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# Control-value theory in the context of teaching: does teaching quality moderate relations between academic self-concept and achievement emotions?

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**Background.** Students' self-concept of ability is an important predictor of their achievement emotions. However, little is known about how learning environments affect these interrelations.

**Aims.** Referring to Pekrun's control-value theory, this study investigated whether teacher-reported teaching quality at the classroom level would moderate the relation between student-level mathematics self-concept at the beginning of the school year and students' achievement emotions at the middle of the school year.

**Sample.** Data of 807 ninth and tenth graders (53.4% girls) and their mathematics teachers (58.1% male) were analysed.

**Method.** Students and teachers completed questionnaires at the beginning of the school year and at the middle of the school year. Multi-level modelling and cross-level interaction analyses were used to examine the longitudinal relations between self-concept, teacher-perceived teaching quality, and achievement emotions as well as potential interaction effects.

**Results.** Mathematics self-concept significantly and positively related to enjoyment in mathematics and negatively related to anxiety. Teacher-reported structuredness decreased students' anxiety. Mathematics self-concept only had a significant and positive effect on students' enjoyment at high levels of teacher-reported cognitive activation and at high levels of structuredness.

**Conclusions.** High teaching quality can be seen as a resource that strengthens the positive relations between academic self-concept and positive achievement emotions.

Students' achievement emotions are important antecedents of successful learning processes, as they are closely related to students' performance, self-regulation, and learning strategies (Isen & Reeve, 2005; Pekrun, Goetz, Daniels, Stupnisky, & Perry, 2010; Pekrun & Stephens, 2010). According to control-value theory (Pekrun, 2006), achievement emotions are defined as emotions tied to achievement activities or achievement outcomes. Of particular relevance for students' educational and occupational pathways are enjoyment and anxiety – students who enjoy working on tasks in a specific domain tend to strive for occupations in these domains (Chow, Eccles, & Salmela-Aro, 2012;

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Eccles, 2005; Lazarides, Dicke, Rubach, & Eccles, 2019), whereas students who perceive high emotional costs of engagement in certain domains report low levels of career plans in these domains over and above their achievements (Watt, Bucich, & Dacosta, 2019). An important antecedent of students' achievement emotions is their academic self-concept (Pekrun, 2006). Functioning as a motivational resource, academic self-concept positively relates to enjoyment and negatively relates to anxiety in achievement situations (Goetz, Cronjaeger, Frenzel, Lüdtke, & Hall, 2010; Goetz *et al.*, 2012). On a theoretical level, control-value theory (Pekrun, 2006) and previous empirical work (Frenzel, Pekrun, & Goetz, 2007b; Lazarides & Buchholz, 2019; Wagner *et al.*, 2016) reveal that both students' expectations about success (e.g., academic self-concept) and their achievement emotions (e.g., enjoyment, anxiety) are predicted by the characteristics of instruction. However, we know little about how characteristics of instruction might enhance or reduce the effects of students' academic self-concept on their achievement emotions. Such studies would help clarify under which conditions of the learning environment students could benefit from high competence beliefs. Our study builds up on previous empirical work that links the constructs of achievement emotion and self-concept (Pekrun, Murayama, Marsh, Goetz, & Frenzel, 2019). We extend previous work by examining relations between academic self-concept and achievement emotions, and by investigating whether dimensions of teaching quality moderate these relations. We focus on the domain of mathematics because students' enjoyment in this domain declines particularly during adolescence (Watt, 2004).

### **Motivational-affective processes in class**

According to control-value theory of achievement emotions (Pekrun, 2006; Pekrun, Frenzel, Goetz, & Perry, 2007), achievement emotions are differentiated into *activity emotions*, such as enjoyment, frustration, and boredom experienced during achievement activities, and *outcome emotions*, such as joy, hope, pride, anxiety, hopelessness, shame, and anger related to achievement outcomes (Pekrun & Stephens, 2010). Control-related and value-related appraisals are proposed to be primary sources of students' academic emotions. Control appraisals refer to causal expectancies (i.e., self-efficacy expectations and outcome expectancies), causal attributions of achievement, and competence appraisals (i.e., academic self-concept) (Pekrun & Stephens, 2010). Enjoyment as a positive activity emotion is, for example, assumed to be triggered by a high level of perceived competence combined with positive task-related value beliefs (Pekrun & Stephens, 2010). Anxiety, defined as a prospective outcome emotion, is, for example, assumed to be triggered when the perceived controllability of success and failure is low but the perceived value is high (Pekrun, 2006; Pekrun & Stephens, 2010). A critical indicator of competence appraisals is an individual's academic self-concept (Pekrun, Goetz, Titz, & Perry, 2002). Academic self-concept is broadly defined as the self-perception of one's own general ability in a domain formed through experience with and interpretations of one's environment (Marsh & Martin, 2011; Shavelson, Hubner, & Stanton, 1976). Previous research within the framework of control-value theory has shown positive relations between students' individual academic self-concept and enjoyment as well as negative relations to anxiety (i.e., Goetz, Cronjaeger, *et al.*, 2010; Goetz *et al.*, 2012; Van der Beek, Van der Ven, Kroesbergen, & Leseman, 2017). Previous work has investigated relations between academic self-concept and achievement emotions mostly on the level of the individual student; however, other empirical work has also shown that academic self-concept is relevant for students' achievement emotions at the classroom level (Pekrun *et al.*, 2019). In this study, we examine relations

between academic self-concept and achievement emotions at the level of the individual student as well as at the classroom level. Based on control-value theory (Pekrun, 2000; Pekrun & Perry, 2014), we further examine how these relations at the individual level vary depending on characteristics of the instructional environment.

### **Teaching quality and achievement emotions**

Research has identified instructional characteristics that deliver information about the level of perceived competence, value, and controllability of learning activities. Such characteristics include the cognitive quality of tasks, value induction in instruction, autonomy support, classroom goal structures, teachers' presentation style, achievement-related feedback, competition, and punishment (Bieg *et al.*, 2017; Frenzel *et al.*, 2007b; Gläser-Zikuda & Fuß, 2008; Goetz, Lüdtke, Nett, Keller, & Lipnevich, 2013). Theoretical frameworks summarize these teaching characteristics in a number of broader quality dimensions (Klieme, Pauli, & Reusser, 2009; Pianta & Hamre, 2009). In their theoretical framework of generic dimensions of teaching quality, Klieme and colleagues (Klieme *et al.*, 2009) describe three basic dimensions of teaching quality: cognitive activation, classroom management, and a supportive climate. The theoretical framework is well established and empirically validated, as many studies have shown that the three proposed dimensions of teaching quality are substantially related to students' achievement and motivational-affective development (for an overview see Praetorius, Klieme, Herbert, & Pinger, 2018). Another internationally well-established framework of teaching quality is the CLASS conceptual framework for classroom interactions described by Pianta and Hamre (2009). The authors identify emotional support, classroom organization, and instructional support as dimensions of classroom interactions, which are closely linked to students' achievement (Allen *et al.*, 2013; Allen, Pianta, Gregory, Mikami, & Lun, 2011). Common to these theoretical frameworks is the requirement that effective teaching be characterized by clear and structured instruction and cognitively activating, stimulating tasks, materials, and discourse.

*Cognitive activation* can be understood as encouraging students to develop their own solutions and exploring their own way of thinking (Praetorius *et al.*, 2018). Teachers who aim to increase cognitive activation in their classrooms would provide challenging tasks to their students, refer to students' prior knowledge (Hiebert & Grouws, 2007), encourage students to find multiple solution ways (Baumert *et al.*, 2010), to generate own solution pathways, or to evaluate own and other's solutions or ideas (Stefanou, Perencevich, DiCintio, & Turner, 2004). Findings on the effects of student-perceived cognitive activation on students' achievement emotions are ambiguous. Some studies did not find significant relations between external ratings of cognitive activation (Kunter *et al.*, 2013) or student-rated cognitive activation (Schiepe-Tiska, Heine, Lüdtke, Seidel, & Prenzel, 2016) and students' enjoyment. Other empirical work (Fauth, Decristan, Rieser, Klieme, & Büttner, 2014) found positive effects of student-reported cognitive activation on students' interest in science, which is theoretically closely linked to enjoyment (Krapp, 2007; Schiefele, 2009). Regarding anxiety, previous work has suggested no significant relation to student-reported cognitive activation (Lazarides & Buchholz, 2019).

