relationship between activity emotions and academic achievement. Firstly, Tze et al. (2016) conducted a meta-analysis on the association between boredom and educational outcomes. They found a moderate negative mean correlation between boredom and overall performance ($r = -.24$), as well as negative correlations with academic motivation, and study learning strategies. Similarly, Loderer et al. (2020) provided a meta-analytic review of the origins and outcomes of achievement emotions in technology-related scenarios. They found a small positive mean correlation between enjoyment and learning outcomes ($r = .18$), whereas, for anger ($r = -.07$), frustration ($r = -.07$), and boredom ($r = -.08$), the relations were near zero.

Although these studies provide substantial evidence for the expected direction of associations between activity emotions and academic achievement, we suggest a further meta-analysis is needed for several reasons. First, Tze et al. (2016) only investigated boredom and did not investigate other activity achievement emotions. Thus, we still know little about how the activity emotions such as enjoyment, anger, and frustration relate to academic achievement. While Loderer et al. (2020) conducted a review examining a broader range of activity emotions, they only did so within technology-related learning scenarios, limiting the ability to generalize to non-technology-enhanced learning settings. Thus, it is crucial to explore whether effects remain stable across non-technology-based forms of learning, given the fact that not all students have access to or use information and communication technology (ICT) for learning purposes (OECD 2015). Finally, both meta-analyses did not make corrections for the biasing effects of measurement error, which is a known statistical artifact that systematically attenuates the size of correlations (Schmidt and Hunter 2015). Thus, to the extent that these meta-analyses included studies containing unreliability in the measurement instruments of performance or emotions, their meta-analyzed correlations will be systematically biased downwards. We address this limitation by correcting for measurement error across all activity emotions.

To summarize, despite the considerable efforts referenced above, a more comprehensive analysis is needed that would include the most studied activity-related emotions, with a view towards synthesizing empirical findings across all existing learning scenarios and

environments. As well, there is a need to examine the role of possible moderating factors of meta-analytic associations, including whether moderators explain heterogeneity in the reported evidence.

The Present Study

In conducting the present study, we had two primary objectives. First, we aimed to systematically locate and meta-analytically review empirical findings on the association between activity-related achievement emotions (i.e., enjoyment, anger, frustration, and boredom) and academic performance, quantifying the aggregate strength of associations across all four emotions. Our second aim was to quantify the heterogeneity in effect sizes and determine whether this could be explained by various moderating factors.

We thereby address the following research questions:

1. Is activity-related enjoyment positively related to academic performance?
2. Are activity-related anger, frustration, and boredom, negatively related to academic performance?
3. What factors moderate relations between activity-related achievement emotions and academic performance?

Method

Search Strategy

Our search strategy involved systematic searches for both published (e.g., journal articles and chapters), and unpublished sources (e.g., masters' theses, doctoral dissertations, conference proceedings). We first searched online databases for relevant items, which were selected on the basis that they would adequately capture a broad range of published and unpublished sources across the social sciences, and in particular the education and psychology research subdomains. This included Web of Science, Educational Resources Information Centre (ERIC) and PsycINFO. In addition, we also searched for unpublished dissertations in ProQuest Dissertations and Theses Global. The electronic searches were conducted using all possible pairwise combinations of the following words: *emotion states*, *enjoyment*, *boredom*, *frustration*, *anger*, along with the linking terms*, performance, academic achievement, student,* and *school*. Truncation symbols (*) were added to the necessary word stems to capture different spellings of these terms. Other search methods included contacting principal authors in educational psychology to identify unpublished sources, as well as reference list checking (retrospective and prospective). The search includes publications from 1986 to 2019.

Inclusion Criteria

Studies had to meet the following five criteria to be included in the meta-analysis. First, the study had to use a student sample. We limited our inclusion to studies in which samples consisted of learners at any academic level, such as university or college, secondary or high school, and primary or elementary school. Studies sampling employees or other professionals in organizational contexts, or clinical samples, were excluded. Second, we only included studies using measures of discrete activity-related emotions. This encompassed self-reports,

other-reports, and facial expression analysis. We thus excluded studies that only used physiological measures (e.g., electrodermal activity, heart rate variability, etc.) or indicators derived from neuroimaging (e.g., EEG, MRT) which do not represent discrete emotions (Calvo and D'Mello 2010; Calvo et al. 2015). We also excluded studies assessing general positive or negative affect, as well as studies using bipolar items that combine discrete emotions (e.g., happy – angry). To evaluate whether items were capturing activity emotions, we assessed the item wording to ensure it was activity- and not outcome-related (e.g., "This activity is a challenge that is enjoyable"; Pekrun et al. 2005). Third, studies had to include an objective measure of academic achievement or performance (e.g., test scores, grades, or a combination of both). All studies using a subjective measure of performance (e.g., perceived competence, perceived success) were excluded. Fourth, studies had to report sufficient statistical information for effect size estimation (e.g., correlation coefficients). Finally, sources had to be available in English.

Selection Strategy

The identification of sources for potential inclusion consisted of four stages, as outlined in Fig. 2. Data searches were conducted in September 2019 and yielded 4871 records. We added 19 sources based on manual searches of reference lists of articles. After removing duplicates, studies with no original data (e.g., reviews and meta-analyses), and non-English language publications, 1672 sources were selected for further consideration. We screened the titles and abstracts and removed 1362 records for clearly failing to meet our inclusion criteria, leaving 310 for full-text review. After screening, an overall pool of 68 sources met our inclusion criteria, containing 57 independent samples for enjoyment, 52 published and five unpublished ($N = 31{,}868$), 25 independent samples for anger, 22 published and three unpublished ($N = 11{,}153$), nine samples for frustration, eight published and one unpublished ($N = 1418$), and 66 samples for boredom, 61 published and five unpublished ($N = 28{,}410$).

Data Extraction and Coding Procedure

The initial pool of studies was independently coded by two authors using a systematic coding sheet (see Appendix 1). Studies were coded on ten pieces of information:

1. Age of participants,
2. Nationality of participants,
3. Education levels (e.g., primary, secondary, and tertiary),
4. Subject domain (e.g., maths, sciences, literacy),
5. Type of performance measure (e.g., test scores, grades, or a combination of both),
6. Function of test scores (institution-based compulsory tests vs tests created for research purposes)
7. Type of learning settings (e.g., technology-enhanced or non-technology-enhanced learning environments),
8. Type of emotion measures (e.g., self-report questionnaire, judgment made by raters, judgment made by peers, facial expression analysis and thinking aloud protocols),
9. Temporal specificity of emotions (e.g., trait or state emotions),
10. Publication status (e.g., published or unpublished)

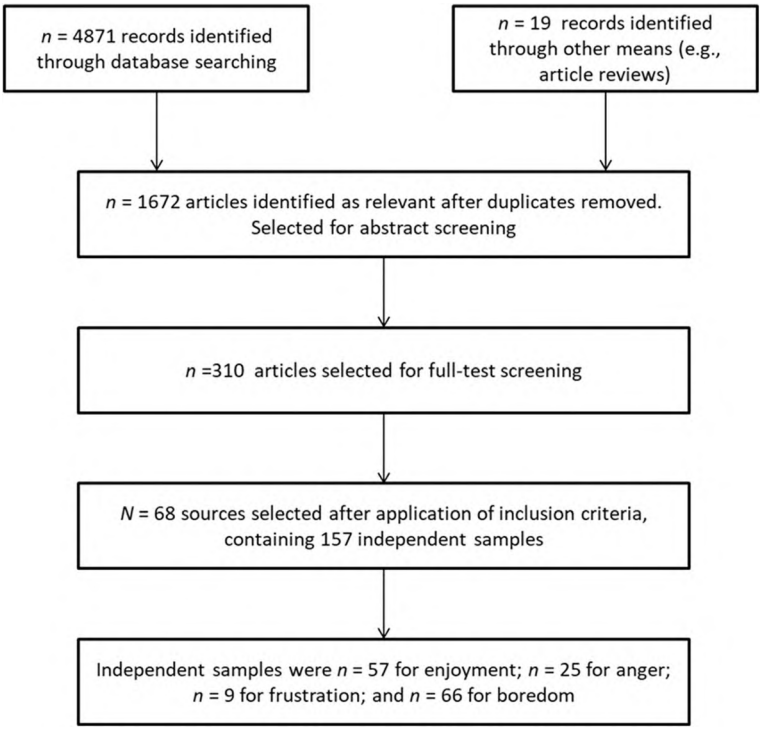

Fig. 2 Diagram illustrating the process for selection of studies included in the quantitative analysis

To reliably distinguish grades from test scores, we used three differentiating criteria and worked on the basis that: (a) grades reflect subjective judgments that are influenced by rater biases, whereas test scores are derived in an algorithmic way, generally independent from rater biases, which makes them more 'objective'; (b) grades are provided by teachers, whereas test scores are provided by trained assistants or machines; and (c) grades typically reflect various types of performance over a period of time, whereas test scores reflect performance on single test at a defined point in time. In addition, the same two coders extracted *r*, *N*, the reliability coefficients for the predictor (emotion), and reliability coefficients for the criterion (performance) for each study.

Disagreements in coding or extraction were resolved by discussion. For nominal variables (nationality of learners, educational level, subject domain, emotion and performance measure, function of test, type of learning setting, temporal specificity of emotions, publication status), Cohen's Kappa was computed between the two coders ratings and demonstrated solid agreement between the coders (Kappa = .68 to .99). For continuous variables (*r*, *N*, R_{xx}, R_{yy}, Age), we calculated a two-way, absolute, single measures intraclass correlation coefficient (ICC; McGraw and Wong 1996), which also showed high agreement between coders (ICCs .97 to 1.00; see Appendix 2 for our full interrater agreement statistics for data extraction and coding items).

Data Transformations

Our approach required some transformations of the data. Specifically, where necessary, we used the formulas provided by Schmidt and Hunter (2015) to aggregate within-study

correlations when a study provided correlations between emotions and two or more measures of academic performance. Noteborn et al. (2012), for example, provided correlations between students' emotions and two metrics of student performance: a) an exam grade, and b) a class presentation grade. In this case, we used the intercorrelations between the two performance measures to compute a composite correlation between each student's emotion and their *overall* academic performance. We followed the same procedure for all other studies that used two or more measures of academic performance. In cases where the correlations between disparate measures of performance were unavailable (and authors did not respond to emails), we used a relatively conservative estimated correlation of $r = .70$ between the measures to generate the composite correlations with emotions (Rosenthal 1993).

