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ARTICLE

Relations between teaching practices and students' achievement emotions in mathematics: The role of control and value

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Abstract

Background: Students' achievement emotions (AEs) are closely linked to their social environment. Consistent with control-value theory (CVT), extensive research has confirmed the relevance of control and value appraisals as antecedents of AEs. However, limited attention has been paid to the relations among students' perceptions of teaching practices, control and value appraisals, and AEs.

Aims: We investigated the associations among teaching practices (conceptualized based on CVT's distinction among task emotional and motivational qualities, autonomy support, and social interactions), control and value appraisals, and AEs.

Sample: The sample comprised 1538 fourth- and seventh-grade students ($M_{age} = 11.10$, $SD_{age} = 1.57$; 51.24% females).

Methods: Students self-reported Positive Teaching (referred to as displayed teacher enthusiasm and value-related motivational messages), Student Involvement, Teacher Warmth, control and value in mathematics, and AEs in mathematics lessons and tests.

Results: Two structural equation models showed that Positive Teaching and Teacher Warmth were positively associated with control and value. Control showed a largely consistent pattern of positive associations with positive emotions and negative associations with negative emotions, whereas value showed a more differentiated pattern, including positive associations with anxiety. Also, a pattern of associations involving the two appraisals emerged, especially for control appraisals in the relations between Teacher Warmth and enjoyment, pride, relaxation, and anxiety across

the two settings. Configural, metric, and (partial for school level) scalar invariance across sex and school level was supported, as well as structural invariance.
Conclusions: Our findings extend the generalizability of CVT and offer insights for supporting students' AEs through positive teaching practices.

KEYWORDS
achievement emotions, cognitive appraisals, control-value theory, lower secondary school, primary school, teaching practices

INTRODUCTION

Students' emotions are closely intertwined with their social environment. This social environment includes teachers, who play an important role in providing support at school. Emotions related to learning activities or outcomes, known as achievement emotions (AEs), are key determinants of students' well-being and performance (Pekrun, 2024). According to control-value theory (CVT; Pekrun, 2006, 2024; Pekrun & Perry, 2014; Pekrun, Marsh, Elliot, et al., 2023), beliefs about control and task value (hereafter value) play a crucial role in the development of AEs across school levels (Forsblom et al., 2022; Peixoto et al., 2017; Putwain et al., 2021; Putwain & Wood, 2023). However, the contribution of contextual factors, such as perceived supportive teaching practices, to students' AEs remains underexplored (Pekrun, 2024; Wentzel, 2026).

We conceptualized supportive teaching practices as characteristics of the school social environment and selected three constructs with reference to CVT's (Pekrun, 2024) broad categories of task emotional and motivational qualities, autonomy support, and social interactions. Specifically, we examined Positive Teaching, whose items refer to displayed teacher enthusiasm and value-related motivational messages, Student Involvement in participatory school practices, and Teacher Warmth as affection and emotional support. We investigated how these constructs were associated with 10 mathematics-related AEs, while also examining the role of mathematics-related control and value appraisals. In line with CVT assumptions on the domain specificity of AEs, we focused on two settings: lessons and tests, in mathematics, due to the importance of this subject for academic learning, everyday life skills, and professional trajectories (Schukajlow et al., 2023).

We involved primary and lower secondary school students, considering their sex and school level. In their everyday school experiences, students are likely to experience the full spectrum of AEs, ranging from positive to negative and from activating to deactivating emotions, depending on the characteristics of the activities and outcomes they encounter (Pekrun, 2024). Previous literature has often neglected the study of a wide range of AEs among these age groups (Pekrun, 2022) – also in mathematics (Schukajlow et al., 2023) – despite their theoretical and applied relevance. Expanding knowledge of the associations between AEs and relatively malleable antecedents, such as control and value beliefs and supportive teaching practices, would provide further evidence relevant to CVT. It would also have important practical implications by identifying multiple points at which teachers may support pleasant emotions and reduce unpleasant emotions during compulsory education.

Achievement emotions

Over the last 25 years, CVT has emerged as a dominant theoretical basis for research on the role of emotions in students' well-being and achievement (Pekrun, 2024). AEs are "related to achievement activities or achievement outcomes, that is, activities and outcomes that are judged according to

competence-based standards of quality" (Pekrun, 2024, p. 9). They are typically described along two dimensions – valence (positive, negative) and physiological arousal (activating, deactivating). While early research mainly focused on a limited set of emotions, such as test anxiety (Putwain, 2024; Zeidner, 2014), CVT emphasizes the broad range of emotions experienced in achievement settings. A key strength of CVT is its focus on a broader range of emotions pervasive in everyday learning, such as enjoyment, pride, and hope (positive activating AEs); relief and relaxation (positive deactivating AEs); anxiety, anger, and shame (negative activating AEs); and hopelessness and boredom (negative deactivating AEs). Nevertheless, while research on a variety of older students' AEs has already flourished (Pekrun, 2024), that involving primary and lower secondary school students is still in development (Pekrun, 2022).

CVT also describes AEs by considering the interrelations between them and a range of antecedents and outcomes. Among the antecedents, control and value play a paramount role as individual proximal antecedents, influenced by other individual distal antecedents, such as gender, and contextual antecedents generally related to social environments, including also teaching practices (Pekrun, 2024). Within CVT, academic achievement represents one of the most extensively investigated outcomes of AEs, with meta-analytic findings indicating positive associations for positive emotions and negative associations for negative emotions, also in mathematics (Barroso et al., 2021; Camacho-Morles et al., 2021; Schoenherr et al., 2025).

It is worth noting that there are two core assumptions of CVT – domain specificity and invariance – which are particularly relevant to this work (Pekrun, 2024). First, AEs are assumed to be domain-specific and should therefore be assessed within a specific domain (e.g., mathematics). Second, CVT assumes that the relations between AEs and associated constructs should be universally invariant across individual characteristics such as gender and age. In this work, testing invariance across sex and school level therefore allowed us to examine whether the proposed pattern of associations between perceived teaching practices, appraisals, and AEs was comparable across relevant student groups.

Control and value

The core determinants of AEs are the cognitive appraisals (hereafter appraisals) of perceived control and value (Pekrun, 2024). Control refers to the extent to which individuals perceive themselves as having influence over their actions and resulting outcomes; value refers to how relevant and meaningful an individual perceives a task to be (Pekrun, 2024). The latter may encompass intrinsic value, when the task is appealing in itself, as well as extrinsic components such as attainment value, when the task matters for self-related goals such as achieving good grades, and utility value, when the task is useful in both the short and long term (Eccles & Wigfield, 2023).

According to CVT (Pekrun, 2024), positive AEs are generally expected when students perceive high levels of control and value, whereas negative emotions are more likely when control is low. However, the specific pattern of relations varies across emotions. For example, negative activating emotions such as anxiety may emerge when students highly value achievement but experience insufficient control, whereas positive deactivating emotions such as relaxation are more likely when high control is accompanied by limited evaluative pressure. A meta-analysis (Schoenherr et al., 2025) of mathematics-related emotions among students from primary to tertiary education confirmed the expectation that perceiving a high degree of control over one's performance is associated with positive emotions, such as enjoyment (but associations with pride and hope were not statistically significant), while perceptions of low control are linked to heightened negative emotions, such as anger and hopelessness (whereas the association with boredom was not statistically significant). Moreover, it indicated that valuing mathematics is associated with positive emotions, such as enjoyment and pride (while the association with hope was not statistically significant), whereas value is negatively associated with several negative emotions, such as anger, boredom, and hopelessness (but associations with shame were not statistically significant).

Focusing on mathematics with younger students, a more limited emotional range is typically explored. In a cross-sectional study with fifth-graders, control and value were related positively to

enjoyment and negatively to anxiety and boredom, with the exception that attainment value was not significantly related to anxiety (Putwain et al., 2021). In a longitudinal study with fifth-graders, Putwain and Wood (2023) reported, over time, negative reciprocal relations between control and anxiety, but no significant relations between value and later anxiety, together with negative relations between anxiety and later value. Longitudinal data with fifth- and seventh-graders confirmed the predictive role of control and value on subsequent AEs, with positive effects on enjoyment and negative effects on anger and boredom (Forsblom et al., 2022). As an exception, in a cross-sectional study, Peixoto et al. (2017) explored seven AEs regarding fourth-to-sixth-graders' lessons and tests, reporting that the two appraisals were related positively to enjoyment and pride (but not relief) and negatively to anxiety, anger, hopelessness, and boredom. Moreover, the relations seemed stronger with activating rather than with deactivating emotions. Nevertheless, knowledge on how control and value are associated with a larger set of AEs at this age is relatively lacking.

Teaching practices

Teaching practices are characteristics of the school social environment, serving as contextual antecedents of AEs (Pekrun, 2024). Adopting Bronfenbrenner's (1979) terminology, focusing on them implies examining reality through a lens that zooms in on the social interactions in which students are involved first-hand with their teachers, that is, their microsystems. Among the categories proposed by Pekrun (2024) to distinguish contextual antecedents, we focused on task emotional and motivational qualities, autonomy support, and social interactions. Within these broad CVT categories, we examined three teaching-practice constructs: Positive Teaching, Student Involvement, and Teacher Warmth, respectively. These constructs represent distinct, although potentially related, characteristics of students' perceived school social environment.