*Structuredness of instruction* be seen as an important facet of classroom management and describes a teacher's ability to prepare students for the lesson content and learning goals, to communicate content and expectations comprehensibly, and to teach things in a

related, step-by-step manner (Cruickshank, 1985). Teachers who are described as well-structured by their students explain their expectations, guidelines, and lesson content in an understandable and clear manner (Klieme *et al.*, 2009). Classrooms in which students perceive their teachers as being able to clearly communicate the lesson content are characterized by high levels of student enjoyment of learning (Lazarides, Dietrich, & Taskinen, 2019; Maulana, Opdenakker, & Bosker, 2016) and by low levels of anxiety (Gläser-Zikuda & Fuß, 2008).

Besides of their direct effects on students' achievement emotions, it might also be possible that instructional characteristics interact with cognitive appraisals when affecting students' enjoyment and anxiety in achievement situations. Such theoretical assumptions were previously tested within the theoretical context of control-value theory (Pekrun, 2000; Pekrun & Perry, 2014). Goetz, Frenzel, Stoeger, and Hall (2010), for example, tested the moderating influence of situational characteristics (achievement vs. non-achievement settings) on the relation between control/value appraisals and positive emotions. Their findings revealed that the strength of the appraisal/positive emotion relations was equivalent across achievement vs. non-achievement settings. Westphal, Kretschmann, Gronostaj, and Vock (2018) tested the interaction between characteristics of students' cognitive appraisals and characteristics of the learning environment and showed that high levels of teacher diagnostic skills combined with high levels of academic self-concept were associated with high enjoyment. However, only little is known about the interactions between characteristics of the learning environment and cognitive appraisals and their relations to achievement emotions.

### **The present study**

This longitudinal study expands on previous research by examining whether theory-driven dimensions of teaching quality (Klieme, Lipowsky, Rakoczy, & Ratzka, 2006) predict achievement emotions and moderate the relation between academic self-concept and achievement emotions. We refer to control-value theory (Pekrun, 2006; Pekrun *et al.*, 2002) and investigate, based on previous empirical studies (Goetz, Frenzel, *et al.*, 2010; Westphal *et al.*, 2018), that have tested whether instructional characteristics moderated the relations between control cognitions and achievement emotions. In this study, we considered teachers' perceptions of instructional characteristics and student-reported achievement emotions to avoid common method bias.

We tested the following hypotheses:

*Hypothesis 1.* Referring to Pekrun's control-value theory (Pekrun, 2006), we expected that students' mathematics self-concept at the beginning of the school year would positively predict their mathematics enjoyment and would negatively predict their mathematics anxiety in the middle of the school year. We tested these relations on the level of the individual student as well as on the classroom level.

*Hypothesis 2.* Referring to previous empirical studies emphasizing the importance of structuredness of instruction (Gläser-Zikuda & Fuß, 2008; Maulana *et al.*, 2016) and cognitive activation (Fauth *et al.*, 2014) for students' achievement

emotions, we expected that teacher-reported structuredness and cognitive activation at the beginning of the school year would positively predict student-reported class-level enjoyment in the middle of the school year. We further assumed that teacher-reported structuredness at the beginning of the school year would negatively relate to class-level student-reported anxiety in the middle of the school year.

*Hypothesis 3.* Building on previous work within the context of control-value theory (Pekrun, 2006) that examined whether cognitive appraisals interact with characteristics of the learning environment (Goetz, Frenzel, *et al.*, 2010; Westphal *et al.*, 2018), we expected that the nature or strength of the relations between students' individual-level mathematics self-concept at the beginning of the school year and their individual-level achievement emotions in the middle of the school year would vary as a function of teacher-reported teaching quality. More specifically, we expected comparably stronger relations between students' individual mathematics self-concept and enjoyment in classrooms that are characterized by high levels of structuredness and high levels of cognitive activation.

We included gender, age, and immigration background as covariates in each model. Girls have been shown to report higher anxiety (Goetz, Bieg, Lüdtke, Pekrun, & Hall, 2013) and less enjoyment (Frenzel, Pekrun, & Goetz, 2007a) in mathematics than boys. Furthermore, students' enjoyment decreases and their anxiety increases as they get older (Hagenauer & Hascher, 2010; Vierhaus, Lohaus, & Wild, 2016; Watt, 2004). Previous studies have further indicated that students with an immigration background experience higher levels of academic anxiety (Gillen-O'Neel, Ruble, & Fuligni, 2011).

## Method

### Sample

Data from this study stem from the longitudinal [removed for reviewing purposes] study that examined the relations between mathematics teachers' beliefs, characteristics of instruction, and students' emotions and motivation. Participating schools were randomly selected, and data were assessed at the beginning of the 2015 school year (T1) and again in the middle of the school year (T2) in 2016 at the end of a compulsory class taught by trained research assistants. Surveys were administered at the end of the compulsory class and took approximately 20–25 min to complete. Before students filled out the questionnaires, research assistants briefly explained to them the purpose of the study. Students were informed that the study focused on affective and motivational development in school and instructional quality. No incentives were provided and students were informed before data collection that participation was voluntary. Teachers were present and filled out the teacher questionnaire during the assessment of student data.

For the present analysis, we analysed data from 807 ninth (47.8%) and tenth graders (52.0%) (age:  $M = 14.58$  years,  $SD = 0.91$ ; 53.4% girls; 51.8% academic-track schools; 69.7% German native speakers; 90.7% born in Germany) with available data from their mathematics teachers ( $N = 42$ ; 58.1% male; years of teaching experience:  $M = 21.54$ ,  $SD = 13.43$ , range: 2–43) from an original sample of  $N = 1117$  students. No additional socio-demographic data were available for the participating teachers. The students were

from 42 classrooms in 13 secondary schools in Germany. The students attended two types of schools: 54.9% attended a 'Gymnasium', which is the academic track in Germany, and 45.1 % attended an 'Integrierte Sekundarschule', which is a secondary school leading to various degree types, also including an academic track. Most students (67.4%) reported that they were native German speakers. In accordance with the local authorities' guidelines (Berlin Senate Administration for Education Youth & Science, 2013), no variables related to family background were assessed and parental consent was obtained for students who were younger than 14. All ethical requirements from the Berlin Senate Administration for Education Youth and Science were fulfilled.

### Measures

Besides the mathematics self-concept, all scales ranged from 1 (*strongly disagree*) to 5 (*strongly agree*). Mathematics self-concept also ranged from 1 to 5, with varying response formats for each item. All measures are validated instruments for German-speaking students and teachers. Information about construct validity can be obtained from the authors. The full list of items for each construct is provided in Appendix B.

#### Mathematics self-concept

Students' self-concept in mathematics was assessed with a 4-item scale based on the SESSKO developed by Schöne, Dickhäuser, Spinath, and Stiensmeier-Pelster (2002). Our short scale of the SESSKO captured each of the four SESSKO dimensions: criterial, individual, social, and absolute self-concept. The internal consistency of our short scale was good (beginning of the school year:  $\alpha_{t1} = .87$ ). An example item is 'In mathematics, I think I am. . .' with responses on a scale from 1 (*not talented*) to 5 (*very talented*). We tested the factorial structure of our measure before we conducted our analyses. The model fit of the confirmatory factor analysis was good,  $\chi^2(4) = 6.32$ , CFI = .99, TLI = .99, RMSEA = .029, SRMR = .008. We also tested retest reliability. Correlational analyses showed that mathematics self-concept at the beginning of the school year (T1) was positively and significantly correlated with mathematics self-concept at the middle of the school year (T2):  $r = .71, p < .001$ .

