Current Psychology (2024) 43:3111–3123
https://doi.org/10.1007/s12144-023-04382-x

How teacher-student closeness and conflict contributes to mathematical problem solving in Chinese adolescents: a multilevel moderated mediation model of self-efficacy and school climate

Yuting Tan[1] · Chuanyue Luo[1] · Benchao Fan[1] · Jianqiang Yang[1] · Yufang Bian[1] · Tao Yang[1]

Accepted: 6 February 2023 / Published online: 27 March 2023

Abstract
The current study investigated how and when two different aspects of teacher-student relationship (TSR; closeness and conflict) influence students' mathematical problem solving ability. Participants were 9163 eighth-grade Chinese adolescents (53.5% male) nested in 908 schools, who took part in a standard mathematics assessment and survey using student questionnaires that were all developed by the Collaborative Innovation Center of Assessment toward Basic Education Quality (CICA-BEQ) in China in 2015. The results indicated that (a) after controlling the factors of gender and SES, teacher-student closeness had a significant and positive effect on mathematical problem solving, while teacher-student conflict did not, (b) the mediating role of mathematical self-efficacy in the relationships of TSRs and mathematical problem solving was confirmed, and (c) school climate negatively moderated the indirect relationships between TSRs and mathematical problem solving.

Keywords Teacher-student closeness · Teacher-student conflict · Mathematical problem solving · Self-efficacy · School climate

Introduction

As a key twenty-first-century competency, problem solving has received extensive attention in education systems around the world and been identified as one of the essential educational targets in many national curriculum standards, including China (Jiang et al., 2014; Cai et al., 2017). In the Chinese mainland, a series of reforms of school mathematics curricula, where problem-solving might be the most relevant (cf. earlier studies on reading, languages, etc.;) (Skaalvik et al., 2015), have been implemented to improve students' abilities to pose, analyze, and solve problems over the years, so that numerous international comparative studies have identified China as producing mathematically high-performing students (Guo et al., 2020). As depicted by ecological system theory (Bronfenbrenner & Morris, 1998), the interaction with the external environment matters greatly in students' learning outcomes, such as teacher-student relationship (TSR). As the most integral component of the school environment, positive TSR represents a pivotal role in engaging students to learn and prompting academic performance, which has been confirmed by multiple meta-analyses (Cornelius-White, 2007; Hattie, 2008; Roorda et al., 2011). However, to our knowledge, little attention has been paid to investigating the potential roles and mechanisms of TSR on mathematical problem solving ability. This study addresses this gap by further investigating the influence and mechanism of TSR on mathematical problem solving ability of adolescents in Chinese culture.

TSRs and mathematics outcomes

As a bidirectional interpersonal exchange taking place in proximal (e.g. interpersonal interactions) and distal systems (e.g. the classroom context) (Bronfenbrenner & Morris, 1998; McCormick et al., 2013), two separate but related compositions of TSR are typically conceptualized and measured (Birch & Ladd, 1997): closeness and conflict. Based on the previous research about the definition of TSR (Ladd & Burgess, 2001; Rudasill et al., 2010, 2013; Hughes et al., 2012, 2014; McCormick & O'Connor,

✉ Tao Yang
yangtao@bnu.edu.cn

[1] Collaborative Innovation Center of Assessment toward Basic Education Quality, Beijing Normal University, No. 19, Xinjiekouwai St, Haidian District, 100875 Beijing, China

2015), teacher-student closeness is defined as students perceiving their teachers' warmth and supports, as well as the student's willingness to approach and engage the teacher, while teacher-student conflict refers to students perceiving high levels of tension and hostility from their teachers in this study. According to self-determination theory (SDT), the good-quality interaction between individual and environment (e.g., positive TSR) would satisfy the basic psychological need for relatedness and affect the individual's subsequent behavioral outcomes (Deci & Ryan, 2000; Ryan & Deci, 2002). However, several research gaps remain.

Firstly, a robust body of scholars only concentrated on the good aspects of TSR construct, in which warmth and trust from teachers are important manifestations for creating a safe school environment to actively and appropriately explore and participate in, consequently leading to positive learning outcomes (Li, 2018; Ma et al., 2018), including mathematics achievement (Barile et al., 2012; McCormick et al., 2013; Hernández et al., 2017; Mason et al., 2017; Lin et al., 2020; Lee, 2021; Liu et al., 2021) and mathematical problem solving ability (Zhou et al., 2020). However, others noted teacher-student closeness had no influential prediction of academic development in mathematics (McCormick & O'Connor, 2015; Hajovsky et al., 2017). In addition, with increasing attention being given to the negative dimension of TSR (Baker et al., 2008; Jerome et al., 2009; Hughes et al., 2012; McCormick & O'Connor, 2015; Hajovsky et al., 2017; Hernández et al., 2017; Mason et al., 2017; Hughes & Cao, 2018), some studies revealed a nonsignificant relation between poor TSR and mathematical outcomes (McCormick & O'Connor, 2015; Hajovsky et al., 2017; Hernández et al., 2017), but Mason et al. (2017) reported that teacher-rated conflict served as a small but significant predictor of subsequent math achievement across measured time points. To sum up, these inconsistencies have been limited in comparing the effects of positive and negative TSR dimensions, and also foreshadow the need for more effort to clarify the potentially different impacts of both teacher-student closeness and conflict on mathematical outcomes.