Self-determination theory (SDT; Ryan & Deci, 2020) offers a complementary perspective on why supportive teaching practices may be relevant to students' experiences. Such practices may contribute to students' needs for competence, autonomy, and relatedness. However, because need satisfaction was not assessed in the present study, SDT is not used as an additional explanatory framework for the empirical model; rather, it provides a secondary interpretive perspective, whereas the hypotheses and tested relations are grounded in CVT. Taken together, supportive teaching practices are expected to relate to students' control and value beliefs, as well as their AEs, but these associations remain underinvestigated.

Task emotional and motivational qualities: Positive Teaching

Among the emotional and motivational qualities of achievement activities described by CVT, we focused on two conceptually distinguishable forms of positive teacher input: displayed teacher enthusiasm and value-related motivational messages. Displayed enthusiasm refers to teachers' expression of teaching-related enjoyment through verbal and non-verbal behaviour (Keller et al., 2016), whereas value-related motivational messages communicate the relevance, usefulness, or importance of learning activities and their underlying reasons (Pekrun, 2024). In the present study, these teacher inputs were assessed using the Positive Teaching subscale of the Multidimensional School Climate Questionnaire (MSCQ; Janosz & Bouthillier, 2007; for the Italian adaptation, see Grazia & Molinari, 2021). Although the items refer to conceptually distinguishable teacher behaviours and messages, they belong to the original unidimensional subscale and were therefore analysed jointly as Positive Teaching. This measurement choice does not imply that teacher enthusiasm and value-related motivational messages constitute a single higher order theoretical construct. From a complementary SDT perspective, these inputs may be relevant to students' need for competence and, potentially, autonomy and relatedness (Ryan & Deci, 2020), although need satisfaction was not assessed in the present study.

While both forms of teacher input represent positive teaching practices that are expected to be associated with AEs and their appraisals, empirical evidence on their associations remains limited. Accordingly, research examining teacher enthusiasm and value-related motivational messages can provide useful evidence regarding the potential links between task emotional and motivational qualities, appraisals, and AEs. For example, from cross-sectional studies with college students, we know that teacher enthusiasm enhanced their academic self-efficacy (Zhang, 2014) and dampened boredom through the mediation of value (Cui et al., 2017), whereas, from a longitudinal study in three waves, we know that it was linked consistently to AEs, positively to enjoyment, and negatively to boredom (Pekrun, Marsh, Elliot, et al., 2023). Between fifth- and tenth-graders and their teachers, reciprocal transmissions of enjoyment have been detected (Frenzel et al., 2018).

Autonomy support: Student Involvement

Within CVT, autonomy support refers to an environment that provides choices between tasks and strategies for performing them (Pekrun, 2024). From a complementary SDT perspective, such environments may also be relevant to students' need for autonomy (Ryan & Deci, 2020). We operationalized teachers' autonomy support by focusing on students' perceptions of their involvement in decisions related to school life, which are typically facilitated and negotiated through interactions with teachers within the school context. We assessed it by using the Student Involvement subscale of the MSCQ (Janosz & Bouthillier, 2007). Accordingly, autonomy support was conceptualized as students' perceived participation opportunities within school interactions, typically mediated by teachers.

Teaching practices that emphasize students' autonomy are expected to be positively associated with – but empirical support is still lacking – both control and value, as well as AEs (Pekrun, 2024), for example, including practices that encourage students' participation in school-related decisions and rule-setting processes (Grazia & Molinari, 2021; Janosz & Bouthillier, 2007). Empirical studies examining autonomy-supportive practices offer preliminary evidence consistent with these theoretical expectations. For example, in a cross-sectional study with middle school students in mathematics, the impact of teacher autonomy support – positively associated with self-efficacy and value – on reducing boredom was fully mediated by the two appraisals (Wang et al., 2017). Also, an intervention study showed that autonomy-supportive practices in physics with ninth-grade classrooms fostered positive AEs such as enjoyment and dampened negative ones such as anger and boredom (Flunger et al., 2019).

Social interactions: Teacher Warmth

A further dimension of Pekrun's (2024) contextual antecedents was social interactions. School social interactions comprise a variety of actors, including teachers. From a complementary SDT perspective, caring interactions with teachers may be relevant to students' need for relatedness, facilitated by the conveyance of care (Martin & Collie, 2016; Ryan & Deci, 2020; Wentzel, 2022). In this work, we operationalized social interactions through Teacher Warmth, an affective-relational quality that, similar to parental warmth – rooted in Bowlby's (1969) attachment theory and related to the concepts of secure base and responsiveness – encompasses affection and positive communication between adult and child (Waller et al., 2018). It reflects the extent to which teachers convey emotional closeness and connectedness through behaviours expressing affection and appreciation, as well as their ability to understand and responsively address students' communicative needs, offering emotional support (Hamre et al., 2013; Pianta et al., 2003; Wentzel, 2022).

Overall, teacher–student relationships are associated with a wide range of motivational and performance indicators (Hattie, 2009; Wentzel, 2022). These findings suggest that supportive social interactions may be associated with students' appraisals and emotions. From an SDT perspective, relatedness need satisfaction represents one possible mechanism, although it was not assessed in

the present study. For example, longitudinal data on 8-year-olds followed for 2 years indicated that parental warmth had positive indirect effects on children's academic achievement through their agency (Gurdal et al., 2016). Positive teacher–student relationships foster students' internalization of teachers' values (Martin & Dowson, 2009). An increase in the number of these relationships predicts engagement among seventh-to tenth-graders, operationalized to include also enjoyment (Martin & Collie, 2019). Perceived teacher support is positively linked to various-age students' positive emotions, such as enjoyment, hope, pride, and relief, and negatively linked to negative emotions such as anxiety, anger, shame, boredom, and hopelessness (Forsblom et al., 2021; Lazarides & Buchholz, 2019; Lei et al., 2018; Monteiro et al., 2017), also in mathematics. Nevertheless, knowledge of the role of Teacher Warmth is still incomplete.

The current study

We studied the role of mathematics-related control and value in the relations between teaching practices and mathematics-related AEs in primary and lower secondary school students. We addressed three gaps in the literature concerning the lack of knowledge on: (a) the relation of teaching practices with a variety of mathematics-related AEs; (b) the role of mathematics-related control and value in the aforementioned relation; and (c) the examination of these associations in two school settings (i.e., lessons and tests), taking into account students' sex and school level. We assessed a broad range of AEs, that is, three positive activating, two positive deactivating, three negative activating, and two negative deactivating AEs. In line with CVT domain specificity assumptions (Pekrun, 2024), we focused on mathematics, for its relevance as a crucial science, technology, engineering, and mathematics (STEM) subject, at the basis of students' performance and career decisions (Putwain et al., 2018), and presumably triggering strong emotions. Therefore, we assessed mathematics-related control, value, and AEs. Furthermore, we distinguished AEs according to two settings, differing in the salience of the evaluative dimension (Raccanello et al., 2013). Differentiating these two settings allowed us to account for the fact that lessons and tests differ in their evaluative salience and are therefore likely to elicit partially different emotional experiences and patterns of associations with appraisals. In contrast, perceived teaching practices were assessed at a broader school-related level to capture students' overall perceptions of supportive interactions with teachers across their everyday school experience. Nevertheless, repeated interactions with teachers across subjects may shape relatively stable perceptions of the supportiveness and motivational quality of the school environment, which may provide a contextual background for students' mathematics-specific control and value appraisals and AEs. However, because the measures were not aligned at the same level of specificity, the observed associations should be interpreted cautiously. This choice was also motivated by the different organization of primary and lower secondary schools in Italy, which implies substantial differences in the number of teachers with whom students interact (Presidente della Repubblica, 2009), as well as by questionnaire-length constraints and the broader project design, which did not allow us to assess teaching practices separately for each academic subject. Consistent with CVT (Pekrun, 2024), teaching practices were conceptualized as contextual antecedents, control and value as proximal appraisals, and AEs as emotional outcomes. Nonetheless, given the cross-sectional nature of the data, the present study cannot test temporal ordering or causal relations among these constructs.

Aim 1

Based on CVT, we tested two models examining the associations among teaching practices (task emotional and motivational qualities, autonomy support, and social interactions), mathematics-related control and value, and mathematics-related AEs in lessons and tests.

Hypothesis 1a. We hypothesized that teaching practices were linked with appraisals. We expected that students with higher scores for task emotional and motivational qualities, autonomy support, and social interactions would have higher scores for control and value.

Hypothesis 1b. We hypothesized that appraisals were associated with AEs for each setting. We expected that students with higher scores for control and value would experience more intense positive AEs (enjoyment, pride, hope, relief, and relaxation) and less intense negative emotions (anxiety, anger, shame, hopelessness, and boredom). However, given the still limited literature on a broad range of AEs among younger students, and based on previous literature and CVT assumptions, we considered the relations involving some emotions, such as relaxation and anxiety, to be more exploratory in nature.

