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ORIGINAL PAPER

Motivational climate in mathematics classrooms: teacher self-efficacy for student engagement, student- and teacher-reported emotional support and student interest

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Abstract
Mathematics interest is highly relevant for students' academical and emotional development in the domain of mathematics. Thus, it appears alarming that students' mathematics interest decreases during the course of secondary school. Teacher self-efficacy is a central facet of teacher motivation and is assumed to be highly relevant for student mathematics interest. However, there is a paucity of research that investigates the longitudinal and indirect relations through which teacher self-efficacy relates to students' interest through their teaching behaviors in mathematics classrooms. Therefore, in the present longitudinal study we aim to contribute to research by identifying how teacher self-efficacy for student engagement contributes to students' mathematics interest in secondary classrooms through student- and teacher-reported support. We used a sample of mathematics teachers ($n = 50$) and their students ($n = 959$). Longitudinal data of three measurement waves collected from German ninth grade mathematics classrooms were included in the analysis. Results of latent-manifest multi-level analysis showed that teacher self-efficacy for student engagement at Time 1 (beginning of ninth grade) positively predicted student-perceived, but not teacher-perceived, teacher emotional support at Time 2 (beginning of tenth grade), which in turn positively predicted students' mathematics interest at Time 3 (middle of tenth grade). A possible implication for mathematics teachers' educational practice involves strengthening mathematics teachers' self-efficacy for student engagement by means of direct interventions and in-servive training for mathematics teachers.

Keywords Mathematics classrooms · Teacher self-efficacy for student engagement · Teacher support · Student interest · Multi-level analysis · Longitudinal modelling

1 Introduction

The domain of mathematics is particularly important for students because mathematics competence represents an important life skill that enables students to participate in modern societies (OECD, 2018). In mathematics classrooms, students' interest is highly relevant for student achievement (e.g. Heinze et al., 2005), and for career aspirations related to mathematics (Watt et al., 2017). Given the significance of mathematics interest for academic development and choices, it is problematic that students' interest in mathematics decreases during the course of secondary school (e.g., Frenzel et al., 2010). Consequently, it is important to examine how and through which processes teachers' beliefs and behaviors in mathematics classrooms can enhance students' mathematics interest. Existing studies concerned with mathematics classrooms showed that student-reported teacher support positively relates to students' interest (Oppermann & Lazarides, 2021). An important predictor of teachers' supportive behaviors, in turn, is teacher self-efficacy (Holzberger et al., 2013; Oppermann & Lazarides, 2021). However, because of a scarcity of longitudinal studies in the field, it remains unclear through which processes teacher self-efficacy indirectly predicts students' mathematics interest. Against this backdrop, in the present longitudinal study we investigated how teacher self-efficacy would relate to students' mathematics interest through its effect on teachers'

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emotional support for students as perceived by students and teachers. In this particular study we focus on teacher self-efficacy for student engagement, which includes teachers' beliefs concerning the importance of providing emotional support and motivating students. We do not focus on teacher self-efficacy for teaching mathematics, which refers to teachers' beliefs concerning the efficient teaching of mathematics while relying on their teaching skills.

1.1 Teachers' self-efficacy and perceived teacher emotional support

Teacher self-efficacy refers to teachers' judgment of their capability to perform successfully teaching tasks such as encouraging students to engage in class and coping with difficult or unmotivated students (Tschannen-Moran & Woolfolk Hoy, 2001). On a theoretical level, it is assumed that teacher self-efficacy, through its effects on teachers' effort and persistence, enhances teachers' effective classroom behaviors (Bandura, 1997). Tschannen-Moran and Woolfolk Hoy (2001) distinguished three dimensions of teacher self-efficacy, namely, teacher self-efficacy for instructional strategies, for classroom management and for student engagement. Teacher self-efficacy for student engagement describes teachers' own capabilities to motivate students—especially those with low interest or who place a low value on learning (Tschannen-Moran & Woolfolk Hoy, 2001). In the present study teacher self-efficacy for student engagement was assessed with items that tap teachers' behavior with regard to helping students value learning, motivating students who show low interest in mathematics, and motivating even those students who often fail school requirements—thus implying supportive teacher behavior. Aligned with this focus of supporting (even the unmotivated students) we also focused on the teachers' behavior in terms of student- and teacher-perceived emotional support with items assessing teachers' emotionally supporting behavior by item-wording referring, for example, to the teacher caring about students' problems.

Empirically, it has been shown that teacher self-efficacy for student engagement correlates with *student-perceived* class-level teachers' autonomy support, which in turn associates with students' emotional engagement (Zee & Koomen, 2020). There is a paucity of longitudinal studies on the specific dimension of teacher self-efficacy for student engagement and its relations to supportive teaching and student motivation. Until now, most previous work considered teacher self-efficacy on a rather general level in regard to a broad array of tasks such as cooperation with parents, colleague support, and interaction with students. Longitudinal results indicated, for example, that mathematics teachers' general self-efficacy predicted teacher-reported (but not student-reported) learning support (Holzberger et al., 2013) or class-level mathematics teacher support as perceived by students (Oppermann & Lazarides, 2021).