Another point worth noting is that all the above-mentioned studies were done for primary students in the United States, which limits the generalizability of the conclusions to other cultural and geographic contexts. Although relatively few empirical studies assessed this issue in Chinese sample, a recent exception for junior school students in China, Li et al. (2021) showed that teacher-student conflict could increase the negative effect of students' low self-control on academic achievement (i.e., combined score of Chinese, math, and English) via mastery goals, whereas teacher-student support failed to moderate this link. This finding demonstrated that, compared with students in America, conflictive behaviors with teachers may act as a risk factor for Chinese students' academic outcomes, such as problem solving ability. To address this aforementioned gap, this study aims to further investigate the influence and mechanism of TSR in the Chinese context.

In the third place, educational data are often nested, but most works on this topic were more likely to limit multilevel variables to the individual level, which may increase statistical errors (McCormick et al., 2013). For instance, Liu et al. (2021) suggested that it is reasonable to explore more about the influences of TSR at the student-level and class-level. Therefore, more empirical research that applied multilevel data analysis methods should be implemented to get a coherent comprehension of the effect of TSR on math performance. Based on the aforementioned evidence and analysis, we speculated that from a multilevel point, teacher-student closeness would heighten Chinese students' mathematical problem solving ability, while teacher-student conflict would prevent it.

Self-efficacy as a mediator

Another limitation of previous works is that more attention has been given to the direct association between TSR and academic performance, while the internal mechanism of this issue was ignored. From the theoretical perspective, social cognitive theory holds the view that behavior is motivated and regulated through a combination of external social environmental and internal self-related factors (Bandura, 1977, 2002), which suggested that the above inconsistent findings may be due to the individual psychological mediators, such as self-efficacy. According to Bandura (1978, 1997), self-efficacy was described as the extent to which people believe they can successfully perform a particular given task, which has been highlighted as a crucial predictor of academic performance in general (Braten et al., 2004; Skaalvik et al., 2015; Zhang & Wang, 2020), including mathematical problem solving (Pajares & Miller, 1994; Cassady, 2014; Özcan & Eren Gümüş, 2019; Voica et al., 2020; Baity, 2021). Moreover, some recent works implied that combining positive TSR with self-efficacy may be more beneficial in discovering its impact on students' cognitive development (Ma et al., 2018; Zhou et al., 2020; Liu et al., 2021), because warm and close TSR, as depicted by SDT, provides a safe and friendly environment for children and thus could satisfy their needs for relatedness, which is a foundation for children's high level of self-confidence and self-efficacy (Deci & Ryan, 2008; Roorda et al., 2011). Furthermore, we know relatively some about the mechanism underlying the link between positive TSR and mathematical achievement, but it has not been proven in problem solving. Moreover, relatively little is known about the effective mechanism of negative elements of TSR on students'

academic development. Therefore, the second purpose of this study is to investigate the mediating process of self-efficacy in the association between TSR (i.e., teacher-student closeness and conflict) and mathematical problem solving ability for Chinese students. Based on the aforementioned evidence, we hypothesized that closeness with teachers would promote adolescents' self-efficacy and subsequent mathematical problem solving ability, while conflict with teachers would weaken self-efficacy and then mathematical problem solving ability.

School climate as a moderator

Apart from mediating mechanisms (i.e., how TSR relates to problem solving ability), moderating mechanisms (i.e., under what conditions the link is most potent) have also received only little attention. Also based on ecological system theory (Bronfenbrenner & Morris, 1998), school, as the innermost layer of the environmental level, is the direct environment for individual activities and interactions, of which teacher-related element is only a part. School climate, defined as the social functioning of the school community, including norms, values, and expectations that support people feeling socially, emotionally, and physically safe (Thapa et al., 2013), has been widely proven to be a powerful indicator in promoting students' development (Trinidad, 2020), and also to be an interpretable moderator for the relationships between many predictors (e.g., background index and motivational factors) and students' academic performance, including for Chinese students (Teng, 2020; Tan et al., 2022). In an exception in PISA 2012, Teng (2020) reported that school climate compensated for the effect of family background on mathematics achievement of participants from Shanghai. In another example, Tan et al. (2022) noted that school disciplinary climate negatively moderated the link between mastery goal orientation and reading literacy. Coinciding with this empirical view, we proposed that school climate might also moderate the indirect relations of the quality of their relationships with their teachers and mathematical outcomes. What is more, by positioning school climate as a moderator that might substantiate or weaken the links between individual psychological variables (i.e., self-efficacy) and mathematical outcomes (i.e., problem solving ability), this study would provide a distinctive perspective to the literature that has primarily addressed TSR as a direct predictor of mathematical promotion.