Hypothesis 1c. We hypothesized that teaching practices were related to AEs. We expected that students with higher scores for task emotional and motivational qualities, autonomy support, and social interactions would feel more intense positive emotions and less intense negative emotions. We further explored how these associations were linked to control and value.

Aim 2

We explored the models' invariance across sex (as a biological status; American Psychological Association, 2024) and school level to examine whether the measurement and structural relations among perceived teaching practices, appraisals, and AEs were comparable across relevant student groups, consistent with CVT assumptions about the universality of these relations.

Hypothesis 2. After verifying the invariance of the measurement models, we expected the tested models to be invariant across sex (males, females) and school level (fourth-graders, seventh-graders), that is, that the relations between the variables remained unchanged.

METHOD

Sample and procedure

The participants were 1538 students ($M_{age} = 11.10$, $SD_{age} = 1.57$; 51.24% females) attending the fourth ($N = 825$, $M_{age} = 9.69$, $SD_{age} = .36$; 47.76% females; 78 classes) or the seventh grade ($N = 713$, $M_{age} = 12.70$, $SD_{age} = .41$; 55.26% females; 55 classes) in Italy. Overall, the sample comprised 133 classes, with an average class size of approximately 11–12 students. The project (including also measures not reported here) was approved by the Ethics Committee of the Department of Human Sciences at the University of Verona, Italy (protocol number 99727, dated 22/02/2023).

Schools from Northern and Central Italy were invited to take part in the study after receiving information about the research aims and procedures. Participation was authorized by school principals, and written informed consent was subsequently obtained from parents or legal guardians before students were enrolled in the study. Data were collected between April 2023 and May 2024 using two paper-and-pencil questionnaires administered during regular classroom hours. Questionnaire administration followed a standardized guided procedure: all items were read aloud by a trained graduating student while participants completed the questionnaires. This approach was adopted to ensure uniform administration conditions across participants and to limit potential differences associated with individual reading skills. Reading the items aloud was intended to reduce

comprehension difficulties among students with varying literacy levels, including those experiencing reading-related challenges such as dyslexia (Schiavo et al., 2021), thereby enhancing the consistency of data collection throughout the sample.

Measures

The Italian and English versions of the items included in this study have been provided in the Supplementary Materials (SM; Table 1 SM).

Achievement emotions

We utilized a brief version of the Achievement Emotions Adjective List (AEAL; Raccanello et al., 2022) to assess the extent to which students experienced 10 AEs during lessons and tests. It includes 10 adjectives about enjoyment ("Happy"), pride ("Proud"), hope ("Hopeful"), relief ("Relieved"), relaxation ("Calm"), anxiety ("Anxious"), anger ("Angry"), shame ("Ashamed"), hopelessness ("Sad"), and boredom ("Bored"), rated on a 5-point scale (1 = Not at all, 5 = Very much) supported by drawings of male/female faces (Drawing Set for the AEAL, DS-AEAL; Raccanello & Burro, 2024). Consistent with previous adaptations of the AEAL for younger students, the adjective sad was used to assess the negative deactivating emotion traditionally labelled as hopelessness in the AEs literature. This choice was made because sad is more developmentally appropriate and readily understandable for children, while still referring to the broader family of negative deactivating emotions. The 10 adjectives were proposed twice, separately for each setting. Single items reduced recall bias and respondent burden (Goetz et al., 2010; Simon et al., 2023) and are appropriate when assessing a single emotion component, as in the present study – that is, the subjective feeling of the emotion (Pekrun et al., 2011).

Control and value

We assessed mathematics-related control (4 items, $\alpha/\omega = .89/.89$; e.g., "I can learn even the most difficult things in mathematics") and value (4 items, $\alpha/\omega = .76/.78$), as intrinsic value (e.g., "I think it is important to learn mathematics"), attainment value (e.g., "It is important for me to get a good grade in mathematics"), and utility value (e.g., "What I learn in mathematics is also useful for other subjects"; Raccanello et al., 2026). Students responded on a 5-point scale (1 = Not at all true for me, 5 = Completely true for me).

Teaching practices

Positive Teaching

We used a subscale of the Classroom Practices Scale (CPS) from the MSCQ (Janosz & Bouthillier, 2007), the Positive Teaching subscale (5 items, $\alpha/\omega = .82/.82$). Items referred to displayed teacher enthusiasm (e.g., "Most teachers appear to love their job") and value-related motivational messages aimed at making learning activities clear, meaningful, and interesting for students (e.g., "Teachers explain why what we study is important"). Students responded on a 6-point scale (1 = Completely disagree, 6 = Completely agree).

Student Involvement

We used another subscale of the CPS, the Student Involvement subscale. Items regarded students' participation in defining school rules, mediated by teachers (4 items, $\alpha/\omega = .66/.68$; e.g., "When it is

important, teachers ask students' opinions before making decisions for them"). Students responded on a 6-point scale (1 = Completely disagree, 6 = Completely agree).

Teacher Warmth

We used a 9-item scale called Teacher Warmth ($\alpha/\omega = .89/.89$), adapted from the Quality of Parental Relationships Inventory (QPRI; Conger et al., 1994) to assess the quality of teacher–student relationships. The original items were translated into Italian and adapted to the teacher–student context. The scale included relational elements such as teachers displaying affection (e.g., "How often do your teachers behave affectionately toward you?") and providing emotional support by understanding students and being responsive to their emotional needs (e.g., "How often do your teachers show support and understanding toward you?"). Students responded on a 5-point scale (1 = Never, 5 = Always).

Data analysis

We utilized the R software (Version 4.5.2; lavaan package; R Core Team, 2025; Rosseel, 2012). We conducted preliminary confirmatory factor analyses (CFAs; Robust Maximum Likelihood estimator, MLR) to verify the structure for teaching practices and appraisals. We tested alternative models (see SM). The best models were a correlated three-factor model (corresponding to the three dimensions of Positive Teaching, Student Involvement, and Teacher Warmth) and a correlated two-factor model (corresponding to control and value), respectively. Internal consistency was assessed using Cronbach's (1951) alpha (α) and McDonald's (1999) omega (ω), with $\alpha/\omega \geq .60$ indicating acceptable, $\alpha/\omega \geq .70$ good, $\alpha/\omega \geq .80$ very good, and $\alpha/\omega \geq .90$ excellent internal consistency.

For Aim 1, we ran two structural equation models (SEMs; MLR) to examine the relations among teaching practices, control and value, and AEs, separately in lessons and tests, examining indirect associations through control and value. We included all variable links and covariances between teaching practices, appraisals, and emotions, respectively. To account for the nested structure of the data (i.e., within classes), two multilevel structural equation models (MSEMs) were estimated for the lesson setting and the test setting, separating within-class and between-class associations. Results highlighted that the associations between study variables were substantially stronger at the within-class level than at the between-class level, suggesting that they primarily reflect individual differences in students' perceptions. Given this evidence, we decided to focus on single-level SEM models to provide a more parsimonious representation of the dominant processes (results of the MSEMs are reported within SM).

SEM fit was evaluated using the comparative fit index (CFI), Tucker–Lewis index (TLI), root mean square error of approximation (RMSEA), and standardized root mean square residual (SRMR). Fit was acceptable with CFI and TLI > .90 (preferably ≈ .95) and RMSEA and SRMR < .10 (preferably ≈ .06; Hu & Bentler, 1999). Consistent with guidelines for SEM adequacy (Kline, 2016), the sample size provided an observation-to-parameter ratio of roughly 11:1 (1538 participants, 145 estimated parameters).

For Aim 2, we conducted measurement invariance (MI) analyses using multi-group SEMs (Putnick & Bornstein, 2016). We applied a series of sequential constraints to the SEMs, progressively testing configural, metric, and scalar invariance, corresponding to equality of model structure, factor loadings, and intercepts, respectively. Subsequently, we examined structural invariance by constraining regression coefficients to equality across sex and school levels. We calculated model fit indices at each step. Invariance was supported with changes in CFI and TLI ≤ .010, in RMSEA ≤ .015, and in SRMR ≤ .030 (Chen, 2007).

RESULTS

Preliminary analyses

The CFAs had a good fit for both teaching practices (CFI = .962, TLI = .956, RMSEA = .044, SRMR = .030) and appraisals (CFI = .978, TLI = .968, RMSEA = .066, SRMR = .042). Internal consistency ranged from acceptable to very good. See Table 1 for descriptive statistics, internal consistency, and factor loadings, and Table 2 for intercorrelations. Overall, teaching practices (except Student Involvement) related positively to control and value appraisals. In turn, the latter were generally linked positively to positive emotions and negatively to negative ones (with some exceptions). Also, a pattern of associations involving the two appraisals emerged, especially for control appraisals in the relations between Teacher Warmth and enjoyment, pride, relaxation, and anxiety across the two settings.

Structural equation models (Aim 1)

Two preliminary SEMs showed no significant relation between Student Involvement and the other variables; thus, for parsimony, it was excluded, and the two SEMs were re-estimated. Moreover, this decision is in line with the slightly broader focus of Student Involvement scale on

TABLE 1 Descriptive statistics, internal consistency, and factor loadings for study variables.

