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Linking Teacher Emotions, Teaching Quality Indicators, and Student Outcomes in Mathematics: Results From the Global Teaching InSights Study

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Using data from the Global Teaching InSights study in eight culturally diverse countries, this study examines the subtle relationships between teachers' emotions, indicators of their teaching quality, and student outcomes in mathematics (Organisation for Economic Co-Operation and Development, 2020a). We hypothesize that the considered indicators of teaching quality—classroom management, supportive teacher–student relationships, and cognitive activation—mediate the relationships between teacher emotions of enjoyment and anger and students' self-efficacy, interest and performance in mathematics. Using latent multigroup multilevel structural equation modeling, we analyze data from 679 teachers and over 17,500 students. The results indicate that teacher enjoyment is positively related to all three indicators of student-reported teaching quality, whereas teacher anger is negatively associated with them. In particular, classroom management mediated the relationship between teachers' enjoyment and anger and student interest. Supportive teacher–student relationships additionally proved to mediate the effect from teacher emotions to student interest and performance, whereas cognitive activation mediated the effect between teacher emotions and student self-efficacy and performance. Our study underlines the vital role of emotional dynamics in education and their impact on teaching quality and educational outcomes, highlighting the importance of supporting teachers' emotional well-being to improve student learning.

Educational Impact and Implications Statement

This study shows that teaching quality largely depends on teachers' emotions: When teachers experience enjoyment, they deliver higher teaching quality, whereas feelings of anger are linked with lower teaching quality in terms of classroom management, supportive teacher–student relationships, and cognitive activation. We further show that these indicators of teaching quality are closely linked with students' self-efficacy beliefs, their interest, and their performance. We conclude that it is important to give priority to teachers' emotions both in teacher training and in educational policy decisions.

Keywords: teacher emotions, teaching quality, student outcomes, multilevel structural equation modeling, classroom dynamics

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The educational environment is inherently social and evokes a wide range of emotions in students and teachers. In recent years, studies have started examining the central role of teachers' emotions in shaping their teaching behavior, which in turn affects student academic outcomes (Frenzel et al., 2021). To date, research has extensively explored how teacher characteristics influence student outcomes, shedding light on the complex dynamics of education (e.g., Bieg et al., 2022; Burroughs et al., 2019; Frommelt et al., 2021; Frühauf, Koeppen, et al., 2025; Hattie, 2008; López-Martín et al., 2023; Wayne & Youngs, 2003). However, although some progress has been made in understanding the mechanisms by which teacher emotions shape teaching quality and subsequently affect student outcomes (Frenzel et al., 2021), compelling empirical evidence on the full proposed mediational chain is still lacking. The present study draws on data from the Global Teaching InSights study (GTI; Organisation for Economic Co-Operation and Development [OECD], 2020a) to fill this gap by exploring how three core indicators of teaching quality—namely, classroom management, supportive teacher–student relationships, and cognitive activation (Klieme et al., 2001; Praetorius et al., 2018)—mediate the relationship between two prevalent teacher emotions, enjoyment and anger, and three fundamental student outcomes in mathematics—self-efficacy, interest, and academic performance.

For decades, the concept of teaching quality has been studied extensively through process-product paradigms to identify effective teaching practices for cognitive, motivational, and emotional student outcomes. However, despite teachers' knowledge of strategies that promote student thinking and learning, many of them still struggle to implement these strategies consistently (Fauth et al., 2019; Gess-Newsome et al., 2019). Recent research highlights the role of affective factors such as emotional exhaustion in explaining why teaching quality varies among teachers (Klusmann et al., 2022). Although considerable proportions of modern teachers suffer from considerably severe emotional exhaustion, its symptoms typically occur less often in daily classroom life, whereas specific, discrete emotional experiences such as anger and enjoyment are part of almost every teacher's everyday experience (Klusmann et al., 2022). Despite their pervasiveness, relatively little is known about how teaching-related emotions—particularly enjoyment and anger, as two of the most prevalent—are related to teaching and student learning processes (e.g., Burić & Frenzel, 2023; Frenzel, 2014). To address this gap, Frenzel et al. (2021) proposed a conceptual framework illustrating how teachers' emotions during teaching affect student outcomes indirectly through shaping teachers' behavior, including relationship building, instructional strategies, and nonverbal communication. Their model positions teacher emotions as proximal predictors of teaching quality and, consequently, students' emotional experiences, beliefs, motivation, discipline, and performance. Based on their work, we expected that teacher enjoyment during teaching facilitates and teacher anger during teaching hinders their teaching quality, which in turn affects student outcomes (Frenzel et al., 2021). To explore these assumptions, we used data from the GTI study (OECD, 2020a) involving 679 teachers and their respective over 17,500 students worldwide. Thus, the nested data structure was ideally suited for applying latent multigroup multilevel structural equation modeling (SEM) while considering country-specific characteristics through grouping.

Teacher Enjoyment and Anger

Teachers navigate a diverse emotional landscape during teaching in which they are confronted with a variety of emotions. Emotions are not simply transient states but complex psychological experiences that include affective, physiological, expressive, cognitive, and motivational components (Scherer, 2005). They manifest themselves through facial expressions, tone of voice, gestures, and observable behavioral patterns and thus become perceptible to the social environment (Gross, 2014; Scherer & Moors, 2019). It has been shown that some teachers are particularly susceptible to experiencing certain emotions more intensely and frequently than others (Burić et al., 2018; Chen, 2016; Frenzel et al., 2016). In the present contribution, we focus on enjoyment and anger. These emotions represent opposite ends of the emotional valence spectrum, involving heightened arousal and activation predisposing individuals to certain action tendencies and expressions (Fredrickson, 2001; Frijda, 1987; Keltner & Haidt, 1999; Pekrun, 2018). Enjoyment and anger have been shown to be the most salient positive and negative emotions experienced by teachers, respectively (Burić & Frenzel, 2019, 2023; Frenzel, 2014; Keller et al., 2014). Enjoyment is reported by as many as 75%–89% of teachers, whereas 14%–39% report experiencing anger, underscoring the significance of these emotions in teachers' everyday professional lives (Frenzel, 2014). Focusing on these prominent discrete emotions allows for important insights into how teachers' emotional experiences are linked with their teaching performance.

With its positive valence, task enjoyment (e.g., in the teaching profession) fosters broadened thought-action tendencies, expanded attention, flexible and creative thinking, and problem-solving approaches (Fredrickson, 2001; Fredrickson & Branigan, 2005). It goes along with greater well-being and a sense of satisfaction (Frenzel, 2014; Pekrun, 2006). Teacher enjoyment is associated with higher well-being, better and more student-centered teaching, and student enjoyment (Chen, 2019; Frenzel, Goetz, Lüdtke, et al., 2009; Russo et al., 2020; Taxer & Frenzel, 2015).

In contrast, anger, with its negative valence, is associated with frustration, tension, and stress. Anger has been shown to bias cognitive processing negatively, to perceptually and conceptually narrow cognitive scope (Gable et al., 2015; Parrott et al., 2005), and to make one more likely to blame others for perceived wrongdoing (Clore & Ortony, 1991). Teacher anger is associated with lower teaching self-efficacy and higher job dissatisfaction, emotional exhaustion, burnout, and attrition from the profession (Burić & Frenzel, 2019; Chang, 2009; Chen, 2019; Sutton, 2007; Sutton & Wheatley, 2003).

Teachers' emotions are not only strongly contributing to their mental health and job satisfaction but also play vital role in shaping how they engage with those around them (Dreer, 2024). Instead of being mere subjective internal experiences that are kept inside, emotions actively affect what decisions are made, which actions are taken, and how interactions with others are formed. Hence it can be expected that teacher emotions significantly shape the interactions, communication, and relationships in the educational environment, ultimately impacting students' learning experiences (Farouk, 2012; Frenzel et al., 2021; Frijda, 1987).

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Teaching Quality

Across various theoretical frameworks, including the Classroom Assessment Scoring System (CLASS; Pianta et al., 2008) and the German Framework of Three Basic Dimensions (Klieme et al., 2001; Praetorius et al., 2018), three core indicators of teaching quality were consistently identified: (a) classroom management, (b) supportive teacher–student relationships, and (c) cognitive activation. Effective classroom management describes creating a structured learning environment with clearly defined and consistently enforced rules and expectations to enable and optimize learning in the classroom setting (Kounin, 1970). Supportive teacher–student relationships foster a sense of community in class and a positive and learning-conducive classroom environment. Cognitive activation goes beyond merely passing on information; it stimulates critical thinking processes and deep engagement and encourages learners to explore complex concepts and ideas (Klieme et al., 2009). Numerous studies have confirmed that these three indicators of teaching quality contribute to student outcomes, including their behavior, emotions, beliefs, interest in the subject, and performance (Burić & Frenzel, 2023; Fauth et al., 2014; Hattie, 2008; Kyriakides et al., 2013; Muijs et al., 2014). However, previous research has mainly relied on data from a single source, either from teachers or students (e.g., Becker et al., 2014; Chen, 2019; Russo et al., 2020). This approach may disguise the exact effect sizes between the constructs. Therefore, we use student-reported measures of teaching quality that have been found to be reliable (e.g., Lüdtke et al., 2007).

