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ORIGINAL PAPER

Classroom transmission processes between teacher support, interest value and negative affect: An investigation guided by situated expectancy-value theory and control-value theory

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Abstract
Are motivated students less likely to express negative achievement emotions in math, and how do teachers impact such academic beliefs? Guided by the situated expectancy-value theory and the control-value theory, this study is interested in how teacher support influences students' negative affect in math through students' perception of teacher support and students' interest value (teacher-to-student transmission between and within classes). Thus, associations were modeled at the individual and classroom levels to investigate cross-level interactions. Using data from 1,429 students in grades 7–12 (49% males, 67% Hispanic Americans, 15% Asian Americans, 18% other racial/ethnic groups), cross-level indirect effects suggested an association of teacher-reported support for collaboration and cognitive support with decreasing negative affect through students' perception of teacher support and students' interest value. These associations were supported within but not between classes.

Keywords Teacher support · Interest value · Negative affect · Teacher-to-student transmission · Control-value theory · Situated expectancy-value theory

Introduction

Are motivated students less likely to express negative achievement emotions in math, and how do teachers impact such academic beliefs? Research has shown that positive achievement emotions and motivational beliefs in math decline during school, whereas negative achievement emotions increase (e.g., Frenzel et al., 2010). The question remains whether these developmental trajectories are interrelated, such as negative achievement emotions increasing with decreasing motivation, or whether they occur independently of one another (see Hembree, 1990; Pekrun & Perry, 2014). This is an important question for math teachers to understand if they support positive growth of their students' achievement motivation and emotion while mitigating negative developmental inclinations in math: Should teachers promote positive motivational beliefs to decrease negative achievement emotions, should they mitigate negative achievement emotions to increase motivational beliefs, or should they do both?

Focusing on teachers, we know that instructional behavior is associated with students' achievement motivation and emotion (Lei et al., 2017). The situated expectancy-value theory (EVT; Eccles et al., 1983; SEVT, Eccles & Wigfield, 2020) and the control-value theory of achievement emotions (CVT, Pekrun, 2006) both emphasize the importance of examining teacher and student interactions for understanding student achievement motivation and emotion. Theoretically, these frameworks postulate that (a) teacher's instructional behavior (CVT, SEVT) influence achievement motivation and emotion through students' interpretation of instructional behavior (teacher-to-student transmission processes; SEVT) and (b) that teacher instructional behavior influence

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students' achievement emotion directly and indirectly through its impact on motivation (SEVT, CVT). Interactions between teacher instructional behavior and student achievement motivation and emotion, as well as the co-development of students' achievement motivation and emotion are complex and rarely empirically investigated (Eccles et al., 1993; Meyer & Turner, 2006). Thus, the present longitudinal study aims to understand the teacher-to-student transmission processes between teacher instructional behavior (emotional and cognitive support, support for collaboration) and student achievement motivation (interest value) and emotion (negative affect) in math, considering relations within and between classrooms. The study will leverage both student- and teacher-reported data to better understand the teacher-to-student transmission processes related to students' achievement motivation and emotion. For clarification, we are using the term motivation and referring to subjective task value beliefs as delineated by SEVT (Eccles et al., 1983), and referring to emotions guided by emotional states as delineated by CVT (Pekrun, 2006).

Situated expectancy-value theory and control-value theory of achievement emotions

Both the SEVT of achievement-related choices, persistence, and performance (EVT—Eccles et al., 1983; SEVT—Eccles & Wigfield, 2020) and the CVT of achievement emotions (Pekrun, 2006) provide an understanding of complex psychological and social processes that take place in classrooms. Both theories point to the interplay between teacher behavior, student achievement motivation and emotion. They postulate that the social environment influences beliefs about being in control over situations and outcomes, beliefs about the degree of value attached to situations for oneself, and one's experiences of achievement emotions in situations. All these factors are critical for student academic performance and behavior.

SEVT (Eccles & Wigfield, 2020; Eccles et al., 1983) is focused on complex interrelations between the environment, student academic development and the importance of achievement motivation, e.g., subjective task values and expectancies of success. Subjective task value beliefs are personal beliefs about how interesting, useful, important, and costly a task will be. Expectancies of success are defined as students' beliefs about how well they think they will perform on a task (Eccles & Wigfield, 2020). The developmental perspective on students and its impact on within- and between-individual achievement-related choices are central to the SEVT framework. Students' characteristics, socializers' beliefs and behavior, and the cultural milieu students grow up in are assumed to influence how students interpret and perceive their social environment, which, in turn, impacts students' social cognitive development. For example, socializers' behavior impacts students' achievement motivation and emotion directly and indirectly through students' interpretations of their socializer's behavior and beliefs. Students' achievement motivation and emotions may depend on how much support the teacher offers to a student in a class and whether the student interprets this behavior as supportive. Hereby, teachers' behaviors influence students' academic and, thus, motivational development based on how students perceive and interpret their teachers' behavior, which is referred to as transmission processes (Tishman et al., 1993). These processes are situational, i.e., depend on time and context.

CVT (Pekrun, 2006) is conceptually aligned with SEVT and (a) presents a taxonomy of achievement emotions that categorizes emotions based on valence and the degree of activation and (b) indicates links between control and value appraisals with achievement emotions and achievement. Described is that teachers impact their students' achievement emotions and performance through students' motivation, i.e., how much control they believe they have over the specific situation (control appraisal) and how much importance they attach to the specific situation (value appraisals). Thus, control and value appraisals are described as proximal determinants of achievement emotions. As in SEVT, transmission processes between teachers and students in classrooms are hypothesized, i.e., teachers influence their students' achievement emotions through students' motivation which influences how students interpret teachers' behaviors.

SEVT and CVT provide comprehensive frameworks to describe psychological classroom processes and how teachers influence their students' academic development. Both frameworks propose that (a) teachers influence students' achievement emotions and motivation and vice versa and (b) situations, context and time impact such links. SEVT indicates the importance of students' perception and interpretation of their teachers' behavior as a mediator between teachers' behavior and students' motivation and emotion and focuses particularly on motivation. CVT indicates control and value appraisals as proximal determinants of achievement emotions and thus focuses on achievement emotions. In contrast, SEVT focuses on the impact of the recall of past emotions in similar situations on motivational beliefs for current and future task engagement. We see the advantages of conceptually integrating both frameworks in the context of classroom processes.

Control-value theory of achievement emotions: Understanding the interplay between achievement motivation and emotion

In CVT, Pekrun (2006) elucidated the interrelations of motivation (control and value appraisals) and various achievement emotions. Control appraisals refer to an individual's perceived control (prospective or retrospective) over their actions and outcomes or that of another person. Control appraisals are often operationalized as ability beliefs (self-efficacy, self-concept of ability) or expectancies of failure or success. Value appraisals refer to the degree of importance (extrinsic and intrinsic values) and are often operationalized as interest, importance, and utility value beliefs (Simonton & Garn, 2020). Thus, control and value appraisals are comparable to components of SEVT, more specifically to expectancies of success and subjective task values (Pekrun & Perry, 2014). Achievement emotions are processes of psychological subsystems composed of affective, cognitive, motivational, expressive, and peripheral physiological components and are linked to achievement activities (Pekrun, 2006). Different emotions and emotional states combine to form a general affect that can be differentiated into negative and positive affect (Linnenbrink, 2006). Both achievement emotions and positive and negative affect are important predictors of students' academic development (Linnenbrink, 2006).

Theoretically, a reciprocal relationship between control and value appraisals and achievement emotions is assumed in both frameworks (achievement emotion ↔ control and value appraisals; Eccles et al., 1983; Pekrun & Perry, 2014). Control and value appraisals and achievement emotions (de)activate each other (Kim & Pekrun, 2014) and are inseparable (Linnenbrink, 2006). On the one hand, negative achievement emotions might deactivate students' motivation to study (Pekrun & Perry, 2014). The underlying process must be explained in the context of cognition and subjective experiences of learning (Ainley, 2006; Ellsworth & Scherer, 2003). Achievement emotions emerge from the processing of events in combination with the recall of experiences and memories, and thus trigger motivation and influence behavior, such as decision making, effort, and the use of cognitive strategies (Levine & Pizarro, 2004). On the other hand, achievement emotion develop as a result of control and value appraisals of a situation, thus, a person's response to a situation (Pekrun, 2006). For instance, a student who is highly interested in a math course based on his/her/them curiosity to understand the content might also have lower negative achievement emotions, such as boredom, as this person encoded and retrieved information in the math course based on their math interest.

Previous studies have often examined unidirectional links of achievement emotions to students' control- and value beliefs or unidirectional links of control- and value beliefs to achievement emotion (Huhtiniemi et al., 2019; Lohbeck et al., 2016; Lazarides & Raufelder, 2021). This cross-sectional research has provided support for either link, e.g., that students enjoy classes more when they are more interested and self-confident about their abilities (Huhtiniemi et al., 2019; Lazarides & Raufelder, 2021) and that students show particular levels of anxiety depending on their self-concept and recalled past emotions (Lohbeck et al., 2016; Lazarides & Raufelder, 2021). All this research has supported the interrelation of motivation and emotion (see also Kim & Hodges, 2012).