Similarly, there were two studies (i.e., Goetz et al. 2010, 2012) that provided correlations between subject-level emotions and subject-level performance across several different subject domains (e.g., mathematics, physics, English, and German). In these cases, calculating composite correlations would require the aggregation of domain-specific emotions with both domain-specific and domain-*irrelevant* performance- which was not justifiable given the domain specificity of emotions (Goetz et al. 2006). Following this procedure would also result in an artificial deflation of the composite correlation due to intercorrelations between emotions and domain-irrelevant performance being close to zero. Thus, to be able to include these studies in our meta-analysis and take stock of available evidence on emotion-performance relations across all subject domains, we contacted the corresponding authors of the studies to request the original data. We then used the original data to generate the composite variables for emotions and performance across subjects for each student, which we then used to compute the composite correlations between emotions and performance for these two studies. We then entered these estimates into the meta-analysis.

Meta-Analytic Procedure

To conduct our meta-analysis, we used the Schmidt and Hunter (2015) meta-analytic procedure, using the "psychmeta" package (Dahlke and Wiernik 2018) of R. We first calculated a sample-size weighted mean correlation between each emotion and performance, and then disattenuated both variables for measurement error by using artifact distributions. All analyses were performed with the unbiased sample variance estimator, which is the default in psychmeta (Dahlke and Wiernik 2018). The unbiased sample variance estimator uses a *t*-distribution to estimate confidence intervals (CIs) and credibility intervals (CVs) and tends to yield less biased estimates with more conservative CIs, particularly for analyses that contain a small number of studies (*k;* Dahlke and Wiernik 2018).

The Schmidt and Hunter (2015) approach to meta-analysis is based on the random effects model, which allows parameters to vary across studies and provides an estimate of the variance in effect sizes. Random effect models are preferable to fixed effect models because they lead to more accurate and generalizable estimates with more realistic CIs (Field 2003; Hunter and Schmidt 2000; Kisamore and Brannick 2008; Schmidt 2010). Because random effect analyses require at least three studies, this was the minimum number required for inclusion in our study for any analysis we conducted.

For all first-order effect and moderator analyses, we report combined sample size (*N*), number of studies (*k*), the meta-analytic correlation corrected only for sampling error (i.e., the "bare bones" estimate: *r*; Schmidt and Hunter 2015), as well as the observed standard deviation SD_r and residual standard deviation (SD_{res}) of the bare bones estimate. We also report the

correlation corrected for both sampling and measurement error (i.e., the estimate for the true-score correlation: ρ), its standard deviation (SD_ρ) and the observed standard deviation of corrected correlations (SD_{r_c}), and the 95% confidence interval (CI) for true-score correlations.

Heterogeneity was assessed in three ways. First, we report the 80% credibility interval (CV), which provides an estimate of heterogeneity around each effect size. The CV is based on SD_ρ and is interpreted such that 80% of the distribution of true-score correlations (i.e., the ρ distribution) lie within this interval. Second, we use SD_ρ, which serves as an indicator of cross-study heterogeneity; greater values of SD_ρ indicate greater heterogeneity. Finally, we report I^2 (Higgins et al. 2003), which represents the percentage of variance in each effect not explained by sampling error or other study artifacts. Higgins et al. (2003) suggests benchmarks of low, moderate, and high to values of 25%, 50%, 75% for I^2, which we apply here, and examined effects of moderators wherever I^2 was above 25%. For categorical moderators, moderators were explored by conducting a series of meta-analyses across different levels of the moderator. We concluded that variables depended on a moderator if the separated CIs across each level of the moderator did not overlap (Borenstein et al. 2009). For continuous moderators (e.g., age), we used meta-regression and concluded that moderation was present if the regression slope CIs did not encompass zero.

To apply our statistical corrections for measurement error, we used two approaches. First, because not every study reported reliability coefficients, we constructed artifact distributions for reliability coefficients by using the available reliabilities in the primary studies (e.g., Cronbach's alpha; see Appendix 3 for reliability distribution descriptive statistics). Statistical corrections were then applied using these artifact distributions. Second, because only a handful of studies reported reliability coefficients for performance, where necessary we used estimated reliability coefficients for performance across the remaining studies. For grades, we used the value for self-reported grades (.90) reported by Kuncel et al. (2005). For test scores, we used the mean of the reported reliability coefficients across reading (.87), writing (.96), and numeracy (.90) that were reported by the Australian National Assessment Program – Literacy and Numeracy (NAPLAN; ACARA 2018), which was .91. These estimates were applied because they were derived from large, population-wide sample sizes: either by meta-analysis (Kuncel et al. 2005), or nation-wide assessment programs (ACARA 2018).

Results

Study Codes and Reported Statistics

Before presenting our meta-analytic results, we first present our included sources showing their most relevant coded variables, reported statistics, and characteristics assigned (Table 2).

Meta-Analysis of First-Order Effect Sizes

Meta-analytic first-order effect results are displayed in Table 3. We used the benchmarks recommended by Gignac and Szodorai (2016) of .15, .25, and .35 to indicate small, moderate, and large effect size magnitudes, which are based on 708 meta-analytically derived correlations and thus have more empirical support than Cohen's (1988) benchmarks. As shown in Table 3, enjoyment exhibited a moderate positive meta-analytic correlation with academic performance ($\rho = .27$ [95% CI = .23, .30]; $k = 57$; $N = 31{,}868$). In contrast, anger showed a

Table 2 List of studies included in the quantitative analysis showing authors, publication year, sample size, emotion, age, nationality of participants, educational level, subject domain, type of emotion measure, type of achievement measure, and correlation coefficient between emotions and academic performance

Study/authors	Emotion	*N*	Age	Nationality of participants	Educational level	Subject domain	Type of emotion measure	Type of performance measure	Correlation coefficient
Ahmed et al. (2010)	Enjoyment	238	13.2	Netherlands	Secondary	Mathematics	AEQ-M	Grades	.50
Ahmed et al. (2013)	Enjoyment	495	12.8	Netherlands	Secondary	Mathematics	AEQ-M	Grades	.22
Artino et al. (2010)	Enjoyment	136	Not specified	USA	Tertiary	Introduction to clinical reasoning (ICR)	AEQ	Test scores	.19
Baek and Touati (2017)	Enjoyment	164	Not specified	South Korea	Primary	Computer game	Enjoyment scale (Fang et al. 2010)	Test scores	.44
Bailey et al. (2014)	Enjoyment	102	Not specified	USA	Secondary	Mathematics	AEQ -G	Grades	.26
Beck (2011)	Enjoyment	74	21	USA	Tertiary	Anatomy	AEQ	Grades	.02
Behrens et al. (2019)	Enjoyment	53	23.8	Chile	Tertiary	Nursing	AEQ	Test scores	−.11
Bowe (2012)	Enjoyment	160	17.32	USA	Secondary	Science	AEQ- Science	Test scores	.06
Butz et al. (2016)	Enjoyment	100	31.12	USA	Tertiary	Business	AEQ	Grades	.25
Camacho-Morles et al. (2019a)	Enjoyment	200	13.48	Australia	Secondary	Collaborative problem-solving	AEQ	Test scores	.40
Chevrier et al. (2019)	Enjoyment	114	21.3	Canada	Tertiary	Literacy	Think-aloud procedure	Test scores	−.11
Daniels et al. (2008)	Enjoyment	1002	Not specified	Canada	Tertiary	Psychology	AEQ	Grades	.12
Daniels (2009)	Enjoyment	251	17 to 26	Canada	Tertiary	Psychology	AEQ	Grades	.07
Daniels et al. (2009)	Enjoyment	669	17.5	Canada	Tertiary	Psychology	AEQ	Grades	.17
Di Leo et al. (2019)	Enjoyment	138	11	Canada	Primary	Mathematics	EES	Test scores	.06
Ganotice Jr. et al. (2016)	Enjoyment	341	13.53	Philippines	Secondary	Mathematics	AEQ-M	Grades	.30
Gibbons et al. (2018)	Enjoyment	758	Not specified	USA	Tertiary	Chemistry	AEQ	Grades	.26
Goetz et al. (2012) (sample 1)	Enjoyment	289	14.09	Germany	Secondary	German/English/ Math/Physics	AEQ-M	Grades	.15
Goetz et al. (2012) (sample 2)	Enjoyment	262	17.16	Germany	Secondary	German/English/ Math/Physics	AEQ-M	Grades	.41
Goetz et al. (2010) (sample 1)	Enjoyment	973	14.37	Germany	Secondary	English/German/ Math/Physics	AEQ-M	Grades	.19
Goetz et al. (2010) (sample 2)	Enjoyment	737	17.46	Germany	Secondary	English/German/ Math/Physics	AEQ-M	Grades	.40

Table 2 (continued)

Study/authors	Emotion	*N*	Age	Nationality of participants	Educational level	Subject domain	Type of emotion measure	Type of performance measure	Correlation coefficient
Hall (2006)	Enjoyment	477	20.46	Canada	Tertiary	Psychology	AEQ	Grades	.13
Kim et al. (2014)	Enjoyment	72	16.7	USA	Secondary	Mathematics	AEQ-M	Grades	.41
Kirwan (2018)	Enjoyment	155	Less than 30	USA	Tertiary	Nursing	AEQ	Test scores	.06
Lichtenfeld et al. (2012) (sample 1)	Enjoyment	594	9.05	Germany	Primary	Mathematics	AEQ-ES	Both test scores and grades	.23
Lichtenfeld et al. (2012) (sample 2)	Enjoyment	595	10.1	Germany	Primary	Mathematics	AEQ-ES	Both test scores and grades	.22
Lichtenfeld et al. (2012) (sample 3)	Enjoyment	163	8.69	USA	Elementary	Mathematics	AEQ-ES	Grades	.14
Luo et al. (2014)	Enjoyment	273	14.39	Singapore	Secondary	Mathematics	AEQ	Grades	.31
McGeown et al. (2015)	Enjoyment	203	6.8	UK	Primary	Reading	Enjoyment of learning to read (McGeown et al. 2015)	Test scores	.27
Muis et al. (2015a)	Enjoyment	439	21.77	Canada, Germany and USA	Tertiary	Climate change	EES	Test scores	.11
Muis et al. (2015a)	Enjoyment	56	21.89	Canada	Tertiary	Climate change	EES	Test scores	.17
Muis et al. (2015b)	Enjoyment	79	11	Canada	Primary	Mathematics	EES	Test scores	.24
Muis et al. 2015c) (Sample 1)	Enjoyment	31	6.13	Canada	Primary	Literacy	AEQ-ES	Test scores	.25
Muis et al. (2015c) (Sample 2)	Enjoyment	33	5.5	Canada	Primary	Literacy	AEQ-ES	Test scores	−.02
Niculescu et al. (2015)	Enjoyment	3451	19	Europe	Tertiary	Mathematics	AEQ	Test scores	.21
Noteborn et al. (2012)	Enjoyment	139	21.45	Not specified	Tertiary	Virtual world	AEQ	Both test scores and grades	.10
Obergriesser and Stoeger (2016)	Enjoyment	200	10.24	Germany	Primary	Science	AEQ	Grades	.24
Peixoto et al. (2017)	Enjoyment	1219	12.53	Portugal	Secondary	Mathematics	AEQ-PA	Grades	.43
Pekrun et al. (2006)	Enjoyment	187	22.39	Germany	Tertiary	Not specified	AEQ	Grades	.04
Pekrun et al. (2009)	Enjoyment	216	19.43	not specified	Tertiary	Psychology	AEQ	Grades	.08
Pekrun et al. (2011)	Enjoyment	389	20.63	Canada	Tertiary	Psychology	AEQ	Grades	.15
Pekrun et al. (2017a)	Enjoyment	2528	15.6	Germany	Secondary	Mathematics	AEQ-M	Grades	.45