1.2 Perceived emotional support and student mathematics interest

Teachers' emotional support refers to teachers' ability to create a warm and respectful classroom climate by fostering positive teacher-student and student–student interactions, by noticing students' difficulties, acknowledging students' emotions and opinions, and by supporting students' social and emotional functioning (Pianta & Hamre, 2009). The emotional support provided by the teacher is assumed to be highly relevant for students' interest (Klieme et al., 2009). Interest is defined as a relational concept that refers to the relationship of a person with a certain object (Krapp, 2007) that can be distinguished in situational interest (situative and dynamic nature) and individual interest (stable, affective orientation) (Schiefele, 2009). In this study, we focused on students' individual interest in mathematics. Based on self-determination theory (e.g., Ryan & Deci, 2000), student intrinsic motivation and the related construct interest are enhanced when students experience feelings of relatedness or belongingness with others. Literature in this context has described how teacher support is expected to relate to socio-emotional outcomes such as student well-being and learning motivation (Praetorius et al., 2018). Accordingly, in the domain of mathematics, research on motivational classroom environment has indicated cross-sectional relations between student-level mastery orientation as perceived by students in classrooms and their (emotional and cognitive) interest in mathematics (Carmichael et al., 2017). With regard to supportive classroom environment, empirical findings showed that individual student-perceived teacher concern about students learning progress is positively associated with student mathematics interest (Tosto et al., 2016). Teacher-reported closeness, which includes warm and open relations with students, was positively related with teacher-reported student motivational attitudes, such as effort and persistence (Zee et al., 2021). Because empirical studies (Oppermann & Lazarides, 2021; Tosto et al., 2016) emphazise the relevance of *student* perception of teacher support for student mathematics interest one might assume that student perception of emotional support would be of particular relevance for student mathematics interest compared to teacher-reported emotional support. In the present study, we included the students' perspective because research has indicated that students' perspectives are particularly important for their motivational development (Clausen, 2002). However, only including students' perspectives of teaching quality might be problematic because students lack pedagogical expertise and their evaluations of teaching quality are biased by their relationships with specific teachers (Göllner et al., 2018). Against this background, current research literature emphasizes the importance of considering both perspectives in order to better understand the relations between teacher motivation, perceived teaching behaviors and student motivation (Lauermann & ten Hagen, 2021). Each of these approaches has its strengths—whereas student perspectives matter particularly for students' motivation (Clausen, 2002), the teachers' perspectives on teaching behaviors might provide an accurate estimation of specific instructional approaches (Kunter & Baumert, 2006).

1.3 Individual characteristics and motivational processes

Given the empirical evidence that students' achievement and students' gender are related to their interest in mathematics (Köller et al., 2001), we included students' mathematics competence in our analyses and assumed that competence would be related to students' interest. Furthermore, we assumed that girls would report less interest in mathematics than boys. Research also points to the relevance of teachers' knowledge for supportive teacher behavior such as caring ethos (Lohse-Bossenz et al., 2015). Thus, we assumed that teachers with high educational knowledge would provide their students with more emotional support. Furthermore, teachers' years of experience seem relevant for supportive classroom climate in mathematics: Recent research results showed that students of more experienced teachers report a particularly high supportive climate in class (Bijlsma et al., 2022)—thus, we assumed more experienced teachers to be more supportive. Results also showed that female teachers report more closeness with students than male teachers (Split et al., 2012). We thus assumed that female teachers would rate themselves to be more emotionally supportive. Considering the relevance of these variables for the relations with teacher supportive behavior and student interest, we included them in our analyses.

1.4 The present study

Most studies examine general teacher self-efficacy, not taking into account that teacher self-efficacy must refer to the teaching behavior of interest (Bandura, 2006). One important teaching behavior in mathematics classrooms is teachers' emotional support for students, as both theoretical and empirical work propose that teachers' emotional support is important to inhibit the decline in students' mathematics interest (Ryan & Deci, 2000). Mathematics teachers' supportive behaviors are, in turn, predicted by their self-efficacy (Holzberger et al., 2013). However, prior research has not considered the role of matching among teachers' self-efficacy facets and teaching behaviors and how it affects students' motivation. In this study, we therefore examined whether mathematics teacher self-efficacy for student engagement relates to students' mathematics interest by means of teachers' emotional support in class as perceived by students and teachers. We examined the following hypotheses:

H1a: Teacher-self efficacy for student engagement (Time 1) relates positively to student-reported emotional support at the individual level and class level (Time 2) in mathematics classrooms.

H1b: Teacher-self efficacy for student engagement (Time 1) relates positively to teacher-reported teacher emotional support (Time 2) in mathematics classrooms.

H2a: Emotional support as reported by students at the individual level and at the class level (Time 2) is assumed to relate positively to students' interest at individual level and at class level (Time 3).

H2b: Emotional support as reported by teachers (Time 2) at the class level, is assumed to relate positively to students' interest at class level (Time 3). We expect weaker relations between emotional support reported by teachers and students' interest in mathematics compared to emotional support as reported by students.

H3a: Teacher-self efficacy for student engagement (Time 1) relates positively and indirectly to student mathematics interest (Time 3) at the individual level and at the class level through student-perceived emotional support at the individual level and class level (Time 2) when controlling for previous levels of student mathematics interest (Time 1).

H3b: Teacher-self efficacy for student engagement (Time 1) relates positively and indirectly to student mathematics interest (Time 3) at the individual level and at the class level through teacher-perceived emotional support (Time 2) when controlling for previous levels of student mathematics interest (Time 1).

2 Method

2.1 Participants and procedure

Data were drawn from the longitudinal Teach study (Lazarides & Schiefele, 2019–2022)—the full title of which is: 'Teach! The Role of Teachers' Beliefs and Instructional Practices for Students' Beliefs and Academic Outcomes'. Participants were secondary school mathematics teachers ($N = 50$; 66.0% female; 94.0% born in Germany) and their ninth-grade (at Time 1) students ($n = 959$; 48.7% girls; $M_{age} = 14.20$, $SD = 0.62$; Range: 13–17 years;

91.7% born in Germany; 18.8% 'German-as-a-second-language' speaking students) from 52 classrooms (two teachers taught classes in two classrooms) in 30 public schools in Germany (52.8% academic track 'Gymnasium'; 47.2% other school types[1]). Teachers were on average 45.54 years old ($SD = 10.45$), had on average 17.53 years of teaching experience ($SD = 13.23$; Range: 1–38), and taught the participating classes between 1 and 4 years ($M = 2.34$, $SD = 0.96$). One third of the teachers (36.0%) were homeroom teachers. The average number of students per classroom was 18.44. From the original sample of $N = 2095$ students participating in the Teach project, we included only those students whose teachers filled in the teacher questionnaire at Time 1, who did not change mathematics teachers across the three measurement occasions and who participated in at least two measurement occasions (excluded were $n = 1136$ students): More precisely, we included students who participated in the questionnaire study for at least two waves (Time 1 and Time 2 OR Time 2 and Time 3 OR Time 1 and Time 3 OR all Times). Thus, in our target sample $n = 959$ students remained.