Scholars furthermore investigated longitudinal bidirectional associations between motivation and negative achievement emotion: Sutter-Brandenberger et al. (2018) investigated reciprocal associations between students' motivation (as operationalized by intrinsic motivation and identified motivation) and emotion (as operationalized by anxiety, anger, and boredom). They found that students' achievement emotions (anxiety, anger) were associated with the development of students' identified and intrinsic motivation but not vice versa. In contrast, Ahmed et al. (2012) found significant reciprocal longitudinal relations between students' ability self-concept and anxiety in math. However, students' math self-concept had a stronger effect on their anxiety than the reverse. Another study investigated the longitudinal links between students' interest value and anxiety in math and found that students reporting higher math interest at the beginning of the academic year reported lower anxiety levels over time (Rubach & Bonanati, 2021). In conclusion, empirical findings indicate mixed results with unidirectional and reciprocal associations between intrinsic motivation and negative achievement emotions.

Teacher instructional behavior, students' achievement motivation and emotion

Both SEVT (Eccles & Wigfield, 2020; Eccles et al., 1983) and CVT (Pekrun, 2006) underscore the importance of teachers cultivating their students' positive academic growth through their interactions with their students. Thus, multiple instructional behavior are suggested that might impact achievement motivation and emotion over time through classroom interactions (Eccles et al., 1993; Pekrun, 2006). In our study, we focus on teachers' rendering of cognitive and emotional support as well as support for collaboration as examples of teachers' instructional behavior.

Teachers' cognitive support consists of teachers' assistance with the acquisition of knowledge, and the development of knowledge, strategies, and skills through deep thinking (Moll et al., 1992). Previous researchers found cross-sectional and longitudinal predictive associations of teachers' cognitive support with students' intrinsic motivation, self-efficacy, and self-esteem (Aldrup et al., 2018; Burić & Kim, 2020; Dorfner et al., 2018) and students' enjoyment, anxiety, and boredom (Lazarides & Buchholz, 2019; Lei et al., 2017; Rubach & Lazarides, 2021).

Students' learning environments are also determined by the quality of social experiences, i.e., relationships and interactions within the classroom (Eccles et al., 1993; Pekrun & Perry, 2014; Wentzel, 2016). Social experiences within the classroom can include interactions between a single student and their teacher, the interactions of the entire classroom and their teacher, and students with their classmates. Teachers' relationships with their students can be strengthened by providing emotional support. Teachers' emotional support refers to teacher-student relationships characterized by emotional closeness and care (Cutrona & Russell, 1990). Research indicates that teachers' emotional support provided for the entire class or individual students impacts students' enjoyment, anxiety, and motivation (Burić & Kim, 2020; Dorfner et al., 2018; Midgley et al., 1989; Rubach & Lazarides, 2021).

Teachers can also help create positive relationships in their classrooms by supporting interaction and collaboration amongst the students in their classrooms. When students feel valued within their classroom and feel emotionally and cognitively supported by their classmates, these beliefs impact their enjoyment, anxiety, and motivation (Fredricks et al., 2018). Student-centered teaching approaches (Vollet et al., 2017), such as fostering collaboration between classmates, are associated with higher student motivation (defined by students' cognitive, behavioral, emotional, and social engagement in classrooms). These associations were also found for students' mastery motivation (Linnenbrink-Garcia et al., 2016).

As stated above, achievement motivation and emotion are inseparable and thus interacting systems, and teacher instructional behavior can actively influence this connection (Linnenbrink, 2006). SEVT, CVT, and empirical evidence supports the direct link from teachers' instructional behaviors to students' achievement motivation and emotions. However, questions remain related to SEVT and CVT: For example, do these instructional behavior impact students' achievement emotions through students' motivation or vice versa, or both? Some research conducted in physical education classes presented cross-sectional mediations and found teachers' cognitive support to impact student enjoyment and anxiety through students' self-efficacy and intrinsic value (Simonton et al., 2017; Zimmermann et al., 2021). We know that events become imbued with emotional stamps (memory) that stimulate one's subjective experience of events (Panksepp, 2000). It remains unclear how instructional behavior might change these emotional stamps and thus change subjective experiences of students. Drawing on the established literature, we aim to investigate associations of teachers' cognitive and emotional support and their support for collaboration amongst classmates with changes in students' negative affect through their interest in math. We are particularly interested in effects within and between classrooms (see SEVT, Eccles & Wigfield, 2020, Pekrun & Marsh, 2022), i.e., how teacher instructional behavior impacts students or an entire class. Thus, we investigate how factors are related within students and between students in classrooms and provide insight into how instructional behavior should be adjusted as a function of class composition or individual students' needs.

Transmission processes in classrooms: From teachers to students?

CVT (Pekrun, 2006) illustrates that teachers directly affect students' achievement emotion through motivation and SEVT (Eccles & Wigfield, 2020; Eccles et al., 1983) emphasizes the relevance of students' interpretation of teacher instructional behavior. More specifically, SEVT proposed that teachers' influence on student achievement motivation and emotion depends in part on students' interpretation of their teacher instructional behavior (see also Helmke, 2009; Könings et al., 2005; Skinner & Belmont, 1993). This process has been termed transmission (Tishman et al., 1993) and finds its origin partly in the data transmission model (Shannon and Weaver, 1949). The underlying mechanism behind such transmission processes is an information transmission from an information source (sender) to a receiver who decodes the information sent (Shannon & Weaver, 1949). This process also takes place in classrooms, for example, when teachers prepare and transmit information to their students while students receive and act on this information (Tishman et al., 1993). As information transmission is necessary for effective student learning (Fend, 1981), researching these transmission processes between teachers and students allows us to investigate whether the teacher's intention to convey certain information (e.g., their emotional care for the student) actually took place and whether students receive this information as such and use it for their own learning processes. Given the substantial empirical evidence on the effectiveness of student perceptions of instructional behavior on their achievement motivation and emotions (Aldrup et al., 2018; Burić & Kim, 2020; Dorfner et al., 2018; Fredricks et al., 2018), we hypothesize based on SEVT (Eccles & Wigfield, 2020) and the data transmission model (Shannon and Weaver, 1949) that instructional behavior influence student achievement motivation and emotion when students perceive their math teachers as emotionally and cognitively supportive and perceive that they offer peer collaborations.

Existing research investigating teacher-to-student transmission processes in classrooms based on instructional quality have relied on students' and teachers' ratings on instructional behavior. Research yielded mixed results so far. Feldlaufer et al. (1988) indicated that teachers and students on average interpreted the frequencies of instructional behavior similarly. However, the overlap of these perceptions declines after the transition into high school (see Midgley & Feldlaufer, 1987; Midgley et al., 1991). By looking at links between teacher and student perceptions, scholars found no significant associations

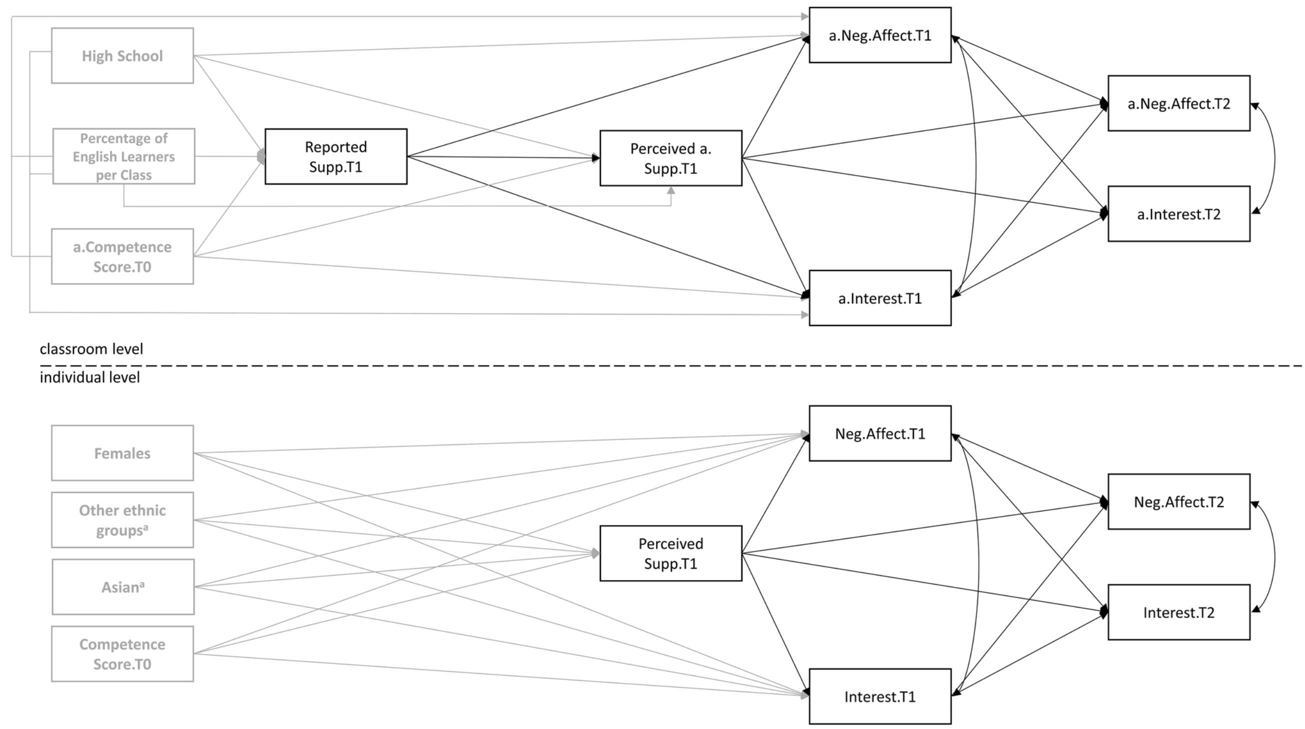

Fig. 1 Theoretical based model with all tested path on individual and classroom level (path from covariates are highlighted grey)