Table 2 (continued)

Study/authors	Emotion	*N*	Age	Nationality of participants	Educational level	Subject domain	Type of emotion measure	Type of performance measure	Correlation coefficient
Pinxten et al. (2014)	Enjoyment	4724	9 to 13	Belgium	Primary	Mathematics	The SDQ I (Marsh 1992)	Test scores	.17
Putwain et al. (2018a)	Enjoyment	1057	9.45	UK	Primary	Mathematics	AEQ-M	Both test scores and grades	.42
Putwain et al. (2013)	Enjoyment	200	20.44	UK	Tertiary	Psychology	AEQ	Grades	.21
Raccanello et al. (2019)	Enjoyment	767	7.97	Italy	Primary	Mathematics	AEQ-ES	Grades	.12
Raker et al. (2019)	Enjoyment	553	Not specified	USA	Tertiary	Chemistry	AEQ-OCHEM	Grades	.16
Ranellucci et al. (2015)	Enjoyment	138	19.75	USA	Tertiary	Not specified	AEQ	Grades	−.17
Rennie and Punch (1991) (sample 1)	Enjoyment	183	13	Australia	Secondary	Science	Affect scale (Rennie 1986)	Grades	.29
Rennie and Punch (1991) (sample 2)	Enjoyment	159	13	Australia	Secondary	Science	Affect scale (Rennie 1986)	Grades	.12
Respondek et al. (2017)	Enjoyment	883	20.23	Germany	Tertiary	STEM	AEQ	Grades	.06
Schukajlow and Rakoczy (2016)	Enjoyment	144	15.22	Germany	Secondary	Mathematics	AEQ	Test scores	.21
Tan and Chun (2014)	Enjoyment	225	14.5	Singapore	Secondary	Chemistry	AEQ	Grades	.24
Tang (2019)	Enjoyment	202	18 to 25	Hong Kong	Tertiary	Not specified	AEQ	Grades	.12
Tempelaar et al. (2012)	Enjoyment	730	20	Several	Tertiary	Mathematics	AEQ	Test scores	.20
Villavicencio and Bernardo (2016)	Enjoyment	1345	16.49	Philippines	Tertiary	Mathematics	AEQ-M	Grades	.36
Westphal et al. (2018)	Enjoyment	1803	13.8	Germany	Secondary	Mathematics	AEQ	Test scores	.16
Beck (2011)	Anger	74	21	USA	Tertiary	Anatomy	AEQ	Grades	− .04
Behrens et al. (2019)	Anger	53	23.8	Chile	Tertiary	Nursing	AEQ	Test scores	− .26
Boekaerts (1994)	Anger	248	11.3	Netherlands	Primary	Dutch language learning	Anger Expression-Control scale (Maes et al. 1987)	Grades	− .09
Bowe (2012)	Anger	160	17.3	USA	Secondary	Science	AEQ- Science	Test scores	− .19
Camacho-Morles et al. 2019a)	Anger	200	13.48	Australia	Secondary	Collaborative problem-solving	AEQ	Test scores	− .37
Cho and Heron (2015)	Anger	229	21.64	not specified	Tertiary	Online mathematics course	AEQ	Grades	− .24
Ganotice Jr. et al. (2016)	Anger	341	13.5	Philippines	Secondary	Mathematics	AEQ-M	Grades	− .27

Table 2 (continued)

Study/authors	Emotion	*N*	Age	Nationality of participants	Educational level	Subject domain	Type of emotion measure	Type of performance measure	Correlation coefficient
Goetz et al. (2012) (sample 1)	Anger	289	14.09	Germany	Secondary	German/English/ Math/Physics	AEQ-M	Grades	−.13
Goetz et al. (2012) (sample 2)	Anger	262	17.1	Germany	Secondary	German/English/ Math/Physics	AEQ-M	Grades	− .43
Goetz et al. (2010) (sample 1)	Anger	973	14.3	Germany	Secondary	English/German/ Math/Physics	AEQ-M	Grades	− .34
Goetz et al. (2010) (sample 2)	Anger	737	17.4	Germany	Secondary	English/German/ Math/Physics	AEQ-M	Grades	− .41
Kim et al. (2014)	Anger	72	16.7	USA	Secondary	Mathematics	AEQ-M	Grades	− .51
Kirwan (2018)	Anger	155	Less than 30	USA	Tertiary	Nursing	AEQ	Test scores	− .02
Obergriesser and Stoeger (2016)	Anger	200	10.2	Germany	Primary	Science	AEQ	Grades	− .27
Peixoto et al. (2017)	Anger	1219	12.5	Portugal	Secondary	Mathematics	AEQ-PA	Grades	− .31
Pekrun et al. (2006)	Anger	187	22.3	Germany	Tertiary	Not specified	AEQ	Grades	− .05
Pekrun et al. (2009)	Anger	216	19.4	not specified	Tertiary	Psychology	AEQ	Grades	− .28
Pekrun et al. (2011)	Anger	389	20.6	Canada	Tertiary	Psychology	AEQ	Grades	− .27
Pekrun et al. (2017a)	Anger	2528	15.6	Germany	Secondary	Mathematics	AEQ-M	Grades	− .42
Putwain et al. (2013)	Anger	200	20.4	UK	Tertiary	Psychology	AEQ	Grades	− .16
Raker et al. (2019)	Anger	553	Not specified	USA	Tertiary	Chemistry	AEQ-OCHEM	Grades	− .17
Stavrova and Urhahne (2010)	Anger	96	14.1	Germany	Secondary	Science	AEQ-M	Test scores	− .26
Tan and Chun (2014)	Anger	225	14.5	Singapore	Secondary	Chemistry	AEQ	Grades	− .14
Tang (2019)	Anger	202	18 to 25	Hong Kong	Tertiary	Not specified	AEQ	Grades	− .09
Villavicencio and Bernardo (2013)	Anger	1345	16.49	Philippines	Tertiary	Mathematics	AEQ-M	Grades	−.31
Chevrier et al. (2019)	Frustration	114	21.3	Canada	Tertiary	Literacy	Think-aloud procedure	Test scores	− .06
Craig et al. (2004)	Frustration	34		USA	Tertiary	Reasoning, causality, and explanations	Judgment made by trained coders	Test scores	− .06
Di Leo et al. (2019)	Frustration	138	11	Canada	Primary	Mathematics	EES	Test scores	− .18
Graesser et al. (2007, July)	Frustration	30		USA	Tertiary	Reasoning, causality, and explanations	Post-experiment self-judgment based on video	Test scores	.04
Huang and Yeh (2019)	Frustration	72	10.77	Taiwan	Primary	Literacy	EATQ-R	Grades	− .06

Table 2 (continued)

Study/authors	Emotion	*N*	Age	Nationality of participants	Educational level	Subject domain	Type of emotion measure	Type of performance measure	Correlation coefficient
Muis et al. (2015a) (Sample 1)	Frustration	439	21.7	Canada, Germany, and USA	Tertiary	Climate change	EES	Test scores	.07
Muis et al. (2015a) (Sample 2)	Frustration	56	21.9	Canada	Tertiary	Climate change	EES	Test scores	− .10
Muis et al. (2015b)	Frustration	79	11	Canada	Primary	Mathematics	EES	Test scores	.21
Novak et al. 2018 (Sample 1)	Frustration	456	20.4	USA	Tertiary	Medicine students	Student frustration with using e-texts scale (Novak et al. 2018)	Test scores	− .07
Ahmed et al. (2013)	Boredom	495	12.8	Netherlands	Secondary	Mathematics	AEQ-M	Grades	− .26
Artino et al. (2010)	Boredom	136	Not specified	USA	Tertiary	Introduction to clinical reasoning (ICR)	AEQ	Test scores	− .23
Bailey et al. (2014)	Boredom	102	Not specified	USA	Secondary	Mathematics	AEQ	Grades	− .01
Beck (2011)	Boredom	74	21	USA	Tertiary	Anatomy	AEQ	Grades	.07
Behrens et al. (2019)	Boredom	53	23.8	Chile	Tertiary	Nursing	AEQ	Test scores	− .24
Bowe (2012)	Boredom	160	17.32	USA	Secondary	Science	AEQ- Science	Test scores	− .14
Butz et al. (2016)	Boredom	100	31.12	USA	Tertiary	Business (MBA)	AEQ	Grades	− .31
Camacho-Morles et al. (2019a)	Boredom	200	13.48	Australia	Secondary	Collaborative problem-solving	AEQ	Test scores	− .38
Chevrier et al. (2019)	Boredom	114	21.3	Canada	Tertiary	Literacy	Think-aloud procedure	Test scores	− .09
Cho and Heron (2015)	Boredom	229	21.64	Not specified	Tertiary	Online mathematics course	AEQ	Grades	− .16
Cowan and Piepgrass (1997)	Boredom	159	Not specified	USA	Tertiary	General studies	Not specified	Grades	− .32
Cowan and Piepgrass (1997)	Boredom	215	Not specified	USA	Tertiary	Science	Not specified	Grades	.08
Craig et al. (2004)	Boredom	34	Not specified	USA	Tertiary	Reasoning, causality, and explanations	Judgment made by trained coders	Test scores	− .39
Daniels et al. (2008)	Boredom	1002	Not specified	Canada	Tertiary	Psychology	AEQ	Grades	− .18

Table 2 (continued)