	Number of items	Mean	*SD*	95% CI	Skewness	Kurtosis	*α*/*ω*	Factor loadings
Positive Teaching	5	4.59	1.05	[4.54, 4.65]	−.77	.02	.82/.82	.59–.77
Student involvement	4	3.99	1.09	[3.93, 4.04]	−.27	−.54	.66/.68	.45–.69
Teacher Warmth	9	3.19	.84	[3.15, 3.25]	−.10	−.50	.89/.89	.51–.81
Control	4	3.61	.91	[3.56, 3.65]	−.39	.06	.89/.89	.77–.86
Value	4	4.07	.75	[4.03, 4.11]	−.88	.37	.76/.78	.44–.86
Enjoyment (lessons)	1	3.41	1.40	[3.34, 3.48]	−.38	−1.13	–	–
Pride (lessons)	1	2.94	1.36	[2.88, 3.01]	.01	−1.18	–	–
Hope (lessons)	1	2.68	1.38	[2.61, 2.75]	.27	−1.18	–	–
Relief (lessons)	1	2.71	1.34	[2.64, 2.78]	.26	−1.08	–	–
Relaxation (lessons)	1	3.74	1.20	[3.68, 3.80]	−.75	−.30	–	–
Anxiety (lessons)	1	2.18	1.34	[2.11, 2.24]	.87	−.51	–	–
Anger (lessons)	1	1.58	1.04	[1.52, 1.63]	1.93	2.91	–	–
Shame (lessons)	1	1.55	.95	[1.50, 1.60]	1.92	3.26	–	–
Hopelessness (lessons)	1	1.53	.95	[1.48. 1.58]	1.99	3.53	–	–
Boredom (lessons)	1	2.42	1.30	[2.36, 2.49]	.63	−.72	–	–
Enjoyment (tests)	1	2.84	1.47	[2.76, 2.91]	.18	−1.34	–	–
Pride (tests)	1	2.87	1.40	[2.80, 2.94]	.09	−1.25	–	–
Hope (tests)	1	3.60	1.34	[1.80, 1.91]	1.34	.83	–	–
Relief (tests)	1	2.69	1.39	[2.62, 2.76]	.29	−1.15	–	–
Relaxation (tests)	1	2.86	1.43	[2.79, 2.93]	.12	−1.28	–	–
Anxiety (tests)	1	3.37	1.53	[3.29, 3.45]	−.34	−1.39	–	–
Anger (tests)	1	1.58	1.05	[1.53, 1.64]	1.91	2.85	–	–
Shame (tests)	1	1.63	1.06	[1.58, 1.69]	1.70	2.01	–	–
Hopelessness (tests)	1	1.83	1.15	[1.77, 1.89]	1.37	.97	–	–
Boredom (tests)	1	1.86	1.18	[1.80, 1.91]	1.34	.83	–	–

Abbreviations: 95% CI, 95% confidence interval; *SD*, standard deviation; *α*, Cronbach's alpha; *ω*, McDonald's omega.

TABLE 2 Latent and manifest correlations among study variables.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1. Positive Teaching	–	–	.69***	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2. Student Involvement	.51***	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
3. Teacher Warmth	.59***	.35***	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
4. Control	.23***	.13***	.25***	–	.53***	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
5. Value	.38***	.21***	.38***	.53***	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
6. Enjoyment (lessons)	.32***	.15***	.34***	.45***	.42***	–	.36***	.17***	.30***	.36***	−.16***	−.24***	−.01	−.28***	−.35***	–	–	–	–	–	–	–	–	–	–
7. Pride (lessons)	.22***	.12***	.28***	.41***	.34***	.52***	–	.26***	.32***	.17***	.04	.01	.10***	−.06*	−.14***	–	–	–	–	–	–	–	–	–	–
8. Hope (lessons)	.07**	.03	.14**	.08**	.15***	.21***	.29***	–	.33***	.04	.15***	.02	.12***	.04	−.07*	–	–	–	–	–	–	–	–	–	–
9. Relief (lessons)	.07**	.02	.15***	.17***	.18***	.35***	.38***	.35***	–	.19***	−.16***	−.24***	.08**	−.05	−.11*	–	–	–	–	–	–	–	–	–	–
10. Relaxation (lessons)	.21***	.13***	.21***	.41***	.29***	.51***	.35***	.09***	.25***	–	−.26***	−.19***	−.18***	−.25***	−.15***	–	–	–	–	–	–	–	–	–	–
11. Anxiety (lessons)	−.10***	−.04	−.07**	−.31***	−.12***	−.28***	−.10***	.12***	−.01	−.36***	–	.22***	.32***	.29***	.13***	–	–	–	–	–	–	–	–	–	–
12. Anger (lessons)	−.24***	−.14***	−.19***	−.25***	−.27***	−.37***	−.14***	−.02	−.10***	−.30***	.28***	–	.13***	.42***	.26***	–	–	–	–	–	–	–	–	–	–
13. Shame (lessons)	−.06*	−.04	−.01	−.14***	−.02	−.07**	.04	.11***	.06*	−.22***	.35***	.15***	–	.20***	.04	–	–	–	–	–	–	–	–	–	–
14. Hopelessness (lessons)	−.15***	−.09***	−.10***	−.22***	−.17***	−.36***	−.16***	.01	−.09***	−.33***	.34***	.47***	.23***	–	.26***	–	–	–	–	–	–	–	–	–	–
15. Boredom (lessons)	−.30***	−.15***	−.26***	−.39***	−.40***	−.52***	−.32***	−.12***	−.18***	−.32***	.23***	.38***	.09***	.34***	–	–	–	–	–	–	–	–	–	–	–
16. Enjoyment (tests)	.30***	.15***	.36***	.49***	.40***	.59***	.45***	.19***	.21***	.40***	−.21***	−.21***	−.05	−.19***	−.41***	–	.39***	.02	.33***	.54***	−.36***	−.16***	−.02	−.26***	−.08**
17. Pride (tests)	.20***	.11***	.27***	.44***	.32***	.39***	.66***	.19***	.27***	.30***	−.09***	−.11***	.01	−.11***	−.24***	.55***	–	.13***	.41***	.29***	−.12***	−.05	.05	−.09	−.01
18. Hope (tests)	.01	.02	.06*	.07**	.12***	.13***	.17***	.35***	.25***	.11***	.02	−.08**	.03	−.01	.01	.07**	.15***	–	.24***	−.04	.21***	−.04	.01	.08**	−.04
19. Relief (tests)	.14***	.07**	.19***	.28***	.24***	.30***	.40***	.24***	.41***	.23***	−.03	−.07**	.07*	−.08**	−.17***	.44***	.50***	.25***	–	.24***	−.08**	−.06*	.07*	−.10***	−.02
20. Relaxation (tests)	.22***	.10***	.24***	.45***	.27***	.39***	.38***	.11***	.14***	.45***	−.28***	−.17***	−.10***	−.18***	−.25***	.66***	.46***	−.01	.35***	–	−.49***	−.19***	−.14***	−.30	.01
21. Anxiety (tests)	−.13***	−.06*	−.12***	−.32***	−.13***	−.22***	−.17***	−.01	−.01	−.25***	.44***	.14***	.20***	.15***	.21***	−.46***	−.26***	.18***	−.17***	−.57***	–	.18***	.17***	.27***	−01
22. Anger (tests)	−.27***	−.14***	−.22***	−.28***	−.27***	−.29***	−.17***	−.04	−.03	−.24***	.27***	.57***	.15***	.37***	.33***	−.32***	−.20***	−.06*	−.16***	−.32***	.26***	–	.14***	.48***	.25***
23. Shame (tests)	−.05*	−.04	.04	−.13***	−.02	−.01	.02	.11***	.10***	−.12***	.26***	.08**	.48***	.14***	.03	−.08**	−.01	.01	.04	−.19***	.22***	.17***	–	.20***	.11***
24. Hopelessness (tests)	−.23***	−.11***	−.20***	−.35***	−.21***	−.30***	.19***	.03	−.01	−.27***	.32***	.36***	.19***	.43***	.32***	−.41***	−.25***	.05*	−.20***	−.44***	.37***	.55***	.23***	–	.24***
25. Boredom (tests)	−.21***	−.14***	−.19***	−.20***	−.28***	−.21***	−.10***	.03	−.03	−.17***	.11***	.32***	.11***	.21***	.38***	−.22***	−.13***	−.07**	−.10***	−.11***	.06*	.33***	.13***	.31***	–

Note: Latent correlations are above the main diagonal and are reported only for constructs with freely estimated covariances in the SEM model (relationships specified as directional paths are represented by regression coefficients and therefore do not have corresponding latent correlations). Manifest correlations (Pearson's *r*) are below the main diagonal.

*$p < .05$. **$p < .01$. ***$p < .001$.

the school compared with the other measures. The resulting models had a good fit (lessons/tests: CFI = .970/.969, TLI = .961/.960, RMSEA = .032/.033, SRMR = .030/.031). See Figure 1 for paths and Table 3 for covariances.