The current study

According to ecological system theory, social cognitive theory, and SDT, the research problems of this study are threefold: (a) whether conflict and closeness of TSR directly predict mathematical problem solving ability, (b) whether mathematical self-efficacy mediates the relationship between TSR (i.e., conflict and closeness) and mathematical problem solving ability, and (b) whether the indirect link between TSR (i.e., conflict and closeness) and mathematical problem solving ability is moderated by positive school climate. We developed two moderated mediation models (see Fig. 1), which can address both multilevel mediation and moderation mechanisms underlying the relations between different dimensions of TSR (i.e., conflict and closeness) and mathematical problem solving ability.

Specifically, this study proposes the following hypotheses:

Hypothesis 1. Teacher-student closeness has a direct and positive effect on mathematical problem solving ability.
Hypothesis 2. Teacher-student conflict has a direct and negative effect on mathematical problem solving ability.
Hypothesis 3. Mathematical self-efficacy mediates the relationship between teacher-student closeness and mathematical problem solving ability.
Hypothesis 4. Mathematical self-efficacy mediates the relationship between teacher-student conflict and mathematical problem solving ability.

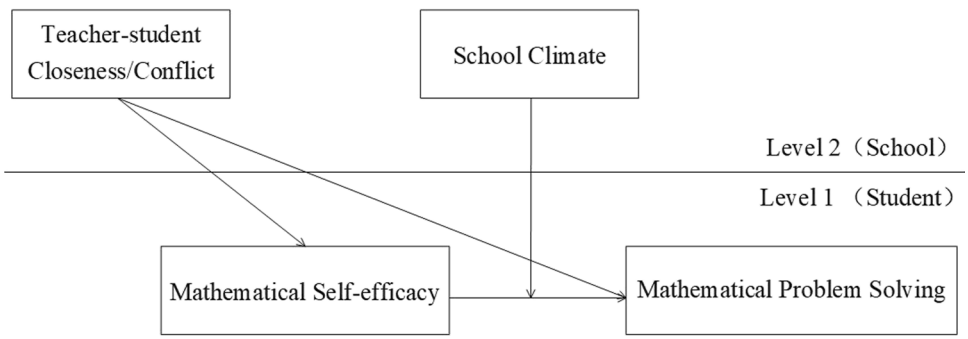

Fig. 1 The hypothetical model

Hypothesis 5. School climate moderates the indirect effect of teacher-student closeness and mathematical problem solving ability through mathematical self-efficacy.
Hypothesis 6. School climate moderates the indirect effect of teacher-student conflict and mathematical problem solving ability through mathematical self-efficacy.

Methods

Data and participants

Data used in this study were from the Program of National Education Assessment implemented in China in 2015 by the Collaborative Innovation Center of Assessment toward Basic Education Quality (CICA-BEQ) at Beijing Normal University, which is a professional assessment center that plays a crucial role in monitoring the quality of compulsory education in China (Liu et al., 2021). The predominant aim of this program is to understand the teaching quality and learning outcomes of basic education in all provinces (cities) in China. According to this objective, CICA-BEQ organized a group of experts with rich experience in mathematics education and educational and psychological assessment to develop instruments under a standard and strict procedure and several pretests to validate these instruments before he formal large-scale test. Additionally, ethics approval was obtained from the Institutional Review Board (IRB) at the CICA-BEQ at Beijing Normal University.

Based on the purpose of this study, we selected a national representative set of data, and a total of 9163 Grade 8 students (53.5% boys) nested in 908 schools in 31 provinces (cities) remained after excluding students with missing data (Enders, 2010). The average school size was 10 (SD = 2.74).

Measures

Mathematical problem solving This test was developed by the CICA-BEQ, in which the characteristics of the mathematical problem solving of the assessment were based on Chinese Full-time Compulsory Mathematics curriculum standards (2011 version). There are four test booklets were designed, which contained 5 items. The concurrent item response theory calibration method was used by simultaneously estimating a combined dataset of the two tests to place students' abilities onto a common scale (Liu et al., 2021). Students' raw scores were scaled with Rasch modeling procedure and were standardized with an average value of 500 and a standard deviation of 100.

Teacher-student relationship This questionnaire was developed by the CICA-BEQ and contained two subscales: teacher-student closeness scale and conflict scale. All items were rated by students on a Likert-type scale ranging from 1 (not true at all) to 4 (very true), respectively. Teacher-student closeness scale consisted of 8 items (a sample item is "I think my math teacher likes me"). The higher response code was indicative of a more positive rating of teacher-student closeness. Reliability was adequate for this scale: Cronbach's raw $\alpha = 0.90$ and McDonald's $\omega_h = 0.90$. A confirmatory factor analysis (CFA) on the 8 items supported a one-factor (ability) structure and hence the construct validity of the construct: $\chi^2/df = 1.61$, the root mean square error of approximation (RMSEA) = 0.01, comparative fit index (CFI) = 1.00, Tucker- Lewis index (TLI) = 1.00, and standardized root mean residual (SRMR) = 0.003. The mean of standardized factor loadings is 0.72 (0.62-0.81).