Students filled in questionnaires on teacher motivation, student motivation, and teaching quality in mathematics, and completed a standardized mathematics competence test on three measurement occasions (Time 1: Fall 2019, Time 2: Fall 2020, Time 3: Spring 2021). On the same measurement occasions, teachers filled in a questionnaire on their motivation and beliefes, student motivation, teaching quality in mathematics, and completed a standardized knowledge test. Trained research assistants carried out the data collection. Students and teachers worked on their questionnaires at the same time. One week after the questionnaire assessment, students participated in a standardized curriculum-sensitive mathematics competence test, while their teachers were presented with a standardized knowledge test. Students and teachers had at each data assessment (questionnaire and mathematics competence test) approximately 40 min to complete the survey measures. Permission for the study was confirmed by the ethics committee of the university. In addition, data assessments were carried out in line with the guidelines for empirical research in schools as provided by the Berlin Senate for Education and the Brandenburg Ministry for Education, Youth and Sports.

2.2 Measures

In this study, we included teachers' self-efficacy for student engagement and teachers' educational knowledge at Time 1, student- and teacher-perceived emotional support at Time 2, students' mathematics competence at Time 1, and students' mathematics interest at Time 1 and Time 3. Additional variables comprised teachers' gender, years of teaching experience and student gender.

2.2.1 Mathematics teacher self-efficacy for student engagement

Teacher self-efficacy for student engagement in mathematics classrooms was assessed with a three-item scale based on Pfitzner-Eden et al.'s (2014) adapted version of the Teacher's Sense of Efficacy Scale (Tschannen-Moran & Woolfolk Hoy, 2001). Original items of teacher self-efficacy for student engagement of Tschannen-Moran and Woolfolk Hoy (2001) were as follows: "How much can you do to help your students value learning?", "How much can you do to motivate students who show low interest in schoolwork?" and "How much can you do to improve the understanding of a student who is failing?" The original stem of teacher self-efficacy for student engagement of Pfitzner-Eden et al. (2014) was, "How certain are you that you can …" followed by the items "…help students value learning?", "… motivate students who show low interest in schoolwork?" and "… improve the understanding of a student who is failing?" Thus, for the present study we adapted only the last two items by changing "schoolwork" into "mathematics" and choosing the wording "motivate even those students, who often fail school requirements" instead of "improve the understanding of a student who is failing" for the third item. Therefore, in the present study we used the wording that follows.

The introductory wording for the items was: "The following statements refer to the mathematics lessons in this particular class." The opening stem for all items was "How certain are you that you can...", followed by these items: "... help students value learning?", "... motivate students who show low interest in mathematics?", and "... motivate even those students, who often fail school requirements?". The scale ranged from 1 (*not certain at all*) to 5 (*totally certain*). Reliability of the scale in the current study was $\alpha = .80$.

2.2.2 Student-perceived emotional support

Student-perceived emotional support in mathematics classrooms was assessed with a five-item scale based on Ramm et al. (2006) and Butler and Shibaz (2014) ranging from 1 (*does not apply at all*) to 5 (*fully applies*). The introductory wording for the items was "To what extent do the following statements apply to your mathematics lessons?" The items were as follows: "Our teacher takes time whenever we want to discuss something with her/him", "Our teacher cares about our problems", "Our teacher tries to fulfill our wishes as much as possible", "Our teacher maintains close

[1] 15.8% Integrierte Sekundarschule, 13.3% Oberschule, 6.6% Gemeinschaftsschule mit gymnasialer Oberstufe, 6.5% Integrierte Sekundarschule mit gymnasialer Oberstufe, 2.9% Gesamtschule, 2.1% Gemeinschaftsschule ohne gymnasiale Oberstufe.

relationships with us", and "Our teacher shows us that we are important to her/him." The reliability of the scale was α = .91.

2.2.3 Teacher-perceived emotional support

Emotional support as reported by mathematics teachers was assessed with a five-item scale based on work of Ramm et al. (2006) and Butler and Shibaz (2014) ranging from 1 (*does not apply at all*) to 5 (*fully applies*). The items of this scale closely mirror those of the student version (see above). Introductory wording for the items was "To what extent do the following statements apply to your mathematics lessons?" Items were "I take time when the students want to discuss something with me", "I care about my students' problems", "I try to fulfill the wishes of my students as much as possible", "I maintain trustful relationships with my students", and "I show my students that I care about them", The reliability of the scale was α = .83.

2.2.4 Student interest in mathematics

In order to measure student interest in mathematics, we used a modified scale originally developed by Schiefele and Schaffner (2015). The response format ranged from 1 (*does not apply at all*) to 5 (*fully applies*). The scale comprised the following four items: "Dealing with mathematics has a positive impact on my mood", "I enjoy working on mathematical assignments", "Mathematics as a subject is personally important to me", and "I think mathematics is interesting". Reliabilities were α = .86 at Time 1 and α = .90 at Time 3.

2.2.5 Covariates

2.2.5.1 Mathematics teachers' educational knowledge We used the subscale "classroom instruction" from a standardized knowledge test for teachers (Kunina-Habenicht et al., 2020). We used the original version of the knowledge test, which was developed in the German language. The classroom instruction subscale comprises 23 multiple-choice items and refers to teachers' knowledge in different areas of classroom instruction (for example classroom management, cooperative learning, teachers responses to student mistakes). Teachers' responses to the test items were summed up in order to indicate individual knowledge levels. Test scores ranged in this study from a minimum of 9.50 to a maximum of 19.50 (Range 0–23) and reliability was satisfactory (ω = .62).

2.2.5.2 Students' mathematics competence Students' mathematics competence was assessed with a curriculum-sensitive standardized competence test that was developed in cooperation with the Institute for Educational Quality Improvement (IQB), Germany. The tests were scaled by means of item response analysis, yielding weighted likelihood estimates (WLEs) as person parameters. The composite reliability (for the formula see, e.g., Embretson & Reise, 2000, p. 18) was calculated by comparing averaged square standard errors to the trait score variance—thus in our study to the test score variance. The mathematics competence test showed a good level of reliability (r = .84).