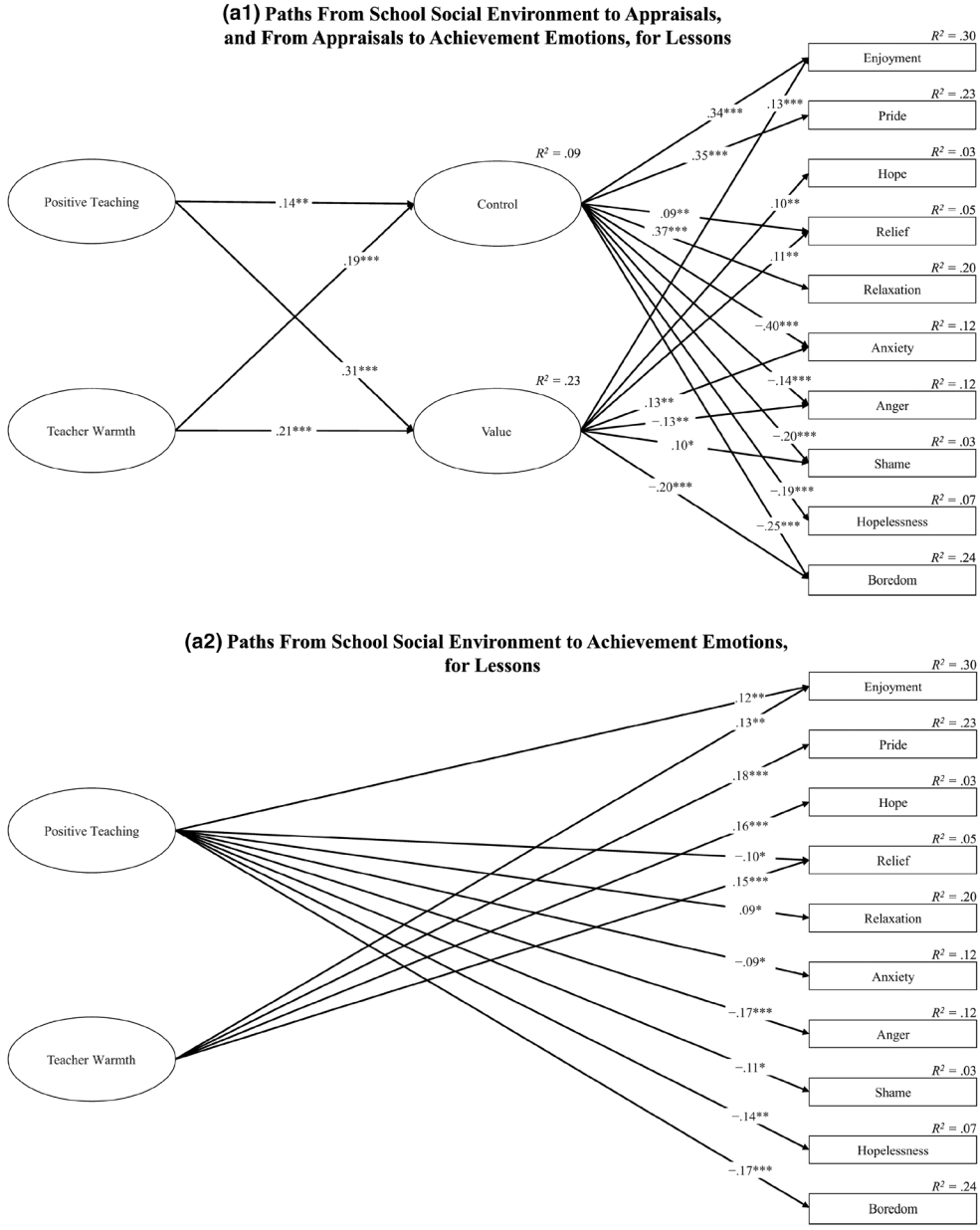

FIGURE 1 Two structural equation models representing the associations between school social environment, control and value, and achievement emotions, for (a) lessons and (b) tests. For clarity, we represented separately (1) the paths from school social environment to control and value, and from control and value to achievement emotions, and (2) the paths from school social environment to achievement emotions. For the sake of brevity, only significant paths are represented.°$p = .05$. *$p < .05$. **$p < .01$. ***$p < .001$.

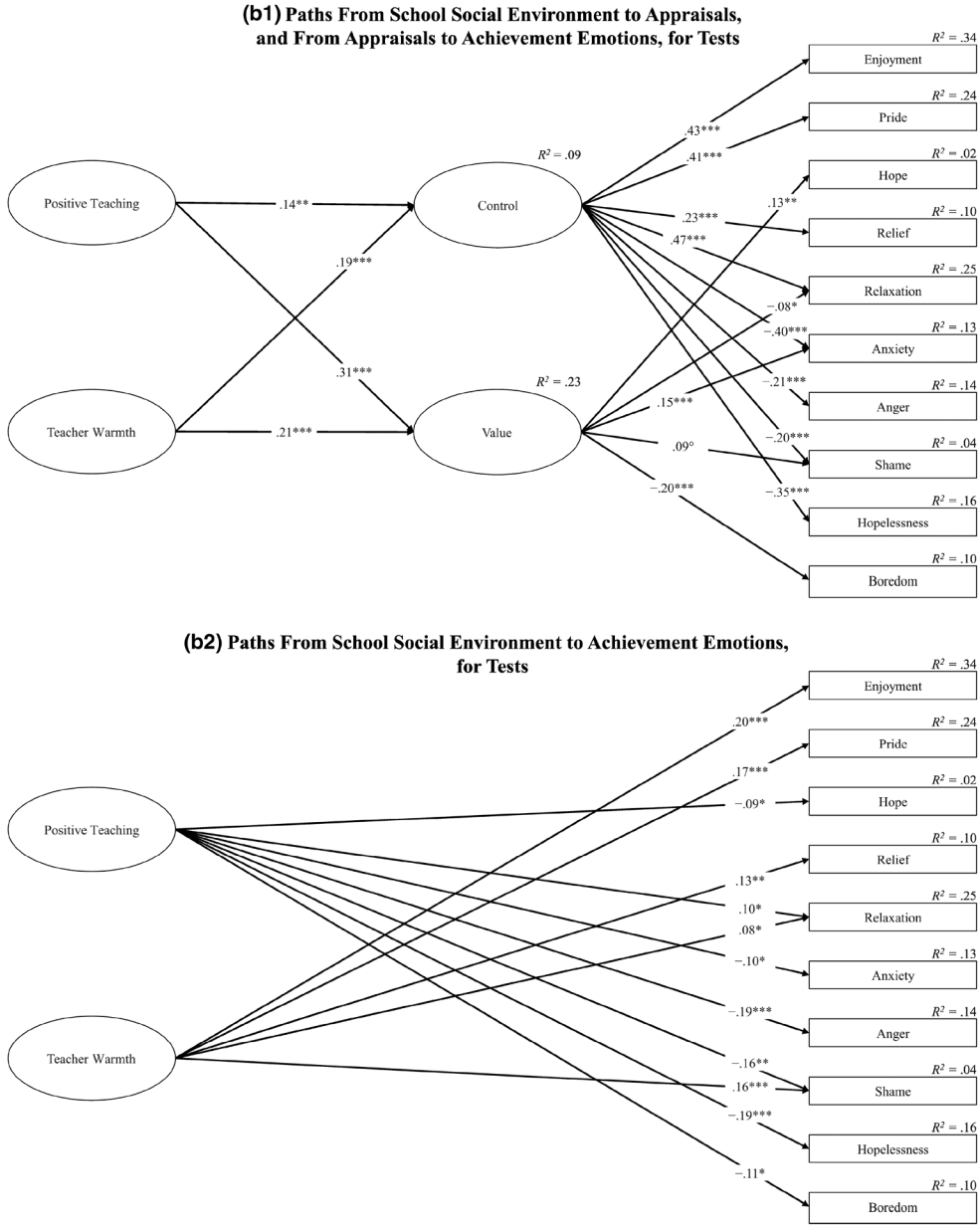

FIGURE 1 (Continued)

Direct associations between teaching practices and appraisals

Across both settings, Positive Teaching and Teacher Warmth were positively related to both appraisals (Hypothesis 1a). Explained variance was higher for value (23%) than for control (9%).

Direct associations between appraisals and achievement emotions

Regarding the paths between appraisals and AEs (Hypothesis 1b), control was positively related to enjoyment, pride, relief, and relaxation. Moreover, it was negatively related to all negative AEs (except

TABLE 3 Covariances estimated in the structural equation models in lessons and tests.