Linking Teacher Emotions, Teaching Quality Indicators, and Student Outcomes

Research has recently started investigating the connections between teacher characteristics, teaching quality indicators, and several student outcomes such as their competence beliefs, motivational-affective outcomes, and performance (Bardach et al., 2022; Bardach & Klassen, 2021; Fauth et al., 2014; Frenzel et al., 2021; Klusmann et al., 2022; Kyriakides et al., 2013; Perry et al., 2007; Seidel & Shavelson, 2007). As emotions shape cognition, attention, and behavior, teacher emotions likely play a pivotal role in shaping teaching practices and the learning environment. Frenzel et al. (2021) presented a framework suggesting that teacher emotions influence student outcomes through teaching behaviors, including relationship building, nonverbal social messages, and instructional strategies. They propose that teacher emotions can affect students directly, which they refer to as direct transmission effects (e.g., through emotional contagion), and indirectly, by shaping their teaching behavior; however, they also propose a potential cyclical relationship in which teacher emotions do not only affect student outcomes but also vice versa through appraisals (Frenzel et al., 2021).

Over the last decades, evidence has accumulated linking teacher emotions with teaching quality indicators, though the findings remain scattered. Generally, positive teacher emotions, specifically enjoyment, contribute positively to various aspects of teaching quality. In contrast, negative emotional experiences, such as emotional exhaustion, correlate with lower teaching quality (Frenzel, Goetz, Stephens, et al., 2009; Klusmann et al., 2008, 2022; Kunter et al., 2008). For instance, previous studies showed that positive teacher emotions are associated with more student-focused teaching approaches. In contrast, teachers who experience more negative emotions tend to adopt a more teacher-focused teaching approach (Chen, 2019; Sutton & Wheatley, 2003; Trigwell, 2012). Kunter et al. (2008) identified a similar link between the related construct of teacher enthusiasm and their efforts in cognitive activation and classroom monitoring. Teachers who reported higher levels of enjoyment were also found to be more caring and supportive than those reporting more anger. In contrast, angry teachers were perceived as more disrespectful toward their students (Frenzel et al., 2018; Kunter et al., 2008).

A recent study by Burić and Frenzel (2023) examined how distinct teacher emotions, including enjoyment and anger, impact teaching quality across different cultural contexts (Croatia and Germany). Their findings show that teaching enjoyment was positively linked with teaching quality, whereas teaching anger was negatively related. A closer inspection of their reported correlative links with the separate teaching quality indicators revealed that teacher enjoyment was positively correlated in the Croatian data set, and teacher anger negatively correlated with student-rated classroom management, student support, and cognitive activation. The correlations with cognitive activation were insignificant in the German data set, but the links with student support and classroom management were even more substantial. Although this study benefited from large sample sizes, particularly in the Croatian data set, the three indicators of teaching quality could not be empirically separated due to very high correlations of the aggregated ratings in that data set. As a result, evidence for these emotion-specific links remains inconclusive. While considering data from two countries, the authors hinted at potential cross-cultural differences without explicitly exploring them. In addition, they did not investigate the potential mediational link between teacher emotions, teaching quality indicators, and student outcomes—the primary focus of the present contribution.

In contrast to the scattered evidence on the link between teacher emotions and teaching quality indicators, substantial research has established how teaching quality practices relate to how students perceive their own capabilities, engage with learning tasks, maintain interest in academic content, and ultimately perform in assessments (Bardach et al., 2022; Burić & Frenzel, 2023; Fauth et al., 2014; Hattie, 2008; Kyriakides et al., 2013; Perry et al., 2007; Seidel & Shavelson, 2007). This body of literature highlights that focusing solely on student performance overlooks other important student outcomes, such as competence beliefs, interest, or engagement, which are essential in their own right and concerning lifelong learning (Bong & Skaalvik, 2003; Mau & Li, 2018). In line with this, we chose to examine three specific student outcomes in the present study: student self-efficacy, student interest, and student performance, all contextualized within the mathematics domain, as addressed by the GTI study (OECD, 2020a).

To summarize, there is robust empirical evidence on the pairwise linkages between certain teacher emotions, indicators of teaching quality, and student outcomes, and solid conceptional reasoning points toward a mediational relationship between teacher emotions and student outcomes via teaching quality indicators (Frenzel et al., 2021; Gill, 2021; Keller et al., 2016; Lazarides et al., 2023). To date, however, no study appears to have empirically investigated the full mediational chain. In general, research examining multiple indicators of teaching quality as

mediators between teacher characteristics and student outcomes remains extremely scarce.

One exception is Klusmann et al. (2022) who addressed and found supportive evidence for the link from emotional exhaustion on student self-concept, interest, and achievement via teaching quality. Another recent study by Jerrim (2024) investigated the indirect effects of job satisfaction on student outcomes through various instructional strategies, also using data from the GTI study (OECD, 2020a). Of not, this study failed to find significant mediation. Importantly, though, Jerrim did not account for country-specific structures, and teaching satisfaction was operationalized on a very abstract level and with a strong notion of cognitive choice instead of actual positive emotional experience (with items such as "if I could decide again, I would still choose to work as a teacher"). In our analyses, we specifically address enjoyment with respect to teaching the target class and utilize multigroup analyses that account for potential variation across countries. As such, the present study promises to reveal new evidence on the degree to which not only teachers' negative, but also their positive emotional experiences are linked with their teaching quality indicators and student outcomes in mathematics.

Classroom Dynamics Across Countries

Research on classroom dynamics has traditionally relied on data from Western, Educated, Industrialized, Rich, and Democratic (WEIRD) countries. This focus is also evident in most of the studies mentioned earlier. Consequently, there is a clear need to broaden the scope and examine the emotional experiences of teachers and students in non-WEIRD contexts, as well as to explore whether findings observed in WEIRD cultural contexts generalize to non-WEIRD settings (e.g., Burić & Frenzel, 2023; Klusmann et al., 2022; Muthukrishna et al., 2020). The GTI data set provides unprecedented opportunities to do so as it includes data from eight economically, politically and socioculturally diverse countries (Chile, China, Colombia, Germany, Japan, Mexico, Spain, and the United Kingdom). This data set thus offers a valuable opportunity to expand the scope of research on classroom dynamics across a wide range of cultural contexts.

Clearly, subjective experiences and expressions of emotions are shaped by both contextual and cultural factors, influenced by factors such as culturally shaped emotion display rules or general appropriateness and the desirability of certain emotions (De Leersnyder et al., 2021; Eid & Diener, 2001; Markus & Kitayama, 1991; Mesquita & Frijda, 1992; Safdar et al., 2009). Drawing on extensive research (e.g., Barroso et al., 2021; Brown & Cai, 2010; Fontaine et al., 2013; Frenzel et al., 2007; Guo et al., 2022; Loderer et al., 2020; Luszczynska et al., 2005; Pekrun & Goetz, 2023), Pekrun and Goetz (2023) argued that despite such level differences in emotional responses based on ethnicity or cultural context, the patterns linking emotions to action tendencies and achievement can be expected to be largely equivalent across contexts—for both students and teachers. Although individual experiences may be unique, Pekrun and Goetz (2023) proposed that generalizable principles exist regarding emotional dynamics in education—a proposition they refer to as the "relative universality of emotional dynamics." The concept of repertoire equivalence complements this perspective (Bosman et al., 2017; Cowen et al., 2024; Fontaine & Breugelmans, 2021), positing that basic emotional experiences—such as enjoyment or anger—share a common nomological network across cultures, meaning that the relations between antecedent and consequent constructs are highly similar across contexts and cultures. Empirical studies on emotions support this view: Enjoyment and anger consistently show similar behavioral tendencies worldwide, although cultural values influence how these emotions are regulated and expressed (Alonso-Arbiol et al., 2011; Bosman et al., 2017; Wang et al., 2023).

Accordingly, we propose that emotion–teaching quality links should demonstrate a certain degree of similarity across all countries sampled in the GTI. In other words, within each country, we would expect that those teachers who experience relatively high levels of teaching enjoyment should be generally more effective in delivering high-quality teaching by broadening their attention and enhancing their flexible thinking than those who experience less enjoyment than their same-country teacher colleagues. Conversely, the cognitive and motivational impediments implied by relatively high levels of teacher anger during teaching should lead to lower teaching quality across cultures and countries (Fredrickson, 2001; Fredrickson & Branigan, 2005).

Furthermore, teaching and learning in classrooms clearly is a cultural activity driven by social practices and shaped by cultural norms and traditions; hence classroom routines show considerable cross-country variation (Bell, Klieme, et al., 2020; Bell, Schweig, et al., 2020; Stigler & Hiebert, 1999). On the other hand, the general structural setup of modern schooling is strikingly similar across the globe, exemplified by the pervasive "principle of the classroom," which involves clustering children into a number of graded classrooms, usually with one teacher per classroom (Anderson-Levitt, 2003). Studies on cross-cultural comparisons are few and far between and reflect patterns of both universality and specificity. Using Program for International Student Assessment (PISA) 2012 student data from multiple Chinese-speaking, English-speaking, French-speaking, German-speaking and Spanish-speaking countries, Fischer et al. (2019) have shown that student ratings of classroom management, student support, and cognitive activation demonstrate factor loading invariance. This suggests that associations between these student-reported teaching quality indicators and other variables can be validly compared across linguistically diverse countries. However, they also reported considerable invariance of item intercepts across the linguistic groups, implying certain levels of variability in the interpretations of items across students from different language groups, and that latent mean comparisons across linguistic groups are problematic.