Teacher-student conflict scale consisted of 6 items (a sample item is "The math teacher would laugh at us"). The higher response code was indicative of a higher rating of teacher-student conflict. Reliability was adequate for this scale: Cronbach's raw $\alpha = 0.83$ and McDonald's $\omega_h = 0.84$. The CFA on the 6 items supported a one-factor (ability) structure and hence the construct validity of the construct: $\chi^2/df = 1.48$, $RMSEA = 0.01$, $CFI = 1.00$, $TLI = 1.00$, and $SRMR = 0.003$. The mean of standardized factor loadings is 0.70 (0.39–0.84).

The student-level TSR was aggregated at the school level as a context variable. To justify the appropriateness of aggregation, the intra-class correlation coefficient (ICC) values of the TSR were calculated to estimate the dependence magnitude (Cohen, 1988). To be specific, the ICC(1) denotes the reliability of individuals' ratings within each group and ICC(2) refers to the reliability of the group means, which were calculated to determine whether aggregated individual-level ratings were reliable indicators of group-level construct (Bliese, 2010). Moreover, the within-group agreement index (Rwg) was also used to test the polymerization criteria (James et al., 1993). The results indicated that the values of these three indices for the aggregated TSR were at acceptable levels: $ICC(1)_{closeness} = 0.19$ (> 0.12), $ICC(1)_{conflict} = 0.13$ (> 0.12), $ICC(2)_{closeness} = 0.70$ (> 0.47), $ICC(2)_{conflict} = 0.58$ (> 0.47), $Rwg_{closeness} = 0.86$ (> 0.70), and $Rwg_{conflict} = 0.84$ (> 0.70).

Mathematical self-efficacy This scale developed by the CICA-BEQ used 3 Likert-type items to measure students' self-efficacy to complete specific mathematics tasks (a sample item is "Compared with most people, working out this math problem is an easy task for me."). Participants responded on a Likert-type scale ranging from 1 (not true at all) to 4 (very true), respectively. All items were positive so that higher scores correspond to a higher self-efficacy. Reliability was adequate for this scale: Cronbach's raw $\alpha = 0.69$ and McDonald's $\omega_h = 0.70$. The CFA on the 3 items was

conducted to verify the construct validity of the self-efficacy : $\chi^2 = 0.00$, $RMSEA = 0.00$, $CFI = 1.00$, $TLI = 1.00$, and $SRMR = 0.00$. The mean of standardized factor loadings is 0.66 (0.51–0.74).

School climate The scale that was developed by the CICA-BEQ used 6 Likert-type items that measured students' feelings about school life and activities (a sample item is "School is a fun place"). The response scale ranges from 1 to 4, indicating from "not true at all" to "very true" respectively. Except for the last one, other items were positive so that higher scores correspond to a better school climate. Reliability was adequate for this scale: Cronbach's raw $\alpha = 0.82$ and McDonald's $\omega_h = 0.83$. The CFA on the 6 items of school climate supported a one-factor (ability) structure and hence the construct validity of the construct: $\chi^2/df = 0.20$, $RMSEA = 0.00$, $CFI = 1.00$, $TLI = 1.00$, and $SRMR = 0.001$. The mean of standardized factor loadings is 0.67 (0.48–0.80). Similarly, the student-level school climate was also aggregated at school level as a context variable. The values of these three indices endorsed the justification of the aggregation for school climate: $ICC(1)_{\text{school climate}} = 0.15$ (> 0.12), $ICC(2)_{\text{school climate}} = 0.64$ (> 0.47), and $Rwg_{\text{school climate}} = 0.88$ (> 0.70).

Covariates

Gender was coded 0 for male students and 1 for female students. Socioeconomic status (SES) was derived from three variables related to family background: the highest occupational status of parents, the highest educational level of parents in years of education, and home possession, using principal components analysis.

Data analysis

In this study, students were nested within schools. The variance between schools in the dependent variable (i.e., mathematical problem solving) was examined. The result showed that level-1variance was 62.33% of the total variance, and level-2 variance was 37.67% of the total variance. These results indicated a significant variance at level-2 for mathematical problem solving (James, 1982). Therefore, multilevel modeling (MLM) was tested with the MLmed Beta 2 macro for SPSS software (Hayes & Rockwood, 2020). Utilizing this analytic approach, it estimated (see Fig. 1) school climate as a level-2 moderator of the indirect impact of teacher-student closeness/conflict (a level-2 dependent variable) on mathematical problem solving via self-efficacy, controlling for SES and gender. All variables in the study were standardized (except gender and dependent variable) before conducting the multilevel moderated mediation analysis.

Results

Preliminary analysis

We use 23 response items measuring the four constructs (8 items of closeness teacher-student relationship, 6 items of conflict teacher-student relationship, 3 items for self-efficacy, and 6 items of school climate) to test the CFA in Mplus 8.0 to merge the variables gradually and examine changes in fitting degrees to verify the discriminant validity of the model. Results supported a clearly four-factor structure with satisfactory fitting indices [$\chi^2/df = 15.01$, $CFI = 0.97$ (≥ 0.95), $TLI = 0.96$ (≥ 0.95), $RMSEA = 0.04$ (≤ 0.05), and $SRMR = 0.03$ (≤ 0.05)] compared to the alternative models (Hu & Bentler, 1999) (see Table 1). And the loading of each item in the four-factor model were shown in Table 2.