	Lessons		Tests	
	Covariances	***p***	**Covariances**	***p***
Positive Teaching ↔ Teacher Warmth	.69	<.001	.69	<.001
Control ↔ Value	.53	<.001	.53	<.001
Enjoyment ↔ Pride	.36	<.001	.39	<.001
Enjoyment ↔ Hope	.17	<.001	.02	.382
Enjoyment ↔ Relief	.30	<.001	.33	<.001
Enjoyment ↔ Relaxation	.36	<.001	.54	<.001
Enjoyment ↔ Anxiety	−.16	<.001	−.36	<.001
Enjoyment ↔ Anger	−.24	<.001	−.16	<.001
Enjoyment ↔ Shame	−.01	.657	−.02	.399
Enjoyment ↔ Hopelessness	−.28	<.001	−.26	<.001
Enjoyment ↔ Boredom	−.35	<.001	−.08	.004
Pride ↔ Hope	.26	<.001	.13	<.001
Pride ↔ Relief	.32	<.001	.41	<.001
Pride ↔ Relaxation	.17	<.001	.29	<.001
Pride ↔ Anxiety	.04	.102	−.12	<.001
Pride ↔ Anger	.01	.975	−.05	.067
Pride ↔ Shame	.10	<.001	.05	.067
Pride ↔ Hopelessness	−.06	.039	−.09	.003
Pride ↔ Boredom	−.14	<.001	−.01	.874
Hope ↔ Relief	.33	<.001	.23	<.001
Hope ↔ Relaxation	.04	.122	−.04	.179
Hope ↔ Anxiety	.15	<.001	.21	<.001
Hope ↔ Anger	.02	.420	−.04	.199
Hope ↔ Shame	.12	<.001	.01	.714
Hope ↔ Hopelessness	.04	.151	.08	.005
Hope ↔ Boredom	−.07	.014	−.04	.134
Relief ↔ Relaxation	.19	<.001	.24	<.001
Relief ↔ Anxiety	.04	.162	−.08	.003
Relief ↔ Anger	−.04	.160	−.06	.017
Relief ↔ Shame	.08	.004	.07	.008
Relief ↔ Hopelessness	−.05	.055	−.10	<.001
Relief ↔ Boredom	−.11	<.001	−.02	.419
Relaxation ↔ Anxiety	−.26	<.001	−.49	<.001
Relaxation ↔ Anger	−.19	<.001	−.19	<.001
Relaxation ↔ Shame	−.18	<.001	−.14	<.001
Relaxation ↔ Hopelessness	−.25	<.001	−.30	<.001
Relaxation ↔ Boredom	−.15	<.001	.01	.773
Anxiety ↔ Anger	.22	<.001	.18	<.001
Anxiety ↔ Shame	.32	<.001	.17	<.001

TABLE 3 (Continued)

	Lessons		Tests	
	Covariances	***p***	**Covariances**	***p***
Anxiety ↔ Hopelessness	.29	<.001	.27	<.001
Anxiety ↔ Boredom	.13	<.001	−.01	.734
Anger ↔ Shame	.13	<.001	.13	<.001
Anger ↔ Hopelessness	.42	<.001	.48	<.001
Anger ↔ Boredom	.26	<.001	.25	<.001
Shame ↔ Hopelessness	.20	<.001	.19	<.001
Shame ↔ Boredom	.04	.166	.11	<.001
Hopelessness ↔ Boredom	.26	<.001	.24	<.001

test-related boredom). In lessons, value was positively linked to enjoyment, hope, relief, anxiety, and shame, and negatively linked to anger and boredom; in tests, value was positively linked to hope, anxiety, and shame, and negatively linked to relaxation and boredom.

Finally, explained variance was higher for enjoyment (30%/34% in lessons/tests), pride (23%/24%), and relaxation (20%/25%). Explained variance was also relatively high for boredom, but only during lessons (24%). For the other AEs, values ranged from 2% to 16%, suggesting the relevance of additional antecedents not included in the present study.

Direct associations between teaching practices and achievement emotions

Considering the paths between teaching practices and positive AEs (Hypothesis 1c), Positive Teaching was positively linked to enjoyment and relaxation (but negatively to relief) in lessons, and to relaxation (but negatively to hope) in tests. Teacher Warmth was positively linked to enjoyment, pride, hope, and relief in lessons, and to enjoyment, pride, relief, and relaxation in tests. Regarding the paths with negative AEs (Hypothesis 1c), Positive Teaching was negatively linked with negative AEs in each setting, while Teacher Warmth was positively linked to shame only in tests.

Indirect associations between teaching practices and achievement emotions

Regarding the role of control (Table 4), significant indirect associations of both Positive Teaching and Teacher Warmth were positive on four positive AEs, namely, enjoyment, pride, relief (except for lesson-related relief for Positive Teaching), and relaxation, and negative on negative AEs (except for test-related boredom). In most relations, these indirect associations co-occurred with significant direct associations, except for the relations of Positive Teaching with test-related enjoyment, and with pride in both settings, and of Teacher Warmth with lesson-related relaxation, for which only an indirect association emerged. Regarding the role of value (Table 4), the significant indirect associations of both Positive Teaching and Teacher Warmth were positive on some positive emotions (enjoyment, hope, and relief in lessons; hope in tests), but also on anxiety (in both settings); moreover, they were negative on some negative emotions (lesson-related anger and boredom in both settings). In most cases, these indirect associations co-occurred with significant direct associations, except for the associations of Positive Teaching with lesson-related hope and of Teacher Warmth with lesson-related anger, test-related hope, as well as with anxiety and boredom in both settings, for which only indirect associations emerged.

Measurement invariance (Aim 2)

Regarding MI (Hypothesis 2; Table 5), configural and metric invariance across sex and school levels was supported for both lessons and tests, as evidenced by negligible changes in fit indices across increasingly constrained models. Full scalar invariance was achieved across sex but not across school levels, as indicated by meaningful declines in model fit ($\Delta CFI \approx -.03$); however, after freeing selected item intercepts, partial scalar invariance was established. The lack of full scalar invariance across school levels was attributable to five item intercepts. Three involved the Teacher Warmth subscale, plausibly reflecting differences in teacher–student relations across primary and lower secondary school contexts, whereas the remaining two concerned control and value. Structural invariance was also confirmed, indicating equivalent latent variances and covariances across sex and school levels.

DISCUSSION

The context in which learning occurs is central to understanding the psychological processes involved, as highlighted by Bronfenbrenner's (1979) ecological framework and CVT (Pekrun, 2024). We extended research on primary and lower secondary school students by shedding light on the associations among supportive teaching practices, control and value, and 10 mathematics-related AEs. In line with CVT (Pekrun, 2024), the teaching-practice constructs examined in this study were selected with reference to the broad contextual categories of task emotional and motivational qualities, autonomy support, and social interactions. These findings are particularly relevant considering that teacher support can play a key role for students' emotions (also towards subjects such as mathematics) which account for as much variance in their achievement as cognitive ability (Pekrun, Marsh, Suessenbach, et al., 2023).

Theoretical and practical implications

Taken together, our findings gave broad support to the hypotheses. The SEM results indicated that most teaching practices were positively associated with students' control and value appraisals (with the exception of Student Involvement). Control was associated with more intense positive emotions and less intense negative emotions, except for hope and test-related boredom, whereas value showed positive associations with anxiety and shame and a negative association with test-related relaxation. The findings also suggested that control and value, and particularly control, played a role in linking Teacher Warmth to students' AEs across both learning settings.

Relations between teaching strategies, appraisals, and achievement emotions

Concerning Aim 1, our data generally corroborated the hypotheses, in line with CVT (Pekrun, 2024) – with a notable exception regarding Student Involvement. Positive Teaching and Teacher Warmth, selected with reference to Pekrun's (2024) broad categories of task emotional and motivational qualities and social interactions, respectively, were positively associated with both control and value, whereas Student Involvement showed no significant associations, thus partially supporting Hypothesis 1a. Our results are consistent with CVT's proposition that supportive contextual characteristics of the learning environment are linked to students' control and value appraisals, which represent the proximal antecedents of AEs (Pekrun, 2024). These findings also align with the sparse literature on similar issues. For example, teacher enthusiasm has previously been associated with higher academic self-efficacy (Zhang, 2014) and greater task value (Cui et al., 2017), whereas relationally supportive interactions have been linked to children's agency beliefs (Gurdal et al., 2016) and to students' internalization of teachers' values (Martin & Dowson, 2009). Our findings extend this evidence by showing that Positive Teaching

TABLE 4 Significant standardized specific indirect effects between school social environment and achievement emotions.