Furthermore, Xie et al. (2023) investigated whether student perceptions of teacher enjoyment predicted their reading achievement using data from the PISA 2018 including students from both Western (United States, United Kingdom, Australia, and New Zealand) and Eastern contexts (Mainland China, Hong Kong SAR, Macau SAR, Taipei, Singapore, Japan, and Korea). Their results showed that student perceptions of teacher enjoyment and reading enjoyment predicted reading achievement among students from both cultural contexts. The authors interpreted their findings in terms of cross-cultural universality. Finally, empirical evidence suggests that the basic psychological needs of students are highly similar across cultures (Chen et al., 2015; Nalipay et al., 2020), and that these needs shape student well-being and motivation, regardless of their cultural context (Reeve et al., 2018).

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In sum, also for teaching quality—student outcome links, we tentatively assume that there are broadly similar patterns across the eight countries sampled in the GTI study. Within the scope of the present work, we thus adopt a cautious and exploratory stance in examining cross-cultural similarities in the links between teaching quality and student outcomes. Our goal is thus not to prove strict universality, but to explore whether robust patterns emerge despite cultural variation.

The Present Study

The present study utilized the extensive GTI data set (OECD, 2020a) to examine the hypothesized relationships in which the linkages between teacher enjoyment and anger and student outcomes in mathematics are indirectly linked via teaching quality indicators. This data set was ideally suited for exploring this complex mediational chain, as it included all the necessary components: (a) teachers' self-reported experiences of enjoyment and anger in one specific target class, (b) student ratings of the corresponding teachers' teaching quality indicators, and (c) student performance, as measured by a highly elaborated, targeted test on the newly introduced topic of quadratic equations in mathematics class, along with student self-reported self-efficacy and interest in this topic.

In a nutshell, we want to replicate the baseline assumption that teaching quality is associated with student outcomes, as a substantial body of literature suggests (e.g., Bardach et al., 2022; Fauth et al., 2014; Hattie, 2008; Kyriakides et al., 2013; Perry et al., 2007; Seidel & Shavelson, 2007), as well as the supposed link between teacher emotions and indicators of teaching quality (Burić & Frenzel, 2023). Different previous theoretical frameworks have suggested the possibility of a mediational pathway from teacher emotions to student outcomes via teaching (Frenzel et al., 2021; Gill, 2021; Keller et al., 2016; Lazarides et al., 2023), but this does not yet seem to have been empirically tested. Therefore, in our key mediational hypothesis, we examine whether teacher emotions (enjoyment and anger) are linked with student outcomes in mathematics (self-efficacy, interest, and performance) through teaching quality indicators (classroom management, supportive teacher–student relationships, and cognitive activation). Specifically, we propose that teacher enjoyment has a positive indirect effect on student outcomes via indicators of teaching quality, whereas teacher anger has a negative indirect effect on student outcomes via indicators of teaching quality.

Method

Participants and Procedure

The GTI study targeted mathematics teachers and their respective students across eight countries[1]: Chile, China, Colombia, Germany, Japan, Mexico, Spain, and the United Kingdom (OECD, 2020a). Teachers and their classes were included if their mathematics curriculum covered the introduction of quadratic equations in six to 12 lessons in grade level 8 or higher with students close to 15 years of age. Focusing on this specific topic and age group enhances comparability between countries, as the topic is a common component of secondary mathematics curricula for students approaching the end of compulsory education in most countries (Klieme, 2020; Opfer, 2020). Special education classes and students with significant special needs were excluded (for detailed information, see McCaffrey, 2020).

The OECD aimed to recruit 85 teachers per country, each with a class of at least 15 students, following a random sampling strategy. Random sampling involved selecting schools randomly from the country and then drawing eligible teachers within those schools (McCaffrey, 2020). However, random sampling was not achieved in the German, Japanese, and Spanish samples. Germany's sample was drawn from volunteer schools, resulting in a convenience sample (Yoo & Propp, 2020). Chile, China, Colombia, Mexico, and the United Kingdom achieved random sampling either within all or selected regions (Yoo & Propp, 2020). Final participation numbers varied, with Germany ($n = 50$) and Colombia ($n = 83$) falling short of the target. Recruitment and data collection periods overlapped across countries. Participants were recruited from March 2017 to October 2018, whereas data were collected from October 2017 to March 2019, with the duration varying from four months in Mexico to 14 months in Germany. The data collection included surveys and tests administered before and after the critical instruction unit on quadratic equations, as well as video recordings of two lessons during the critical instruction unit. Specifically, teachers and students completed the postquestionnaires at the end of the quadratic equations unit. The mathematics performance test on quadratic equations was administered within two weeks following the end of the unit.

The GTI sample consisted of $N = 679$ teachers and $N = 17{,}544$ students, out of whom $N = 642$ teachers (55.5% female, 44.1% male) and $N = 15{,}990$ students (48.5% female, 47.3% male) participated at the measurement time point of interest to the present study. Participating teachers ranged in age from 20 to 74 years ($M = 40.42$, $SD = 10.41$) and reported an average of 14.21 years of teaching experience ($SD = 9.76$). In terms of educational attainment, 59.1% held at least an undergraduate degree, 33.4% a master's degree, and 1.9% a doctorate. Students had a mean age of 14.84 years ($SD = 1.10$[2]), with an average of 23 students per class participating in the study. Overall, 8.9% of students in the total sample had a non-native background, ranging from 0% first- or second-generation immigrants in Colombia and China to 17% in Spain (Doan & Mihaly, 2020; OECD, 2020c).

Measures

The GTI study included teacher and student questionnaires administered before and after the focal unit on quadratic equations (Praetorius et al., 2020). Both the pre- and postquestionnaires assessed (a) teachers' emotional experiences when teaching the target class, (b) students' ratings of their mathematics teacher's instructional behaviors, and (c) students' self-efficacy and interest in mathematics. In

[1] Most participating countries collected data only from selected regions, as nationwide sampling was often not feasible (see McCaffrey, 2020). Specifically, data were collected from the following regions: (a) Chile—Biobío, Metropolitana, and Valparaíso; (b) China—Shanghai; (c) Japan—Kuagaya, Shizuoka, and Toda; (d) Spain—Madrid; and (e) the United Kingdom—England.

[2] The large variation in student age can be explained by the fact that quadratic equations are introduced at different grade levels across countries. Most countries teach this topic in Grade 9. However, in China, it is introduced as early as Grade 8, whereas in Chile, it is introduced in Grade 11.

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addition, a mathematics performance test was administered at both time points. Prequestionnaire and pretest items were framed more generically, whereas postquestionnaire and posttest items referred specifically to the focal unit on quadratic equations. In this study, we chose to exclusively use the postquestionnaire ratings and posttest data for two reasons. First, this focus ensured that all measures referenced the same clearly defined instructional context, that is, the focal unit on the topic of quadratic equations. Second, the interval between the two administrations varied considerably across classes (1–168 days; $M = 39.7$, $SD = 27.9$), potentially compromising comparability and confounding mediation estimates, when using prequestionnaire teacher emotion ratings as predictors or student instructional quality ratings as covariates. Table 1 presents all scales used in the analysis, along with the descriptive statistics and reliability coefficients obtained for the present sample.

Teacher Emotions

Teacher enjoyment and anger in the target class were assessed using the Teacher Emotions Scale (Frenzel et al., 2016). Teachers were first asked an introductory question about how they did *feel while teaching their class* (OECD, 2020d). They then rated their agreement with four items each for enjoyment and anger on a 4-point Likert scale, ranging from 1 (*strongly disagree*) to 4 (*strongly agree*). To assess teacher enjoyment, items included statements such as, "I had so much fun teaching these students that I gladly prepared and taught my lessons" (OECD, 2020d, p. 17). For teacher anger, items included statements like, "Sometimes I got really mad at these students" (OECD, 2020d, p. 17). In assessing the internal consistencies of the scales, we followed the guidelines by George and Mallery (2003) and, in consequent, classified internal consistency as excellent ($\omega \geq .90$), good ($\omega \geq .80$), acceptable ($\omega \geq .70$), questionable ($\omega \geq .60$), poor ($\omega \geq .50$), or unacceptable ($\omega < .50$). Across all countries, the emotion scales demonstrated good internal consistency, with teacher enjoyment of $\omega = .87$ and teacher anger of $\omega = .86$ (see George & Mallery, 2003). Within each country, internal consistencies for teacher enjoyment ranged from acceptable ($\omega = .79$ in Japan) to excellent ($\omega = .92$ in China). For teacher anger, reliability ranged from good ($\omega = .81$ in Germany) to excellent ($\omega = .92$ in China), with one exception: Colombia showed questionable internal consistency at $\omega = .69$.

Student-Rated Teaching Quality

When assessing teaching quality, the choice between using teacher or third-party ratings is critical, with each method carrying its own set of benefits. In the context of our analyses, we opted for student ratings, as they provide a robust method for evaluating educational effectiveness due to their various advantages. Unlike teacher reports, student ratings do not carry the risks of being susceptible to biases such as social desirability and common method bias. Students, in turn, can show biases in judging their teachers' instructional behavior or form holistic impressions of teachers, which can lead to generalizations that overlook the nuances of specific lessons (den Brok, 2001; Fraser, 1998). By aggregating and averaging student ratings, one can achieve results largely free from personal biases (den Brok, 2001). Such aggregated ratings reflect students' shared perspectives shaped by their individual experiences (Wubbels & Brekelmans, 1998). The reliability of such class-level aggregated teaching quality ratings can be judged by the intraclass correlation coefficients ICC(1), which quantifies the consistency of students' responses within clusters, and ICC(2), which quantifies the reliability of aggregated student-reported measures (e.g., teaching quality) at the second level (Lüdtke et al., 2007). Constructs are considered reliable with ICC(1) values > .05 (Lüdtke et al., 2008, 2011) and ICC(2) > .70 (Klein & Kozlowski, 2000; Morin et al., 2014). Overall, we deemed the benefits of student ratings as significant, prompting us to utilize student ratings on three critical indicators of teaching quality as assessed in the GTI: classroom management, supportive teacher–student relationships, and cognitive activation.