2.2.6 Other covariates

At the class level (L2), we included teachers' work experience assessed with the following open-ended question: "How long have you been teaching? Please state the number of years teaching." Further, we included teachers' gender (0 = male; 1 = female). At the student level (L1), we included student gender (0 = male; 1 = female) and students' mathematics competence at Time 1.

2.3 Statistical analyses

At the student level, we included student mathematics interest at Time 1 and Time 3, student-perceived emotional support at Time 2, and as covariates, students' mathematics competence at Time 1 and student gender. At the class level, we included teacher-reported mathematics self-efficacy for student engagement at Time 1, student-perceived and teacher-perceived emotional support at Time 2 and student interest at Time 3, controlling for student interest at Time 1 and teacher gender, years of teaching experience, teachers' educational knowledge, and classroom aggregates of students' mathematics competence. Intraclass correlations (ICC) were computed for students' mathematics interest and student-perceived emotional support in mathematics classrooms (Raudenbush & Bryk, 2002). ICC_1 values indicate the proportion of observed variance in students' ratings due to their particular group membership (LeBreton & Senter, 2008). An ICC_1 value greater than .05 implies that more than 5% of the variance in individual ratings can be attributed to group membership (LeBreton & Senter, 2008). ICC_2 values are used to assess the accuracy of class-mean ratings and should be above .70 (LeBreton & Senter, 2008). The average reliability of the class mean ratings was low for students' mathematics interest at both Time 1 (ICC_2 = .57) and Time 3 (ICC_2 = .47). However, because this variable was central to our analyses and because statistical literature states that to ignore a small ICC can lead to underestimation of standard errors if the number of members per group is large (Murray et al., 2004), this variable remained in the analyses. The ICC_1 and ICC_2 values of the variables in this study are reported in Table 1.

Because student mathematics interest was an essencial outcome variable in order to investigate our research questions, we tested whether data were systematically missing, using Little's MCAR test (Little & Rubin, 2002). Findings from the missing data analyses showed that our dependent variable (students' interest at Time 3) was not systematically missing when considering students' mathematics grade and gender as categorical variables in the analyses, $\chi^2(2) = 3.49$, $p = .175$. The data included in the present study were missing at random (MAR).

Due to the fact that we used longitudinal and hierarchically structured data with students nested in classrooms, we tested invariance across levels for student-reported interest and for student-perceived emotional support. Furthermore, we tested measurement invariance across time for student interest because this variable was assessed at two time points. Analysis confirmed that metric invariance was fulfullied in our study, indicating that the items reported by students were measuring the same constructs over time (and levels). Results of measurement invariance testing are reported in Appendix 1 (Table 5 and Table 6).

To test our hypotheses, we used a latent-manifest approach (Marsh et al., 2009) indicating that constructs at each level were measured by multiple indicators (to control for measurement error), which were aggregated at the group level using manifest aggregation.

The program M*plus* version 8.6 was used for all analyses (Muthén & Muthén, 1998–2017). Missing data were handled using full-information maximum likelihood (FIML) estimation. For all analyses, we used a maximum likelihood estimator with robust standard errors and chi-squares (MLR) (Muthén & Muthén, 1998–2017).

Because we were interested in relations at the classroom level *and* at the individual level, we used a multi-level modelling approach in which we examined cross- and cluster-level mediation (Pituch & Stapleton, 2012). Moreover, the equality of the regression parameters of teacher and student perceptions of teacher emotional support at Time 2 on mathematics interest at Time 3 was examined by the Wald Chi Square Test (Asparouhov & Muthén, 2007). Goodness of model fit was evaluated using the following criteria (Tanaka, 1993): Yuan-Bentler scaled χ^2 (YB χ^2, mean-adjusted test statistic robust to non-normality), Tucker and Lewis index (TLI), comparative fit index (CFI), root mean square of approximation (RMSEA), and standardized root mean residual (SRMR). TLI and CFI values greater than 0.95 (Hu & Bentler, 1999), RMSEA values lower than 0.06, and SRMR values lower than 0.08 (Hu & Bentler, 1999) were taken as indicators of sufficient model fit.

3 Results

3.1 Descriptive statistics and correlations

Manifest mean values, standard deviations, and ranges for the variables included in the model are reported in Table 1. Latent bivariate correlations are reported in Table 2 for the student level and in Table 3 for the class level. At the student level, student mathematics interest at Time 1 and Time 3 were strongly positively intercorrelated indicating a high rank-order stability of mathematics interest across time.

Further student-perceived emotional support at Time 2 was positively associated with student mathematics interest at Time 3. At the class level, student mathematics interest at Time 1 and Time 3 were also strongly positively intercorrelated. Mathematics teacher self-efficacy for student engagement at Time 1 was positively associated with emotional support as perceived by students in mathematics classrooms at Time 2, which in turn was strongly positively associated with student mathematics interest at Time 3. In contrast, teacher self-efficacy for student engagement at Time 1 was not significantly associated with emotional support as perceived by mathematics teachers at Time 2, which was not significantly associated with student mathematics interest at Time 3. Student-perceived emotional support at Time 2 and teacher-perceived emotional support at Time 2 intercorrelated significantly.