#### Cognitive activation

Teacher-reported cognitive activation in mathematics classrooms was operationalized as cognitive autonomy support based on Kunter *et al.* (2008) and assessed using a 3-item scale. Reliability was  $\alpha = .75$  (T1). An example item is 'I work on the basis of the students' suggestions and continue working until the students notice that something doesn't add up'.

#### Structuredness

Teacher-reported classroom management was operationalized through the clarity and structuredness of content and expectations in class. It was assessed with a 3-item scale based on Hertel, Hochweber, Mildner, Steinert, and Jude (2014). Reliability was  $\alpha = .62$  (T1). An example item is 'I explain in advance what I expect from the students'.



*Mathematics anxiety*

Anxiety was assessed with a 3-item scale based on Pekrun, Götz, and Perry (2005). Our anxiety measure refers to both the affective and cognitive components of students' anxiety. The affective component refers to feelings of nervousness, tension, and unpleasant physiological reactions (Wigfield & Meece, 1988) and is reflected in the item 'Because I am so nervous, I would rather not take mathematics exams'. The worry component referring to self-deprecatory thoughts about one's performance is reflected in the item 'In math I am worried that I comprehend less than all the others'. Reliabilities were  $\alpha = .81$  (T1) and  $\alpha = .79$  (T2).

*Mathematics enjoyment*

Students' enjoyment was assessed with a 4-item scale based on Pekrun *et al.* (2005). Reliabilities were  $\alpha = .90$  (T1) and  $\alpha = .90$  (T2). An example item is 'I look forward to mathematics lessons'.

*Covariates*

Students' gender was coded 0 if the respondent was a boy and 1 if a girl. Students' immigration background was assessed by asking which language the students had spoken at home in childhood and was coded as a dummy-coded variable (0 = native German speakers; 1 = German-as-a-second-language (GSL) speakers). The language spoken at home is one of various indicators for the assessment of immigration background (Stanat, 2006). Students were asked to report their age in years at time 1.

**Data analyses**

We examined how student achievement emotions in the middle of the school year (T2) were related to mathematics self-concept and teaching quality at the beginning of the school year (T1) when controlling for achievement emotions at T1. In the first step, we examined whether data from our subsample ( $n = 807$ ) of students whose mathematics teachers participated in our study systematically differed from student data in the full sample ( $N = 1117$ ) in terms of enjoyment, anxiety (T1 and T2) or self-concept (T1). Using a missing data variable coded as '1' for cases in the subsample and '0' for cases not in the subsample but in the full sample, we conducted independent *t*-tests. Results showed that students' achievement emotions and mathematics self-concept did not differ across samples. More detailed information is provided in Appendix C. Missing data mechanisms within the subsample we used were analysed using Little's MCAR test, which indicated that missing data on the outcome variables (enjoyment and anxiety) were not systematically missing,  $\chi^2(5) = 2.74, p = .740$ . We addressed missing data accordingly using full-information maximum likelihood (FIML) estimation. All analyses were conducted using maximum likelihood with robust standard errors and chi-square (MLR) values in Mplus Version 7 (Muthén & Muthén, 1998-2019). To assess the reliability of the aggregated student variables, intraclass correlations (ICC) were computed for all variables in the model (Raudenbush & Bryk, 2002). Table 1 reports the ICC values. An  $ICC_1$  value greater than .05 reveals that individual ratings are attributable to group membership (LeBreton & Senter, 2008). Although only 3% of the variance in student anxiety was attributable to classroom membership, we decided to retain the variable in

the analyses because it was central to our analyses. An  $ICC_2$  value above .70 indicates an acceptable reliability of class-mean ratings (Lüdtke, Robitzsch, Trautwein, & Kunter, 2009). The results of measurement invariance testing showed scalar measurement invariance for enjoyment and anxiety, indicating that the constructs were comparable at both time points (see Tables A1-A2 in Appendix A). We conducted doubly manifest multi-level regression analyses (Marsh *et al.*, 2012) and analysed separate models for each dimension of teaching quality because of the complexity of the estimated models. In the first step, we tested random intercept models to examine the hypothesized direct effects of mathematics self-concept at T1 on achievement emotions at T2. In the second step, we tested three random slope models to test the cross-level interaction effects of the three teaching characteristics (Bosker & Snijders, 1999). We used group mean centring for the predictor variables at the student level and grand mean centring for the predictors at the classroom level (Enders & Tofghi, 2007). In all the models, we controlled for achievement emotions at the beginning of the school year.

## Results

### *Descriptive statistics*

The descriptive statistics in Table 1 show that students reported moderate levels of enjoyment and anxiety in mathematics class. The results of the class-level correlations showed that students' enjoyment in the middle of the school year was significantly and positively associated with mathematics self-concept at the beginning of the school year. Teacher-reported structuredness of instruction in mathematics class was negatively and significantly correlated with mathematics anxiety. The correlations are reported in Table 2.

### *Mathematics self-concept and achievement emotions*

In line with our Hypothesis1, at the student level, mathematics self-concept at T1 was significantly and positively related to mathematics enjoyment at T2 ( $\beta = .23$ ,  $SE = .05$ ,  $p < .001$ ) when controlling for gender ( $\beta = .03$ ,  $SE = .05$ ,  $p = .50$ ), immigration background ( $\beta = -.06$ ,  $SE = .04$ ,  $p = .09$ ), age ( $\beta = .04$ ,  $SE = .04$ ,  $p = .25$ ), and

**Table 1.** Descriptive statistics: means, standard deviations, and intraclass correlation coefficients

	$M_{\text{Level 1}}$	$SD_{\text{Level 1}}$	$M_{\text{Level 2}}$	$SD_{\text{Level 2}}$	$ICC_1$	$ICC_2$
Enjoyment T1	2.61	1.06	2.52	0.26	.06	.56
Enjoyment T2	2.68	1.03	2.61	0.28	.08	.62
Anxiety T1	1.79	0.95	2.26	0.14	.03	.35
Anxiety T2	1.77	0.89	2.12	0.17	.04	.46
Self-concept T1	3.13	0.86	3.14	0.14	.03	.35
Cog Activ (T) T1	–	–	3.35	0.66	–	–
Structure (T) T1	–	–	4.09	0.49	–	–

Note.  $ICC_1$  and  $ICC_2$  = Intraclass correlation coefficients. T1 = First measurement occasion; T2 = Second measurement occasion; Cog Activ = Cognitive activation; Structure = Clarity and structuredness of instruction; (T) = Teacher-rated. All scales ranged from 1 (*strongly disagree*) to 5 (*strongly agree*).

**Table 2.** Intercorrelations of the study variables

Student level	1	2	3	4	5	6	7
1) Girl							
2) Age	-.05						
3) Immigrant	-.01	-.11***					
4) Enjoyment T1	-.14***	.05	.01				
5) Enjoyment T2	-.06	.04	-.02	.56***			
6) Anxiety T1	.15***	.07	.07*	-.31***	-.29***		
7) Anxiety T2	.06	-.05	.08	-.25***	-.32***	.43***	
8) Self-concept T1	-.17***	-.04	.01	.63***	.47***	-.45***	-.32***

Classroom level	1	2	3	4	5
1) Enjoyment T2					
2) Anxiety T2		-.24			
3) Self-concept T1 (T)		.53***	-.49		
4) Structuredness T1 (T)		-.21	-.48*	.07	
5) Cog Activ T1 (T)		-.18	-.12	.15	.22

Note. Cog Activ = Cognitive activation, Structuredness = Clarity and structuredness of instruction. T1 = First measurement occasion; T2 = Second measurement occasion; T = Teacher-reported.