Model	Significant specific indirect effect	Mediation	Unstandardized coefficient	*β*	*p*	*SE*	BCa 95% CI
Lessons	Positive Teaching → Control → Enjoyment	Partial	.06	.05	.005	.02	[.02, .11]
	Positive Teaching → Control → Pride	Total	.06	.05	.005	.02	[.02, .11]
	Positive Teaching → Control → Relaxation	Partial	.06	.05	.006	.02	[.02, .10]
	Positive Teaching → Control → Anxiety	Partial	−.07	−.06	.005	.03	[−.12, −.02]
	Positive Teaching → Control → Anger	Partial	−.02	−.02	.022	.01	[−.04, −.01]
	Positive Teaching → Control → Shame	Partial	−.03	−.03	.014	.01	[−.05, −.01]
	Positive Teaching → Control → Hopelessness	Partial	−.02	−.03	.011	.01	[−.05, −.01]
	Positive Teaching → Control → Boredom	Partial	−.04	−.03	.007	.02	[−.08, −.01]
	Positive Teaching → Value → Enjoyment	Partial	.05	.04	.003	.02	[.02, .09]
	Positive Teaching → Value → Hope	Total	.04	.03	.018	.02	[.01, .08]
	Positive Teaching → Value → Relief	Partial	.04	.03	.018	.02	[.01, .09]
	Positive Teaching → Value → Anxiety	Partial	.05	.04	.005	.02	[.02, .09]
	Positive Teaching → Value → Anger	Partial	−.04	−.04	.014	.02	[−.08, −.01]
	Positive Teaching → Value → Boredom	Partial	−.08	−.06	<.001	.02	[−.12, −.04]
	Teacher Warmth → Control → Enjoyment	Partial	.14	.07	<.001	.04	[.07, .22]
	Teacher Warmth → Control → Pride	Partial	.14	.07	<.001	.04	[.07, .22]
	Teacher Warmth → Control → Relief	Partial	.04	.02	.030	.02	[.01, .08]
	Teacher Warmth → Control → Relaxation	Total	.13	.07	<.001	.04	[.07, .21]
	Teacher Warmth → Control → Anxiety	Partial	−.16	−.08	<.001	.04	[−.25, −.08]
	Teacher Warmth → Control → Anger	Partial	−.04	−.03	.010	.02	[−.09, −.02]
	Teacher Warmth → Control → Shame	Partial	−.06	−.04	.003	.02	[−.10, −.03]
	Teacher Warmth → Control → Hopelessness	Partial	−.05	−.04	.003	.02	[−.10, −.03]
	Teacher Warmth → Control → Boredom	Partial	−.10	−.05	.001	.03	[−.16, −.05]
	Teacher Warmth → Value → Enjoyment	Partial	.06	.03	.004	.02	[.02, .10]
	Teacher Warmth → Value → Hope	Partial	.05	.02	.022	.02	[.01, .09]
	Teacher Warmth → Value → Relief	Partial	.05	.02	.014	.02	[.02, .09]
	Teacher Warmth → Value → Anxiety	Total	.06	.03	.011	.02	[.02, .11]
	Teacher Warmth → Value → Anger	Total	−.04	−.03	.016	.02	[−.09, −.01]
	Teacher Warmth → Value → Boredom	Total	−.08	−.04	.001	.02	[−.14, −.04]
Tests	Positive Teaching → Control → Enjoyment	Total	.08	.06	.005	.03	[.03, .15]
	Positive Teaching → Control → Pride	Total	.08	.06	.005	.03	[.03, .13]
	Positive Teaching → Control → Relief	Partial	.04	.03	.010	.02	[.01, .08]
	Positive Teaching → Control → Relaxation	Partial	.09	.07	.004	.03	[.03, .15]
	Positive Teaching → Control → Anxiety	Partial	−.08	−.06	.004	.03	[−.14, −.03]

(Continues)

TABLE 4 (Continued)

Model	Significant specific indirect effect	Mediation	Unstandardized coefficient	*β*	*p*	*SE*	BCa 95% CI
	Positive Teaching → Control → Anger	Partial	−.03	−.03	.009	.01	[−.05, −.01]
	Positive Teaching → Control → Shame	Partial	−.03	−.03	.012	.01	[−.05, −.01]
	Positive Teaching → Control → Hopelessness	Partial	−.05	−.05	.004	.02	[−.09, −.02]
	Positive Teaching → Value → Hope	Partial	.05	.04	.007	.02	[.02, .10]
	Positive Teaching → Value → Anxiety	Partial	.07	.05	.002	.02	[.03, .12]
	Positive Teaching → Value → Boredom	Partial	−.07	−.06	.001	.02	[−.12, −.04]
	Teacher Warmth → Control → Enjoyment	Partial	.19	.08	<.001	.05	[.10, .28]
	Teacher Warmth → Control → Pride	Partial	.17	.08	<.001	.04	[.09, .26]
	Teacher Warmth → Control → Relief	Partial	.09	.04	<.001	.03	[.05, .15]
	Teacher Warmth → Control → Relaxation	Partial	.20	.09	<.001	.05	[.10, .31]
	Teacher Warmth → Control → Anxiety	Partial	−.18	−.08	<.001	.05	[−.28, −.10]
	Teacher Warmth → Control → Anger	Partial	−.06	−.04	.002	.02	[−.11, −.03]
	Teacher Warmth → Control → Shame	Partial	−.06	−.04	.002	.02	[−.11, −.03]
	Teacher Warmth → Control → Hopelessness	Partial	−.12	−.07	<.001	.03	[−.19, −.06]
	Teacher Warmth → Value → Hope	Total	.06	.03	.009	.02	[.02, .11]
	Teacher Warmth →Value → Anxiety	Total	.07	.03	.004	.03	[.03, .13]
	Teacher Warmth → Value → Boredom	Total	−.08	−.04	.001	.02	[−.13, −.04]

Note: Indirect effects were estimated using non-parametric bootstrapping with 5000 resamples and bias-corrected and accelerated 95% confidence intervals (Hayes, 2018). Indirect effects are considered significant when the confidence interval does not include zero.

Abbreviations: BCa 95% CI, bias-corrected and accelerated 95% confidence interval; *SE*, standard error.

and Teacher Warmth are positively associated with both control and value appraisals in mathematics among primary and lower secondary school students.

The two appraisals, in turn, were linked to a variety of AEs (mainly confirming Hypothesis 1b). Extending research on similar-age students in mathematics (Forsblom et al., 2022; Peixoto et al., 2017; Putwain et al., 2021; Putwain & Wood, 2023) by considering a larger set of AEs, we found that control was associated positively with all positive AEs (except hope) and negatively with all negative AEs (except test-related boredom), consistently in the two settings. Value was linked positively to some positive AEs (lesson-related enjoyment, hope, and lesson-related relief) and negatively to some negative AEs (lesson-related anger and boredom in both settings). However, it was also related negatively to some positive AEs (test-related relaxation) and positively to some negative AEs (anxiety and shame). At the same time, some associations involving value deviated from the expected pattern, particularly those with anxiety, shame, and relaxation, suggesting a more complex role of value appraisals in younger students. The positive associations of value with anxiety and shame suggest that valuing mathematics does not necessarily protect students from negative emotions. When achievement is perceived as highly important, the possibility of failure may become more consequential, thereby increasing anxiety and self-conscious emotions such as shame, particularly when perceived control is insufficient. Consistently, the negative association between value and test-related relaxation may indicate that attaching greater importance to performance reduces calmness in evaluative situations. Overall, these findings are consistent with the central proposition of CVT that AEs are closely linked to students' control and value appraisals (Pekrun, 2024). At the same time, the stronger and more pervasive associations involving control

TABLE 5 Results of invariance analyses across sex (male and female) and school levels (fourth-graders and seventh-graders).

Condition	Groups	Model	χ^2	df	p	CFI	TLI	RMSEA	SRMR	ΔCFI	ΔTLI	ΔRMSEA	ΔSRMR
Lessons	Sex	Configural invariance	1287.784	766	< .001	.970	.962	.031	.032	–	–	–	–
		Metric invariance	1315.410	784	< .001	.970	.962	.031	.035	−.001	.0002	−.0001	.003
		Scalar invariance	1405.903	812	< .001	.966	.959	.033	.036	−.004	−.003	.002	.001
		Structural invariance	1452.206	856	< .001	.966	.961	.032	.042	−.0001	.002	−.001	.006
	School level	Configural invariance	1181.831	766	< .001	.973	.965	.028	.032	–	–	–	–
		Metric invariance	1255.570	784	< .001	.969	.961	.030	.036	−.004	−.004	.002	.004
		Scalar invariance	1698.439	812	< .001	.942	.930	.040	.048	−.027	−.031	.010	.012
		Partial scalar invariance[a]	1408.527	807	< .001	.961	.952	.033	.041	−.008	−.009	.003	.005
		Structural invariance	1473.115	815	< .001	.960	.953	.033	.043	−.001	.001	−.0002	.002
Tests	Sex	Configural invariance	1349.803	766	< .001	.968	.958	.033	.034	–	–	–	–
		Metric invariance	1378.671	784	< .001	.967	.959	.033	.036	−.001	.001	−.0001	.002
		Scalar invariance	1493.949	812	< .001	.963	.955	.035	.038	−.004	−.004	.002	.002
		Structural invariance	1545.290	856	< .001	.962	.956	.034	.043	−.001	.001	−.001	.005
	School level	Configural invariance	1161.548	766	< .001	.975	.968	.027	.032	–	–	–	–
		Metric invariance	1237.717	784	<.001	.971	.964	.029	.036	−.004	−.004	.002	.004
		Scalar invariance	1699.208	812	< .001	.944	.932	.040	.051	−.027	−.032	.011	.015
		Partial scalar invariance[a]	1401.968	807	<.001	.963	.954	.033	.043	−.008	−.0098	.004	.007
		Structural invariance	1504.944	851	< .001	.959	.952	.033	.048	−.004	−.002	.0001	.005

Note: Configural, metric, scalar, and structural invariance models are reported in a single table for parsimony. Structural invariance represents an additional nested model in which regression coefficients were constrained to equality across groups.

Abbreviations: CFI, comparative fit index; df, degrees of freedom; RMSEA, root mean square error of approximation; SRMR, standardized root mean square residual; TLI, Tucker–Lewis index; Δ, change.