Study/authors	Emotion	*N*	Age	Nationality of participants	Educational level	Subject domain	Type of emotion measure	Type of performance measure	Correlation coefficient
Daniels (2009)	Boredom	251	17 to 26	Canada	Tertiary	Psychology	AEQ	Grades	− .33
Daniels et al. (2009)	Boredom	669	17.5	Canada	Tertiary	Psychology	AEQ	Grades	− .31
Di Leo et al. (2019)	Boredom	138	11	Canada	Primary	Mathematics	EES	Test scores	− .19
Eren and Coskun (2016)	Boredom	557	15.58	Turkey	Secondary	Mathematics	Level of boredom scale (Van Tilburg and Igou 2012)	Grades	− .22
Fritea and Fritea (2013)	Boredom	187	Not specified	Romania	Secondary	Literacy	AEQ	Grades	− .19
Ganotice Jr. et al. (2016)	Boredom	341	13.53	Philippines	Secondary	Mathematics	AEQ-M	Grades	− .25
Goetz et al. (2012) (sample 1)	Boredom	289	14.09	Germany	Secondary	English/German/ Math/Physics	AEQ-M	Grades	− .08
Goetz et al. (2012) (sample 2)	Boredom	262	17.16	Germany	Secondary	English/German/ Math/Physics	AEQ-M	Grades	− .31
Goetz et al. (2010) (sample 1)	Boredom	973	14.37	Germany	Secondary	English/German/ Math/Physics	AEQ	Grades	− .22
Goetz et al. (2010) (sample 2)	Boredom	737	17.46	Germany	Secondary	English/German/ Math/Physics	AEQ	Grades	− .27
Graesser et al. (2007, July)	Boredom	30	Not specified	USA	Tertiary	Reasoning, causality, and explanations	Post-experiment self-judgment based on video	Test scores	− .14
Hall (2006)	Boredom	477	20.46	Canada	Tertiary	Psychology	AEQ	Grades	− .30
Kim et al. (2014)	Boredom	72	16.7	USA	Secondary	Mathematics	AEQ-M	Grades	− .19
Kirwan (2018)	Boredom	155	Less than 30	USA	Tertiary	Nursing	AEQ	Test scores	.04
Laukenmann et al. (2003)	Boredom	600	Not specified	Germany	Secondary	Physics	Single item scale (I felt bored)	Test scores	− .17
Lichtenfeld et al. (2012) (sample 1)	Boredom	594	9.05	Germany	Elementary	Mathematics	AEQ-ES	Both test scores and grades	− .21
Lichtenfeld et al. (2012) (sample 2)	Boredom	595	10.1	Germany	Elementary	Mathematics	AEQ-ES	Both test scores and grades	− .16
Lichtenfeld et al. (2012) (sample 3)	Boredom	163	8.69	USA	Elementary	Mathematics	AEQ-ES	Grades	− .23
Luo et al. (2014)	Boredom	273	14.39	Singapore	Secondary	Mathematics	AEQ	Grades	− .25

Table 2 (continued)

Study/authors	Emotion	*N*	Age	Nationality of participants	Educational level	Subject domain	Type of emotion measure	Type of performance measure	Correlation coefficient
Maroldo (1986)	Boredom	223	20.13	USA	Tertiary	Not specified	College student boredom scale (no details)	Grades	− .15
Muis et al. (2015a)	Boredom	439	21.77	Canada, Germany, and USA	Tertiary	Climate change	EES	Test scores	− .09
Muis et al. (2015a)	Boredom	56	21.89	Canada	Tertiary	Climate change	EES	Test scores	− .20
Muis et al. (2015b)	Boredom	79	11	Canada	Primary	Mathematics	EES	Test scores	.14
Muis et al. (2015c)	Boredom	31	6.13	Canada	Primary	Literacy	AEQ-ES	Test scores	− .47
Muis et al. (2015c)	Boredom	33	5.5	Canada	Primary	Literacy	AEQ-ES	Test scores	.02
Niculescu et al. (2015)	Boredom	3541	19	Europe	Tertiary	Mathematics	AEQ	Test scores	− .20
Noteborn et al. (2012)	Boredom	139	21.45	Not specified	Tertiary	Virtual world	AEQ	Both test scores and grades	.10
Obergriesser and Stoeger (2016)	Boredom	200	10.24	Germany	Primary	Science	AEQ	Grades	− .18
Peixoto et al. (2017)	Boredom	1219	12.53	Portugal	Secondary	Mathematics	AEQ-PA	Grades	− .06
Pekrun et al. (2006)	Boredom	187	22.39	Germany	Tertiary	Not specified	AEQ	Grades	− .04
Pekrun et al. (2009)	Boredom	216	19.43	Not specified	Tertiary	Psychology	AEQ	Grades	− .13
Pekrun et al. (2010) (sample 1)	Boredom	122	23.43	Germany	Tertiary	Psychology and Education	AEQ	Grades	− .32
Pekrun et al. (2010) (sample 2)	Boredom	389	20.63	Canada	Tertiary	Psychology and Education	AEQ	Grades	− .24
Pekrun et al. (2010) (sample 3)	Boredom	211	19.75	Canada	Tertiary	Psychology	AEQ	Grades	− .36
Pekrun et al. (2011)	Boredom	389	20.63	Canada	Tertiary	Psychology	AEQ	Grades	− .15
Pekrun et al. (2014)	Boredom	424	20.46	Canada	Tertiary	Psychology	AEQ	Grades	− .31
Pekrun et al. (2017a)	Boredom	2528	15.6	Germany	Secondary	Mathematics	AEQ-M	Grades	− .45
Perry et al. (2001)	Boredom	234	19	Canada	Tertiary	Psychology	College students' boredom scale (Pekrun 1993; Pekrun et al. 2002)	Grades	− .37
Putwain et al. (2018a)	Boredom	1057	9.45	UK	Primary	Mathematics	AEQ-M		− .42

Table 2 (continued)

Study/authors	Emotion	*N*	Age	Nationality of participants	Educational level	Subject domain	Type of emotion measure	Type of performance measure	Correlation coefficient
								Both test scores and grades	
Putwain et al. (2013)	Boredom	200	20.44	UK	Tertiary	Psychology	AEQ	Grades	− .10
Raccanello et al. (2019)	Boredom	767	7.97	Italy	Primary	Mathematics	AEQ-ES	Grades	− .17
Raker et al. (2019)	Boredom	553	Not specified	USA	Tertiary	Chemistry	AEQ-OCHEM	Grades	− .13
Randler (2009)	Boredom	426	Not specified	Germany	Secondary	Science	Student emotions scale (Gläser-Zikuda et al. 2005)	Test scores	− .27
Ranellucci et al. (2015)	Boredom	138	19.75	USA	Tertiary	Not specified	AEQ	Grades	− .06
Respondek et al. (2017)	Boredom	883	20.23	Germany	Tertiary	STEM	AEQ	Grades	− .14
Schukajlow and Rakoczy (2016)	Boredom	144	15.22	Germany	Secondary	Mathematics	AEQ	Test scores	− .16
Stavrova and Urhahne (2010)	Boredom	96	14.14	Germany	Secondary	Science	AEQ-M	Test scores	− .08
Tang (2019)	Boredom	202	18 to 25	Hong Kong	Tertiary	Not specified	AEQ	Grades	− .29
Tempelaar et al. (2012)	Boredom	730	20	Several	Tertiary	Mathematics	AEQ	Test scores	− .28
Tze et al. (2013) (sample 1)	Boredom	254	23.29	China	Tertiary	Education	AEQ	Grades	− .12
Tze et al. (2013) (sample 2)	Boredom	151	21.03	Canada	Tertiary	Education	AEQ	Grades	.05
Westphal et al. (2018)	Boredom	1803	13.8	Germany	Secondary	Mathematics	AEQ	Test scores	− .13

N sample size, *UK* United Kingdom, *USA* United States of America, *AEQ* Achievement Emotions Questionnaire, *AEQ-M* Achievement Emotions Questionnaire for Mathematics, *AEQ-S* Achievement Emotions Questionnaire for Science, *AEQ-PA* Achievement Emotions Questionnaire for Pre-adolescents, *AEQ-ES* Achievement Emotions Questionnaire for Elementary school, *AEQ-OCHEM* Achievement Emotions Questionnaire for Organic Chemistry, *AEQ-G* Achievement Emotions Questionnaire for Geography, *EES* Epistemic Emotion Scale, *EATQ-R* Early Adolescence Temperament Questionnaire – Revised, *SDQ I* Self-Description Questionnaire I

Table 3 Meta-analytic first-order effect correlations between enjoyment, boredom, anger, and frustration with performance in academic settings

Variable	*k*	*N*	*r*	SD_r	SD_{res}	ρ	SD_{r_c}	SD_ρ	95% CI	80% CR	I^2 (%)
Enjoyment	57	31,868	.23	.12	.12	.27	.14	.13	[.23, .30]	[.09, .44]	89
Anger	25	11,153	− .31	.11	.10	− .35	.13	.12	[− .40, − .30]	[− .50, − .19]	85
Frustration	9	1418	− .02	.10	.06	− .02	.12	.07	[− .11, .07]	[− .13, .08]	39
Boredom	66	28,410	− .22	.12	.11	− .25	.13	.12	[− .28, − .21]	[− .40, − .09]	85

k number of studies contributing to meta-analysis, *N* total sample size, *r* mean observed correlation, SD_r observed standard deviation of *r*, SD_{res} residual standard deviation of *r*, ρ mean true-score correlation, SD_{r_c} observed standard deviation of corrected correlations (r_c), SD_ρ residual standard deviation of ρ, CI confidence interval around ρ, *CR* credibility interval around ρ. I^2 percentage of variance not explained by sampling error or other study artifacts. Correlations corrected using artifact distributions

strong negative correlation with achievement (ρ = − .35 [95% CI = −.40, −.30]; *k* = 25; *N* = 11,153), while for boredom, our results indicated a moderate negative association with academic performance (ρ = − .25 [95% CI = −.28, −.21]; *k* = 66; *N* = 28,410). Finally, frustration showed a near zero and non-significant correlation with academic performance (ρ = − .02 [95% CI = −.11, .07]; *k* = 9; *N* = 1418).

Also shown in Table 3 is the substantial amount of between-study heterogeneity in the strength of the observed correlations, indicated by the broad width of the credibility intervals as well as the amount of variance in effects not explained by sampling and measurement error (represented by I^2). These results suggest that the substantial variability in effect sizes across studies may be caused by moderating factors, which we turn to next.