3.2 Teachers' self-efficacy for student engagement, student- and teacher-reported emotional support, and students' mathematics interest

The hypothesized model with standardized regression coefficients is reported in Fig. 1 and Table 4 and showed a good fit to the empirical data ($\chi^2 = 7964.501$, $df = 405$, CFI = .95, TLI = .93; RMSEA = 0.04, $SRMR_{within} = 0.03$, $SRMR_{between} = 0.13$). The model specifications included correlations between the same worded item residuals on the individual level and class level.[2] The error variance of one student interest item (Time 3) at the class level was estimated to a negative value. Because this value was not significantly different from zero, it was constrained to zero (Hox, 2002, p. 215). At the student level, student-perceived emotional support at Time 2 was positively related to students' mathematics interest at Time 3 ($\beta = .12$, $SE = 0.05$, $p = .006$). Students' interest in mathematics at Time 1 was further positively associated with students' mathematics competence at Time 1 ($\Phi = .16$, $SE = 0.03$, $p < .001$), and was positively related to their mathematics interest at Time 3

[2] Item wording for Time 1 and Time 3 was (included on L2): "Mathematics as a subject is personally important to me", "I think mathematics is interesting", and (additionally included on L1), "Dealing with mathematics has a positive impact on my mood".

Table 1 Descriptive statistics: ranges, mean values, standard deviations, reliabilities and intraclass correlations

Variable	Range	*M*	*SD*	α	ICC1	ICC2
Emotional support T2 (T)	1–5	4.16	0.57	.83	–	–
Emotional support T2 (S)	1–5	3.55	0.98	.91	.15	.77
Mathematics interest T1	1–5	2.81	1.01	.86	.07	.57
Mathematics interest T3	1–5	2.67	1.07	.90	.05	.47
Teacher self-efficacy T1	1–5	3.39	0.58	.80	–	–
Teachers' educational knowledge T1	0–23	14.66	2.33	–	–	–
Mathematics competence T1	-	0.02	1.48	–	–	–

$N_{Teacher}$= 50, $N_{Students}$ = 959, *S* = Student-reported, *T* = Teacher-reported, *T1* = Time 1, *T2* = Time 2, *T3* = Time 3

Table 2 Latent bivariate correlations among all study variables at the student level

	1	2	3	4	5
1. Perceived emotional support T2	–				
2. Mathematics interest T1	.28***	–			
3. Mathematics interest T3	.29***	.63***	–		
4. Girls[a]	.02	− .03	− .07	–	
5. Mathematics competence test T1	.12***	.16***	.19***	.01	–

N = 959

**p* < .05, two-tailed

***p* < .01, two-tailed

****p* < .001, two-tailed

[a]Students' gender: male = 0, female = 1, T1 = Time 1, T2 = Time 2, T3 = Time 3

(β = .58, *SE* = 0.04, *p* < .001). Neither students' mathematics competence nor students' gender were significantly related to students' mathematics interest at Time 3. The model explained a significant amount of variance in individual student mathematics interest at Time 3 (R^2 = .42) and in student-perceived emotional support at Time 2 (R^2 = .08) at the student level. At the class level, mathematics teachers' self-efficacy for student engagement at Time 1 was positively and significantly related to class-level emotional support in mathematics classrooms as reported by students at Time 2 (β = .34, *SE* = 0.17, *p* = .041), which in turn was positively and significantly related to student mathematics interest at Time 3 (β = .56, *SE* = 0.16, *p* < .001). However, the class-level-only indirect effect was not significant (b_{ind} = .16, *SE* = 0.09, *p* = .066; [CI 95% -0.011, 0.330]). Teacher-reported self-efficacy for student engagement at Time 1 was not related to teacher-reported emotional support at Time 2 in mathematics classrooms (β = .09, *SE* = 0.18, *p* = .604), which in turn did not relate to students' mathematics interest at Time 3 (β = .05, *SE* = 0.20, *p* = .825). Additional analyses indicated that teacher self-efficacy for student engagement at Time 1 was not significantly stronger related to students' perception of teacher emotional support at Time 2 than to teachers' perception of their emotional support at Time 2, according to the Wald χ2 test: χ2 (*df* = 1) = 0.853, *p* = .356. Results indicated that students' perception of teacher emotional support (Time 2), however, was significantly more strongly related to student mathematics interest (Time 3) than teacher-reported emotional support, according to the

Table 3 Latent bivariate correlations among variables at the classroom level

Variable	1	2	3	4	5	6	7	8	9
1. Teacher self-efficacy for SE T1	–								
2. Emotional support (S) T2	.45**	–							
3. Emotional support (T) T2	.16	.29*	–						
4. Mathematics interest T1	.36**	.37**	.23	–					
5. Mathematics interest T3	.13	.62***	.18	.71***	–				
6. Mathematics competence T1	.02	.14	− .08	− .18	− .08	–			
7. Teachers' years of experience	.02	− .04	− .37*	− .03	.13	.23	–		
8. Female teachers[a]	− .32*	− .22	− .32*	− .32*	− .08	− .04	.35**	–	
9. Teacher educational knowledge T1	− .19	− .06	.08	− .23	− .21	.18	.13	.16	–