Students indicated their perceptions of teacher classroom management by responding to four items to *describe the general climate in their mathematics class during the unit on quadratic equations*, such as, "Our teacher managed to stop disruptions quickly" (OECD, 2020b, p. 13). Responses were scored on a 4-point Likert scale, from 1 (*strongly disagree*) to 4 (*strongly agree*). The scale showed considerable consistency across students within each class cluster, with an overall ICC(1) of .18 (range: .08–.27; see Table 2). The reliability of class-level mean scores was acceptable, as indicated by an overall ICC(2) of .85 (range: .72–.89).

To capture the hypothesized relational mediation linking teacher emotions to student outcomes, as outlined in Frenzel et al.'s (2021) framework, we used an aggregate of the student–teacher relationship scale from the GTI study (Mihaly et al., 2020). This scale is one of five subdomains of socioemotional support measured in the GTI (i.e., teacher support for learning, perceived support for competence, perceived support for autonomy, student–teacher relationship, and student–student relationship; Mihaly et al., 2020). Among these, the student–teacher relationship scale best reflects the "relationship building" component described in the initial framework we sought

Table 1
Descriptive Statistics and Correlation Coefficients Within and Across Countries

Measure	*M*	*SD*	1	2	3	4	5	6	7	8
1. Enjoyment	3.41	0.50	—							
2. Anger	1.53	0.54	−.54**	—						
3. Classroom management	3.14	0.59	.23**	−.06	—	.48**	.29**	.22**	.27**	.07**
4. Teacher–student relationship	3.12	0.68	.26**	−.12**	.69**	—	.33**	.31**	.39**	.12**
5. Cognitive activation	2.74	0.72	.29**	−.01	.54**	.59**	—	.23**	.25**	.03**
6. Self-efficacy	2.48	0.78	.23**	.03	.58**	.52**	.54**	—	.53**	.31**
7. Interest	2.61	0.75	.15**	.03	.63**	.57**	.40**	.74**	—	.21**
8. Performance	0.43	1.48	−.15**	.16**	.28**	.18**	.06	.29**	.40**	—

Note. Values above the diagonal present manifest within-cluster correlations. Values below the diagonal present manifest between-cluster correlations.
* $p < .05$. ** $p < .01$.

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Table 2
Reliability Measures Within and Across Countries

Measure	Chile	China	Colombia	Germany	Japan	Mexico	Spain	United Kingdom	Overall
Enjoyment									
Internal consistency	.87	.92	.91	.85	.79	.88[a]	.82	.91	.87
Anger									
Internal consistency	.88	.92	.69	.81	.91	.83	.84	.91	.86
Classroom management									
Internal consistency	.92	.91	.85	.89	.89	.88	.89	.89	.89
ICC(1)	.13	.08	.09	.27	.10	.12	.18	.22	.18
ICC(2)	.79	.74	.72	.89	.75	.77	.82	.86	.85
Teacher–student relationship									
Internal consistency	.94	.95	.90	.93	.91	.91	.92	.94	.93
ICC(1)	.18	.16	.17	.26	.11	.14	.18	.20	.20
ICC(2)	.85	.85	.84	.88	.77	.80	.82	.85	.86
Cognitive activation									
Internal consistency	.82	.78	.72	.64	.77	.79	.61	.77	.75
ICC(1)	.09	.08	.06	.06	.11	.09	.07	.11	.18
ICC(2)	.71	.72	.61	.59	.78	.71	.59	.73	.84
Self-efficacy									
Internal consistency	.93	.95	.84	.91	.95	.88	.91	.92	.92
ICC(1)	.08	.08	.09	.04	.03	.07	.08	.09	.22
ICC(2)	.66	.73	.71	.47	.45	.66	.64	.70	.87
Interest									
Internal consistency	.92	.93	.83	.85	.93	.84	.86	.90	.91
ICC(1)	.06	.07	.13	.10	.06	.09	.08	.10	.20
ICC(2)	.62	.70	.79	.70	.62	.72	.65	.72	.86
Performance									
Internal consistency[b]	.84	.72	.65	.76	.82	.68	.75	.80	.75
ICC(1)	.43	.30	.29	.23	.13	.20	.19	.48	.61
ICC(2)	.95	.93	.91	.86	.81	.86	.83	.95	.98

Note. Internal consistency was assessed using McDonald's Ω. ICC = intraclass correlation coefficient; GTI = Global Teaching InSights.
[a] Estimated using confirmatory factor analysis due to nonconvergence of the exploratory approach. [b] The internal consistency of the item response theory based performance values is derived from the GTI technical report, based on empirical reliability estimates (Cronbach's α; Castellano & McCaffrey, 2020).

to cover. Specifically, students were asked to *think about their mathematics teacher and class during the unit on quadratic equations* based on five items, such as "I got along well with my mathematics teacher" (OECD, 2020b, p. 15). They rated their level of agreement on a 4-point Likert scale, from 1 (*strongly disagree*) to 4 (*strongly agree*). The scale was consistent and reliable with an overall ICC(1) of .20 (range: .11–.26) and an ICC(2) of .86 (range: .77–.88).

Finally, to assess teachers' cognitive activation efforts, items for student ratings were introduced by the question, "How often did your teacher do the following things?" (OECD, 2020b, p. 10). Students indicated their responses on four items, such as "Our mathematics teacher gave tasks that required us to think critically" on a 4-point Likert scale, ranging from 1 (*rarely*) to 4 (*frequently*). Overall, the measure was consistent within clusters and reliable as an aggregated measure, with an overall ICC(1) of .18 (range: .06–.11) and an ICC(2) of .84 (range: .59–.78).

Student Outcomes

The OECD assessed students' mathematic self-efficacy using an adapted version of the Manual for the Use of the Motivated Strategies for Learning Questionnaire (MSLQ; OECD, 2018; Pintrich, 1991). Students indicated *how true the presented statements* were for them by responding on a 4-point Likert scale ranging from 1 (*not at all true of me*) to 4 (*extremely true of me*) to five topic-specific items, such as "I was confident I could do an excellent job on the assignments and tests during the unit on quadratic equations" (2020b, p. 5). In general, the scale was consistent and reliable on the class-aggregated level, with an overall ICC(1) of .22 (range: .03–.09) and ICC(2) of .86 (range: .45–.73).

Students' interest in mathematics was measured using the OECD-adapted version of the Student Interest Questionnaire (SIQ; Schiefele et al., 1993). Students rated *the extent of their agreement* with four topic-specific items, such as "I often thought that what we were talking about in my mathematics class during the unit on quadratic equations was interesting" (OECD, 2020b, p. 6). Responses were recorded on a 4-point Likert scale from 1 (*strongly disagree*) to 4 (*strongly agree*). Overall, the scale showed acceptable reliability on the class-aggregated level, with an overall ICC(1) of .20 (range: .06–.13) and ICC(2) of .86 (range: .62–.79).

For the GTI study, the OECD developed a test comprising 25 single-choice items on quadratic equations to assess students' mathematics performance (McCaffrey et al., 2020). Administered within 2 weeks after the unit on quadratic equations, the test included questions about quadratic equations (80%–90%) and their applications (10%–20%; McCaffrey et al., 2020). Each item was presented with four response options, with just one correct answer, for example, "Find a positive integer x so that the square of x minus twice x is 35. A. 4; B. 5; C. 6; D. 7" (OECD, 2020c, p. 270). Item response theory (IRT) based performance scores were reliable on the class-aggregated level, with an overall ICC(1) of .61 (range: .13–.48) and ICC(2) of .98 (range: .81–.95; Castellano & McCaffrey, 2020).

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Statistical Analyses

All analyses were performed using *RStudio* (Posit team, 2025). Our initial and preliminary steps involved calculating descriptive statistics and bivariate within- and between-cluster correlations. In our latent variable models, we evaluated model fit using several fit indices: Comparative Fit Index (CFI), Tucker–Lewis Index (TLI), Root Mean Square Error of Approximation (RMSEA), and Standardized Root Mean Square Residual (SRMR). Although the chi-squared statistic was reported, its sensitivity to large sample sizes limited its interpretative weight. Following recommendations by Byrne (1994), Hu and Bentler (1999), and Jöreskog and Sörbom (1994), model fit is categorized as good with CFI/TLI $\geq .95$, RMSEA $\leq .05$, SRMR $\leq .06$, and categorized as acceptable with CFI/TLI $\geq .90$, RMSEA $\leq .06$, and SRMR $\leq .08$.