\* $p < .05$ , \*\*\* $p < .001$ .

mathematics enjoyment at T1 ( $\beta = .43$ ,  $SE = .04$ ,  $p < .001$ ). Mathematics self-concept at T1 was, at the student level, negatively and significantly related to mathematics anxiety at T2 ( $\beta = -.18$ ,  $SE = .05$ ,  $p < .001$ ) when controlling for gender ( $\beta = -.02$ ,  $SE = .04$ ,  $p = .60$ ), immigration background ( $\beta = .04$ ,  $SE = .06$ ,  $p = .55$ ), age ( $\beta = -.09$ ,  $SE = .06$ ,  $p = .09$ ), and mathematics anxiety at T1 ( $\beta = .35$ ,  $SE = .05$ ,  $p < .001$ ).

At the classroom level, mathematics self-concept at T1 was significantly positively related to mathematics enjoyment ( $\beta = .47$ ,  $SE = .19$ ,  $p = .01$ ), but was not significantly related to mathematics anxiety at T2 ( $\beta = -.49$ ,  $SE = .26$ ,  $p = .06$ ). At the student level, the random intercept models explained 22% of the variance in anxiety and 37% of the variance in enjoyment at T2. At the classroom level, the random intercept models explained 22% of the variance in enjoyment and 24% of the variance in anxiety between classes at T2.

### **Does teaching quality predict and moderate the relation between mathematics self-concept and achievement emotions?**

Contrary to our expectations (Hypothesis 2), teacher-reported cognitive activation at T1 did not significantly relate to class-level achievement emotions. Teacher-reported structuredness at T1 was not significantly related to student-reported class-level enjoyment at T2. In line with our previous expectations, teacher-reported structuredness of instruction at T1 was significantly and negatively related to class-level anxiety at T2.

In line with our previous assumptions (Hypothesis 3), teacher-reported cognitive activation at T1 significantly moderated the student-level relation between mathematics self-concept at T1 and achievement emotions in mathematics class at T2. At low levels of teacher-reported cognitive activation, student-level mathematics self-concept

at T1 was not significantly related to student-level mathematics enjoyment ( $-1SD$ ;  $\beta = .13$ ,  $SE = 0.08$ ,  $p = .10$ ). At high levels of teacher-reported cognitive activation, student-level mathematics self-concept at T1 was positively and significantly related to student-level mathematics enjoyment ( $+1SD$ ;  $\beta = .38$ ,  $SE = 0.09$ ,  $p < .001$ ). Also in line with Hypothesis 3, teacher-reported structuredness of instruction at T1 significantly moderated the relation between student-level mathematics self-concept at T1 and mathematics enjoyment at T2. At low levels of teacher-reported structuredness of instruction, student-level mathematics self-concept at T1 was not significantly related to student-level mathematics enjoyment ( $-1SD$ ;  $\beta = .15$ ,  $SE = 0.08$ ,  $p = .08$ ). At high levels of teacher-reported structuredness of instruction, student-level mathematics self-concept at T1 was positively and significantly related to student-level mathematics enjoyment ( $+1SD$ ;  $\beta = .38$ ,  $SE = 0.07$ ,  $p < .001$ ). The coefficients of the random slope models are reported in Table 3 for teacher-reported cognitive activation and in Table 4 for teacher-reported structuredness. The cross-level interaction effects are depicted in Figure 1 for teacher-reported cognitive activation and in Figure 2 for teacher-reported structuredness.

## Discussion

This study expanded upon previous research on academic self-concept and achievement emotions (i.e., Goetz, Cronjaeger, *et al.*, 2010; Goetz *et al.*, 2012; Westphal *et al.*, 2018) by showing that teacher-reported teaching quality moderated the relation between students' mathematics self-concept and their enjoyment in mathematics. However, teacher-reported teaching quality was not found to moderate the relation between students' mathematics self-concept and their anxiety in mathematics.

**Table 3.** Unstandardized regression coefficients from the intercepts-and-slopes-as-outcomes model: cognitive activation

	Enjoyment T2			Anxiety T2		
	<i>B</i>	<i>SE</i>	<i>p</i>	<i>B</i>	<i>SE</i>	<i>p</i>
Student level						
Intercept	<b>.41</b>	<b>.04</b>	<b>&lt;.001</b>	<b>.36</b>	<b>.05</b>	<b>&lt;.001</b>
Age	.09	.05	.07	-.14	.08	.08
Girl	-.04	.08	.61	-.01	.08	.89
Immigrant background	<b>-.18</b>	<b>.08</b>	<b>.03</b>	.03	.13	.83
Classroom level: Random intercept						
Self-concept T1 (S)	<b>.55</b>	<b>.21</b>	<b>.01</b>	-.17	.18	.34
Cog Activ T1 (T)	-.06	.08	.43	.01	.06	.98
Classroom level: Random slope						
Self-concept T1 (S)	<b>-.39</b>	<b>.20</b>	<b>.05</b>	-.04	.16	.81
Cog Activ T1 (T)	<b>.12</b>	<b>.65</b>	<b>.03</b>	-.06	.04	.14

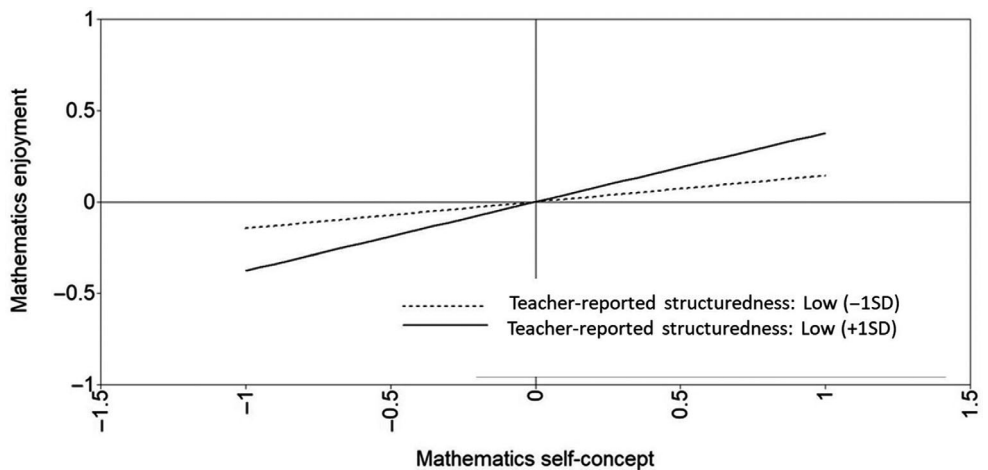
Note. T1 = First measurement occasion; T2 = Second measurement occasion; (S) = Student-rated; (T) = Teacher-rated; Cog Activ = Cognitive activation.

Relations that are significant at  $p \leq .05$  are depicted in bold.

**Table 4.** Unstandardized regression coefficients from the intercepts-and-slopes-as-outcomes model: structuredness

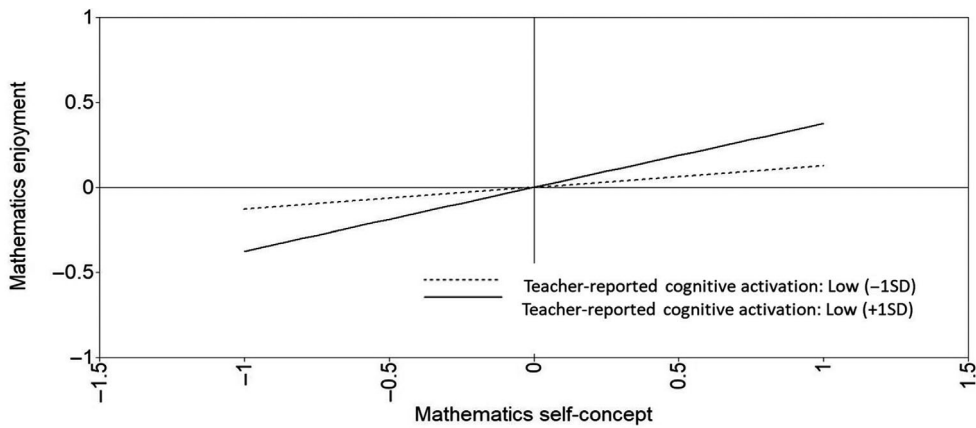
	Enjoyment T2			Anxiety T2		
	B	SE	p	B	SE	p
Student level						
Intercept	<b>.43</b>	<b>.04</b>	<b>&lt;.001</b>	<b>.33</b>	<b>.05</b>	<b>&lt;.001</b>
Age	.06	.05	.29	-.13	.04	.09
Girl	.04	.09	.65	-.04	.08	.65
Immigrant background	<b>-.15</b>	<b>.08</b>	<b>.05</b>	.07	.12	.57
Classroom level: Random intercept						
Self-concept T1 (S)	<b>.48</b>	<b>.21</b>	<b>.02</b>	-.23	.14	.11
Structuredness T1 (T)	-.02	.09	.84	<b>-.10</b>	<b>.05</b>	<b>.05</b>
Classroom level: Random slope						
Self-concept T1 (S)	-.25	.18	.16	-.05	.13	.68
Structuredness T1 (T)	<b>.12</b>	<b>.06</b>	<b>.04</b>	.01	.06	.94