Moderator Analyses

We next examined whether correlations systematically varied according to the presence of potential moderating variables. Specifically, because I^2 was at least 25% for each emotion, we used categorical moderator analyses to examine whether the strength of the correlations varied depending on the selected moderators. Tables 4 and 5 display the results of these analyses across each emotion for categorical moderators. We distinguish moderator analyses according to those that are theory-driven (education level, subject domain, and nationality, shown in Table 4), from those that are methodological (emotion and achievement measures, temporal specificity of emotions, function of test scores, type of learning settings, publication status, shown in Table 5).

For theory-driven moderator analyses, results showed evidence of moderation by educational level, with secondary school settings showing significantly stronger findings for enjoyment and anger. For every emotion, tertiary settings showed the weakest effects, although there was some overlap in the CIs. Of note, moderation by level of education pertained only to the strength of relations, but not their direction. Thus, meta-analytic relations between enjoyment and achievement were positive at all levels of education, and negative for anger and boredom at all levels of education.

For subject domain, meta-analytic correlations were slightly stronger for mathematics than for other subjects, though these differences did not reach significance except for enjoyment where studies targeting math-related achievement reported stronger effects than those targeting the domain of psychology. Moderator analyses also showed that effects were in some instances moderated by country, including for enjoyment, where effects were stronger for German than Canadian samples, and for boredom where effects were stronger for German than US samples. Like education level, moderation pertained only to the strength of the relations, but not their direction.

Table 4 Moderator analyses for theory-relevant factors

Moderator, emotion, and level	*k*	*N*	*r*	SD_r	SD_{res}	ρ	SD_{r_c}	SD_ρ	95% CI	80% CR
Nationality of participants										
Enjoyment										
Germany	12	9195	.27	.15	.14	.30	.17	.16	[.20, .41]	[.08, .53]
Canada	11	3239	.12	.06	.03	.14	.07	.03	[.09, .19]	[.10, .18]
United States of America	11	2411	.17	.12	.10	.19	.14	.12	[.10, .29]	[.03, .36]
United Kingdom	3	1460	.37	.10	.09	.42	.11	.10	[.14, .70]	[.22, .62]
Australia	3	542	.28	.14	.12	.32	.16	.14	[− .07, .71]	[.06, .58]
Anger										
Germany	8	5272	− .37	.10	.10	− .42	.12	.11	[− .52, − .32]	[− .57, − .26]
United States of America	5	1014	− .17	.13	.11	− .19	.15	.12	[− .37, − .01]	[− .38, .00]
Frustration										
Canada	4	387	− .05	.17	.13	− .06	.19	.15	[− .37, .24]	[− .31, .18]
United States of America	3	520	− .06	.03	.00	− .07	.04	.00	[− .16, .02]	[− .07, − .07]
Boredom										
Germany	16	10,439	− .25	.13	.12	− .28	.14	.13	[− .36, − .21]	[− .46, − .10]
Canada	16	4648	− .24	.11	.10	− .26	.12	.11	[− .33, − .20]	[− .41, − .12]
United States of America	15	2314	− .13	.12	.09	− .14	.14	.10	[− .22, − .07]	[− .28, − .00]
Subject domain										
Enjoyment										
Mathematics	20	19,055	.28	.12	.11	.31	.13	.13	[.25, .37]	[.14, .48]
Science	4	702	.19	.11	.08	.21	.12	.09	[.02, .40]	[.07, .35]
Chemistry	3	1536	.22	.06	.04	.25	.06	.04	[.09, .41]	[.17, .33]
Psychology	7	3204	.13	.04	.00	.15	.04	.00	[.11, .19]	[.15, .15]
Other	3	527	.02	.14	.12	.02	.16	.14	[− .38, .42]	[− .24, .28]
Anger										
Science	3	456	− .24	.05	.00	− .27	.05	.00	[− .40, − .15]	[− .27, − .27]
Mathematics	5	5505	− .36	.07	.06	− .41	.08	.07	[− .51, − .32]	[− .52, − .30]
Psychology	3	805	− .25	.06	.02	− .28	.07	.02	[− .45, − .11]	[− .32, − .24]
Boredom										
Science	5	1097	− .15	.14	.13	− .17	.16	.14	[− .37, .03]	[− .38, .05]
Literacy	4	365	− .16	.13	.09	− .18	.15	.10	[− .42, .06]	[− .34, − .02]
Mathematics	19	13,534	− .25	.13	.12	− .28	.14	.14	[− .35, − .21]	[− .47, − .10]

Table 4 (continued)

Moderator, emotion, and level	*k*	*N*	*r*	SD_r	SD_{res}	ρ	SD_{r_c}	SD_ρ	95% CI	80% CR
Psychology	10	4073	− .25	.09	.08	− .28	.10	.08	[− .35, − .21]	[− .39, − .16]
Other	4	750	− .14	.11	.09	− .16	.13	.10	[− .36, .04]	[− .32, .00]
Educational level										
Enjoyment										
Primary	13	8748	.21	.10	.09	.24	.11	.10	[.17, .31]	[.10, .38]
Secondary	19	10,403	.32	.13	.13	.36	.15	.14	[.29, .43]	[.17, .55]
Tertiary	25	12,717	.18	.10	.09	.21	.12	.10	[.16, .25]	[.07, .34]
Anger										
Secondary	12	7102	− .35	.09	.08	− .40	.10	.09	[− .47, − .34]	[− .53, − .28]
Tertiary	11	3603	− .23	.10	.08	− .26	.11	.10	[− .33, − .18]	[− .39, − .13]
Frustration										
Primary	3	289	− .04	.20	.17	− .05	.23	.20	[− .63, .53]	[− .43, .33]
Tertiary	6	1129	− .01	.08	.02	− .01	.09	.02	[− .11, .08]	[− .04, .02]
Boredom										
Primary	10	3657	− .25	.13	.12	− .27	.15	.14	[− .38, − .17]	[− .46, − .08]
Secondary	20	11,464	− .25	.13	.12	− .28	.14	.14	[− .34, − .21]	[− .46, − .09]
Tertiary	36	13,289	− .19	.10	.09	− .21	.11	.10	[− .25, − .18]	[− .34, − .09]

k number of studies contributing to meta-analysis, *N* total sample size, *r* mean observed correlation, SD_r observed standard deviation of *r*, SD_{res} residual standard deviation of *r*, ρ mean true-score correlation, SD_{r_c} observed standard deviation of corrected correlations (r_c), SD_ρ residual standard deviation of ρ, *CI* confidence interval around ρ *CR* credibility interval around ρ. Correlations corrected using artifact distributions

Table 5 Moderator analyses for study-level methodological factors

Moderator, emotion, and level	*k*	*N*	*r*	SD_r	SD_{res}	ρ	SD_{r_c}	SD_ρ	95% CI	80% CR
Emotion measure										
Enjoyment										
AEQ	26	13,055	.18	.08	.07	.20	.09	.08	[.16, .24]	[.09, .30]
AEQ-ES	6	2183	.18	.06	.03	.20	.07	.04	[.13, .28]	[.14, .26]
AEQ-M	11	8337	.37	.10	.10	.42	.12	.11	[.34, .50]	[.26, .57]
EES	4	712	.12	.06	.00	.14	.07	.00	[.03, .24]	[.14, .14]
Other	4	5230	.18	.06	.05	.21	.07	.06	[.10, .31]	[.10, .31]
Anger										
AEQ	12	2330	− .20	.11	.08	− .23	.12	.10	[− .30, − .15]	[− .36, − .09]
AEQ-M	9	6643	− .36	.08	.07	− .42	.09	.08	[− .48, − .35]	[− .53, − .30]
Boredom										
AEQ	33	14,141	− .20	.09	.07	− .22	.10	.08	[− .26, − .19]	[− .33, − .12]
AEQ-ES	6	2183	− .18	.05	.02	− .20	.06	.02	[− .27, − .14]	[− .23, − .18]
AEQ-M	10	6850	− .34	.12	.11	− .38	.13	.13	[− .47, − .28]	[− .56, − .20]
EES	4	712	− .09	.11	.08	− .10	.12	.09	[− .30, .09]	[− .25, .04]
Other	3	1217	− .27	.07	.05	− .30	.08	.05	[− .48, − .11]	[− .40, − .19]
Type of performance measure										
Enjoyment										
Grades	34	16,670	.26	.15	.14	.30	.17	.16	[.24, .35]	[.09, .50]
Test score	19	12,813	.19	.07	.06	.21	.08	.07	[.17, .25]	[.12, .30]
Both test scores and grades	4	2385	.30	.12	.12	.35	.14	.13	[.12, .57]	[.13, .56]
Anger										
Grades	20	10,489	− .31	.11	.10	− .35	.12	.12	[− .41, − .30]	[− .51, − .20]
Test score	5	664	− .22	.14	.12	− .25	.17	.14	[− .46, − .05]	[− .46, − .04]
Boredom										
Grades	41	17,117	− .23	.13	.12	− .26	.14	.13	[− .30, − .21]	[− .43, − .08]
Test score	21	8908	− .19	.07	.06	− .21	.08	.06	[− .25, − .17]	[− .30, − .13]
Both test scores and grades	4	2385	− .27	.17	.17	− .30	.19	.19	[− .61, − .00]	[− .61, .00]
Function of test score										
Enjoyment										
Tests created for research purposes	14	5835	.21	.09	.08	.24	.11	.09	[.18, .30]	[.12, .37]
Institution-based compulsory tests	5	6978	.16	.03	.00	.18	.03	.00	[.15, .22]	[.18, .18]
Boredom										
Tests created for research purposes	17	6654	− .20	.08	.06	− .22	.09	.07	[− .27, − .18]	[− .31, − .14]
Institution-based compulsory tests	4	2254	− .16	.06	.05	− .17	.07	.06	[− .29, − .06]	[− .27, − .08]
Type of learning setting										
Enjoyment										

Table 5 (continued)