To determine measurement invariance across the eight groups before conducting the latent multigroup multilevel SEM analyses, we conducted separate CFAs for each variable of interest, as is best practice in large-scale assessments (e.g., Mihaly et al., 2020). Given that different survey languages were used in the groups, translations could have potentially changed the item meaning. Certain formulations might also be interpreted differently in different cultural contexts, even if stated in the same language. The resulting potential variability of the measured constructs would preclude collapsing the data across subsamples. We first tested for configural invariance, which assumes that the factorial structure is consistent across groups, but in which all model parameters are free to vary across groups. Next, we evaluated metric invariance by constraining measurement weights to be uniform across groups. Establishing metric invariance is often considered as a prerequisite for meaningful comparisons of relationships between latent variables. When metric invariance is achieved, observed differences reflect actual variations in the constructs rather than differences in group responses. Following the recommendations by Rutkowski and Svetina (2014, 2017) for large-scale data, we generally accepted the assumption of invariance when the introduction of invariance constraints resulted in a model fit loss of ΔCFI $\geq -.020$ and ΔRMSEA $\leq .030$.

Our main statistical analyses were suited to the hierarchical data structure, which involved students nested within teacher clusters and those grouped by their respective countries. To address this structure, we employed a latent multilevel SEM with a multigroup approach. This allowed us to treat each country as a distinct group while maintaining the two-level structure of students nested within teacher clusters. By applying multigroup multilevel SEM, we effectively managed the nested data and captured variances both within and across country groups.

Following Pekrun and Goetz's (2023) assumption of relative universality, we propose that relations are similar across all countries sampled in the GTI. To test this assumption, we conducted a competitive model allowing structural weights to vary freely across countries. We compared model fit across the model constraining structural weights to be equal across countries with the model allowing them to vary freely using chi-square difference tests and differences in classic fit indices.

We conducted latent multigroup multilevel SEMs using maximum likelihood estimation to test the hypothesized mediation model. Assuming relative cultural universality, we constrained the structural weights for those models to be equal across all eight groups. Model fit was evaluated using robust model fit indices, which account for nonnormality (Brosseau-Liard et al., 2012; Savalei, 2018). The models at Level 1 (students) included student-perceived teaching quality and student outcomes in mathematics. At Level 2 (teachers/classes), models incorporated teacher emotions and class-aggregated Level 1 variables (teaching quality indicators and student outcomes in mathematics) using multiple indicators for each construct (except for student performance, which was integrated using the mathematics test's IRT scores). We report and interpret parameters on Level 2, as our key mediation hypothesis pertains to this level only. Unfortunately, we encountered convergence problems when employing FIML to address missing data in the latent multigroup multilevel SEM analyses; therefore, we opted for using listwise deletion.

We argue that listwise deletion did not notably bias the results for two reasons. First, the level of missing data was tenable. No more than 10% of the available 15,990 teacher–student tandems who participated at the measurement point of interest for the present analyses demonstrated partial item-level missingness—specifically, 8.7% in the enjoyment model ($N = 14{,}602$) and 8.9% in the anger model ($N = 14{,}564$). Methods for handling missing data, such as FIML, are particularly relevant for data sets with more than 10% missing data, whereas smaller amounts of missing data are unlikely to lead to significant practical differences, as outlined in Newman's (2014) guidelines for handling missing data. Second, we are confident that the bias associated with the listwise deletion approach was minimal, which we confirmed through a class-level mean comparison of observed mean estimates both before and after listwise deletion, which showed no significant differences.

Transparency and Openness

This study utilized secondary data and the respective materials from the GTI study (OECD, 2020a), which was openly accessible at the time of our analyses (https://www.oecd.org/en/about/projects/global-teaching-insights.html). The design and analysis plan for the present study were not preregistered. All analyses were conducted using *RStudio* (Posit team, 2025), and the complete syntax for these analyses is available in the trusted repository OSF (https://osf.io/sxhnd; Pfeifer et al., 2025). All models were performed using *lavaan* (Rosseel, 2012). We have used ChatGPT-4 to improve the readability and language of the article (OpenAI, 2025). The content has been thoroughly reviewed and edited where necessary; therefore, we take full responsibility for the content of the published article.

Results

All variables showed weak to moderate correlations within and between clusters (see Table 1). Multivariate normality analyses using the Shapiro–Wilk and Kolmogorov–Smirnov tests revealed violations of normality assumptions across all variables, necessitating robust estimators in subsequent analyses.

Measurement Invariance Testing

We conducted measurement invariance tests to ensure equivalence across the eight participating groups (i.e., countries): Chile, China, Colombia, Germany, Japan, Mexico, Spain, and the United Kingdom. Based on theoretical assumptions and the data structure,

we anticipated configural invariance, indicating a consistent factorial structure across groups, and metric invariance, signifying equivalent measurement weights across groups. According to Rutkowski and Svetina's recommendations (2014, 2017), no major discrepancies emerged between the configural and metric model specifications for the separate constructs, apart from the CFI threshold for teacher anger, suggesting that overall metric invariance could be assumed across groups (see Table 3). This supported our assumption that the self-report instruments demonstrated equivalent measurement functionality across all eight participating counties and their languages.

Multigroup Multilevel SEM

After confirming measurement invariance, we specified two separate latent multigroup multilevel SEMs for teacher enjoyment and teacher anger, further assuming structural invariance across country groups. The results indicated sufficient fit for both models. For teacher enjoyment, the fit indices were χ^2_{scaled} (5,511, N = 14,602) = 22,536.11, $p_{scaled} < .001$, CFI_{robust} = .91, TLI_{robust} = .90, $RMSEA_{robust}$ = .04, $SRMR_{within}$ = .07, $SRMR_{between}$ = .15. For teacher anger, they were χ^2_{scaled} (5,511, N = 14,564) = 22,939.62, $p_{scaled} < .001$, CFI_{robust} = .91, TLI_{robust} = .90, $RMSEA_{robust}$ = .04, $SRMR_{within}$ = .07, $SRMR_{between}$ = .15.

To evaluate the tenability, there is a substantive similarity across countries; we created two models where the constraints on structural weight were released, allowing them to vary freely across the eight country groups. For teacher enjoyment, the fit indices for the released model were χ^2_{scaled} (5,322, N = 14,602) = 21,691.21, $p_{scaled} < .001$, CFI_{robust} = .91, TLI_{robust} = .91, $RMSEA_{robust}$ = .04, $SRMR_{within}$ = .05, $SRMR_{between}$ = .12. The change in fit from the invariant model was $\Delta\chi^2_{scaled}$ (189, N = 14,602) = 844.90, $p < .001$, with $\Delta CFI_{robust} = -.004$, $\Delta TLI_{robust} = -.001$, $\Delta RMSEA_{robust} < .001$, $\Delta SRMR_{within}$ = .013, and $\Delta SRMR_{between}$ = .032. For teacher anger, the fit indices for the released model were χ^2_{scaled} (5,322, N = 14,564) = 22,120.42, $p_{scaled} < .001$, CFI_{robust} = .91, TLI_{robust} = .90, $RMSEA_{robust}$ = .04, $SRMR_{within}$ = .05, $SRMR_{between}$ = .12. When compared with the invariant model, the changes were $\Delta\chi^2_{scaled}$ (189, N = 14,564) = 819.20, $p < .001$, with $\Delta CFI_{robust} = -.004$, $\Delta TLI_{robust} = -.001$, $\Delta RMSEA_{robust} < .001$, $\Delta SRMR_{within}$ = .012, and $\Delta SRMR_{between}$ = .025.

Although the release of structural weight invariance resulted in a significant loss of model fit as indicated by the chi-square difference test, the overall impact on model fit remained minimal when assessed using all other fit index comparisons. Given the complexity of our model and the large number of structural weights released simultaneously, it is not surprising that the chi-square difference test was significant. An inspection of the freely estimated structural weights across the eight countries showed considerable variability; however, the overarching patterns remained clearly comparable (see Supplemental Material for a detailed report).

Table 3
Measurement Invariance Results Using Separate Multigroup Multilevel CFAs per Construct

Model	*df*	χ^2	*p*	CFI	TLI	RMSEA	$SRMR_{within}$	$SRMR_{between}$
Enjoyment								
Configural	16	35.33	.004	.983	.949	.122	.022	
Metric	37	74.43	<.001	.967	.957	.112	.079	
ΔMetric-configural	21	39.10	.010	−.016	.008	−.010	.057	
Anger								
Configural	16	52.07	<.001	.965	.896	.168	.036	
Metric	37	100.24	<.001	.939	.921	.146	.095	
ΔMetric-configural	21	48.17	.001	−.026	.025	−.022	.059	
Classroom management								
Configural	144	5,784.30	<.001	.824	.706	.142	.079	.110
Metric	214	6,115.86	<.001	.815	.793	.119	.080	.084
ΔMetric-configural	70	331.56	<.001	−.009	.087	−.023	.001	−.026
Teacher–student relationship								
Configural	80	852.79	<.001	.984	.968	.070	.021	.017
Metric	136	1,031.75	<.001	.981	.978	.058	.023	.019
ΔMetric-configural	56	178.96	<.001	−.003	.010	−.012	.002	.002
Cognitive activation								
Configural	32	265.86	<.001	.981	.944	.061	.022	.044
Metric	74	490.95	<.001	.967	.957	.054	.030	.079
ΔMetric-configural	42	255.09	<.001	−.014	.013	−.007	.008	.035
Self-efficacy								
Configural	80	606.33	<.001	.989	.979	.058	.018	.025
Metric	136	932.77	<.001	.984	.981	.054	.023	.030
ΔMetric-configural	56	326.43	<.001	−.005	.002	−.004	.005	.005
Interest								
Configural	32	1,272.49	<.001	.960	.880	.140	.036	.040
Metric	74	1,534.08	<.001	.953	.939	.100	.040	.036
ΔMetric-configural	42	261.60	<.001	−.007	.059	−.040	.004	−.004

Note. Configural invariance describes equal factor structure across groups. Metric invariance describes equal factor loadings in addition to this, allowing for comparisons of how constructs relate to one another across groups. Rutkowski and Svetina (2014, 2017) recommend the following cutoff values $\Delta CFI \geq -.020$ and $\Delta RMSEA \leq .030$. CFI = comparative fit index; TLI = Tucker–Lewis index; RMSEA = root-mean-square error of approximation; SRMR = standardized root-mean-square residual.