between students' and teachers' reports on teacher support, whereas others found significant associations (Aldrup et al., 2018; Clausen, 2002; Skinner & Belmont, 1993). Upon further review, existing methodological inconsistencies across studies highlight the need to use consistent and objective items for both teachers and students when studying teachers' and students' points of view (see Aldrup et al., 2018; Feldlaufer et al., 1988; Dicke et al., 2021).

To achieve our second study aim, we examined the teacher-to-student transmission process of instructional behavior on negative affect through students' interest value by leveraging data from two different sources: teacher-reported and student-reported measures of teachers' cognitive and emotional support along with teachers' support for peer collaborations. To our knowledge, no study has actually tested within and between-person transmission processes between teachers and students to examine whether teachers influence students' achievement motivation and emotion through students' perception of teachers' instructional behavior. With that, we aim to combine theorist assumptions of CVT (teacher student motivation student emotion, Pekrun, 2006) and SEVT (teacher student perception of teachers student motivation, Eccles et al., 1983) to understand within and between-student processes related to student achievement motivation and emotion in math classes.

Research questions

We examined the following research questions (see hypothesized associations in Fig. 1):

RQ1: To what extent do students' interest value and negative affect co-develop across one school year (a) within and (b) between classes?

RQ2: To what extent are associations between teachers' reported instructional behavior (cognitive and emotional support, and support for collaboration) and students' negative affect mediated by students' perceptions of their teachers' instructional behavior (emotional and cognitive support, as well as support for collaboration) and students' interest value?

We also tested whether the inclusion of important background variables that influence student math achievement and classroom processes, e.g., prior math performance, racial/ethnic background, and gender, changed the patterns of associations. Further information is provided in the descriptions of used instruments.

Method

Design

Data from the California Achievement Motivation Project (CAMP) were used for this study. CAMP is a National Science Foundation-funded longitudinal study of students' math motivation and achievement. Data were obtained from five public schools in one district in Southern California. By using a cohort-sequential design, six students' cohorts were surveyed in their math classrooms in grades 6 through 12. Students' math motivation were surveyed in the fall and spring of each academic year. Students' demographic data and standardized achievement data were obtained from school district records.

Participants

To examine the associations of the constructs of interest within middle school (grades 7–8) and high school (grades 9–12), the study sample was comprised of students' data for grades 7–12 from the beginning (Time 1 in October) and end (Time 2 in May) of one academic year, as well as teacher-reported data for the same classrooms. Teacher data were collected during a professional development workshop shortly before the start of the academic year. For analysis of students' developmental changes, the study sample was restricted to classrooms with the same teachers in both semesters (fall and spring), thus providing a relatively stable math classroom environment across the academic year.

This final sample[1] consisted of 1,429 students (49% male) in 78 classes and 26 teachers in five schools (48% middle school). Teachers were 48% female and the average years of professional job experience were between 4–5 years and 6–10 years. The mean number of students per class was 18. Approximately 68% of the student sample was Hispanic,[2] 15% was Asian[3] and 18% of the students belonged to other ethnic groups. [4]Students' average math achievement as measured by an annually assessed standardized achievement measure (California Standards Test [CST]) was 343.45 with scores ranging from 212 to 600 (SD = 61.99) in middle school and 317.92 ranging from 210 to 537 (SD = 51.73) in high school. Approximately 35% of the students were classified as English Language Learners, and 64% were eligible for free-reduced lunch (as reported by district records). Table A1 in the Supplemental Material provides the descriptive statistics of the analysis sample.

Measures

All items are listed in Table A2 and A3 in the Supplemental Material.

Student questionnaires

Negative affect in math. Three items from the Positive and Negative Affect Schedule-Expanded Form (PANAS-X; Watson & Clark, 1994) were used to assess different negative trait-like emotions (irritated, bored, exhausted). Students were asked how often they felt different types of negative emotions within their math classes or while doing math in school (e.g., "How often do you feel exhausted in your math class?"). The response scale ranged from 1 = *Never* to 5 = *Always*). Reliabilities were acceptable for both time points (Time 1: $\omega = 0.70$; Time 2: $\omega = 0.71$).

Interest value in math. Five items assessed students' math interest value (Eccles & Wigfield, 1995; Conley, 2012). Students were asked about their thoughts and feelings about math (e.g., "I enjoy the subject of math."). The response scale ranged from 1 = *Not at all true for me* to 5 = *Very true for me*. Reliabilities were good for both time points (Time 1: $\omega = 0.95$; Time 2: $\omega = 0.94$).

Perceived teacher's support for collaboration. Student-reported perceptions of their teachers' support for collaboration in their classrooms was measured with four items (Pianta et al., 2008) (e.g., "Our math teacher encourages us to help other students with their math work."). The response scale ranged from 1 = *Not at all true* to 5 = *Very true*. Reliability was good (Time 1: $\omega = 0.80$).

Perceived teacher's emotional support. Student-reported perceptions of their teachers' emotional support were assessed with three items (e.g., Duchesne & Larose, 2007; Fast et al., 2010) (e.g., "Our math teacher listens to what I have to say."). The response scale ranged from 1 = *Not at all true* to 5 = *Very true*. Reliability was good (Time 1: $\omega = 0.81$).

Perceived teacher's cognitive support. Student-reported perceptions of their teachers' cognitive support were measured using a subscale of students' perceived academic press with four items (PALS: academic press; Midgley et al., 2000) (e.g., "Our teacher asks us to explain how we got our answers in math."). The response scale ranged from 1 = *Not*

[1] A detailed explanation about the selection of cases can be found in the section "statistical analysis".

[2] We use the term Hispanic to be consistent with the school district records identification of race. The CA Department of Education defines Hispanic as "A person of Cuban, Mexican, Puerto Rican, South or Central American, or other Spanish culture or origin" (https://www.cde.ca.gov/).

[3] Asian students are identified according to the classifications of the U.S. Census Bureau and include Vietnamese, Korean, Japanese, Chinese, Asian Indian, Laotian, Cambodian, and other Asian cultures.

[4] Students in the other ethnic groups include White, Black, American Indian, etc. and were too small to include in subgroup analyses.

at all true to 5 = *Very true*. Reliability was satisfactory (Time 1: ω = 0.77).

Teacher questionnaires

Teachers' reported support for collaboration. Four items were used to assess teachers' support for collaboration within math classrooms (Karabenick & Maehr, 2007). Teachers were asked at the beginning of the school year (Time 1) about the frequency of their use of collaborative classroom activities in which students can work with each other (e.g., "Students discuss their work with classmates."). The response scale ranged from 1 = *Not often* to 5 = *Very often*. Reliability was good (Time 1: ω = 0.92).

Teachers' reported emotional support. Four items were used to assess teachers' rendering of emotional support to their students from all teachers in their school (Karabenick & Maehr, 2007) (e.g., "Teachers make students feel good about themselves."). The response scale ranged from 1 = *Not at all true* to 5 = *Very true*. Reliability was good (Time 1: ω = 0.90).

Teachers' reported cognitive support. Four items were used to assess teachers' cognitive support for their students in their math classes (Karabenick & Maehr, 2007). Teachers were asked about the frequency in which they encourage students' explanations, understanding, and thinking in math classes (e.g., "Students explain how they got their answers in math."). The response scale ranged from 1 = *Not often* to 5 = *Very often*. Reliability was good (Time 1: ω = 0.89).

Covariates

Covariates on the individual level Gender, ethnicity, and prior achievement were included as covariates at the individual level.

Gender. Students' gender (0 = *male*, 1 = *female*) was included as a covariate because research demonstrates mean differences between males and females in their perceived level of teacher support, interest value, and negative affect in math (Lazarides & Buchholz, 2019; Möller et al., 2015).