Note. T1 = First measurement occasion; T2 = Second measurement occasion; (S) = Student-rated; (T) = Teacher-rated. Random intercept = Main effect of class-level self-concept and teacher-reported instruction on class-level achievement emotions. Random slope = Interaction effect of student-level academic self-concept with class-level teacher-reported instruction on student-level achievement emotions. Relations that are significant at  $p \leq .05$  are depicted in bold.

**Figure 1.** Cross-level interaction between teacher-reported cognitive activation and student-level academic self-concept predicting student-level enjoyment.

### Academic self-concept and achievement emotions

As expected (H1) and according to Pekrun's control-value theory (Pekrun, 2006), at the student level, mathematics self-concept was positively related to enjoyment in mathematics and negatively related to their anxiety. From a theoretical perspective, the relation between academic self-concept and achievement emotions is explained by the higher level of control over the achievement activities and outcomes that students perceive when feeling competent in a domain (Pekrun, 2006; Pekrun & Stephens, 2010). Control-value theory states that appraisals of control as implied by competence appraisals (e.g.,



**Figure 2.** Cross-level interaction between teacher-reported structuredness and student-level academic self-concept predicting student-level enjoyment.

self-concepts of ability) are important antecedents of emotions such as enjoyment (activity emotions) and anxiety (outcome emotions) (Pekrun & Stephens, 2010). In line with previous research (Goetz, Cronjaeger, *et al.*, 2010; Goetz *et al.*, 2012), our findings showed that students' individual mathematics self-concept was significantly related to their individual achievement emotions. At the classroom level, mathematics self-concept was substantially related to enjoyment in mathematics. This finding corresponds to those of previous work (Pekrun *et al.*, 2019) that also showed substantial relations between class-level self-concept and enjoyment and highlight the importance of group-level competence beliefs for positive emotions in class.

### **The role of teaching quality**

Our expectations about the substantial role of teaching quality in students' achievement emotions (H2) were only partially confirmed because only teacher-reported structuredness of instruction was negatively related to anxiety in class, whereas teacher-reported cognitive activation was not significantly related to students' achievement emotions. A possible theoretical explanation for our findings is provided by Klieme's framework of teaching quality (Lipowsky *et al.*, 2009) as well as by Deci and Ryan's self-determination theory (Deci & Ryan, 1985), both of which propose that particularly characteristics of the learning environment which enhance respectful and caring interactions between teachers and their students and which support students in their perceptions of competence should be relevant for students' motivation and emotion. Our findings suggest that teacher-reported structure of instruction might be, in that sense, relevant for students' feelings of competence and social relatedness, which in turn increase their enjoyment. Accordingly, Kunter, Baumert, and Köller (2007) found that student-perceived classroom management (rule clarity and monitoring) was positively related to students' satisfaction of intrinsic needs for autonomy, competence, and social relatedness, which in turn were positively related to students' interest in learning. However, further studies are needed that examine whether similar mediational processes can explain the positive relation between teacher reports of structuredness and students' positive emotions.

An important contribution of this study to previous work was the examination of whether theory-driven teacher-reported characteristics of teaching quality moderated the relation between student-level mathematics self-concept and achievement emotions. In line with our expectations (H3), we found that students' individual academic self-concept was only positively related to their individual enjoyment at high levels of teacher-reported cognitive activation and at high levels of teacher-reported structuredness. The contribution of this study to theory development is that our findings suggest that control cognitions and achievement emotions are not only predicted by characteristics of instruction as described in Pekrun's control-value theory (Pekrun, 2006), but that the relation between control cognitions, such as mathematics self-concept and students' achievement emotions, might vary depending on characteristics of the learning environment. Each dimension of teacher-reported teaching quality in class considered here interacted with students' mathematics self-concept in a way that strengthened the positive relation between mathematics self-concept and enjoyment.

Our expectations about moderating effects (Hypothesis 3) were, however, only partially confirmed, because the relation between academic self-concept and negative achievement emotions (anxiety) was not moderated by teacher-reported teaching quality. A possible explanation for our finding lies in the selection of achievement emotions and characteristics of teaching quality. Control-value theory (Pekrun, 2006) describes the cognitive quality of tasks, but also value induction, autonomy support, goal structures, and achievement-related feedback as prerequisites of students' control cognitions and achievement emotions. Our study only investigated cognitive challenge and structuredness, however, other characteristics of teaching quality might be more relevant as potential moderators to be considered in future studies. Furthermore, we only assessed the teachers' subjective perceptions of their own teaching characteristics which might be biased, but more importantly, teachers' perceptions might only correspond to a certain extent to students' perceptions of teaching quality in class (Wagner *et al.*, 2016). Consequently, future research should also take into account students' perceptions of teaching quality when investigating interrelations between teaching quality, academic self-concept, and achievement emotions.

Our findings matter by showing that high teaching quality enables students to make effective use of their own motivational resources. An implication of these findings is that students who are confident in their abilities not always also enjoy learning if they are not provided with a learning environment that is well-structured and cognitively activating. Consequently, teachers need to be sensitive to students' need for clarity of instruction in their classrooms when aiming to enable students to make use of their high competence beliefs. However, when discussing educational implications, it is important to mention that our findings cannot be interpreted in terms of causal effects and, as teaching is highly complex, more teaching characteristics are interrelated with students' emotions than only cognitive activation or structuredness of instruction.

### **Limitations**

This study has several limitations that need to be considered when interpreting its findings. The first is that we only measured teaching quality from the perspective of teachers. Teacher reports on instructional quality might be biased because teachers

might overestimate their teaching skills (Spearman & Watt, 2013). Further research on teaching quality and achievement emotions that also includes student-reported teaching quality measures is therefore needed to validate the findings of this study. This would allow the researcher to control for differences among teacher and student perspectives and thus lead to a possibly less biased measure of teaching quality. The second limitation is that we tested our models using a doubly manifest modelling approach, which does not correct for sampling or measurement error (Marsh *et al.*, 2009); thus, further studies with larger sample sizes on the student and classroom levels are needed to validate our findings.

## Conclusions

Our findings inform educational research by showing that students' self-concept of ability interacts with teaching characteristics when affecting students' emotions in class. More concretely, our study indicates that students with higher competence beliefs might particularly benefit from learning environments that are described as cognitively activating and well-structured. Future research should build upon these results and further examine interactions between students' individual motivational characteristics and characteristics of their learning environment, as such questions are also relevant for adaptive teaching (Corno, 2008).

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## Author contribution

Rebecca Lazarides (Conceptualization; Data curation; Investigation; Methodology; Project administration; Resources; Writing – original draft) Diana Raufelder (Conceptualization; Supervision; Writing – review & editing).

## Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

## References

- Allen, J. P., Gregory, A., Mikami, A., Lun, J., Hamre, B., & Pianta, R. (2013). Observations of effective teacher–student interactions in secondary school classrooms: Predicting student achievement with the classroom assessment scoring system—secondary. *School Psychology Review*, *42*(1), 76–98. <https://doi.org/10.1080/02796015.2013.12087492>
- Allen, J. P., Pianta, R. C., Gregory, A., Mikami, A. Y., & Lun, J. (2011). An interaction-based approach to enhancing secondary school instruction and student achievement. *Science*, *333*, 1034–1037. <https://doi.org/10.1126/science.1207998>



- Baumert, J., Kunter, M., Blum, W., Brunner, M., Voss, T., Jordan, A., . . . Tsai, Y.-M. (2010). Teachers' mathematical knowledge, cognitive activation in the classroom, and student progress. *American Educational Research Journal*, *47*(1), 133–180. <https://doi.org/10.3102/0002831209345157>.
- Berlin Senate Administration for Education Youth and Science (2013). Verfahren zur Genehmigung empirischer Studien an Berliner Schulen [Permission procedure for empirical studies in schools in Berlin]. Retrieved from [http://www.ewi-psy.fu-berlin.de/service/Genehmigung\\_empirische\\_r\\_Untersuchungen\\_in\\_Berliner\\_Schulen\\_April\\_2013.pdf](http://www.ewi-psy.fu-berlin.de/service/Genehmigung_empirische_r_Untersuchungen_in_Berliner_Schulen_April_2013.pdf).
- Bieg, M., Goetz, T., Sticca, F., Brunner, E., Becker, E., Morger, V., & Hubbard, K. (2017). Teaching methods and their impact on students' emotions in mathematics: an experience-sampling approach. *ZDM Mathematics Education*, *49*, 411–422. <https://doi.org/10.1007/s11858-017-0840-1>
- Bosker, R., & Snijders, T. (1999). *Multilevel analysis: An introduction to basic and advanced multilevel modeling*. New York, NY: Sage.
- Chow, A., Eccles, J. S., & Salmela-Aro, K. (2012). Task value profiles across subjects and aspirations to physical and IT-related sciences in the United States and Finland. *Developmental Psychology*, *48*, 1612–1628. <https://doi.org/10.1037/a0030194>
- Corno, L. (2008). On teaching adaptively. *Educational Psychologist*, *43*, 161–173. <https://doi.org/10.1080/00461520802178466>
- Cruickshank, D. R. (1985). Applying research on teacher clarity. *Journal of Teacher Education*, *36*(2), 44–48. <https://doi.org/10.1177/002248718503600210>
- Deci, E. L., & Ryan, R. M. (1985). *Self-determination*. New York, NY: Wiley.
- Eccles, J. S. (2005). Subjective task value and the Eccles et al model of achievement-related choices. In A. J. Elliot & C. S. Dweck (Eds.), *Handbook of competence and motivation* (pp. 105–131). New York, London: Guilford.
- Enders, C. K., & Tofighi, D. (2007). Centering predictor variables in cross-sectional multilevel models: a new look at an old issue. *Psychological Methods*, *12*, 121–138. <https://doi.org/10.1037/1082-989X.12.2.121>
- Fauth, B., Decristan, J., Rieser, S., Klieme, E., & Büttner, G. (2014). Student ratings of teaching quality in primary school: Dimensions and prediction of student outcomes. *Learning and Instruction*, *29*, 1–9. <https://doi.org/10.1016/j.learninstruc.2013.07.001>.
- Frenzel, A. C., Pekrun, R., & Goetz, T. (2007a). Girls and mathematics - A "hopeless" issue? A control-value approach to gender differences in emotions towards mathematics. *European Journal of Psychology of Education*, *22*, 497–514. <https://doi.org/10.1007/BF03173468>.
- Frenzel, A. C., Pekrun, R., & Goetz, T. (2007b). Perceived learning environment and students' emotional experiences: A multilevel analysis of mathematics classrooms. *Learning and Instruction*, *17*, 478–493. <https://doi.org/10.1016/j.learninstruc.2007.09.001>
- Gillen-O'Neel, C., Ruble, D. N., & Fuligni, A. J. (2011). Ethnic stigma, academic anxiety, and intrinsic motivation in middle childhood. *Child development*, *82*, 1470–1485. <https://doi.org/10.1111/j.1467-8624.2011.01621.x>
- Gläser-Zikuda, M., & Fuß, S. (2008). Impact of teacher competencies on student emotions: A multi-method approach. *International Journal of Educational Research*, *47*, 136–147. <https://doi.org/10.1016/j.ijer.2007.11.013>
- Goetz, T., Bieg, M., Lüdtke, O., Pekrun, R., & Hall, N. C. (2013). Do girls really experience more anxiety in mathematics? *Psychological Science*, *24*, 2079–2087. <https://doi.org/10.1177/0956797613486989>
- Goetz, T., Cronjaeger, H., Frenzel, A. C., Lüdtke, O., & Hall, N. C. (2010). Academic self-concept and emotion relations: Domain specificity and age effects. *Contemporary Educational Psychology*, *35*(1), 44–58. <https://doi.org/10.1016/j.cedpsych.2009.10.001>.
- Goetz, T., Frenzel, A. C., Stoeger, H., & Hall, N. C. (2010). Antecedents of everyday positive emotions: An experience sampling analysis. *Motivation and Emotion*, *34*(1), 49–62. <https://doi.org/10.1007/s11031-009-9152-2>

- Goetz, T., Lüdtke, O., Nett, U. E., Keller, M. M., & Lipnevich, A. A. (2013). Characteristics of teaching and students' emotions in the classroom: Investigating differences across domains. *Contemporary Educational Psychology*, *38*, 383–394. <https://doi.org/10.1016/j.cedpsych.2013.08.001>
- Goetz, T., Nett, U. E., Martiny, S. E., Hall, N. C., Pekrun, R., Dettmers, S., & Trautwein, U. (2012). Students' emotions during homework: Structures, self-concept antecedents, and achievement outcomes. *Learning and Individual Differences*, *22*, 225–234. <https://doi.org/10.1016/j.lindif.2011.04.006>
- Hagenauer, G., & Hascher, T. (2010). Learning enjoyment in early adolescence. *Educational Research and Evaluation*, *16*, 495–516. <https://doi.org/10.1080/13803611.2010.550499>
- Hertel, S., Hochweber, J., Mildner, D., Steinert, B., & Jude, N. (2014). *PISA 2009 Skalenbandbuch [PISA 2009 Measures]*. Münster; New York: Waxmann.
- Hiebert, J., & Grouws, D. A. (2007). The effects of classroom mathematics teaching on students' learning. In F. K. Lester (Ed.), *Second handbook of research on mathematics teaching and learning*, Vol. 1 (pp. 371–404). Charlotte, NC: Information Age.
- Isen, A. M., & Reeve, J. (2005). The influence of positive affect on intrinsic and extrinsic motivation: Facilitating enjoyment of play, responsible work behavior, and self-control. *Motivation and Emotion*, *29*, 295–323. <https://doi.org/10.1007/s11031-006-9019-8>
- Klieme, E., Lipowsky, F., Rakoczy, K., & Ratzka, N. (2006). Qualitätsdimensionen und Wirksamkeit von Mathematikunterricht [Dimensions of instructional quality and effectiveness of math teaching]. In M. A.-N. Prenzel & L. Allolio-Näcke (Eds.), *Untersuchungen zur Bildungsqualität von Schule* (pp. 127–146). Münster, Germany: Waxmann.
- Klieme, E., Pauli, C., & Reusser, K. (2009). The Pythagoras study: investigating effects of teaching and learning in Swiss and German mathematics classrooms. In T. Janik & T. Seidel (Eds.), *The power of video studies in investigating teaching and learning in the classroom* (pp. 137–160). Münster, Germany: Waxmann.
- Krapp, A. (2007). An educational–psychological conceptualisation of interest. *International Journal for Educational and Vocational Guidance*, *7*(1), 5–21. <https://doi.org/10.1007/s10775-007-9113-9>.
- Kunter, M., Baumert, J., & Köller, O. (2007). Effective classroom management and the development of subject-related interest. *Learning and Instruction*, *17*, 494–509. <https://doi.org/10.1016/j.learninstruc.2007.09.002>
- Kunter, M., Klusmann, U., Baumert, J., Richter, D., Voss, T., & Hachfeld, A. (2013). Professional competence of teachers: Effects on instructional quality and student development. *Journal of Educational Psychology*, *105*, 805–820. <https://doi.org/10.1037/a0032583>
- Kunter, M., Tsai, Y.-M., Klusmann, U., Brunner, M., Krauss, S., & Baumert, J. (2008). Students' and mathematics teachers' perceptions of teacher enthusiasm and instruction. *Learning and Instruction*, *18*, 468–482. <https://doi.org/10.1016/j.learninstruc.2008.06.008>
- Lazarides, R., & Buchholz, J. (2019). Student-perceived teaching quality: How is it related to different achievement emotions in mathematics classrooms? *Learning and Instruction*, *61*, 45–59. <https://doi.org/10.1016/j.learninstruc.2019.01.001>.
- Lazarides, R., Dicke, A.-L., Rubach, C., & Eccles, J. (2019). Profiles of motivational beliefs in math: Exploring their development, relations to student-perceived classroom characteristics and impact on future career aspirations and choices. *Journal of Educational Psychology*, *112*(1), 70–92. <https://doi.org/10.1037/edu0000368>.
- Lazarides, R., Dietrich, J., & Taskinen, P. H. (2019). Stability and change in students' motivational profiles in mathematics classrooms: The role of perceived teaching. *Teaching and Teacher Education*, *79*, 164–175.
- LeBreton, J. M., & Senter, J. L. (2008). Answers to 20 questions about interrater reliability and interrater agreement. *Organizational Research Methods*, *11*, 815–852. <https://doi.org/10.1177/1094428106296642>
- Lipowsky, F., Rakoczy, K., Pauli, C., Drollinger-Vetter, B., Klieme, E., & Reusser, K. (2009). Quality of geometry instruction and its short-term impact on students' understanding of the Pythagorean