Common method bias

In this study, Harman's One-Factor Test was done to test the common method biases. And the variance explained by the first factor was 36.99% (< 40%), which indicated that the influence of the homologous coefficient of variance was not serious.

Descriptive statistics and correlation analysis

The significant coefficients of pairwise correlation range between −0.59 and 0.55 (see Table 3). Results show that mathematics problem solving was positively related to SES, teacher-student closeness, self-efficacy, and school climate, while negatively related to teacher-student conflict.

Table 1 CFAs for four models

	χ^2/df	*CFI*	*TLI*	*RMSEA*	*SRMR*
One-factor model	28.45	0.943	0.928	0.055	0.050
Two-factor model	26.26	0.947	0.934	0.063	0.048
Three-factor model	16.68	0.967	0.959	0.041	0.036
Four-factor model	15.01	0.970	0.963	0.039	0.030

Note. One-factor model: teacher-student closeness + teacher-student conflict + self-efficacy + school climate

Two-factor model: teacher-student closeness + self-efficacy + school climate, and teacher-student conflict

Three-factor model: teacher-student closeness + self-efficacy, teacher-student conflict, and school climate

Four-factor model: teacher-student closeness, teacher-student conflict, self-efficacy, and school climate

Table 2 The loading of each item

Scale	Items' number & loading							
Teacher-student closeness	1	2	3	4	5	6	7	8
	0.68	0.78	0.62	0.74	0.74	0.72	0.68	0.81
Teacher-student conflict	1	2	3	4	5	6		
	0.39	0.72	0.84	0.72	0.83	0.71		
Self-efficacy	1	2	3					
	0.74	0.51	0.72					
School climate	1	2	3	4	5	6		
	0.79	0.76	0.69	0.80	0.49	0.48		

Table 3 Descriptive statistics and correlation coefficient ($n = 9163$)

	M	SD	1	2	3	4	5	6
1 Gender	0.45	0.50	-					
2 SES	0.06	0.99	-0.01	-				
3 Teacher-student closeness	3.11	0.64	0.07***	0.15***	-			
4 Teacher-student conflict	1.62	0.57	-0.10***	-0.01	-0.59***	-		
5 Self-efficacy	2.70	0.67	-0.02	0.14***	0.55***	-0.29***	-	
6 School climate	3.28	0.54	0.14***	0.00	0.50***	-0.37***	0.45***	
7 Mathematical problem solving	500.11	99.56	0.03**	0.31***	0.29***	-0.15***	0.41***	0.14***

Note: SES = Socioeconomic status. $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Table 4 Indirect effect and moderated mediation effect

	Teacher-student closeness				Teacher-student conflict			
	Effect	SE	LL	UL	Effect	SE	LL	UL
Indirect effect	26.79	2.07	22.88	30.89	-81.57	6.42	-94.72	-69.33
Index of moderated mediation	-4.83		-6.57	-3.14	11.91		7.43	16.67
Low(-1SD)	31.62	2.35	27.12	36.25	-93.48	7.43	-108.87	-79.10
High(+1SD)	21.96	2.13	17.86	26.13	-69.66	6.19	-82.34	-57.89

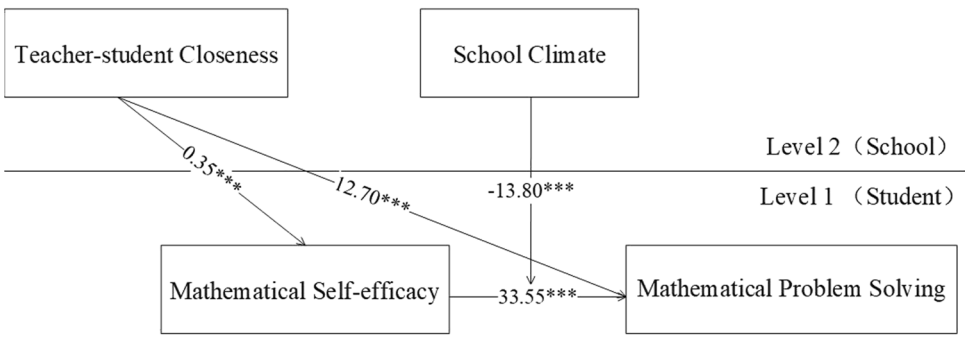

Fig. 2 Multilevel moderated mediation analysis for Hypothesis 1, 3 and 5

Hypothesis testing

MLM was employed to verify the hypothesis of the present research. There are two models to be tested because there are two independent variables (i.e., teacher-student closeness and conflict). The results of the moderated mediation analysis are reported in Table 4; Figs. 2 and 3. As seen in Fig. 2, the direct effect of teacher-student closeness on mathematical problem solving at the school level was significant and positive [effect = 12.70, 95% CI (7.37, 18.02)], accordingly Hypotheses 1 was supported. And in Fig. 3, the direct effect of teacher-student conflict on mathematical problem solving was non-significant [effect = 1.81, 95% CI (-13.73, 17.35)], so Hypotheses 2 was not confirmed.