Race/ethnicity. Race/ethnicity was assessed through district records. Given the heterogeneity of the sample, we used two dummy variables (Asian Americans: 0 = *students without Asian background*, 1 = *students with Asian background*; Other races/ethnicities: 0 = *students with Hispanic or Asian background*, 1 = *students with another racial/ethnic background*; Hispanic Americans acted as the reference group) to empirically test differences in perceptions between Hispanic Americans, Asian Americans and students with other races/ethnicities. Prior research has documented mean-level math interest differences across racial/ethnic groups using similar racial-ethnic populations in middle school (Safavian, 2016) and high school (Safavian, 2013). Other studies have found differential predictive effects of various styles of teacher instructional behavior for Hispanic-, European-, or Asian Americans (Denver & Karabenick, 2011; Lei et al., 2017).

Math achievement. Prior achievement was operationalized using the district reported exam scores for the California Standards Test (CST) in math—an end of the year exam that measures students' mastery of content standards in compliance with state accountability requirements. Students' math CST scores from the prior year (Time 0) were used as a measure for students' math competency. This test is adapted to the grade level. Scaled scores range from 150 to 600, with proficiency determined by a score of 350 or greater. As previous studies show, students' math competence is (1) associated with their interest value and negative affect (Aldrup et al., 2019; Lazarides & Buchholz, 2019) as well as (2) their perception of teacher support (Fast et al., 2010; Lazarides & Buchholz, 2019).

Covariates on the classroom level Grade level, frequency of English Learner students within the classroom, and the average of student math achievement were included as covariates at the classroom level.

Grade level. Students' grade level (0 = *middle school*, 1 = *high school*) was included as a covariate at the classroom level[5].

Composition of English Language Learners. English learner status was assessed through district records. Students are evaluated according to standards adopted by the California Department of Education. English Language Learners are students who are not yet proficient in English. Previous studies suggest that teachers adapt their teaching based on class conditions and treat classes differently when English learners' levels are high (Ovando & Combs, 2012). Thus, we were interested in examining the impact of the percentage of English learner students (ELS-students) in class on the average of teacher support and the average of interest value and negative affect in math classes.

Class Average Math Achievement. Finally, as explained above, we hypothesized that the average class competence level (aggregated CST) in math impacts classes' interest value and negative affect in math.

Statistical analyses

To take the hierarchical data structure of students within classrooms into account, we used multilevel modeling to analyze the data in M*plus* Version 8.1 (Muthén & Muthén,

[5] Math classes in high school often included more than one grade level. Therefore, we created a variable (0 = middle school, 1 = high school) to test differences between classes in middle school and high school.

1998–2016, type = twolevel). More precisely, we used the doubly-manifest approach based on our research question and the number of paths to be modeled (Lüdtke et al., 2011; Marsh et al., 2009). With this, we excluded classes with less than ten students from our analyses (Hox, 2010). The subsample consists of 78 classes with an average of 18 students per class.

ICC. To analyze the data based on our research questions, we took several steps in the analysis. Interclass correlation coefficients (ICC_1 & ICC_2) were examined for all student reported variables (Hox, 2010; Raudenbush & Bryk, 2002). The amount of variability located in classes (ICC_1) was more than 10 percent for all variables (see Table 2, Varnell, et al., 2004). To determine the reliability of the group average of all aggregated variables, we used the ICC_2, which was between 0.7 and 0.8 (see Table 2, Marsh et al., 2012).

Model specification. After testing measurement invariance (see Table A4), three doubly-manifest multilevel regression models were conducted to address RQ 1 (Lüdtke et al., 2011). The doubly-manifest approach neither controls for measurement error nor sampling error. We decided that the doubly-manifest approach deals best with given data conditions and the complexity of the models. Student reported constructs were split into (a) manifest scales that indicated students' individual mean and (b) manifest scales that indicated class means.

To avoid confounding effects (multicollinearity), we ran three different multilevel path models for all three analyzed types of teacher behavior: support for collaboration (Model 1), emotional support (Model 2), cognitive support (Model 3). We tested multiple models, one for each type of instructional behavior. For each model, we took the same steps to examine associations. In the first step, we ran null models (no predictor models) for negative affect in math and interest value with the goal of assessing the total variance of the outcome variables between Level 1 and Level 2. Afterwards, we specified autoregressive relations of students' interest value and negative affect in math as well as cross-lagged effects of both constructs between Time 1 and Time 2. In the second step, we included students' perceived teacher behavior at both levels and teachers' reported behavior on the classroom level. In the final step 3, all important background indicators were included. Figure 2 represents the final tested model. Student-level predictors, including students' interest value (T1), negative affect (T1), gender, and perceived instructional behavior (T1) were group-mean centered within each model to get statistical information of all tested associations in consideration of students' class affiliation. Students' math test score and the ethnicity indicators were grand-mean centered. At the classroom level, the school type was also grand-mean centered to facilitate the analysis of the general effect of classes in high school compared to middle school (Sommet & Morselli, 2017).

With a focus on transmission processes between teachers and students, we tested same-level and cross-level mediation for each model (Pituch & Stapleton, 2012). For cross-level mediations, we specified 2–1-1–1 and similar models (see Table 3), including teachers' reported instructional behavior (L2), student perceived teacher instructional behavior (L1), and students' interest value or negative affect (L1, T1 and T2). We report standardized coefficients, which show the amount of effects in standard deviation units. The example syntax is provided in the Supplemental Material A9.

In all models, the maximum likelihood with robust standard errors (MLR) estimation was used (Muthén & Muthén, 1998–2016). To evaluate the goodness of model fit, the following indicators were used: robust χ^2 test statistic, the comparative fit index (CFI), Tucker and Lewis index (TLI), the root mean square of approximation (RMSEA), and the standardized root mean residual (SRMR). TLI and CFI values greater than 0.90, RMSEA, and SRMR values lower than 0.08 were accepted as indicators of an acceptable model fit (Brown, 2015; Hu & Bentler, 1999). Next to the indicators of model fits, we checked R^2 and the changes of variances with ICC_1 after including all predictors. To interpret the effect of our models, we used Benjamin and Berger's (2019) recommendation to interpret $p \leq 0.005$ as meaningful and $p \leq 0.05$ as suggestive. We also avoid the language of "statistically significant" in line with Wasserstein et al., (2019). Information about missing data are provided in the Supplement Material A5. We used the full information maximum likelihood algorithm (FIML) to handle missing data (Schafer & Graham, 2002). All analyses were conducted using the maximum likelihood with robust standard errors (MLR) estimation in Mplus 8 (Muthen & Muthen, 1998–2015).

Results

Descriptive results

Descriptive statistics and intercorrelations for all variables on the individual level are reported in Table A6 and Table A7 in the Supplemental Material.

On the *individual level*, all variables measuring students' perception of teacher support were positively associated with one another and students' interest value at Time 1 and Time 2. Students' negative affect was negatively related to all variables measuring students' perception of teacher instructional behavior at the beginning of the academic year. Students' interest value and negative affect were negatively associated at both time points.