- Theorem. *Learning and Instruction*, 19, 527–537. <https://doi.org/10.1016/j.learninstruc.2008.11.001>
- Lüdtke, O., Robitzsch, A., Trautwein, U., & Kunter, M. (2009). Assessing the impact of learning environments: How to use student ratings of classroom or school characteristics in multilevel modeling. *Contemporary Educational Psychology*, 34, 120–131. <https://doi.org/10.1016/j.cedpsych.2008.12.001>
- Marsh, H. W., Lüdtke, O., Nagengast, B., Trautwein, U., Morin, A. J., Abduljabbar, A. S., & Köller, O. (2012). Classroom climate and contextual effects: conceptual and methodological issues in the evaluation of group-level effects. *Educational Psychologist*, 47, 106–124. <https://doi.org/10.1080/00461520.2012.670488>
- Marsh, H. W., Lüdtke, O., Robitzsch, A., Trautwein, U., Asparouhov, T., Muthén, B., & Nagengast, B. (2009). Doubly-latent models of school contextual effects: Integrating multilevel and structural equation approaches to control measurement and sampling error. *Multivariate Behavioral Research*, 44, 764–802. <https://doi.org/10.1080/00273170903333665>
- Marsh, H. W., & Martin, A. J. (2011). Academic self-concept and academic achievement: Relations and causal ordering. *British Journal of Educational Psychology*, 81(1), 59–77. <https://doi.org/10.1348/000709910X503501>
- Maulana, R., Opdenakker, M.-C., & Bosker, R. (2016). Teachers' instructional behaviors as important predictors of academic motivation: Changes and links across the school year. *Learning and Individual Differences*, 50, 147–156. <https://doi.org/10.1016/j.lindif.2016.07.019>
- Muthén, L., & Muthén, B. (1998–2019). *Mplus user's guide*. Los Angeles, CA: Muthen & Muthen.
- Pekrun, R. (2000). A social-cognitive, control-value theory of achievement emotions. In J. Heckhausen (Ed.), *Advances in psychology*, 131. *Motivational psychology of human development: Developing motivation and motivating development* (pp. 143–163). Oxford, UK: Elsevier Science. [https://doi.org/10.1016/S0166-4115\(00\)80010-2](https://doi.org/10.1016/S0166-4115(00)80010-2)
- Pekrun, R. (2006). The control-value theory of achievement emotions: Assumptions, corollaries, and implications for educational research and practice. *Educational Psychology Review*, 18, 315–341. <https://doi.org/10.1007/s10648-006-9029-9>
- Pekrun, R., Frenzel, A., Goetz, T., & Perry, R. P. (2007). The control-value theory of achievement emotions: An integrative approach to emotions in education. In P. A. Schutz & R. Pekrun (Eds.), *Emotion in education* (pp. 13–36). San Diego, CA: Academic Press.
- Pekrun, R., Goetz, T., Daniels, L. M., Stupnisky, R. H., & Perry, R. P. (2010). Boredom in achievement settings: Exploring control-value antecedents and performance outcomes of a neglected emotion. *Journal of Educational Psychology*, 102, 531–549. <https://doi.org/10.1037/a0019243>
- Pekrun, R., Goetz, T., Titz, W., & Perry, R. P. (2002). Academic emotions in students' self-regulated learning and achievement: A program of qualitative and quantitative research. *Educational Psychologist*, 37(2), 91–105. [https://doi.org/10.1207/S15326985EP3702\\_4](https://doi.org/10.1207/S15326985EP3702_4)
- Pekrun, R., Götz, T., & Perry, R. P. (2005). Achievement Emotions Questionnaire (AEQ). User's manual. Munich: Unpublished Manuscript. University of Munich.
- Pekrun, R., Murayama, K., Marsh, H. W., Goetz, T., & Frenzel, A. C. (2019). Happy fish in little ponds: Testing a reference group model of achievement and emotion. *Journal of Personality Social Psychology of Education*, 117(1), 166–185. <https://doi.org/10.1037/pspp0000230>
- Pekrun, R., & Perry, R. P. (2014). Control-value theory of achievement emotions. In R. Pekrun & L. Linnenbrink-Garcia (Eds.), *International handbook of emotions in education* (pp. 120–141). New York, NY: Taylor & Francis.
- Pekrun, R., & Stephens, E. J. (2010). Achievement emotions: A control-value approach. *Social and Personality Psychology Compass*, 4, 238–255. <https://doi.org/10.1111/j.1751-9004.2010.00259.x>
- Pianta, R. C., & Hamre, B. K. (2009). Conceptualization, measurement, and improvement of classroom processes: Standardized observation can leverage capacity. *Educational Researcher*, 38, 109–119. <https://doi.org/10.3102/0013189X09332374>