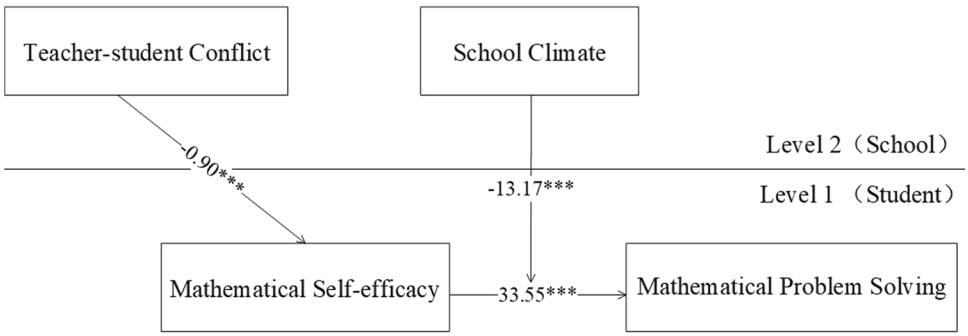

Fig. 3 Multilevel moderated mediation analysis for Hypothesis 2, 4 and 6

Both Hypothesis 3 and 4 tested the mediating role of self-efficacy in the association between TSR (i.e., teacher-student closeness and conflict) and mathematics problem solving. As shown in Table 4, the indirect effect of teacher-student closeness on mathematics problem solving via self-efficacy at the school level was significant and positive [indirect effect = 26.79, 95% CI (22.88, 30.89)], so hypothesis 3 was verified. By contrast, the indirect effect of teacher-student conflict on mathematics problem solving via self-efficacy at the school level was also significant and negative [effect = -81.57, 95% CI (-94.72, -69.33)], so hypothesis 4 was confirmed.

Both Hypothesis 5 and 6 tested the moderated role of school climate on the indirect effect of TSR (i.e., teacher-student closeness and conflict) on mathematics problem solving through self-efficacy. Figures 2 and 3 show that the significant and negative interaction effects were found in school climate moderated the link between self-efficacy and mathematics problem solving [β = -13.80, 95% CI (-18.60, -9.01); β = -13.17, 95% CI (-18.06, -8.29)]. The negative interaction effects of school climate and self-efficacy indicated that the relation between self-efficacy and mathematical problem solving was weakened by a high level of positive school climate.

The results in Table 4 show that a significant and negative index of moderated mediation was observed in which school climate moderated the link between teacher-student closeness and mathematical problem solving via self-efficacy [effect = -4.83, 95% CI (-6.57, -3.14)]. The conditional indirect effect of teacher-student closeness on mathematical problem solving at a low level of positive school climate [effect = 31.62, 95% CI (27.12, 36.25)] was higher than the effect at a high level of positive school climate [effect = 21.96, 95% CI (17.86, 26.13)], Hypotheses 5 was proved (see Table 4; Fig. 4). By contrast, Table 4 also shows that a significant and positive index of moderated mediation was observed in which school climate moderated the link between teacher-student conflict and mathematical problem solving via self-efficacy [effect = 11.91, 95% CI (7.43, 16.67)]. The conditional indirect effect of teacher-student conflict on mathematical problem solving at a low level of positive school climate [effect = -93.48, 95% CI (-108.87, -79.10)] was stronger than the effect at a high level of positive school climate [effect = -69.66, 95% CI (-82.34, -57.86)], Hypotheses 6 was proved (see Table 4; Fig. 5).

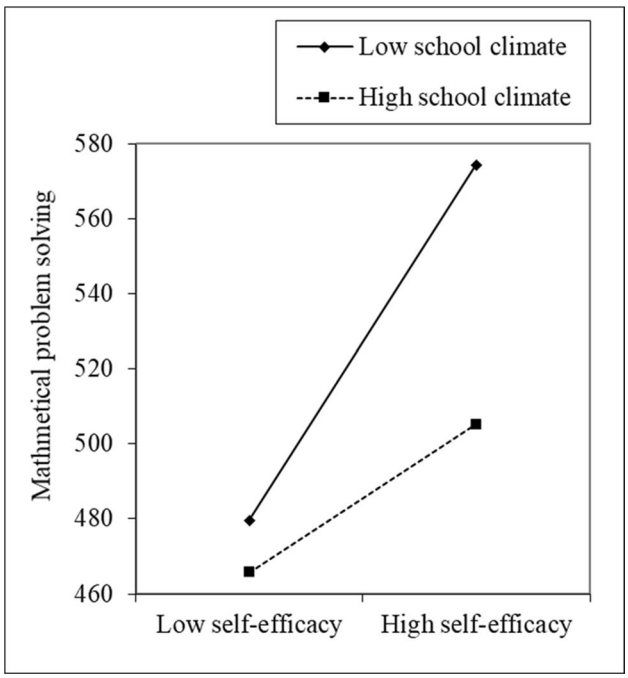

Fig. 4 Multilevel moderated mediation plot of Hypothesis 5

Discussion

The current study developed two multilevel moderated mediation models to test whether teacher-student closeness/conflict would directly influence mathematical problem solving ability, whether teacher-student closeness/conflict would be indirectly related to mathematical problem solving ability via mathematical self-efficacy, and whether the indirect relationships are moderated by school climate. These findings extend the existing theories and literature on the mechanisms underlying links between TSR and