Moderator, emotion, and level	*k*	*N*	*r*	SD_r	SD_{res}	ρ	SD_{r_c}	$SD_ρ$	95% CI	80% CR
Non-technology-enhanced	46	29,702	.23	.12	.12	.26	.14	.13	[.22, .31]	[.09, .44]
Technology-enhanced	8	1134	.23	.16	.14	.26	.19	.16	[.11, .42]	[.03, .49]
Anger										
Non-technology-enhanced	21	10,450	−.31	.11	.10	−.35	.13	.12	[−.41, −.29]	[−.51, −.20]
Technology-enhanced	3	501	−.33	.12	.09	−.38	.13	.11	[−.71, −.05]	[−.58, −.18]
Frustration										
Non-technology-enhanced	4	403	−.05	.16	.13	−.06	.19	.15	[−.35, .24]	[−.29, .18]
Technology-enhanced	5	1015	−.01	.08	.04	−.01	.09	.04	[−.12, .11]	[−.07, .05]
Boredom										
Non-technology-enhanced	53	26,115	−.22	.12	.11	−.25	.13	.12	[−.28, −.21]	[−.41, −.09]
Technology-enhanced	10	1263	−.15	.16	.13	−.17	.17	.14	[−.30, −.05]	[−.37, .03]
Temporal specificity of emotions										
Enjoyment										
Trait	45	30,240	.24	.12	.12	.27	.14	.13	[.23, .31]	[.10, .44]
State	11	1426	.14	.15	.12	.16	.17	.14	[.05, .27]	[−.03, .34]
Anger										
Trait	20	10,373	−.31	.11	.10	−.35	.13	.12	[−.41, −.29]	[−.51, −.20]
State	4	578	−.29	.07	.00	−.33	.08	.00	[−.46, −.21]	[−.33, −.33]
Boredom										
Trait	46	24,803	−.23	.12	.11	−.25	.13	.12	[−.29, −.22]	[−.41, −.09]
State	18	3182	−.17	.12	.10	−.19	.13	.11	[−.26, −.13]	[−.34, −.05]
Publication status										
Enjoyment										
Published	52	30,751	.24	.12	.12	.27	.14	.13	[.23, .31]	[.10, .44]
Unpublished	5	1117	.09	.04	.00	.10	.05	.00	[.04, .16]	[.10, .10]
Anger										
Published	22	10,764	−.31	.11	.10	−.36	.12	.11	[−.41, −.30]	[−.50, −.21]
Unpublished	3	389	−.09	.10	.05	−.11	.11	.05	[−.39, .17]	[−.21, −.01]
Boredom										
Published	61	27,293	−.22	.12	.11	−.25	.13	.12	[−.28, −.21]	[−.40, −.09]
Unpublished	5	1117	−.21	.16	.15	−.24	.18	.17	[−.46, −.01]	[−.49, .02]

k number of studies contributing to meta-analysis, *N* total sample size, *r* mean observed correlation, SD_r observed standard deviation of *r*, SD_{res} residual standard deviation of *r*, ρ mean true-score correlation, SD_{r_c} observed standard deviation of corrected correlations (r_c), $SD_ρ$ residual standard deviation of ρ, *CI* confidence interval around ρ *CR* credibility interval around ρ. Correlations corrected using artifact distributions

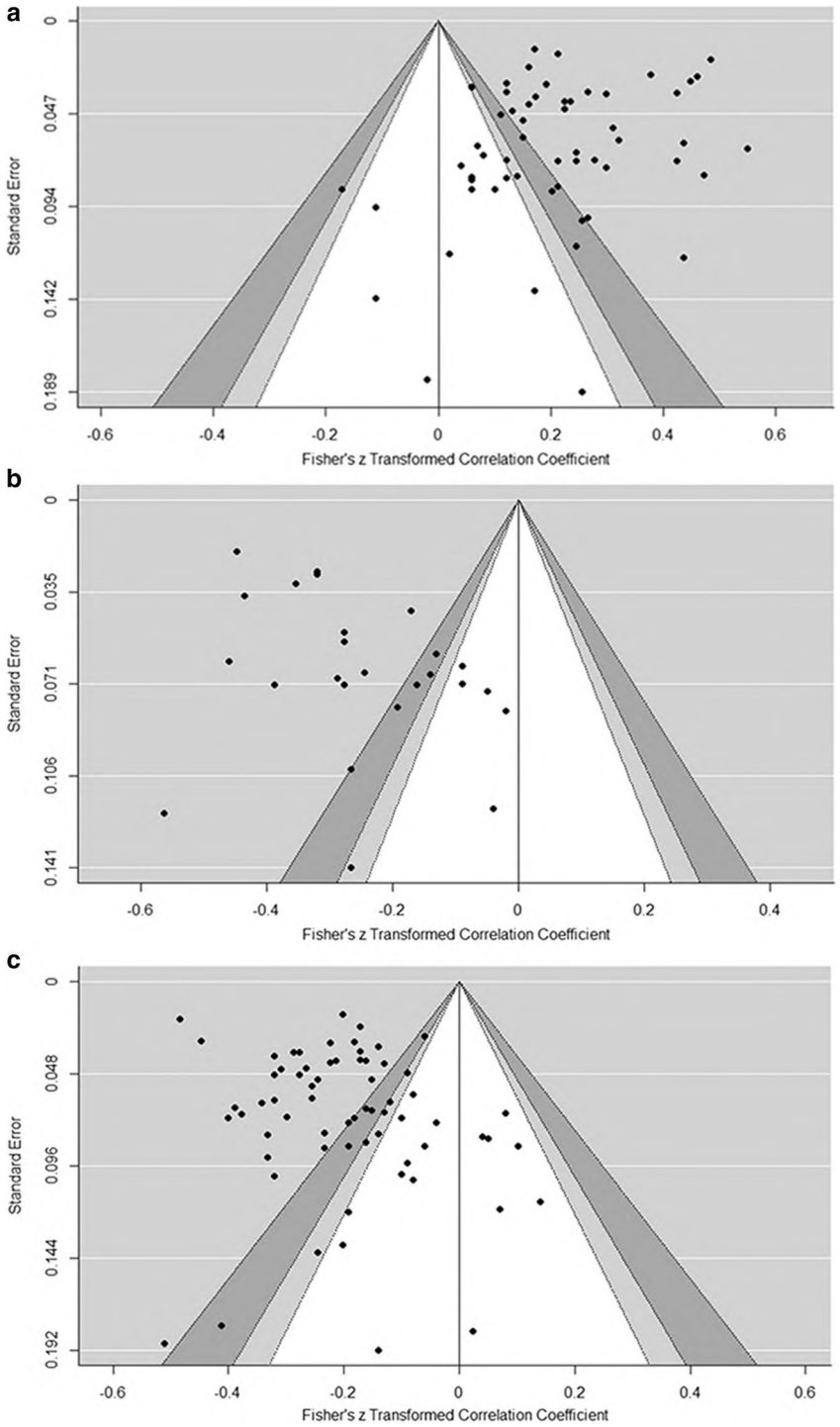

Fig. 3 Funnel plot diagrams showing studies plotted against effect size and standard error. A enjoyment, B anger, C boredom

For methodological moderators, we found evidence of moderation by type of emotion measure, with the AEQ-M generally showing stronger correlations than the other measures. We did not find evidence of moderation by type of performance measure, with at least some overlap in the CIs in each case. However, for enjoyment there was only marginal overlap in CIs between grades and test scores, with grades showing a stronger correlation. Again, moderation pertained only to the strength of the relations, and not the direction. There was no evidence of moderation according to the function of test score, type of learning settings, or the temporal specificity of emotions.

Finally, we also used meta-regressions to examine whether correlations were related to the mean age of participants. Results showed no evidence of moderation for enjoyment ($\beta = -.009$, $SE = .005$, [95% CI = −.018, .001]), boredom ($\beta = .003$, $SE = .004$, [95% CI = −.005, .010]), or anger ($\beta = .006$, $SE = .008$, [95% CI = −.010, .022]), with all CIs encompassing zero. Again, we did not run this analysis for frustration due to lack of power (Kepes et al. 2012). Since educational level is related to age, we also examined whether mean age explained incremental variance in the meta-analytic correlations after controlling for educational level (which we recoded as 1 = primary, 2 = secondary, and 3 = tertiary for the purpose of this analysis). The results showed that mean age did not show significant incremental variance in meta-analytic correlations for any emotion after controlling for educational level.

Publication Bias

Our final step was to test whether our findings are subject to potential publication bias. To do this, we used three approaches. First, to examine whether published and unpublished studies reported emotion-performance relations differing in effect size, we report separate meta-analytic correlations for published and unpublished sources (e.g., unpublished articles, dissertations, conference presentations). We did this whenever three or more studies were available for each moderator sub-group for an emotion, which excluded frustration. For enjoyment, results suggest that effect sizes for unpublished studies are closer to zero, indicating stronger effects in the published literature (Table 5). For anger, while effect sizes for unpublished sources were lower than published sources, there was still overlap in the 95% CIs across published and unpublished sources. Effect sizes for boredom were very similar across both sub-groups.

Second, we examined publication bias with contour-enhanced funnel plots (see Fig. 3) in which z-transformed effect sizes were plotted against standard errors. In line with established recommendations, we only ran this analysis for emotions that contained 10 or more studies (Kepes et al. 2012), which excluded frustration. The symmetry of zero-centered funnel plots can be visually inspected with the aid of contour lines that represent different levels of statistical significance based on common conventions: $p < .01$ (external gray zone), $p < .05$ (funnel's dark gray zone), $p < .10$ (funnel's light gray zone), and $p > .10$ (funnel's white zone; see Peters et al. 2008). If bias is present, plots will generally display a pattern of missing weak effects near zero (the white zone) among small studies with high standard errors. As shown in Fig. 3, asymmetry is present for enjoyment, anger, and boredom. However, the missing studies are more evident in the external gray zone and less evident in the internal white zone – where they would generally materialize if publication bias was present. Peters et al. (2008) describe such a pattern as indicative of variable study quality or other factors that can limit the power to yield substantive effect sizes (see meta-analysis example 38 in Peters et al. 2008). This may also explain why we found smaller effect sizes in our unpublished studies, which also generally contained smaller sample sizes, which is an imperfect proxy for study quality: enjoyment (published: mean $N = 591$, SD = 856.08, median $N = 232$; unpublished: mean

$N = 223$, $SD = 138.63$, median $N = 160$); Anger (published: mean $N = 489$, $SD = 566.45$, median $N = 239$; unpublished: mean $N = 130$, $SD = 39.42$, median $N = 155$), and boredom (published: mean $N = 447$, $SD = 583.27$, median $N = 232$; unpublished: mean $N = 223$, $SD = 138.63$, median $N = 160$).