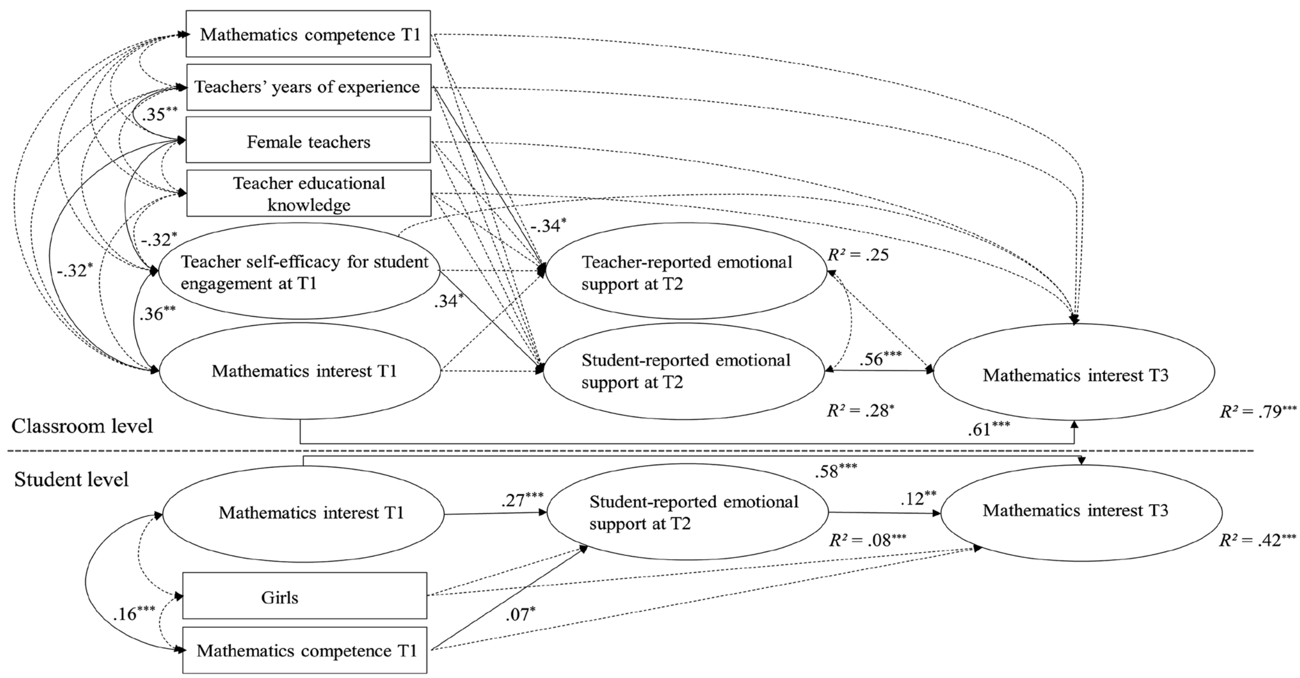
$N_{Teachers}$= 50, $N_{Classrooms}$ = 52. Classroom level

**p* < .05, two-tailed

***p* < .01, two-tailed

****p* < .001, two-tailed. S = Student-reported; T = Teacher-reported

[a]Teachers' gender: male = 0, female = 1, T1 = Time 1, T2 = Time 2, T3 = Time 3, SE = Student engagement



Note. $N_{Teacher}$= 50, $N_{Students}$= 959; Dotted lines represent nonsignificant relations; bold lines represent significant paths. *$p < .05$; **$p < .01$; ***$p < .001$. $\chi^2 = 7964.501$, $df = 405$, CFI = 0.95, TLI = 0.93; RMSEA = .04, SRMRwithin = .03, SRMRbetween = .13; T1 = Time 1,T2 = Time 2, T3 = Time 3.

Fig. 1 Empirical multilevel structural equation model for the examined relations between teacher self-efficacy for student engagement, perceived emotional support and students' mathematics interest

Wald $\chi2$ test: $\chi2$ (df = 1) = 4.335, p = .037. Both student- and teacher-reported emotional support at Time 2 were not significantly associated (Φ = .20, SE = 0.17, p = .244). Results further showed that years of teaching experience at Time 1 was negatively related to teacher-reported emotional support at Time 2 (β = -.34, SE = 0.16, p = .027), indicating that less experienced teachers perceived themselves to provide more emotional support than more experiences teachers. Students' mathematics competence at the class level at Time 1 (β = -.01, SE = 0.17, p = .947) and teachers' gender (β = -.15, SE = 0.17, p = .387) did not relate to teacher-reported emotional support at Time 2. The model explained a significant amount of variance in class-level student interest at Time 3 (R^2 = .79) and a significant amount of variance in student-reported class-level emotional support at Time 2 (R^2 = .28), but not of teacher-reported emotional support at Time 2 (R^2 = .25).

4 Discussion

The aim of this study was to examine whether mathematics teacher self-efficacy for student engagement at the beginning of grade nine would relate to students' mathematics interest in the middle of grade ten through student- and teacher-reported emotional support in mathematic classrooms at the beginning of grade ten. Our study contributes to research on mathematics instruction by showing that teacher self-efficacy for student engagement positively related to teacher emotional support in mathematics classrooms as perceived by students, but not by teachers. Student-reported emotional support in turn positively related to students' mathematics interest.

4.1 Teachers' self-efficacy for student engagement and perceived teacher emotional support in mathematics classrooms

According to our assumptions (H1a), teacher self-efficacy for student engagement was positively and significantly related to students' class-level perception of emotional support in mathematics classrooms. In extension to prior results investigating general teachers self-efficacy (Holzberger et al., 2013), we found that teacher self-efficacy for student engagement was not significantly related to teachers' perception of emotional support (H1b). One explanation may be that teachers' self-efficacy for student engagement did not transfer to their own perception of emotional support

Table 4 Standardized regression coefficients: classroom level and student level

Classroom level	Emotional support (S) T2			Emotional support (T) T2			Mathematics interest T3		
	β	*SE*	*p*	β	*SE*	*p*	β	*SE*	*p*
Teacher self-efficacy SE T1	**.34**	**(0.17)**	**.041**	.09	(0.18)	.604	− .34	(0.18)	.051
Mathematics competence T1	.-20	(0.13)	.128	− .01	(0.17)	.947	− .06	(0.19)	.749
Teachers' years of experience	−.10	(0.13)	.453	**− .34**	**(0.16)**	**.027**	.20	(0.15)	.178
Female teachers[a]	.01	(0.15)	.933	− .15	(0.17)	.387	.10	(0.15)	.517
Teacher educational knowledge	.05	(0.14)	.728	.21	(0.12)	.082	−.13	(0.15)	.371
Mathematics interest T1	.29	(0.17)	.093	.18	(0.19)	.345	**.61**	**(0.17)**	**.000**
Emotional support (S) T2							**.56**	**(0.16)**	**.000**
Emotional support (T) T2							.05	(0.20)	.825
Student level	Emotional support (S) T2						Mathematics interest T3		
	β	*SE*	*p*				β	*SE*	*p*
Mathematics competence T1	**.07**	**(0.03)**	**.022**				.08	(0.05)	.105
Girls[b]	.02	(0.05)	.631				− .05	(0.03)	.098
Emotional support (S) T2							**.12**	**(0.05)**	**.006**
Mathematics interest T1	**.27**	**(0.04)**	**.000**				**.58**	**(0.04)**	**.000**