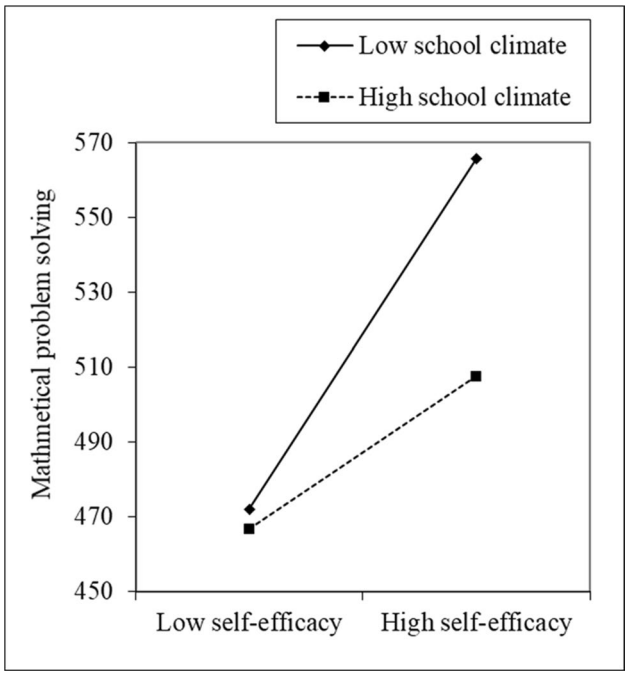

Fig. 5 Multilevel moderated mediation plot of Hypothesis 6

academic performance and provide a practical basis for further interventions concerning adolescent problem solving ability to be developed.

The direct effect of TSR on mathematical problem solving

Firstly, our findings supported the positive and direct effect of teacher-student closeness on mathematical problem solving ability, while the direct impact of teacher-student conflict on mathematical problem solving ability was non-significant. The former was in line with a study on Chinese students' mathematical problem solving (Zhou et al., 2020), and the latter was consistent with previous studies for American students (McCormick & O'Connor, 2015; Hajovsky et al., 2017; Hernández et al., 2017). Prior studies have not identified the potential effect of the negative aspect of TSR on academic performance for Chinese students. Therefore, this approach would allow for a greater understanding of the forms of TSR that are improved interpretation of the students' learning outcomes linked with that relationship. Combining ecological system theory and SDT, this study supported that good TSR-closeness, trust and warmth-which directly contribute to increasing psychological satisfaction and learning engagement and thus reinforce cognitive capacities. However, the result of conflict with teachers did not mean that it is meaningless to students.

The mediating effect of self-efficacy

In the second place, the effect of teacher-student closeness on mathematical problem solving ability was partially mediated by self-efficacy. This result was in agreement with the previous research results (Zhou et al., 2020). A respect and support relationship between students and teachers makes students more likely to have positive motivation beliefs, such as self-efficacy (Yildirim, 2012; Ma et al., 2018; Liu et al., 2021), more positive expectations of success, and more engagement to school work (Sakiz et al., 2012), thus students are more likely to persist in the face of setbacks and achieve better performance in problem solving (Pongsakdi et al., 2019; Özcan & Eren Gümüş, 2019; Voica et al., 2020; Zhou et al., 2020). This finding implied that teachers could develop students' motivational beliefs (e.g., self-efficacy) through a close relationship (Bandura, 1997). Considering the importance of self-efficacy on students' learning outcomes, promoting students' self-efficacy can be considered from positive TSR.

An even more valuable finding was that self-efficacy completely mediated the link between teacher-student conflict and mathematical problem solving ability. To be specific, students who experience teacher-student conflict might perceive higher level of tension and hostility from their teachers (Pianta et al., 2003), and then tend to suffer from higher levels of negative emotions (e.g., anxiety and stress) (Muris, 2002) and perform lower level of self-efficacy (Yildirim, 2011, 2012), which would decrease complex learning strategies and self-regulation (Burić & Sorić, 2012), and thus negatively predict the ability to solve mathematical problems (Pajares & Miller, 1994; Cassady, 2014; Özcan & Eren Gümüş, 2019; Voica et al., 2020; Baity, 2021). In summary, these conclusions validated social cognitive theory. That is, teachers, as main socializers in students' school life, play a crucial role in students' self-efficacy and problem solving ability (Xuan et al., 2019). This type of effort represented in this study also unfolds the powerful significance of conflict and tension between teachers and students for student development, broadens our understanding of TSR nature, and provides different perspectives for addressing practical issues related to the teacher-student interactions.