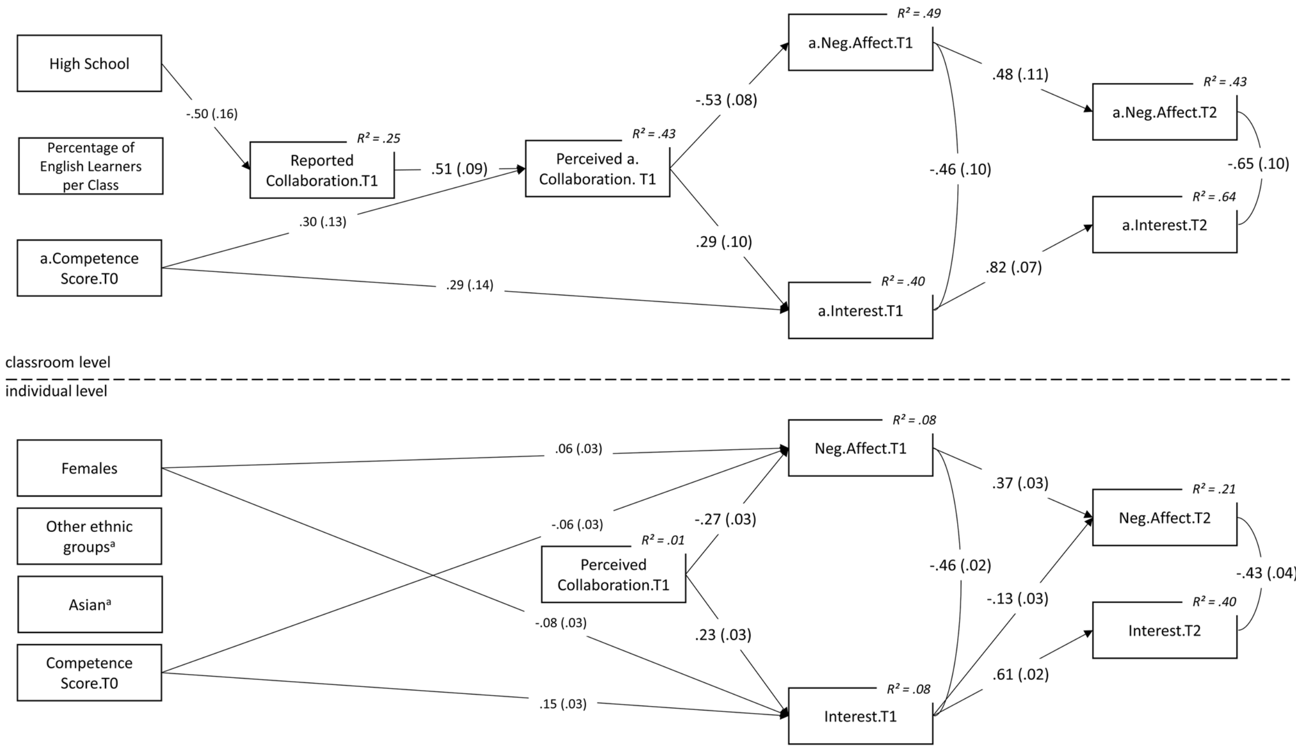

Fig. 2 Results for Testing Effects from Teachers' reported collaboration support and Students' Perceived Support for Collaboration (Model 1—Teachers as Facilitator). Reported are only significant standardized coefficients. Model fit: $\chi2$ (16) = 34.52, $p \leq .05$, CFI = .99, TLI = .96, RMSEA = .03, $SRMR_{within} = .02$, $SRMR_{between} = .04$. [k] reference group are Hispanic students

On the *classroom level*, apart from emotional support, teachers' reported instructional behavior and students' perceived teacher instructional behavior in classrooms were positively related to each other. The class average of interest value was positively related to all variables measuring math classrooms' perception of teacher instructional behavior. The class average of negative affect was negatively related to all variables measuring math classrooms' perception of teacher instructional behavior.

Multilevel analyses

Tables 1 and 2 report the results of the first steps of our model specifications (step 1: null model without predictors and covariates; step 2: model without covariates, see also Supplemental Material, Table A8). The results of the three final models are illustrated in Fig. 2 (Model 1: support for collaboration), Fig. 3 (Model 2: emotional support), and Fig. 4 (Model 3: cognitive support). Fit indices for each model are reported alongside their corresponding figures.

Associations between interest value and negative affect (RQ 1)

For RQ1, we examined associations between students' interest value and negative affect in math at the individual and classroom levels from the beginning to the end of one academic year.

On the *individual level*, students' interest value at Time 1 was meaningfully negatively associated with students' change of negative affect in math from the beginning to the end of the academic year. No direct link was found from students' negative affect to changes in students' interest throughout the academic quarter.

On the *classroom level*, we found no meaningful cross-lagged links between class averages of interest value and negative affect in math.

Teachers' reported support on students' perceived support, interest value, and negative affect (RQ 2)

RQ2 focused on teacher-to-student transmission processes in classrooms. The results of indirect effects are reported in Table 3.

Indirect effects at Time 1 on the *classroom level* showed that teachers' reported support for collaboration was

Table 1 Standardized Estimates of First Step in our Model Specification and the Second Step for Teachers' Support for Collaboration without Covariates Included

	Step 1						Step2														
							Model 1—Support for collaboration														
	Interest.T2			Neg.Aff.T2			a.Coll.Sup.T1b			Interest.T1b			Interest.T2b			Neg.Aff.T1b			Neg.Aff.T2b		
	ß	*S.E*	p	ß	*S.E*	p	ß	*S.E*	p	ß	*S.E*	p	ß	*S.E*	p	ß	*S.E*	p	ß	*S.E*	*p*
Individual level (L1)																					
Interest.T1b	.62	.02	.00	− .14	.03	.00				–	–		.61	.02	.00	–	–		− .14	.03	.00
Neg.Aff.T1b	− .04	.02	.09	.38	.03	.00				–	–		− .04	.02	.09	–	–		.38	.03	.00
Coll.Sup.T1b	–	–	–	–	–	–				.23	.03	.00	.01	.02	.78	− .28	.03	.85	− .01	.03	.85
Classroom level (L2)																					
a.Interest.T1b	.81	.06	.00	− .16	.09	.08				–	–		.82	.07		–	–		− .14	.09	.14
a.Neg.Aff.T1b	.02	.08	.85	.54	.08	.00				–	–		− .02	.09		–	–		.48	.11	.00
a.Coll.Sup.T1b	–	–	–	–	–					.41	.11		− .07	.09		− .56	.09	.00	− .10	.15	.49
t.Coll.Sup.T1a	–	–	–	–	–		.60	.07	.00	.21	.12	.08	–	–	–	− .18	.09	.03	–	–	–
R^2																					
L1	.40	.02	.00	.21	.03	.00	–	–		.08	.02	.00	.40	.02	.00	.08	.02	.00	.22	.02	.00
L2	.64	.07	.00	.42	.08	.00	.37	.08	.00	.31	.07	.00	.64	.07	.00	.47	.07	.00	.43	.09	.00

Coll.Supp = Support for collaboration, *Interest* = Interest Value, *Neg.Aff* = Negative Affect, *a* = aggregated (students report), *t* = teachers reports, *T1a* = first measurement point before beginning of the academic year, *T1b* = first measurement point at the beginning of the academic year

Table 2 Standardized Estimates of the Second Step of Model Specification for Teachers' Emotional Support and Teachers' Cognitive Support without covariates included

Step2

	Model 2—Emotional support															Model 2—Cognitive support														
	a.Emo.Sup.T1b			Interest.T1b			Int.T2			Neg.Aff.T1b			Neg.Aff.T2b			a.Cog.Sup.T1b			Interest.T1b			Int.T2			Neg.Aff.T1b			Neg.Aff.T2		
	ß	*S.E*	p	ß	*S.E*	p	ß	*S.E*	p	ß	*S.E*	p	ß	*S.E*	p	ß	*S.E*	p	ß	*S.E*	p	ß	*S.E*	p	ß	*S.E*	p	ß	*S.E*	*p*
Individual level (L1)																														
Interest.T1b				–	–		.61	.02	.00	–	–		− .14	.03	.00				–	–		.61	.02	.00	–	–		− .14	.03	.00
Neg.Aff.T1b				–	–		− .05	.02	.04	–	–		.39	.03	.00				–	–		− .03	.02	.12	–	–		.38	.03	.00
Emo.Sup. T1b				.28	.03	.00	.01	.02	.67	− .30	.03	.00	.01	.03	.79															
Cog.Sup.T1b																			.21	.03	.00	.03	.02	.17	− .25	.03	.00	− .02	.03	.57
Classroom level (L2)																														
a.Interest. T1b				–	–		.80	.06	.00	–	–		− .14	.09	.14				–	–		.83	.07	.00	–	–		− .14	.11	.18
a.Neg.Aff. T1b				–	–		.05	.09	.55	–	–		.46	.11	.00				–	–		− .00	.08	.96	–	–		.52	.09	.00
a.Emo.Sup. T1b				.56	.08	.00	.07	.06	.25	− .67	.07	.00	− .13	.12	.27															
t.Emo.sup. T1a	− .20	.10	.04	.13	.08	.09	–	–		.01	.08	.90	–	–																
a.Cog.Sup. T1b																–	–		.57	.09		− .05	.08	.52	− .60	.07	.00	− .04	.11	.71
t.cog.sup. T1a																.43	.08	.00	.09	.10		–	–		− .04	.07	.56	–	–	
R^2																														
L1	–	–		.08	.02	.00	.40	.02	.00	.09	.02	.00	.23	.02	.00	–	–		.08	.02	.00	.49	.02	.00	.12	.02	.00	.27	.02	.00
L2	.04	.04	.30	.30	.09	.00	.64	.07	.00	.45	.09	.00	.43	.09	.00	.37	.08	.01	.21	.08	.00	.64	.07	.00	.47	.07	.00	.43	.09	.00

Emo.Supp = Emotional Support, *Cog.Supp* = Cognitive Support, *Interest* = Interest Value, *Neg.Aff* = Negative Affect, *a* = aggregated (students report), *t* = teachers report, *T1a* = first measurement point before beginning of the academic year, *T1b* = first measurement point at the beginning of the academic year