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Consequently, we concluded that our assumptions were robust over and above cultural influences; thus, we could proceed with the model that set both measurement and structural weights to equality across all eight groups.

Below, we report the results from these two separate latent multigroup multilevel SEMs for teacher enjoyment and anger. We first present the associations between indicators of teaching quality and student outcomes in mathematics. Next, we report the links between teacher emotions, enjoyment and anger, and student-rated teaching quality. Last, we report the results for our key mediational hypothesis, assuming a mediational link between teacher emotions and student outcomes via indicators of teaching quality.

Linking Teaching Quality and Student Outcomes

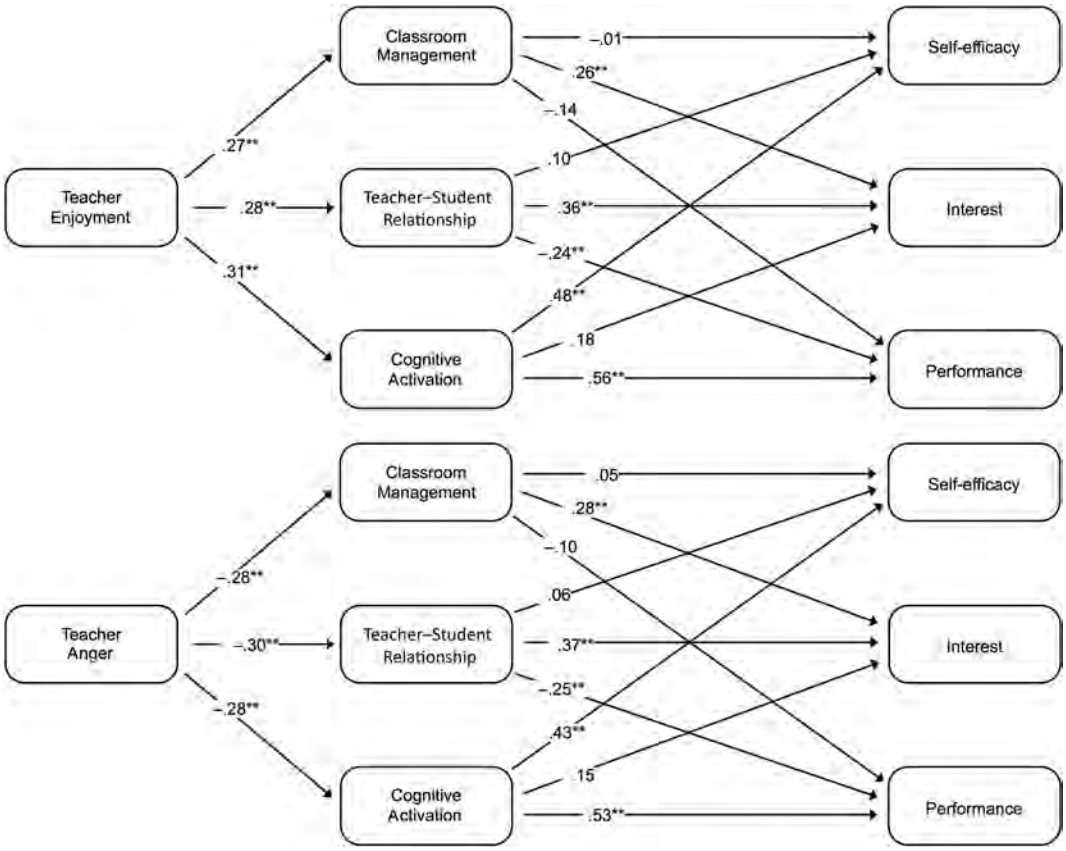
Generally, our results reflected earlier findings in terms of positive associations between the three teaching quality indicators (classroom management, supportive teacher–student relationships, and cognitive activation) and student outcomes in mathematics (self-efficacy, interest, and mathematics performance) in both the teacher enjoyment and anger model (see Figure 1). Classroom management was weakly but positively linked to student interest (enjoyment/anger: $\beta = .26/.28$, $ps < .01$); however, it had no significant direct effect on either student self-efficacy or performance. Supportive teacher–student relationships demonstrated a moderately sized positive effect on student interest (enjoyment/anger: $\beta = .36/.37$, $ps < .01$) and a counterintuitive negative effect on student performance (enjoyment/anger: $\beta = -.24/-.25$, $ps < .01$); the latter potentially originates in multicollinearity. No significant link was observed between supportive teacher–student relationships and student self-efficacy (see Table 4). Last, cognitive activation, as rated by students, showed a considerable and significant association with student self-efficacy (enjoyment/anger: $\beta = .48/.43$, $ps < .01$), and performance (enjoyment/anger: $\beta = .56/.53$, $ps < .01$); however, cognitive activation had no significant effect on student interest (see Table 4).

Linking Teacher Emotions and Teaching Quality

We further posited that teacher emotions would be linked with their teaching quality. Specifically, we expected enjoyment to be positively associated with teaching quality indicators, whereas anger would exhibit a negative association. The results confirmed these expectations. Teachers who reported higher enjoyment during teaching were found to manage their classroom more effectively ($\beta = .27$, $p < .01$), had more supportive teacher–student

Figure 1

Results From Multigroup Multilevel SEMs for the Direct Effects Between Teacher Emotions and Teaching Quality Indicators, as Well as Between Teaching Quality Indicators and Student Outcomes



Note. SEM = structural equation modeling.
* $p < .05$. ** $p < .01$.

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Table 4

Results From Multigroup Multilevel SEMs for the Effects of Teaching Quality on Student Outcomes in the Enjoyment and Anger Models

Effect	Enjoyment model			Anger model		
	β	*SE*	*p*	β	*SE*	*p*
Classroom management						
On self-efficacy	–.01	.13	.96	.05	.13	.65
On interest	.26	.12	<.01	.28	.12	<.01
On performance	–.14	.10	.12	–.10	.09	.25
Teacher–student relationship						
On self-efficacy	.10	.12	.32	.06	.12	.52
On interest	.36	.11	<.01	.37	.11	<.01
On performance	–.24	.09	<.01	–.25	.09	<.01
Cognitive activation						
On self-efficacy	.48	.17	<.01	.43	.17	<.01
On interest	.18	.15	.11	.15	.15	.16
On performance	.56	.12	<.01	.53	.12	<.01

Note. SEM = structural equation modeling.

relationships ($\beta = .28$, $p < .01$), and engaged more in cognitive activation practices ($\beta = .31$, $p < .01$). Conversely, teachers who reported higher anger demonstrated less effective classroom management ($\beta = -.28$, $p < .01$), less supportive teacher–student relationships ($\beta = -.30$, $p < .01$), and less cognitive activation practices ($\beta = -.28$, $p < .01$), as perceived by their students (see Figure 1).

Mediation Between Teacher Emotions, Teaching Quality, and Student Outcomes

For our key mediational hypothesis, we stated that teacher emotions would be indirectly linked with student outcomes via indicators of teaching quality. Mediation analyses within the multigroup multilevel SEM supported this hypothesis (see Table 5). First, classroom management was a significant mediator for the effect of both teacher emotions on student interest, with an indirect effect of .07 ($p = .01$) for enjoyment, and $-.08$ ($p < .01$) for anger. However, no significant mediation effects were found for classroom management on student self-efficacy or performance. Second, a supportive teacher–student relationship was a significant mediator for the effect of teacher emotions on student interest and performance. Specifically, the indirect effect via teacher–student relationship quality on student interest was .10 ($p < .01$) for enjoyment and $-.11$ ($p < .01$) for anger. The indirect effects from teacher emotions via teacher–student relationship on student performance reflected the pattern of the counterexpected negative links between teacher–student relationship quality and performance; it was $-.07$ ($p = .01$) for enjoyment and .07 ($p = .01$) for anger. Third, cognitive activation served as a significant mediator, positively linking teacher enjoyment to student outcomes in mathematics, with indirect effects of .15 ($p < .01$) on self-efficacy and .17 ($p < .01$) on performance. In contrast, teacher anger was indirectly and negatively associated with student outcomes through cognitive activation, demonstrating significant indirect effects of $-.12$ ($p < .01$) on self-efficacy and $-.15$ ($p < .01$) on performance. No significant mediation effect was observed for the link between teacher emotions and student interest via cognitive activation.

Notably, the three teaching quality indicators, in almost all cases, fully explained the effects of teacher enjoyment and anger on student outcomes. The only exception was a remaining direct, negative effect of teacher anger on student self-efficacy ($\beta = -.16$, $p < .01$), suggesting that other, additional mechanisms beyond the mediation via teaching quality may be at play here (see Table 5).