[a]Partial scalar invariance refers to a model in which most item intercepts are constrained to equality across groups, with a limited number freely estimated (Putnick & Bornstein, 2016). It was achieved by freeing five item intercepts, three associated with Teacher Warmth, reflecting expected differences in teacher–student relationships across school levels (primary vs. lower secondary). The remaining two intercepts were associated with control and value.

suggest that perceptions of competence may be particularly salient for younger students' emotional experiences in mathematics.

Regarding teaching practices and students' AEs, we extended the limited literature on teachers' support, including studies on teacher enthusiasm, positive teacher–student relationships, and perceived teacher support (Forsblom et al., 2021; Lazarides & Buchholz, 2019; Lei et al., 2018; Martin & Collie, 2019; Monteiro et al., 2017; Pekrun, Marsh, Elliot, et al., 2023), with findings largely consistent with CVT (Pekrun, 2024; Hypothesis 1c). Previous research has shown that teacher enthusiasm is positively associated with enjoyment and negatively associated with boredom (Pekrun, Marsh, Elliot, et al., 2023), whereas supportive teacher–student relationships and perceived teacher support are linked to higher levels of positive emotions and lower levels of negative emotions (Forsblom et al., 2021; Lazarides & Buchholz, 2019; Lei et al., 2018; Martin & Collie, 2019; Monteiro et al., 2017). Our findings are consistent with this body of evidence and further suggest that these associations are linked to students' control and value appraisals, particularly control appraisals. This pattern is in line with CVT's assumption that contextual factors are associated with AEs largely through their relations with students' control and value appraisals (Pekrun, 2024). Indirect effects involving control emerged in the relations of Positive Teaching and Teacher Warmth with AEs, being associated with more intense positive emotions and less intense negative emotions (with some exceptions). Indirect effects involving value emerged for a relatively lower number of relations, positively for some positive AEs and anxiety, and negatively for some negative AEs. Moreover, considering together the larger indirect effects and the higher proportion of variance for some AEs highlighted the relative prominence of Teacher Warmth on specific AEs. In both settings, students who perceived their teachers as caring and emotionally supportive were happier, prouder, and more relaxed, as well as less anxious; with slightly weaker associations, they were also less bored during lessons and less hopeless during tests – consistent with the relative opposite salience of these two emotions for non-evaluative versus evaluative settings (Raccanello et al., 2013). These indirect effects were particularly pronounced when the associations involved control.

The findings are primarily interpreted within CVT, according to which contextual characteristics of the learning environment are associated with students' AEs through their relations with control and value appraisals (Pekrun, 2024). From a complementary SDT perspective, the teaching practices examined may also be relevant to students' needs for competence, autonomy, and relatedness; however, the three needs were not directly assessed and should therefore be examined in future research. A plurality of mechanisms may help explain the significant associations involving Positive Teaching and Teacher Warmth. The associations regarding teacher enthusiasm can be interpreted in light of emotional contagion (Hatfield et al., 1993), which potentially contributes to the diffusion of positive emotions from teachers to students (Frenzel et al., 2018; Keller et al., 2016). Value-related motivational messages may be associated with greater perceived subject value, as suggested by the positive association between Positive Teaching and value. Additionally, vicarious learning, rooted in Bandura's (2001) social-cognitive learning theory, may also be at stake (Keller et al., 2016). Observing teachers as competent actors who display enthusiasm for teaching and learning tasks, emphasize their value, express affection, and model how to be responsive to students' emotional needs can act as a catalyst for students to replicate their behaviours, as well as endorse their beliefs within their own systems, with cascading effects on their AEs. Furthermore, socio-emotional communication (Durlak et al., 2022) could, in turn, foster a plurality of other emotional and motivational dimensions that characterize learning and influence both appraisals and AEs, whose role should be further investigated.

As for Student Involvement through participatory practices, which may be relevant to students' need for autonomy from an SDT perspective (Ryan & Deci, 2020), we found that although it showed bivariate correlations with appraisals and AEs, these associations did not remain significant when considered alongside the other teaching practices in the SEMs. While this result may partly reflect the different levels of generality adopted for the assessed constructs – with teaching practices referring to the broader school context and appraisals and AEs specifically referring to mathematics – it may also suggest that students' perceptions of school-level participation opportunities are less strongly related to domain-specific emotional experiences than the other examined teaching practices. This finding is noteworthy

because autonomy support is considered an important contextual antecedent within CVT, and therefore weaker associations than expected warrant careful consideration. An additional consideration is that the relatively lower reliability of the Student Involvement measure may have attenuated its associations with the other variables, thus contributing to the absence of significant findings. From an applied perspective, this encourages teachers to focus on autonomy-supportive practices within specific domains, in line with previous research (Flunger et al., 2019; Wang et al., 2017).

Universality of the relations

Regarding Aim 2, configural and metric invariance across sex and school levels was supported for both lessons and tests. Full scalar invariance was supported across sex, whereas partial scalar invariance was supported across school levels. Finally, structural invariance was confirmed, indicating that the latent variances and covariances were equivalent across sex and school levels. Documenting that contextual factors, such as Positive Teaching and Teacher Warmth, were associated with control and value beliefs, and AEs, similarly for boys and girls, and for primary and lower secondary school students, is consistent with CVT's universality assumptions (Pekrun, 2024) and expands a body of research that provides practitioners with multiple ways to intervene in the classroom to foster the most adaptive emotions. Teachers and professionals interested in promoting students' learning and well-being should benefit from the advantages of the mechanisms already discussed – e.g., emotional contagion, value induction, vicarious learning, and socio-emotional learning (Bandura, 2001; Durlak et al., 2022; Hatfield et al., 1993; Keller et al., 2016) – together with a variety of other techniques to impact AEs favourably, considering the multiple access points offered by CVT (Pekrun, 2024).

Limitations and future directions

This study has several limitations. First, we did not include all facets of teaching practices; future research should explore the impact of a broader range. Second, the operationalization of autonomy support through the Student Involvement subscale may also capture broader school-level participation processes not exclusively related to student–teacher interactions; future research should adopt more fine-grained measures to better disentangle classroom-level and school-level forms of autonomy support. Third, we measured AEs using single items. Although single-item measures are appropriate for capturing the subjective feeling component of discrete emotions (Pekrun et al., 2011) and allowed us to administer a shorter questionnaire, thereby reducing participant burden, they may provide a less comprehensive representation of the constructs, offer limited information about reliability, and do not permit the explicit modelling of measurement error. Future studies could investigate whether the pattern of relations observed in the present study holds when AEs are modelled as latent variables assessed through multiple indicators. Moreover, one of the two negative deactivating emotions was assessed through the adjective sad, which is developmentally more appropriate for younger students than hopeless. Although this choice was consistent with previous adaptations of the AEAL for children (i.e., the DS-AEAL; Raccanello & Burro, 2024), it may not fully capture the more specific construct of hopelessness as conceptualized in CVT. Future research should further investigate the extent to which sadness and hopelessness can be distinguished in younger students' achievement-related emotional experiences. Fourth, we used self-report instruments, prone to memory and desirability biases; however, self-reports remain a key means of accessing individuals' inner experiences, although physiological or observational measures are needed for triangulation. Fifth, we measured teaching practices at a broader school-related level, whereas appraisals and AEs were assessed specifically in mathematics. Future research should align all constructs at the same level of generality, for example by focusing on domain-specific perceptions of teachers' practices. Sixth, we utilized a cross-sectional design. Consequently, the directionality of the associations among teaching practices, appraisals, and AEs cannot be empirically established, and alternative patterns of relations may also be plausible. Although the ordering of the variables in the present

study was theoretically grounded in CVT (Pekrun, 2024), the data do not permit causal conclusions or definitive tests of temporal precedence. Future research should employ longitudinal and experimental designs to examine reciprocal relations among these variables and to better clarify their temporal ordering. Seventh, the Student Involvement subscale showed lower internal consistency than the other measures. Although its reliability remained within the acceptable range according to the adopted criteria, measurement imprecision may have attenuated its associations with appraisals and AEs. Future research should employ more reliable and fine-grained measures of autonomy support.

CONCLUSION

We advanced knowledge about the role of control and value in the associations between perceived teaching practices and AEs in mathematics. These findings further support CVT as a useful framework for understanding the associations among contextual antecedents, control and value appraisals, and students' AEs. They also highlight several aspects of the learning environment that may be relevant to teachers seeking to support students' emotional experiences in mathematics.

AUTHOR CONTRIBUTIONS

Enrica Ciucci: Conceptualization; methodology; data curation; investigation; validation; supervision; project administration; resources; writing – review and editing. **Giada Vicentini:** Methodology; software; data curation; investigation; validation; formal analysis; visualization; writing – review and editing. **Daniela Raccanello:** Conceptualization; methodology; software; data curation; investigation; validation; formal analysis; supervision; visualization; project administration; resources; writing – original draft. **Andrea Baroncelli:** Conceptualization; methodology; software; data curation; investigation; validation; formal analysis; visualization; resources; writing – review and editing.

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CONFLICT OF INTEREST STATEMENT

The authors have no conflict of interest to declare.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are openly available in Open Science Framework (OSF) at https://osf.io/r6b45/overview?view_only=b9532ec6968a4949a9bf1775f1845844, reference number R6b45.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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