Finally, we used cumulative meta-analysis (CMA) to examine whether meta-analytic effects are inflated as small studies are added into the analysis (Schmidt and Hunter 2015). In CMA, studies are ranked based on sample size and are then entered into the analysis one at a time, starting with the largest study. If small study bias is present, it will cause the mean effect size to trend upwards as smaller studies are added (Borenstein et al. 2009; Schmidt and Hunter 2015). We compared the average effect sizes based on the largest studies (those making up the top tertile of the set), against average effects where all studies are included. If the CIs for the two effect sizes are overlapping, then it suggests a high degree of similarity and bias is likely absent. Using this procedure, we found little evidence of small study bias for enjoyment (top tertile: $k = 19$, $N = 24{,}883$, $\rho = .28$ [CI = .22, .34]; full set: $k = 57$, $N = 31{,}868$, $\rho = .27$ [CI = .23, .30]); anger (top tertile: $k = 8$, $N = 8085$, $\rho = -.39$ [CI = −.47, −.32]; full set: $k = 25$, $N = 11{,}153$, $\rho = -.35$ [CI = −.40, −.30]); frustration (top tertile: $k = 3$, $N = 1033$, $\rho = -.03$ [CI = −.34, .28]; full set: $k = 9$, $N = 1418$, $\rho = -.02$ [CI = −.11, .07]), or boredom (top tertile: $k = 22$, $N = 20{,}979$, $\rho = -.26$ [CI = −.32, −.21]; full set: $k = 66$, $N = 28{,}410$, $\rho = -.25$ [CI = −.28, −.21]), with effect size CIs overlapping in each case. Moreover, in agreement with the funnel plots, the effect sizes in the full sets (with both large and small studies included) are closer to zero, showing evidence of smaller effects in smaller studies. Overall, we take these analyses to conclude that publication bias and small study bias are not inflating effect sizes in this literature.

Discussion

The term 'achievement emotions' refers to emotions that learners experience when completing academic activities, namely tests or exams, attending classes, doing homework, and studying (Pekrun 2014). The number of studies focusing on activity emotions (e.g., enjoyment, anger, frustration, and boredom) and academic performance has increased substantially in recent years. This proliferation of studies, though, has produced seemingly inconsistent results that have become the subject of debate within the field. The primary objective of this work, therefore, was to meta-analyze existing studies investigating the role of activity emotions for academic performance to determine, in aggregate, the strength and general direction of their relation. We also aimed to examine whether relevant moderators could explain current discrepancies in the literature.

Study Findings and Contributions

Our results contribute to the literature in several ways. First, our findings affirm the positive association of enjoyment and student achievement. These findings provide further support for existing theoretical propositions stating that positive emotions are beneficial for learning and performance as they enhance attention and flexible cognition (Fredrickson and Joiner 2002) and creative thinking (Ashby and Isen 1999), perhaps because they strengthen intrinsic motives for learning (Ryan and Deci 2017), facilitate the use of flexible learning strategies, and self-regulation of learning (Pekrun 2006).

Our study also confirms the negative association between anger and academic achievement. Out of all the activity emotions included in this review, our results showed that anger exhibited the strongest correlation with student performance. These results are consistent with the idea

that anger undermines motivation (Pekrun et al. 2011; Kim and Hodges 2012), and potentially reduces students' willingness to learn (Darban and Polites 2016), leading to low performance.

An interesting finding was that frustration, a negative activating emotion, showed no association with academic achievement. There may be three reasons for this surprising lack of a relation between frustration and performance. First, effects of emotions on performance depend on their activating versus deactivating nature. Whereas enjoyment and anger are clearly activating emotions, and boredom is a deactivating emotion, the status of frustration on the arousal dimension is less clear. Frustration occurs when there are unexpected obstacles that hinder goal attainment and cannot be easily removed. As such, frustration may involve a blend of anger and disappointment about the non-attainability of one's goal. Given that anger is activating, and disappointment is deactivating, the consequences for action and performance may be variable, but these propositions have yet to be examined empirically.

Second, in terms of the reverse causal direction, it may be that failure generates frustration, which would amount to a negative effect of performance on this emotion (the better one's performance, the less frustration). However, it may also be that high-achieving students expect to be successful, thus being more frustrated about failure than low-achieving students who expected to fail. This would amount to a positive effect of performance on subsequent occurrence of frustration. Taken together, these negative and positive effects may cancel each other out and result in a zero-overall correlation.

Finally, it is possible that correlations between frustration and performance may vary within individuals, which is something that between-person correlations cannot really reflect. The impact of frustration on performance might vary, just like the impact of confusion on cognitive performance has been found to vary (e.g., D'Mello et al. 2014; Vogl et al. 2020). The argument is that under certain circumstances, frustration and confusion can be "productive" (i.e., conducive to performance) if they lead individuals to invest more effort to solve cognitive conflicts.

Consistent with previous meta-analytical reviews on boredom and educational outcomes (Tze et al. 2016), our results offered evidence that corroborates the detrimental impact of negative deactivating emotions such as boredom for student academic achievement. We found an almost identical but slightly stronger correlation coefficient ($r = -.25$) than the one reported by Tze et al. (2016; $r = -.24$). Altogether, we can infer that student performance decreases as boredom experienced by students during class or studying increases. An explanation for these results may be that boredom reduces intrinsic motivation and engagement during academic activities (Pekrun et al. 2010), creates cognitive interference, which, in turn, undermines on-task attention (Sarason et al. 1996), and reduces effort regulation and task performance (Camacho-Morles et al. 2019a). These findings are particularly relevant in today's education as recent evidence indicates that academic boredom is not only routinely experienced (Bieg et al. 2013), but it is also considered a persistent and enduring emotion (D'Mello et al. 2010).

We found significant true-score associations between emotions and performance of students across different educational levels. This was particularly strong for secondary students where emotion effects were stronger than for primary and university students. These patterns might partly be explained by the propositions made by Ekman et al. (2001), suggesting that young adolescents experience emotions in different ways to adults who tend to conceal their emotions. For example, students tend to enjoy learning more when they are young, whereas older adults tend to experience less enjoyment (Vierhaus et al. 2016). This lessened enjoyment in older-aged samples might create less variance in enjoyment for these population groups, which can potentially attenuate the correlation magnitudes among such samples. It could be

also that individuals become more effective regulators of their emotions as they get older, as suggested by (John and Gross 2004). Meaning that adults may be more inclined to downregulate their emotions, thereby altering the potential impact of an emotion experienced on (subsequent) experience, motivation, and behavior.

We believe there are several possible explanations of our findings suggesting stronger effects for secondary students compared with primary students. First, when entering school, children often enjoy attending and do not report much boredom, anger, or anxiety (see Hembree 1988; Zhang et al. 2019). High levels of enjoyment and low levels of negative emotions across students imply fewer individual differences, (i.e., less between-person variation) and, as such, lower interindividual correlations given that significant/substantial correlation requires sufficient variance of the variables involved. Second, in terms of the reverse causal direction, repeated feedback about achievement over a longer period may be needed to create a stronger link between performance and subsequent emotions, especially for trait-level emotions (which is what was investigated most frequently across primary studies).

Our findings also indicate that associations between activity emotions and students' achievement vary in terms of magnitude depending on subject domains. In particular, relations of enjoyment and anger with achievement were significantly stronger in math as compared with other subject domains (e.g., literacy, science). Similar observations have been reported by Goetz and Hall (2013), who note that relations between emotions and academic achievement generally seem to be stronger in math and science domains as compared with, for instance, verbal domains. However, our moderation analyses for subject domain are limited due to being heavily weighted towards math, with comparatively fewer studies focused on other subject areas. A consequence of this is smaller aggregate samples in non-math domains, and thus more probability for second-order sampling error (Schmidt and Hunter 2015), which also lessens power.

Furthermore, primary study effect sizes may vary due to methodological differences in construct alignment between emotion and achievement measures. As argued by Goetz and Hall (2013), relations between emotions and achievement should be stronger when both are measured in domain-specific ways and at the same level of temporal granularity. Specifically, state-level emotions may be strongly related to test performance on a given occasion, but less so to cumulative achievement scores (e.g., cumulative course grades). Trait-level emotions implying habitual experiences in a given course or subject, in contrast, may be more strongly related to cumulative achievement within that course. This type of alignment varied across primary studies included in our review, and implies an interaction between two methodological moderators considered in our analysis, namely 'temporal specificity of emotions' and 'type of performance measure'. We were unable to test for such interaction effects due to insufficient power but consider this a possible source variation in magnitudes of effects. More research is needed to explain why relations differ across subjects, in terms of magnitude.

In addition, our results indicate that activity emotions are critical factors associated with the performance of students from different countries and cultures. Importantly, in terms of direction of effects, associations between emotions and achievement were consistent across moderator sub-groups representing different cultural contexts. As such, our findings align with prior cross-cultural research, including, for instance, those obtained in PISA (Programme for International Student Assessment) 2015 (OECD 2017). However, mean emotion-achievement relations varied in terms of magnitude for two emotions. In particular, boredom was found to have a stronger association with achievement in German students compared with American students, while enjoyment showed a stronger relation with achievement in German than Canadian students. A possible explanation for these results might be that almost 90% of

German students were adolescents in the secondary level of education, compared with both Canadian and American samples which primarily consisted of university students. We argue that these findings might be explained by a possible interaction effect confounding nationality and level of education. As argued previously, reduced enjoyment and therefore increased boredom in adult samples may entail reduced variance, which would attenuate correlations.

In this study, the links between activity emotions and performance were found to be stronger for academic grades than for test scores. These results are likely to be related to the nature in which the performance outcomes have been measured. Grades are typically provided by the teacher of the students, whereas test scores provide a standardized metric to quantify student achievement or competence and are typically detached from everyday classroom activities. Grades are more proximal measures of achievement and are thus more relevant in activity settings, whereas test scores are divorced from the actual activity.

Theoretical and Practical Implications

The findings from our analysis are in line with the propositions of CVT for relations between enjoyment, anger, and boredom, on the one hand, and achievement, on the other. They are also consistent with the relative universality proposition of CVT, which states that the functional relations of achievement emotions with appraisal antecedents and achievement outcomes should be universal across different groups of individuals and different contexts. Such functional consistency is an important prerequisite for designing emotional interventions. Specifically, the moderator analyses show that the findings are robust in terms of direction of relations across various individual-level and contextual moderators (age of participants, function of test scores, type of learning settings, temporal specificity of emotions, publication status) in terms of the existence and the positive versus negative direction of relations with achievement. The strength of the relations varied across a few moderators (e.g., nationality of participants, subject domain, educational level, type of emotion measure, and type of performance measure); however, this is not inconsistent with theory and may simply be a function of differences in study design and the quality of measures. Importantly, the direction of effects was consistent across different levels of these moderators. It is possible that differences in the strength of effects were caused by sampling error, or by hidden moderators for which insufficient relevant information was available to fully examine in our meta-analysis (e.g., cognitive ability, SES). This issue remains an open question for future research. However, by providing evidence of moderation of the magnitude of correlations, our results help explain some of the observed heterogeneity of correlations reported in the literature.