Table 5

Results From Multigroup Multilevel SEMs for the Indirect Effects of Teacher Enjoyment and Anger on Student Outcomes via Teaching Quality Indicators as Mediators

Mediator	Enjoyment			Anger		
	β	*SE*	*p*	β	*SE*	*p*
On self-efficacy						
Via classroom management	–.00	.04	.96	–.01	.04	.65
Via teacher–student relationship	.03	.04	.33	–.02	.04	.52
Via cognitive activation	.15	.06	<.01	–.12	.06	<.01
Remaining effect	.10	.07	.06	–.16	.07	<.01
On interest						
Via classroom management	.07	.04	<.01	–.08	.04	<.01
Via teacher–student relationship	.10	.04	<.01	–.11	.05	<.01
Via cognitive activation	.06	.05	.11	–.04	.04	.16
Remaining effect	–.03	.07	.49	.05	.07	.31
On performance						
Via classroom management	–.04	.03	.15	.03	.03	.26
Via teacher–student relationship	–.07	.03	.01	.07	.03	.01
Via cognitive activation	.17	.05	<.01	–.15	.05	<.01
Remaining effect	.07	.06	.16	–.08	.06	.11

Note. SEM = structural equation modeling.

Discussion

The present study, guided by the conceptual framework proposed by Frenzel et al. (2021), examined the direct and indirect relationships between teacher emotions—specifically, enjoyment and anger—indicators of teaching quality and student outcomes in mathematics. It focused on understanding the mediating role of teaching quality in these associations. To this end, data from the GTI study (OECD, 2020a) was used, involving several hundred mathematics teachers and their students from eight countries worldwide. Supporting the robustness of this international, multilanguage research endeavor, we also found evidence for measurement invariance for all constructs considered. Hence, in line with previous findings (Barroso et al., 2021; Fontaine et al., 2013; Frenzel et al., 2007; Loderer et al., 2020; Luszczynska et al., 2005), we found minimal evidence of systematic mis-conceptualizations in certain sample groups, suggesting that the items used to assess the constructs of teacher emotions, indicators of teaching quality, and student outcomes in mathematics were interpreted consistently across all language versions of the survey and across all cultural backgrounds sampled in this study.

Our results supported our key mediational hypothesis: Teachers' experiences of enjoyment and anger shape the quality of their instruction, which in turn is linked with student self-efficacy beliefs, interest, and performance in mathematics. Below, we first address our baseline assumption that the established relationship between teaching quality and student outcomes can be replicated in our data. We then discuss how teacher emotions and indicators of teaching quality are related and finally elaborate on the

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relationship of teacher emotions and student outcomes with the mediating role of teaching quality—our key mediational hypothesis. We conclude by discussing the intricate details of this mediational chain and address the relative universality of these mechanisms across the highly culturally diverse countries sampled in the present study.

Associations Between Teaching Quality and Student Outcomes

We proposed a direct association between teaching quality and student outcomes. Extensive research has investigated the effects of teaching quality indicators, such as classroom management, supportive teacher–student relationships, and cognitive activation (Bardach et al., 2022; Burić & Frenzel, 2023; Fauth et al., 2014; Hattie, 2008; Kunter et al., 2007; Kyriakides et al., 2013; Perry et al., 2007; Seidel & Shavelson, 2007). Our results align with this research, indicating that high teaching quality enhances student academic outcomes. Specifically, students in well-managed classrooms also showed higher interest in mathematics, indicating that effective classroom management and clear instructions benefit students' interest development (Kunter et al., 2007).

Likewise, supportive teacher–student relationships emerged as conducive to student's interest in mathematics. In fact, this supports previous research, stating that caring, supportive interpersonal relationships foster student engagement (Klem & Connell, 2004). However, contrary to previous findings, we found no evidence of positive linkages neither between classroom management and student self-efficacy (Eshel & Kohavi, 2003) and performance (Chen, 2019; Yan et al., 2011), nor between supportive teacher–student relationships and self-efficacy (Ryan & Grolnick, 1986; Teven & McCroskey, 1997). In contrast, our results even implied a negative link between supportive teacher–student relationships and student performance.

Nonetheless, we found substantial effects between cognitive activation and student self-efficacy and performance. Specifically, our results support the proposition that cognitive activation stimulates thinking, fosters deep engagement, and encourages exploring complex concepts and ideas (Klieme et al., 2009), and that mastering complex mathematics tasks can boost students' self-efficacy. Despite this finding, students who perceived their teachers as providing cognitively activating lessons performed better on standardized mathematics tests. In other words, students who engaged more deeply with the subject matter and developed a more thorough conceptual understanding were better able to handle the tasks. Yet, in contrast to previous research—such as findings in the subject of biology (Förtsch et al., 2017)—cognitive activation did not significantly enhance students' interest in our study.

However, given that cognitive activation shared considerable variance with the other two teaching quality indicators, it might be that cognitive activation captured the variance in the student outcome variables (i.e., performance), rendering the predictive value of the other teaching quality indicators low, and potentially even leading to suppression effects resulting in negative partial effects of supportive teacher–student relationships on student performance. Yet another potential explanation of this might be evocative effects from student characteristics back on the teaching behavior: When teachers perceive that their students are struggling with a topic, this perception may prompt them to adjust their teaching strategies and increase social support with the aim to foster student performance (Frenzel et al., 2021; Nurmi & Kiuru, 2015). Likewise, teachers may more easily and frequently apply cognitively activating instruction in classes that show a high level of subject performance. Nevertheless, a seemingly counterintuitive association may persist, in which a positive teacher–student relationship coexists with comparatively low academic performance.

Association Between Teacher Emotions and Teaching Quality

We further expected that teacher emotions are linked with teaching quality, explicitly arguing that teacher enjoyment should be positively associated with classroom management, supportive teacher–student relationships, and cognitive activation. In contrast, teacher anger was expected to be negatively associated with these three indicators of teaching quality. Our results indeed revealed consistent links between both teacher enjoyment and teacher anger, and all three indicators of student-rated teaching quality considered in the present study. To put it in another way, teachers who more strongly enjoy teaching mathematics in their classes are perceived as better teachers along all three teaching quality indicators. In contrast, teachers who experience more anger in their day-to-day teaching are perceived as demonstrating poorer classroom management, creating less supportive teacher–student relationships, and being less engaged in cognitive activation. In their broaden-and-build-theory, Fredrickson and Branigan (2005) posited that individuals experiencing positive emotions have a broadened thought-action repertoire, prompting teachers to engage in more beneficial teaching quality. In contrast, teachers' negative emotional experiences may limit their resourceful teaching quality. Our findings contribute to existing research also pointing toward positive links between positive teacher emotions, or more general affective teacher well-being, and teaching quality indicators, and a negative link between negative teacher emotions, or teacher ill-being, and teaching quality indicators (Burić & Frenzel, 2023; Frenzel, Goetz, Stephens, et al., 2009; Klusmann et al., 2008, 2022; Kunter et al., 2008). Although obviously other predictors also shape teaching quality, our results indicate that teacher emotions may be an underestimated predictor in teaching quality research.

This is particularly relevant as teaching quality is a primary predictor of student academic outcomes, as addressed in our baseline assumption. Therefore, it is essential to holistically investigate the potential mediating effect of teaching quality in linking teacher emotions to student outcomes, as outlined in detail in Frenzel et al. (2021).

The Full Mediational Chain From Teacher Emotions, via Teaching Quality, on Student Outcomes

For our key hypothesis, we evaluated the conceptual framework proposed by Frenzel et al. (2021), which suggests that teacher emotions are linked to student outcomes, with teaching quality indicators acting as mediators. Teacher emotions were associated with classroom management effectiveness, supportive teacher–student relationships, and cognitive activation, and additional mediational effects on student outcomes in mathematics. Specifically, teachers who report higher levels of enjoyment were more effective in their classroom management and provided more

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supportive teacher–student relationships, which positively shaped their students' interest. Conversely, angry teachers seemed to undermine their students' interest due to less effective classroom management and building less supportive relationships with their students. This suggests that an emotionally more positive teacher tends to manage their classroom environment more effectively, thus allowing more time on task and making room for the development of student interest in the subject (Rakoczy et al., 2007; Seidel & Shavelson, 2007).

Furthermore, our results underscored the significant role of teacher–student relationships as a mediator of the link between teacher emotions and student interest. Consistent with previous research, we found that teacher enjoyment seems to foster supportive teacher–student relationships, in turn enhancing student interest (Frenzel, Goetz, Lüdtke, et al., 2009; Frenzel, Goetz, Stephens, et al., 2009; Hagenauer et al., 2015; Klieme et al., 2009). In contrast, anger goes in line with less favorable teacher–student relationships, negatively impacting student interest. This pattern resonates with insights brought forward in the context of attachment theory, which suggests that the presence of a "safe haven" through supportive interpersonal relationships fosters exploration, whereas conflictual relationships may inhibit risk-taking and deep engagement (Birch & Ladd, 1997). Similarly, our findings seem to align well with principles from self-determination theory, particularly the idea that the need for relatedness—alongside competence and autonomy—supports the development of intrinsic motivation (Deci & Ryan, 1985; Kunter et al., 2007).