$N_{Teacher} = 50$, $N_{Students} = 959$, *S* = student-reported, *T* = teacher-reported

[a]Teachers' gender: male = 0, female = 1

[b]Students' gender: male = 0, female = 1 T1 = Time 1, T2 = Time 2, T3 = Time 3, SE = Student engagement

because the belief of teachers in having the capabilities of motivating students is not the most important characteristic for their evaluation of their own classroom behaviors. More relevant for self-reported emotional support might have been other factors such as their level of empathy (Aldrup et al., 2022). A potential underlying mechanism for this result might be that theoretically it is proposed that self-efficacious teachers set themselves realistic goals regarding their teaching strategies, and persist in reaching these goals (Bandura, 1997). In the present study, one would assume that teachers with high self-efficacy for student engagement set themselves reachable goals in terms of student motivation and engagement, and persist to reach these goals—which in turn is perceived by the students, who feel motivationally and emotionally supported in class. Although, consequently, students might capture the efforts of their teachers, the high self-efficacy of the teachers might not enable them to capture accurately the climate that they created.

Another reason for the nonsignificant effect between teacher self-efficacy and their perception of teaching might be the item wording: Items regarding teacher self-efficacy for student engagement refer to the value for learning, motivation of unmotivated students, and are partly content-related with motivational support. Emotional support refers to whether teachers take time for students and their problems more generally—thus a content-related dimension of engagement is not included there. However, teachers' self-efficacy was related with whether students' experienced that their teacher takes time, builds trustful relationships—hence, teachers' behavior to motivate students for the content relates to students' feeling of being important to their teacher. Surprisingly, this feeling seems not to be supported by teachers, which indicates that they care in a more general way.

Further, a possible explanation for this result might be that students' reactions to teacher behavior which they perceive as emotionally supportive is one of the sources for teachers' self-efficacy—thus the student perception might relate to teacher self-efficacy for student engagement. Although researchers found positive relations between student-perceived cognitive activation or classroom management and general teacher self-efficacy, such relations were not found for student-perceived support and general teacher self-efficacy (Holzberger et al., 2013). Because, theoretically, mastery experience is a source of self-efficacy (Bandura, 1997) students' perceptions of teacher emotional support, thus showing their reactions for teachers visibly to perceive, might allow teachers to experience mastery. Future studies need to investigate these paths with matching facets of teacher self-efficacy and teaching behavior and need to consider possible effects from student interest to teacher emotional support and teacher self-efficacy, as teachers support their students more because more interested students are more enjoyable to teach (Nurmi, 2012).

4.2 Perceived teacher emotional support and students' mathematics interest: Whose perception matters?

In line with our second hypothesis, aligned with theoretical work (Ryan & Deci, 2000) and previous research (Oppermann & Lazarides, 2021), we showed that students' perception of teacher emotional support at student and class level positively predicted student mathematics interest at student and class level (H2a). Against our assumptions, teachers' perception of teacher emotional support was not significantly related to student mathematics interest at class level (H2b).

Interestingly, we found that students' but not teachers' perception of emotional support predicted student mathematics interest. Consequently, students' *own* experience and therefore their own evaluation of emotional support seems to be a reliable predictor for student interest. One possible explanation might be that individual interest is an affective orientation of students themselves (Schiefele, 2009), which is thus also more closely related to their own perceptions of their learning environment rather than to the evaluations of external others, such as teachers. One might assume, however, that the teacher's perception of teaching behavior is a more distal predictor of student motivation and engagement, as suggested by Lauermann and Berger (2021).

Moreover, student- and teacher-reported emotional support did not covary significantly ($\Phi = .20$, $SE = 0.17$, $p = .244$), suggesting that teachers might have a different perspective on what is supportive for their students than students have. Contrary to current research literature, which refers to a low to moderate agreement between teacher- and student-perceived teaching quality (Lauermann & ten Hagen, 2021), we found only a significant latent correlation between the two perceptions of emotional support—yet in the model both perceptions were unrelated. In our study the mean for teacher-reported emotional support (Time 2; $M = 4.16$, $SD = 0.57$) was higher than the mean for student-reported emotional support (Time 2; $M = 3.55$, $SD = 0.98$), and both perspectives were not associated in the model. A possible explanation might be that teachers might have a different concept of support than their students. More precisely, in the present study teacher items of emotional support referred to the actual supportive behavior that they intended to carry out in class, whereas student measures refer to the interpretations of this behavior, thus, how students experienced teacher behavior. This means if both perspectives are not linked, the teachers' intended behaviors are not transmitted to the students.

One reason for this might be that in the present study, there was a larger standard deviation in the student ratings of emotional support than in the teacher ratings: one could assume that the larger heterogeneity in the student perception of emotional support contributed to the lack of correspondence with the teacher perspective. Another reason could be that teachers report their intentions rather than their actual behaviors in class—which would explain why students do not perceive the teachers' behaviors to an extent similar to the teachers report of them. Furthermore, one reason might be that students have the opportunity to directly observe the teachers' behavior, whereas the teacher needs to conclude whether and how the support was perceivable for students (Lauermann & Butler, 2021). Moreover, students constantly have access to their socio-emotional needs and the extent to which the teacher supports their own needs (Lauermann & ten Hagen, 2021)—however, this information is most likely inaccessible for teachers.

Furthermore, we did not find cross-level-only or other indirect effects of mathematics teacher self-efficacy for student engagement on student mathematics interest through student- or teacher-perceived emotional support. Thus, our third hypothesis was not confirmed (H3a&b) as we found no evidence for cross- and cluster-level mediation in the present study. Possibly these effects could not be confirmed in this study due to the relatively small sample size at class level—thus future studies need to intestigate these relations with larger samples.

4.3 Relations of individual characteristics and motivational processes

Regarding our assumed relations with the included covariates, we found that at individual level students' gender was marginally, significantly related to students' interest at Time 3 ($\beta = -.05$, $SE = 0.03$, $p = .098$) indicating that girls tended to report less interest. This tendency is congruent with previous results that showed significant relations of boys reporting more mathematics interest than girls (e.g., Köller et al., 2001). Therefore, it is possible that with a larger sample this relation might have become significant. Furthermore, we found that student achievement was associated with their interest in mathematics (at individual level), which is in line with current research (Heinze et al., 2005).