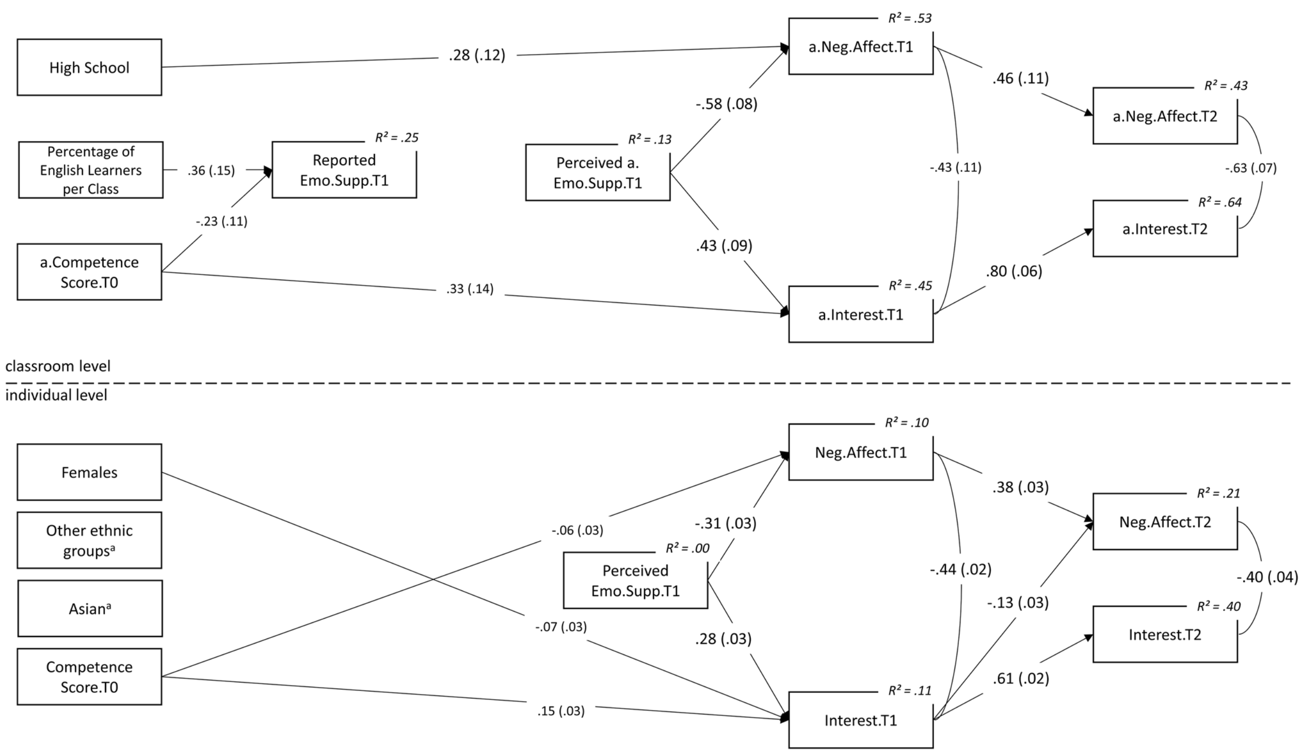

Fig. 3 Results for Testing Effects from Teachers' Reported Emotional Support and Students' Perceived Emotional Support (Model 2—Teachers as Buddy). Reported are only significant standardized coefficients. Model fit: χ^2 (16) = 38.01, $p \leq .05$, CFI = .99, TLI = .96, RMSEA = .03, $SRMR_{within}$ = .02, $SRMR_{between}$ = .05. [a] reference group are Hispanic students

meaningfully linked to the average level of negative affect and suggested a link to interest value in their classroom that operated through classes' average perceived teacher support for collaboration. The same holds true for cognitive support: Teachers' reported cognitive support was indirectly meaningfully associated with their classes' average perceived negative affect and effects suggested an indirect effect to interest value through classes' average perceived cognitive support in math (unique class-level indirect effect, see Table 3). These described associations were cross-sectional (2–2–2), but not found longitudinally (2–2–2–2). Possible reasons for the lack of longitudinal correlations could be statistical, such as the low variance in anxiety at the class level. Teachers' reported emotional support was not related to students' perceived emotional support and did not affect interest value and average negative affect through students' perceived emotional support at the classroom level.

Cross-level mediation analysis demonstrated that teachers' reported support for collaboration was meaningfully cross-sectionally related to students' interest value and negative affect mediated through individual students' perception of teachers' support for collaboration (2–1-1). Results also suggested that students' negative affect at Time 2 was longitudinally predicted by teachers' reported support for collaboration through individual students' perception of teachers' support for collaboration and students' interest value at Time 1 (2–1–1–1). The same results were found for teachers' cognitive support (total indirect effect; see Table 3). The cross-level mediation of teachers' emotional support on students' interest value and negative affect was not supported.

In addition, teachers' reported support for collaboration and cognitive support were directly meaningfully but cross-sectionally associated with students' individual interest value and negative affect. Results also point to a meaningful total effects from teachers' reported emotional support to higher negative affect of individual students longitudinally and suggested a total effect, but cross-sectionally (total effect, see Table 3).

Association with students' gender, prior achievement, and race/ethnicity

Results on links with important background variables are illustrated in Figs. 2, 3 and 4. At the *individual level*, results suggested that female students reported lower interest value and higher negative affect in math than males. Male and female students perceived the same level of teacher support

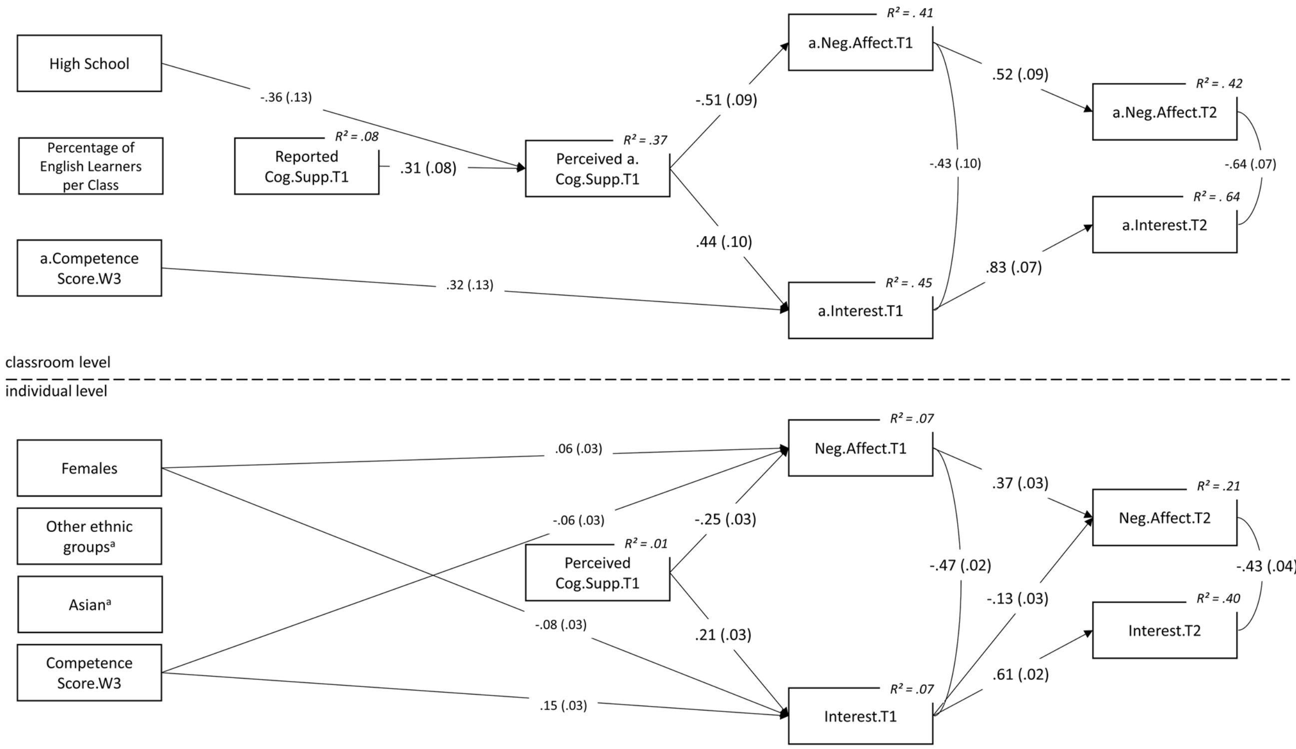

Fig. 4 Results for Testing Effects from Teachers' Reported Cognitive Support and Students' Perceived Cognitive Support (Model 2—Teachers as Tutor). Reported are only significant standardized coefficients. Model fit: χ^2 (16) = 31.03, $p \leq .05$, CFI = .99, TLI = .97, RMSEA = .03, $SRMR_{within}$ = .02, $SRMR_{between}$ = .04. [a] reference group are Hispanic students

in all three models. Asian American students and students from other racial/ethnic groups reported the same level of interest value, negative affect, and perceived teacher support in all three models relative as Hispanic American students. Students' prior performance was meaningfully positively associated with their interest value and results suggested a negative link between prior performance and later negative affect in math.