Moreover, our findings indicated that teachers' use of cognitive activation is relevant for linking teacher enjoyment and anger to student outcomes in mathematics, specifically self-efficacy and performance. Teachers' enjoyment is indirectly linked with higher student self-efficacy and performance in mathematics, as these teachers follow a more cognitively activating approach to instruction. On the same principle, students of angry teachers showed reduced self-efficacy and performance in mathematics.

This underscores the significance of teachers' emotions on their instructional practices, thereby impacting student outcomes in mathematics. Our results show that teachers experiencing enjoyment are more likely to employ intellectually stimulating methods that enhance student critical thinking, that is, cognitive activation (Fredrickson, 2001; Fredrickson & Branigan, 2005). In our sample, this resulted in increased self-efficacy and performance in mathematics among students of teachers with higher levels of enjoyment, suggesting that such teachers foster beneficial self-efficacy beliefs and performance by cognitively engaging their students.

In contrast, angry teachers might act more authoritatively and less patiently in class. Prior research indicates that anger can narrow instructional focus, leading to reliance on rote learning and control-oriented instead of cognitively activating strategies, maybe even creating a hostile classroom atmosphere that discourages participation and inquiry. This results in students feeling less capable, negatively affecting performance, as our data suggest. Angry teachers, thus, hinder students' development of self-efficacy beliefs and performance by failing to engage them cognitively. In sum, our data support the claims by Frenzel, Goetz, Stephens, et al. (2009) that teacher emotions significantly impact how engaging and intellectually stimulating learning environments are, which in turn affects students' cognitive development and academic achievement.

In consequence, angry teachers can become trapped in a vicious cycle: Their anger-implied compromised teaching quality leads to poorer student outcomes, which teachers appraise as an indication of failing their teaching goals, further fueling their frustration and anger. Conversely, teachers who experience enjoyment frequently may enter a virtuous cycle, with their enjoyment-driven high teaching quality producing desirable student outcomes, which teachers appraise as success at reaching their teaching goals, further strengthening their positive emotions, including joy and pride. Such reciprocal emotional dynamics highlight the complex interplay of teacher emotions and student outcomes in the classroom (Frenzel et al., 2021). To optimally inform effective teacher training that enhances both emotional well-being and educational quality, future studies should systematically investigate the temporal relationships between teacher characteristics—such as emotions, enthusiasm, motivation, communication style, and teaching quality—and a broad range of student outcomes above and beyond those addressed in the present contribution.

In our data, neither classroom management nor supportive teacher–student relationships functioned as effective mediators linking teacher enjoyment and anger to student self-efficacy and performance. The complexity of our model, which included multiple mediation regressions instead of simpler multiple regression models without mediating effects, could have contributed to the observed nonsignificant effects. However, the results of Waldis et al. (2010), who analyzed data from the Trends in International Mathematics and Science Study (TIMSS 1999), paint a similar picture to ours: Like in our study, cognitive activation was significantly associated with student performance, and classroom management correlated with student interest but not performance. However, in contrast to our findings, they also reported a significant link between cognitive activation and student interest. In addition, the data underscore the comparatively greater importance of cognitive activation—both in terms of statistical significance and effect size—compared with classroom management and supportive teacher–student relationships in explaining student outcomes in mathematics (Dorfner et al., 2018; Fauth et al., 2014).

In conclusion, teachers who experience enjoyment tend to manage their classrooms more effectively, build more supportive teacher–student relationships, and use more cognitively activating teaching practices, which in turn foster higher self-efficacy, interest, and performance in mathematics among their students. Conversely, students taught by more angry teachers show lower self-efficacy, interest, and performance.

Are Classroom Dynamics Universal Across the Globe?

This study examined the mediational relationships between teacher emotions, teaching quality indicators, and student outcomes in mathematics across eight countries with considerably differing cultural backgrounds. This allowed us to test the notion of the relative universality of classroom dynamics, proposed by Pekrun and Goetz (2023). They suggested that although variable means (e.g., reported levels of emotions) may vary across cultural contexts, the underlying mechanisms connecting these variables remain largely consistent. Our findings provided some support for this claim: Although the highly sensitive chi-square test signaled significant loss of fit upon constraining all structural weights to

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equality across the eight country subsamples, model fit loss based on classical fit indices was in fact minimal in comparison to the constrained model. Overall, we thus propose that the relationships among teacher emotions, indicators of teaching quality, and student outcomes can be considered largely similar. Future research may dig deeper into potential country-specific peculiarities of those links. The detailed results for the freely estimated structural weights across all eight countries are made available (see Supplemental Material).

Limitations and Future Research

This study has several limitations that should be considered when interpreting the findings. First, the cross-sectional design limits its causal inferences, as it captures associations between teacher emotions, indicators of teaching quality, and student outcomes assessed at a single point in time. The present contribution focused on exploring the theoretically plausible mediational path from teachers' emotions, via their teaching quality, to student outcomes in mathematics. However, given the correlational nature of the present data, the pattern of findings might also have been driven by opposite-ordered effects, hence effects of students on teachers' behavior and emotions. Overall, dynamic recursive links across these variables also seem highly plausible and have explicitly been proposed by Frenzel et al. (2021). Particularly, teacher's appraisals regarding classroom events and student behaviors likely play a decisive role in forming their emotions and should be taken into account in future studies. Using longitudinal data, Burić and Frenzel (2023) have provided the first evidence for such potential reciprocal effects between teachers' emotions and their teaching quality. Their findings revealed that teacher emotions at the beginning of the school year predicted midterm teaching behavior, which in turn predicted teacher emotions at the end of the school year, even after controlling for beginning-of-year emotions. However, student outcomes were not considered in their study. Finally, third variables could have driven the observed covariations, including, but not limited to, context variables such as class size, or availability of instructional tools and general school supplies, which might have driven covariations across the variables. Future studies may dig deeper into such context variables and the temporal alignment of emotionally driven classroom dynamics to further deepen our understanding of correlational patterns across teacher variables, their instructional behavior, and student outcomes.

Future research should also consider additional mediators and covariates to better capture the complexity of classroom dynamics. For example, an enthusiastic teaching style has shown to be conducive to students' mastery goal orientation and their perceived social relatedness support (Frommelt et al., 2021), as well as to students' experiences of enjoyment and boredom (Bieg et al., 2022). Recent empirical findings further emphasize the relevance of teacher communion and agency for student competence (Frühauf, Koeppen, et al., 2025) and emotional experiences (Frühauf, Etzel, et al., 2025). Teacher enjoyment may also directly transmit to students through emotional contagion processes (Frenzel, Goetz, Lüdtke, et al., 2009; Frenzel et al., 2018, 2024). Furthermore, above and beyond the indicators of teaching quality considered in the present analyses, a range of other variables likely relevant for predicting the student outcomes, including learning task design, assessment strategies, as well as contextual personal variables such as students' own emotional states, self-discipline, peer support, or informal teacher–student interactions outside the classroom, and warrant closer examination in future studies.

Another limitation pertains to the fact that teacher emotions were measured through self-reports, which may be prone to biases such as social desirability or inaccurate recall. In addition, the sampling strategy and sample sizes across countries posed certain limitations. Specifically, the volunteer-based sampling in Germany and the smaller-than-expected samples in some countries may limit the generalizability of the findings. Future research could benefit from longitudinal designs, multimethod data collection, and larger samples per group to overcome the limitations of the present study. Moreover, it would be interesting to explore whether the findings can be replicated in student samples with students of other age groups and in domains other than mathematics.

Conclusions and Implications

In conclusion, this study provided new insights into the critical role of teacher emotions in shaping teaching quality and student outcomes. Although prior research has predominantly focused on the importance of high teaching quality for student academic outcomes, or directly explored links between teacher emotions and student outcomes, this study is among the first to show that teachers' emotional experiences during teaching play a central role in shaping teaching quality, specifically their classroom management, supportive teacher–student relationships, and cognitive activation, which in turn are linked with important student outcomes. These findings indicate that teacher emotions are not merely a byproduct of educational processes, but instead an active contributor. In other words, what we have previously understood as purely behavioral pathway from teaching quality to student outcomes can be better understood when viewed through an affective lens: It is the emotions teachers experience during teaching that make a difference for their teaching quality. Teachers who experience more joy are the ones who deliver high-quality instruction, and thus create more self-efficacious, interested, and better performing students. In contrast, teachers who are prone to anger tend to provide poorer instructional quality, and their students are less self-efficacious, less interested, and perform more poorly.

In practice, our findings underscore the need for structures that protect teachers' emotional well-being and equip them with evidence-based emotion regulation strategies, not only for the sake of their own occupational well-being but also for their teaching effectiveness and the self-efficacy, interest, and performance of their students. For example, education systems and schools can reduce avoidable job stressors—especially for teachers experiencing high strain—and offer programs that support teachers' emotional resources, such as mindfulness-based interventions that have been shown to reduce occupational stress and burnout among teachers (Roeser et al., 2013). Burić and Frenzel (2019) argued that understanding the contextual triggers and dynamics of teacher anger can inform professional development programs designed to strengthen teachers' emotion regulation, support their well-being, and promote more constructive responses to challenging classroom situations. The psychological processes identified in the present contribution—emotions of individuals in educating roles driving their behavior, with downstream effects on learners—likely also apply to learning contexts beyond school, such as

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educational centers and families. For example, recent work has linked negative parental emotions during homework support to more controlling practices, with implications for student academic outcomes (Cohen et al., 2024). This suggests that comparable patterns exist across formal and informal learning contexts.

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