- Praetorius, A.-K., Klieme, E., Herbert, B., & Pinger, P. (2018). Generic dimensions of teaching quality: the German framework of Three Basic Dimensions. *ZDM*, *50*, 407–426. <https://doi.org/10.1007/s11858-018-0918-4>
- Raudenbush, S. W., & Bryk, A. S. (2002). *Hierarchical linear modeling. Applications and data analysis methods* (2nd ed.). Thousands Oaks, CA: Sage.
- Schiefele, U. (2009). Situational and individual interest. In K. R. Wentzel & A. Wigfield (Eds.), *Handbook of motivation at school* (pp. 197–222). New York/London: Routledge.
- Schiepe-Tiska, A., Heine, J.-H., Lüdtke, O., Seidel, T., & Prenzel, M. (2016). Mehrdimensionale Bildungsziele im Mathematikunterricht und ihr Zusammenhang mit den Basisdimensionen der Unterrichtsqualität. *Unterrichtswissenschaft*, *44*, 211–225.
- Schöne, C., Dickhäuser, O., Spinath, B., & Stiensmeier-Pelster, J. (2002). *Scales for the assessment of students' ability self-concept in school (SESSKO) [Skalen zur Erfassung des schulischen Selbstkonzepts (SESSKO)]*. Manual. Göttingen: Hogrefe.
- Shavelson, R. J., Hubner, J. J., & Stanton, G. C. (1976). Self-concept: Validation of construct interpretations. *Review of Educational Research*, *46*, 407–441. <https://doi.org/10.3102/00346543046003407>
- Spearman, J., & Watt, H. M. G. (2013). Perception shapes experience: The influence of actual and perceived classroom environment dimensions on girls' motivations for science. *Learning Environments Research*, *16*, 217–238. <https://doi.org/10.1007/s10984-013-9129-7>
- Stanat, P. (2006). Schulleistungen von Jugendlichen mit Migrationshintergrund: Die Rolle der Zusammensetzung der Schülerschaft. In J. Baumert, P. Stanat & R. Watermann (Eds.), *Herkunftsbedingte Disparitäten im Bildungswesen: Differenzielle Bildungsprozesse und Probleme der Verteilungsgerechtigkeit* (pp. 189–219). Wiesbaden, Germany: VS verlag für Sozialwissenschaften.
- Stefanou, C. R., Perencevich, K. C., DiCintio, M., & Turner, J. C. (2004). Supporting autonomy in the classroom: Ways teachers encourage student decision making and ownership. *Educational Psychologist*, *39*(2), 97–110. [https://doi.org/10.1207/s15326985ep3902\\_2](https://doi.org/10.1207/s15326985ep3902_2)
- Van der Beek, J. P., Van der Ven, S. H., Kroesbergen, E. H., & Leseman, P. P. (2017). Self-concept mediates the relation between achievement and emotions in mathematics. *British Journal of Educational Psychology*, *87*, 478–495. <https://doi.org/10.1111/bjep.12160>
- Vierhaus, M., Lohaus, A., & Wild, E. (2016). The development of achievement emotions and coping/emotion regulation from primary to secondary school. *Learning and Instruction*, *42*, 12–21. <https://doi.org/10.1016/j.learninstruc.2015.11.002>
- Wagner, W., Göllner, R., Werth, S., Voss, T., Schmitz, B., & Trautwein, U. (2016). Student and teacher ratings of instructional quality: Consistency of ratings over time, agreement, and predictive power. *Journal of Educational Psychology*, *108*, 705–721. <https://doi.org/10.1037/edu0000075>
- Watt, H. M. G. (2004). Development of adolescents' self-perceptions, values, and task perceptions according to gender and domain in 7th-through 11th-grade Australian students. *Child Development*, *75*, 1556–1574. <https://doi.org/10.1111/j.1467-8624.2004.00757.x>
- Watt, H. M. G., Bucich, M., & Dacosta, L. (2019). Adolescents' Motivational Profiles in Mathematics and Science: Antecedents and consequences for engagement and wellbeing. *Frontiers in Psychology*, *10*, 990. <https://doi.org/10.3389/fpsyg.2019.00990>
- Westphal, A., Kretschmann, J., Gronostaj, A., & Vock, M. (2018). More enjoyment, less anxiety and boredom: How achievement emotions relate to academic self-concept and teachers' diagnostic skills. *Learning and Individual Differences*, *62*, 108–117. <https://doi.org/10.1016/j.lindif.2018.01.016>
- Wigfield, A., & Meece, J. L. (1988). Math anxiety in elementary and secondary school students. *Journal of Educational Psychology*, *80*, 210–216. <https://doi.org/10.1037/0022-0663.80.2.210>

## Appendix A:

**Table A1.** Measurement invariance tests for anxiety

	M1	M2	M3	M4
$\chi^2$	46.297	32.141	46.156	34.225
<i>p</i>	.0000	.0038	.0002	.0118
<i>df</i>	10	14	17	18
CFI	.978	.989	.982	.999
RMSEA	.067	.040	.046	.034
$\Delta$ CFI		.011	-.007	.008
$\Delta$ RMSEA		-0.027	.006	-.012

Note. M1 = measurement model variant (configural model); M2 = loadings time- but not level-invariant; M3 = loadings time- but not level-invariant, intercepts at the classroom-level time-invariant; M4 = loadings completely time- and level-invariant and intercepts partially time-invariant at the classroom level.

**Table A2.** Measurement Invariance Tests for Enjoyment

	M1	M2	M3	M4
$\chi^2$	29.678	40.098	42.909	44.017
<i>p</i>	.5846	.3344	.3893	.4709
<i>df</i>	32	37	41	44
CFI	1.00	.999	1.000	1.000
RMSEA	.00	.010	.006	.001
$\Delta$ CFI		-.010	.010	.000
$\Delta$ RMSEA		.010	-.004	-.005

Note. M1 = measurement model variant (configural model); M2 = loadings time- but not level-invariant; M3 = loadings partially time- but not level-invariant, intercepts at the classroom level time-invariant; M4 = loadings partially time- and completely level-invariant and intercepts time-invariant at the classroom level.

## Appendix B:

Wording of the items used in the analyses

Mathematics self-concept (student report)

Self1

I think I am. . . . . at mathematics

(1) not talented.

(2) rather less talented.

(3) average.

(4) talented.

(5) highly talented.

Self2

I can handle mathematical tasks. . .

(1) worse than before.

*Continued*

	(2) rather worse than before.
	(3) the same as before.
	(4) rather better than before.
	(5) better than before.
Self3	In mathematics, I think I am. . .
	(1) less talented than my classmates.
	(2) rather less talented than my classmates.
	(3) just as talented as my classmates.
	(4) rather more talented than my classmates.
	(5) more talented than my classmates.
Self4	When I think about what I should know in mathematics, I consider myself. . .
	(1) not talented.
	(2) rather less talented.
	(3) average.
	(4) talented.
	(5) highly talented.
Cognitive activation (teacher report)	
Introductory sentence: 'How much do the following statements apply to you as a mathematics teacher?'	
coga1	If students make mistakes when working on new topics, I first accept their suggestions and continue to work with them on the problem until their mistake becomes obvious.
coga2	Sometimes I let students follow incorrect solution pathways on purpose until they realize
	by themselves that something is wrong.
coga3	I work based on the students' suggestions and carry on with that until the students notice that something doesn't add up'
Structuredness (teacher report)	
Introductory sentence: 'How much do the following statements apply to you as a mathematics teacher?'	
inst1	I explain in advance what I expect from the students.
inst2	I grade students' work.
inst3	I encourage students to ask questions regarding their mathematics tasks.
Mathematics enjoyment (student report)	
jo1	I look forward to mathematics lessons.
jo2	I find tasks and materials so exciting that mathematics lessons are fun for me.
jo3	Math class is so much fun that I am happy to participate.
jo4	I am in a good mood when doing mathematics homework.
Mathematics anxiety (student report)	
ax1	I am afraid of mathematics.
ax3	In math I am worried that I comprehend less than all the others.
ax5	Because I am so nervous, I would rather not take mathematics exams.

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**Appendix C:****Table C1.** Results of independent t-tests using a missing data variable

	G1 M (SD)	G2 M (SD)	G1 n	G2 n	T	df	p
Mathematics enjoyment t1	2.54 (1.01)	2.49 (0.95)	799	307	-0.67	1104	.502
Mathematics enjoyment t2	2.65 (0.98)	2.53 (0.97)	540	207	-1.50	754	.134
Mathematics anxiety t1	2.06 (0.98)	2.06 (1.01)	798	308	0.46	1104	.963
Mathematics anxiety t2	1.97 (0.92)	1.96 (0.95)	539	207	-0.43	744	.664
Mathematics self-concept t1	3.13 (0.86)	3.18 (0.82)	798	308	0.79	1104	.430

Note. G1 = students in subsample for present analyses. G2 = students not in subsample.