Furthermore, the marginally significant relation between teachers' educational knowledge and teacher-perceived emotional support ($\beta = .21$, $SE = 0.12$, $p = .082$) is interesting because one would expect that knowledge of teachers relates to their teaching behavior (Lohse-Bossenz et al., 2015). Recent research results, however, did not find relations between teacher educational knowledge and teaching quality (Lazarides & Schiefele, 2021)—thus, knowledge of teaching may indirectly relate to teachers' behavior through teachers' motivation to show this knowledge in the form of instructional behavior.

In contrast to previous results indicating that students report the higher supportive classroom climate of more experienced teachers (Bijlsma et al., 2022), we did not find significant relations between student-perceived emotional support and teachers' years of experience. One possible explanation for this might be a non-linear relation between years of teaching experiences and supportive teaching behaviors: A study examining rater-reported teaching quality found that teachers with a moderate amount of teaching experience demonstrated more negative classroom climate behaviors than new and more experienced teachers (Graham et al., 2020). However, teachers' years of experience was negatively and significantly related to teacher-perceived emotional support, indicating that more experienced teachers perceive themselves to provide less emotional support. Possibly, more experienced teachers know how complex support of students can be. Supporting this assumption, empirical results showed that expert teachers, in their performance, focus more on students and make more suggestions for alternative decisions concerning the teacher and context than do novices teachers' (Stahnke & Blömeke, 2021)—thus experienced teachers seem to evaluate teaching quality more competently.

Moreover, we found a significant correlation between teacher gender and teacher-perceived emotional support, which means that female teachers rated themselves less emotionally supportive. Previous research for related classroom characteristics such as closeness with students found that female teachers report higher closeness with students (Split et al., 2012). Although teachers perceive closeness to their students they might feel as if they are neglecting the proper support of students' emotional needs, thus the two concepts of closeness and emotional support seem rather distinct.

4.4 Limitations and future research

There are some limitations to consider when interpreting these results. First, this study included only mathematics teacher self-efficacy for student engagement, but other facets of teacher motivation might also be relevant, or even more so, for teacher emotional support and need to be considered. Previous work, for example, found positive associations between teacher educational interest and (student- and teacher-perceived) emotional support of teachers (Lazarides & Schiefele, 2021) or between teacher enthusiasm and student-reported learning support (Kunter et al., 2013).

Second, we included only emotional supportive teaching behaviors; there are, however, also other forms of support in mathematics classrooms, which might also be important for students' mathematics interest, such as instructional support, adaptive teaching strategies, or effective scaffolding. To fully understand how mathematics teachers can enhance a supportive motivational climate in class, future research needs to consider a broad variety of teachers' supportive behaviors and their relations with student motivation in mathematics.

Third, although we included both teacher and student perceptions of emotional support, we did not take external raters' observations of emotional support into account. Given that students' perceptions of teacher emotional support are interrelated with teachers' expectations towards their students (Wentzel et al., 2016), future studies are in need of investigation of objectively rated emotional support. Another remaining question regarding the different perspectives of teaching support for future research is whether teacher-reported support is more relevant for students' self-beliefs, such as, for example, students' self-efficacy (Hughes, 2011).

4.5 Conclusions

The present study contributed to current research in mathematics education by examining a specific facet of mathematics teachers' self-efficacy and its relations to teacher emotional support, and to students' mathematics interest. A possible implication for mathematics teachers' educational practice involves strengthening mathematics teachers' self-efficacy for student engagement by means of direct interventions and in-service training. Theoretical work suggests that various sources (such as, for example, mastery experiences or verbal persuasion) are suitable for enhancing teacher self-efficacy (Bandura, 1997). Therefore, developing teachers' skills and expertise by means of video-based training might be a promising route to enhance mathematics teachers' self-efficacy (e.g. Gold et al., 2017).

Appendix 1

See Tables 5, 6.

Table 5 Measurement invariance test: Level and time invariance testing of student-reported mathematics interest (Time 1 and Time 3)

	χ^2	*df*	CFI	Δ CFI	RMSEA	ΔRMSEA	SRMRb	ΔSRMRb
1. Configural invar	145.410	38	.969		.054		.062	
2. Metric invar[a]	161.810	47	.967	− .002	.050	− .004	.112	.050

CFI comparative fit index, *RMSEA* root mean square error of approximation, *SRMRb* standardized root mean square residual for between level, *1* all parameters free, *2* loadings invariant across levels and across time; Models were evaluated in line with Chen (2007): changes of ≥ − .010 in CFI, ≥ .015 in RMSEA, *and* ≥ .030 in SRMR indicate non-invariance

[a]Standardized factor loadings: Time 1, L1: λmin = .70 – λmax = .88, Time 1; L2: λmin = .65 – λmax = .91, Time 3, L1: λmin = .71 – λmax = .89, Time 3, L2: λmin = .67 – λmax = .96

Table 6 Measurement invariance test: Level invariance testing of student-reported emotional support (Time 2)

	χ^2	*df*	CFI	Δ CFI	RMSEA	ΔRMSEA	SRMRb	ΔSRMRb
1. Configural invar	144.704	10	.949		.124		.034	
2. Metric invar[a]	175.886	14	.939	− .010	.115	− .009	.196	.162

CFI comparative fit index, *RMSEA* root mean square error of approximation, *SRMRb* standardized root mean square residual for between level, *1* all parameters free, *2* loadings invariant across levels; Models were evaluated in line with Chen (2007): changes of ≥ − .010 in CFI, ≥ .015 in RMSEA, and ≥ .030 in SRMR indicate non− invariance

[a]Standardized factor loadings: L1: λmin = .76 – λmax = .86, L2: λmin = .85 – λmax = .95

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Declarations

Conflict of interest No potential conflict of interest was reported by the authors.

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