At the *classroom level*, results on the class-average standardized math achievement test score (CST) suggested that the average math interest value level was lower when students were also lower achieving on average. Students, on average, perceived greater support for collaborative work with a higher class average CST. Interestingly, results suggested that teachers reported lower emotional support with a lower class average CST. The ratio of English learners within a classroom was neither associated with teacher-reported nor classes' average perceived teacher support nor with class-average of interest value and negative affect. Results also suggested that high school teachers were more likely to support collaborative work in their math classrooms than middle school teachers.

Model results without controlling for important background variables

We only see three differences in effects comparing models without and with covariates (see Tables 1 and 2; Figs. 2, 3 and 4). First, focusing on support for collaboration, effects suggested that teachers' reported support for collaboration was associated with negative affect when further covariates were not controlled for. Second, focusing on emotional support, the link between teachers' reported emotional support with students' reported emotional support was only suggested when covariates were not controlled for. Third, again for emotional support, negative affect (T1) was only suggested to be linked to changes in interest value (T2) without controlling for covariates.

Discussion

We were interested in the longitudinal association between students' interest value and negative affect in math. We investigated teacher-to-student transmission processes within and between classrooms, i.e., short- and long-term associations between different types of instructional behavior, students' interest value, and negative affect in

Table 3 Standardized Estimates and 95% Confidence Intervals for Same-Level Indirect Effects, Total Indirect Effect and Total Effects

				B	*SE*	*p*	*95% [CI]*
Unique class-level indirect effect (2–2–2[–2])							
t.Coll.Sup.T1	a.Coll.Sup.T1	a.Interest.T1		.12	.05	.01	[.02; .21]
t.Coll.Sup.T1	a.Coll.Sup.T1	a.Interest.T1	a.Neg.Aff.T2	− .01	.01	.22	[− .03; .01]
t.Coll.Sup.T1	a.Coll.Sup.T1	a.Neg.Aff.T1		− .16	.04	.00	[− .24; − .08]
t.Coll.Sup.T1	a.Coll.Sup.T1	a.Neg.Aff.T1	a.Interest.T1	.00	.02	.94	[− .03; .04]
t.Emo.sup.T1	a.Emo.Sup.T1	a.Interest.T1		− .07	.04	.11	[− .15; .02]
t.Emo.sup.T1	a.Emo.Sup.T1	a.Interest.T1	a.Neg.Aff.T2	.01	.01	.18	[− .004; .02]
t.Emo.sup.T1	a.Emo.Sup.T1	a.Neg.Aff.T1		.07	.04	.10	[− .01; .15]
t.Emo.sup.T1	a.Emo.Sup.T1	a.Neg.Aff.T1	a.Interest.T1	.01	.01	.53	[− .01; .02]
t.Cog.Sup.T1	a.Cog.Sup.T1	a.Interest.T1		.12	.05	.01	[.03; .22]
t.Cog.sup.T1	a.Cog.Sup.T1	a.Interest.T1	a.Neg.Aff.T2	− .01	.01	.24	[− .04; .01]
t.Cog.Sup.T1)	a.Cog.Sup.T1	a.Neg.Aff.T1		− .11	.04	.00	[− .18; − .03]
t.Cog.sup.T1	a.Cog.Sup.T1	a.Neg.Aff.T1	a.Interest.T1	.00	.01	.96	[− .02; .02]
Total indirect effect (2–1–1[–1])							
t.Coll.Sup.T1	Coll.Sup.T1	Interest.T1		.25	.07	.00	[.12; .38]
t.Coll.Sup.T1	Coll.Sup.T1	Interest.T1	Neg.Aff.T2	− .04	.02	.01	[− .07: − .01]
t.Coll.Sup.T1	Coll.Sup.T1	Neg.Aff.T1		− .28	.06	.00	[− .40; − .16]
t.Coll.Sup.T1	Coll.Sup.T1	Neg.Aff.T1	Interest.T2	.02	.02	.43	[− .02; .05]
t.Emo.sup.T1	Emo.Sup.T1	Interest.T1		− .12	− 07	.09	[− .26; .02]
t.Emo.sup.T1	Emo.Sup.T1	Interest.T1	Neg.Aff.T2	.02	.02	.12	[− .01; .05]
t.Emo.sup.T1	Emo.Sup.T1	Neg.Aff.T1		.11	.07	.09	[− .02; .24]
t.Emo.sup.T1	Emo.Sup.T1	Neg.Aff.T1	Interest.T2	.00	.01	.99	[− .02; .02]
t.Cog.Sup.T1	Cog.Sup.T1	Interest.T1		.19	.07	.00	[.07; .32]
t.Cog.Sup.T1	Cog.Sup.T1	Interest.T1	Neg.Aff.T2	− .04	.02	.04	[− .07; − .002]
t.Cog.Sup.T1	Cog.Sup.T1	Neg.Aff.T1		− .17	.05	.00	[− .27; − .07]
t.Cog.Sup.T1	Cog.Sup.T1	Neg.Aff.T1	Interest.T2	.01	.01	.56	[− .02; .03]
Cross level indirect effect (2–2–2–1)							
t.Coll.Sup.T1	Coll.Sup.T1	Interest.T1	Neg.Aff.T2	− .01	.01	.03	[− .03; − .001]
t.Coll.Sup.T1	Coll.Sup.T1	Neg.Aff.T1	Interest.T2	.01	.01	.15	[− .003; .02]
t.Emo.sup.T1	Emo.Sup.T1	Interest.T1	Neg.Aff.T2	.01	.01	.14	[− .002; .02]
t.Emo.sup.T1	Emo.Sup.T1	Neg.Aff.T1	Interest.T2	− .00	.00	.27	[− .01; .003]
t.Cog.Sup.T1	Cog.Sup.T1	Interest.T1	Neg.Aff.T2	− .01	.01	.02	[− .03; − .002]
t.Cog.Sup.T1	Cog.Sup.T1	Neg.Aff.T1	Interest.T2	.00	.00	.22	[− .003; .01]
Cross level indirect effect (2–1–1–1)							
t.Coll.Sup.T1	Coll.Sup.T1	Interest.T1	Neg.Aff.T2	− .02	.01	.00	[− .02; − .01]
t.Coll.Sup.T1	Coll.Sup.T1	Neg.Aff.T1	Interest.T2	.01	.00	.18	[− .003; .02]
t.Emo.sup.T1	Emo.Sup.T1	Interest.T1	Neg.Aff.T2	.01	.00	.11	[− .001; .01]
t.Emo.sup.T1	Emo.Sup.T1	Neg.Aff.T1	Interest.T2	− .00	.00	.28	[− .01; .002]
t.Cog.Sup.T1	Cog.Sup.T1	Interest.T1	Neg.Aff.T2	− .01	.00	.01	[− .01; − .002]
t.Cog.Sup.T1	Cog.Sup.T1	Neg.Aff.T1	Interest.T2	.00	.00	.23	[− .002; .01]
Total effects							
t.Coll.Sup.T1		Interest.T1		.36	.09	.00	[.18; .53]
		Interest.T2		.07	.06	.26	[− .05; .19]
		Neg.Aff.T1		− .36	.08	.00	[− .51; − .20]
		Neg.Aff.T2		− .09	.08	.27	[− .24; .07]
t.Emo.sup.T1		Interest.T1		.00	.09	.99	[− .17; .17]
		Interest.T2		− .06	.04	.20	[− .14; .03]
		Neg.Aff.T1		.16	.08	.05	[.00; .32]
		Neg.Aff.T2		.15	.04	.00	[.07; .23]
t.Cog.Sup.T1		Interest.T1		.27	.08	.00	[.11; .42]
		Interest.T2		.02	.06	.76	[− .09; .13]
		Neg.Aff.T1		− .20	.06	.00	[− .32; − .08]
		Neg.Aff.T2		− .02	.07	.75	[− .15; .11]

Coll.Supp = support for collaboration, *Emo.Supp* = emotional support, *Cog.Supp* = cognitive support, *Interest* = Interest Value, *Neg.Aff* = Negative Affect, *a* = aggregated (students report), *t* = teachers report math. The main findings of this study are (a) interest value influenced changes in students' negative affect but not vice versa only at the individual level and (b) links were suggested between teacher reported cognitive support and support for collaboration and individual student negative affect through student perceptions of these instructional behaviors and student interest value.

Longitudinal associations between students' interest value and negative affect

Students' interest value and negative affect were negatively correlated with each other both within and between classes. Prior theory (Eccles et al., 1983; Pekrun, 2006; Pekrun & Perry, 2014) and scholars (Ahmed, van der Werf, et al., 2010) suggest bidirectional relations between students' interest value and negative affect. Our findings, however, supported only a unidirectional impact from initial interest value to change in negative affect over time on the individual level but not on the class level: students' negative affect was lower at the end of the academic year when they reported a higher interest value at the beginning of the academic year (see also Rubach & Bonanati, 2021).