An important implication following from the analysis is that more work on frustration is needed. The antecedents and outcomes of frustration in achievement contexts are not addressed in CVT and are not considered in any more detail in other theories, such as Weiner's attributional theory (Weiner 1972), either. More theoretical and empirical work on this emotion is needed. In addition, there is remarkable lack of research on deactivating achievement emotions such as activity-related relief (e.g., triggered by completion of unpleasant activities) and relaxation. More work on these emotions is needed as well.

The findings of this study have several important implications for future educational practice. Specifically, our results suggest that academic achievement may depend on students' ability to effectively regulate the emotions elicited by achievement activities. Emotion regulation is understood as a process of recognizing, managing, and modifying the experience of emotions (Gross and Thompson 2007), or the impact of an emotional episode on subsequent

behavior, and could assist students to successfully engage in academic achievement activities and increase performance. Specifically, our results imply that equipping students with strategies for upregulating enjoyment, and downregulating anger and boredom during learning, can boost academic success (cf. Harley et al. 2019, for a theoretical model and review of the literature on achievement emotion regulation). Teachers are encouraged to foster students' emotion regulation and implement interventions in the classroom in order to promote the occurrence of positive emotions, such as enjoyment (see reviews from Morrish et al. 2017; Quoidbach et al. 2015), and to reduce the incidence of negative emotions such as boredom and anger (see, e.g., Linnenbrink-Garcia et al. 2016). Finally, evidence suggests that teachers' affect and emotions experienced during classes are transmissible to students (Frenzel et al. 2009). Hence, it may be advisable for teachers to monitor their emotions (see Frenzel et al. 2016, for a scale to measure teacher emotions), which are relevant not only for their own well-being but to class functioning (Frenzel et al. 2018).

Our findings also have further implications for recent movements in education that position student well-being as central to education, including social-emotional learning and "positive education" (Ng and Vella-Brodrick 2019; Slemp et al. 2017). These movements share the aim of enabling students to better understand well-being, to learn related skills (e.g., emotional regulation), and to use these skills in useful ways (e.g., in the pursuit of academic performance). In education, practitioners may often view well-being as primarily affective, and academic performance as primarily cognitive. Moreover, some may view emotional well-being as instrumental to academic performance. To many stakeholders in education, academic performance is paramount. Yet, a focus on achievement emotions provides a natural bridge between academic performance and these well-being movements in education. That is, achievement emotions, by definition, combine affective components and academic performance in ways that may not be immediately obvious to many practitioners. For this reason, learning about emotions can be leveraged as promoting achievement, beyond a focus on mental illness. Our results broadly support initiatives that assist students to identify and regulate emotions, which our findings suggest is important for performance on academic activities. Current research on well-being literacy is consistent with these aims (Oades 2018; Oades et al. 2020), which considers the efficacy with which students communicate about well-being. It is possible that students could draw from techniques in well-being literacy to enable better communication about the extent to which they are experiencing discrete activity emotions during learning activities. This may shift the discourse away from the counterproductive labeling of students as "bored," "lacking in motivation," or "disengaged," with all responsibility placed on individual students, to one where stakeholders in education proactively assist students to understand, regulate, and promote more productive patterns of discrete activity emotions during learning activities.

Limitations and Recommendations for Future Research

Despite the strengths of meta-analysis (Schmidt and Hunter 2015), our results should be interpreted in light of some limitations. First, our results for frustration should be interpreted with caution, given the comparatively small number of studies for this emotion. A possible explanation for this paucity of research on frustration may be the lack of available self-report measures to assess this emotion in academic settings. Still, it is likely that the number of studies for this emotion will increase in upcoming years due to the recent validation of the Epistemically-Related Emotion Scales (Pekrun et al. 2017b), which includes a multi-item scale to measure frustration.

Second, while our results shed light on the strength of associations between activity achievement emotions and academic performance, as well as moderators of those associations,

given the cross-sectional or correlational nature of many of the included studies, we cannot infer causal processes. While it is likely that emotions affect academic performance, attaining high or low performance is also likely to yield corresponding emotional experiences. We suggest a fruitful direction for future research is to use experimental procedures that allow for stronger causal inferences.

In addition to these considerations, linkages between activity-related emotions and academic performance might also vary across different task demands as reflected in the achievement measures in different primary studies. Enjoyment, for instance, might boost performance on tasks that require critical thinking or deep learning (e.g., elaboration), because enjoyment can foster the use of deep learning strategies and creative, flexible problem-solving. Consequently, for tasks that require memorization and recall of single facts, for instance, the use of rehearsal-based learning strategies may be conducive, such that activity-related enjoyment may be unrelated to, or even negatively impact, task performance. We see this as an interesting avenue for future research.

Finally, we did not include activity-related relaxation in our analysis because of its low frequency of occurrence during achievement activities (Pekrun et al. 2011). More research is needed on relaxation, including the development of an instrument that can be used to assess its incidence and functions during achievement activities.

Conclusion

The relevance of activity-related emotions to academic performance is clearly supported by the current findings. Specifically, results suggest that enjoyment of achievement academic activities can be beneficial to academic performance. In contrast, the experience of boredom and anger can be detrimental to educational outcomes. Frustration shows no substantive association with academic achievement. Interestingly, activity emotions seem to have a stronger influence on the academic performance of adolescents compared with university or primary school students. However, importantly, for all of the theory-derived and methodological possible moderators of the link between emotions and achievement that we inspected (age of participants, nationality of participants, education levels, subject domain, type of performance measure, function of test scores, type of learning settings, type of emotion measures, temporal specificity of emotions, and publication status), we found that they influenced the strength of relations only, but not their direction. As such, the findings support claims about the robustness and generalizability of the relations between students' emotions and their achievement (i.e., relative universality of achievement emotions; Pekrun 2006, 2009). The evidence from this study establishes the foundations for education policy and practice to pay more attention to the affective factors (i.e.., emotions, feelings, and moods) associated with learning and performance.

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Appendix 1.Coding sheet

Year and citation
Insert citation and year of study

Sample
N used to compute *r*

Nationality of participants
Insert country/region of nationality of the participants of the study

1. Australia
2. Belgium
3. Canada
4. Chile
5. Europe
6. Germany
7. Hong Kong
8. Italy
9. Netherlands
10. Philippines
11. Portugal
12. Singapore
13. South Korea
14. United Kingdom
15. United States of America

Age
Insert the age of participants expressed in years and months

Subject domain
Insert the content-domain of the activity performed by students when achievement emotions were measure

1. Chemistry
2. Climate change
3. Collaborative problem-solving
4. Computer game (Minecraft)
5. German
6. Introduction to Clinical Reasoning (ICR)
7. Literacy
8. Maths
9. Master of Business administration (MBA)
10. Nursing
11. Psychology
12. Reading
13. Science
14. Virtual world

Educational level
Insert the level of academic study of participants

1. Primary (Elementary)
2. Secondary (Mid school/high school)
3. Tertiary (College/University)

Publication status (Published?)
1. Y
2. N

Type of emotion measure (IV measure)
Name and citation for achievement emotion measure, and # items where necessary

1. Achievement Emotions Questionnaire for Organic Chemistry (AEQ-OQEM)
2. Achievement Emotions Questionnaire (AEQ)
3. Achievement Emotions Questionnaire - Science (AEQ-S)
4. Achievement Emotions Questionnaire - Maths (AEQ-M)
5. Achievement Emotions Questionnaire - Geometry (AEQ-G)
6. Achievement Emotions Questionnaire - Elementary School (AEQ-ES)
7. Achievement Emotions Questionnaire - Preadolescents (AEQ-PA)
8. College Students Boredom Scale
9. Epistemic Emotions Scale (EES)
10. Early Adolescence Temperament Questionnaire – Revised (EATQ-R)
11. Judgement made by trained coders
12. Post-experiment self-judgement of emotions based on video
13. Think aloud protocols
14. Single-item (e.g., I feel bored)
15. Other

IV reliability
Reliability coefficient for achievement emotion measure

Type of performance measure (DV measure)
Name and citation for academic performance measure

1. Test scores
2. Grades
3. Both test scores and grades

Function of test score
Insert the type of test score

1. Institution-based compulsory tests
2. Tests created for research purposes

Type of learning setting
Insert the type of learning environment

1. Technology-enhanced
2. Non-technology-enhanced

Temporal specificity of emotions
Insert the temporal specificity of emotions

1. Trait
2. State

DV reliability
Reliability coefficient for academic performance measure
r
Correlation coefficient between IV (achievement emotion measure) and DV (academic performance measure)

Time lag
Time between IV and DV measurement in months (if 0 write cross-sectional)

Appendix 2. Interrater agreement statistics

Variable	ICC	Kappa
r	.97	
N	.99	
r_{xx}	.99	
r_{yy}	.99	
Age	1.00	
Subject domain		.68
Education level		.99
Performance measure		.94
Function of test		.95
Emotion measure		.94
Nationality of participants		.94
Temporal specificity of emotions		.95
Type of learning settings		.99
Publication status		.99

r effect size, N study sample size, r_{xx} reliability of the achievement emotion variable, r_{yy} reliability of the performance criterion variable

Appendix 3. Reliability distribution descriptive statistics for the relations between activity achievement emotions and academic achievement

Variable	Reliability coefficients for activity achievement emotions				Reliability coefficients for performance			
	N_R	N_E	M	SD	N_R	N_E	M	SD
Enjoyment	52	--	.85	.07	7	50	.91	.03
Anger	22	--	.84	.09	1	24	.85	--
Frustration	6	--	.80	.06	--	9	--	--
Boredom	57	--	.87	.07	6	60	.91	.03

Note: N_R = Number of reliability coefficients reported; N_E = Number of reliability coefficients estimated; M = Mean; SD = Standard Deviation

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*Studies included in the meta-analysis are denoted by an asterisk.

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Affiliations

Jesús Camacho-Morles[1] · Gavin R. Slemp[1] · Reinhard Pekrun[2,3,4] · Kristina Loderer[5] · Hanchao Hou[1] · Lindsay G. Oades[1]

[1] Centre for Positive Psychology, Melbourne Graduate School of Education, The University of Melbourne, Level 2, 100 Leicester St., Parkville, Victoria 3010, Australia

[2] Department of Psychology, University of Essex, Colchester, UK

[3] Institute for Positive Psychology and Education, Australian Catholic University, Sydney, Australia

[4] Department of Psychology, University of Munich, Munich, Germany

[5] Department of Psychology, University of Augsburg, Augsburg, Germany