Unlike previous studies and contrary to what both CVT and SEVT predict, we did not find that students' initial negative affect caused changes in students' interest value across time. In contrast, Sutter-Brandenberger et al. (2018) found that seventh-grade students enjoyed math less at the end of the year when they reported higher anxiety and anger at the beginning of the academic year and not vice versa. They, however, were not focused on within and between-classes effects. We see several reasons for the differences in results. Their seventh-grade student sample was asked directly after they transitioned from primary to secondary school, and only at this time did the authors find significant associations from motivation to emotions. Research suggests that students' positive achievement emotions and value appraisals are likely to be negatively impacted by the middle-to-high school transition (Eccles et al., 1998). This might result in a stronger effect of negative emotions on the positive development of students' motivation within new, unstable environments after a school transition (Eccles et al., 1998).

Another reason for differences in results might be the use of different instruments of emotional valence in general (i.e., negative affect) vs. specific emotions (i.e., anger, anxiety). Theoretically, students' interest value influences students' negative affect and is important for students' general negative valence in emotions, but there are inter-individual differences in associations between students' interest value and specific negative emotions (Ahmed et al., 2010a, 2010b). We generally expect that positively valenced value beliefs counteract negative affect (Pekrun & Perry, 2014). However, future research needs to examine hypothesized inter-individual differences in these associations by considering multiple negative achievement emotions.

When discussing the relevance of distinct emotions, consideration should also be given to links to positive emotions. More research is needed to investigate bidirectional links between interest, as well as positive and negative emotions. However, we would like to emphasize that conceptually separating positive emotion from interest value is a methodological challenge since existing interest value instruments often capture positive emotion such as excitement or joy.

Transmission processes from teachers to students in math classes

Our findings demonstrated teacher-to-student transmission processes for support for classroom collaboration and cognitive support (Helmke, 2009; Könings et al., 2005; Skinner & Belmont, 1993). Findings suggested that both teachers' reported cognitive support and support of peer collaboration within the classroom were positively associated with lower negative affect through higher interest value when their students perceived their teachers as supportive. These behaviors might cultivate students to be more interested and have lower negative affect in math. The transmission between teacher and student perceptions was supported within (2–1–1–1) but not between classrooms (2–2–2–2). Indeed, our results support theoretical assumptions of both CVT (Pekrun, 2006) and SEVT (Eccles & Wigfield, 2020): teachers impact their students' achievement motivation and emotion (CVT) through students' individual interpretation of their teachers' behavior (SEVT). Our results also highlight the importance of teacher-to-student transmission. How teachers' intentions are projected (i.e., the behavioral manifestation of their intentions) and perceived/interpreted subjectively by students within their classrooms has important consequences for their students' achievement motivation and emotions (Helmke, 2009; Maulana et al., 2016). As we did not support longitudinal between-class teacher-to-student transmission processes, our results suggests that instructional behavior, i.e., teacher support, needs to address students' individual beliefs rather than be adapted to average class needs. Another reason might be the low variance at the class level. Therefore, we believe that teachers have to ensure that students see their teachers as supportive by (a) changing their attitudes to provide improved support to students and (b) transparently communicating to students how support is provided and what the purpose of such support is for students' academic development.

Teacher- and student-reported emotional support was not significantly associated both within and between classes. This finding might relate to the objectivity of measurement items and their ease of evaluation (Aldrup et al., 2018). Considering the nature of the used questionnaire items (see Table A2 and A3), it could be easier to reflect on the occurrence of behaviors that speak to cognitive and collaborative support (e.g., discussions, questions, and collaboration activities) than reporting on caring behavior which is relatively subjective and related to personal preferences and interpretations. Socio-cultural variations in what constitutes teacher caring or emotional support might shed light on these mechanisms (den Brok et al., 2002; Umarji, 2021). However, Aldrup et al. (2018) and Hughes (2011) also identified no significant association between student and teacher perceptions of teacher emotional support. We suggest future research to investigate transmission processes between teachers and students using identical measures and factors that might influence such processes in classrooms.

Another crucial question that needs to be investigated is whether teachers' instructional behavior impacts students' achievement through (a) students' perceived instructional behavior and (b) students' interest and negative affect. Scholars highlighted that emotion, motivation and cognition are inseparable factors (see Linnenbrink, 2006). We highly recommend testing these longitudinal associations to understand the complex interplay over time broadly.

Limitations of the study

There are several limitations to this study that warrant discussion as a function of using secondary data. Teacher and student' perceptions of classroom experiences were captured roughly at the same measurement point (Aldrup et al., 2018; Clausen, 2002). In detail, teacher data were assessed shortly before instruction began whereas student data were assessed during the beginning of the academic year. When testing the transmission of classroom experiences from teacher to student, it would be ideal to assess transmissions across at least two time points (Mitchell & James, 2001; Ployhart & Vandenberg, 2010), but assess teacher behavior in class and not their intended instructional behavior. The ideal study design would also have at least three measurement points to test mediation (Chan, 1998). To control for measurement errors and investigate true change, our findings should be replicated in future studies using even larger datasets that examine students' perception of classroom experiences as a mediator between teacher-reported instructional behavior and students' achievement motivation and emotion (Ployhart & Vandenberg, 2010).

Based on the complexity of the model and the limited number of teachers (n = 26), we were not able to account for the fact that teachers were teaching multiple classrooms. Future research needs to replicate our findings by using a larger teacher sample and by collecting teacher reports for each class. This would allow for more advanced modeling (such as three-level multilevel models). It would also allow us to investigate the variability of one teacher's beliefs and instructional behavior and their students' perception of this teacher across classes (e.g., Fauth et al., 2020; Voss et al., 2022).

Another limitation is the use of affective instruments (negative affect) instead of instruments that assess emotions accounting for valence (Levine & Pizarro, 2004). As we used the *California Achievement Motivation Project* (CAMP) dataset for secondary analysis, we did not have the chance to investigate associations between interest value and distinct negative emotions. Emotions captured in the instrument used were exhaustion, boredom and irritation which refer to negative, deactivating emotions. We strongly recommend linking interest value with various negative (activating and deactivating) achievement emotions aiming to understand any potential differential correlation patterns in future research.

Lastly, we acknowledge that the data were collected in 2004 and 2006, and students' experiences may have changed since then due to new pedagogical approaches and increased use of technology in classrooms. Further research is needed on whether and how these changes might have changed the way students experience cognitive and emotional support or collaboration in their classes. One could also argue that the theoretical understanding of high-quality teaching has remained consistent over the last few decades (see Pianta & Hamre, 2009) and that psychological processes underlying the impact of teaching quality on motivation and emotion are universal. To prove these assumptions, it is essential to use data from various decades to investigate if teaching processes have different effects on students' academic development across time. We see this study as one step in the accumulation of the needed evidence.

Theoretical, empirical, and practical implication

Combining theoretical models of classroom environment processes enriches research by using different perspectives to explain psychological functioning. Using assumptions about social interactions between teachers and students from SEVT (Eccles et al., 1983) and CVT (Pekrun, 2006) allowed us to investigate within and between-person teacher-to-student transmission in depth. Our results supported CVT (Pekrun, 2006) by highlighting teacher-to-student-transmissions, i.e., that teachers' cognitive support and support for collaboration lowers students' negative affect in math across one academic year through students' interest value at the individual level. Our result also supports SEVT (Eccles & Wigfield, 2020) by highlighting that teachers only influence students' negative affect when students interpret their teachers as supportive. In sum, our study sheds light on classroom processes and factors that need to be considered in understanding students' positive academic growth in math.

An important empirical implication relates to using teacher and student data to explain student motivational and emotional development. As seen in our study, teacher and student reports on teacher instructional behavior correlated between $0.43 \geq r \geq 0.60$ for support for collaboration and cognitive support. This might indicate that students can provide valid evaluations for these two forms of instructional behavior, supporting the use of student data on teacher behavior in research. This conclusion can not be drawn for ratings of teacher emotional support. However, an open question is the extent to which the congruence between the two perspectives or the respective unique perspective of student and teacher' perceptions of instructional behavior predict student positive academic growth.

Two practical implications can be highlighted. Students' learning environment can be designed well qualitatively (Könings et al., 2005), but students' perception of their learning environment matters for their academic outcome. Teachers' understanding of whether their students perceive and understand their instructional behavior might be important. The use of evaluation loops can help to identify possible discrepancies and reduce them by adapting teachers' behavior or students' perception (Könings et al., 2005).

Another practical implication is that teachers can support students' interest value and counteract the development of negative affect in math through their instructional behavior. Our study demonstrates that two instructional behaviors can be implemented in classrooms. First, teachers can implement collaborative processes between classmates, i.e., discussions, exchanges of ideas, projects or peer support. A second strategy involves rendering cognitive support, where the teacher can encourage students to explain how they find solutions and reflect on the content they learn in their classes.

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Data availability The data that support the findings of this study are available from Dr. Nayssan Safavian upon request.

Declarations

Conflict of interest We have no conflict of interest to disclosure.

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