The moderated effect of school climate

Ultimately, the results showed that in the mechanism between TSR and mathematical problem solving, the mediating effect of self-efficacy is regulated by school climate. Specifically, the conditional indirect effect that teacher-student closeness plays on mathematical problem solving via self-efficacy at a low level of school climate was higher than the effect at a high level of school climate. Firstly, data analysis revealed that the possible reason is that the

impact of self-efficacy on mathematical problem solving would be weakened by a more positive school climate, but be enhanced by a more negative school climate. To be specific, in good-performed Chinese schools, where students do better academically, both strict school rules and a depressing competitive atmosphere would establish a poorer school climate, where students are easy to lose independence and autonomy, while students with high level of engagement and self-efficacy in learning activities tend to grow up better in such climate, which consequently implied that low level of school climate strengthen the relatedness between self-efficacy and mathematical problem solving. What is more, students suffered in the negative school climate would rely more on the intimate relationship with their teacher for individual self-improvement. On the other hand, students under a positive school atmosphere, where reflects shared beliefs, safe environment, friendly peer relationships, and fair discipline (Ho, 2005; Reynolds et al., 2017), are usually easy to gain satisfaction for their relationship and emotional needs, and thus less dependent on the close association with their teachers (Wentzel et al., 2010).

Another momentous conclusion is that under the condition of high level of teacher-student conflict, the relation between self-efficacy and mathematical problem solving was weakened by a high level of school climate. Similarly, data analysis also suggested that the possible reason is that the effect of self-efficacy on mathematical problem solving would be weakened by a more positive school climate, but be enhanced by a more negative school climate, as mentioned above. Another possible explanation is that a more positive school climate, as an environmental protective factor, would have the capacity to strengthen students' reliance to compensate or adjust the adverse effects of risk environmental factors (Papanastasiou, 2002; Teng, 2020), such as negative aspect of TSR. Similar protective effects of positive school climate were examined in preventing undesirable family background (Berkowitz et al., 2015, 2017), emotional and behavioral problems (Loukas & Murphy, 2007), because students in a positive school climate are more likely to be less involve in violent behavior, which protect them to be safe and be beneficial to their physical and mental health development (Ruiz-Narezo & Santibáñez Gruber, 2020). In a word, for those students who suffered with higher conflict and tension with their teachers, the significant interaction between psychological energy (i.e., self-efficacy) and positive school climate is considered as a powerful protective factor against the negative TSR.

Limitations and future directions

This study still faces the following limitations that require further improvement for the purposes of future research. First of all, this study is a cross-sectional design which limits causal and directional assumptions. Future research may examine the mechanism of these variables by longitudinal data to explore the causal relationship between the TSR and mathematical problem solving over an extended time period. Secondly, the current study indicates that mathematical self-efficacy plays a vital mediating role in the relationship between TSR and mathematical problem solving, which means that there may be other mediating variables that can be investigated in follow-up studies. What's more, individual cognitive factors such as self-efficacy have been widely explored as a mediating role (Ma et al., 2018; Liu et al., 2021), while the mediating role of other variables (e.g., emotional factors) in this mechanism is not fully tested, so further exploration is needed. Thirdly, aside from mathematical problems solving, most measures of the present study relied on self-report methods. Different students have different response styles, which might not be objective enough. It is possible that TSR can be reported by teachers, and future studies may wish to incorporate a more diverse body of methods to address this. Fourthly, by incorporating school climate as a moderator into the model, this study detected effects that would otherwise have been overlooked. However, school climate is a multidimensional concept, and future studies could focus on other types of school climate (e.g., disciplinary climate) and explore its predictors across different domains to offer more evidence of comprehension of the role of school environment on student influence. Finally, based on this particular data set from a National Education Assessment Program implemented in China in 2015 that is 7 years ago, to some extent it may reduce the generalizability and applicability of these findings, especially in light of the many changes to educational area following the COVID-19 pandemic. Therefore, whether the findings of this study for the relationships among variables can be replicated and generalized for current educational situation need to be confirmed by future research.

Theoretical and practical implications

This study makes several theoretical contributions to the TSR literature and our understanding of how to meaningfully affect mathematical problem solving ability. Firstly, our findings not only revealed how both supportive and conflictive teacher-student interactions deeply and differently influence students' ability to solve mathematical problems, but also from a systematic perspective addressed the moderating role of school-level factors (i.e., school climate) in the above relationships, which all broaden our understanding of TSR nature, make exclusive contributions to TSR literature, and even shed new light on potential ways to understand which form of student-teacher exchanges and what level of school climate might be more appropriate in heightening positive or mitigating the chance of poor learning outcomes,

and how teacher-related and school-related variables interact and contribute to individual development. What is more, this research has been done in the Chinese context, which is generally regarded as a unique Eastern cultural characteristic, rather than in Western counties where most similar empirical studies have been done, which profoundly illustrate dimensions of these theoretical relations that are related to cultural difference by accounting for learner characteristics and contexts. According to various educational cultures with various school atmosphere and administrative norms may draw diverse conclusions, these relationships identified apparently advanced current research by incorporating finer granularity from a unique Eastern cultural vision.

Alongside its contribution to theory, this study also offers several important practical considerations for teachers, school managers and related organizations. Firstly, this type of effort represented in this study unfolds the powerful significance of conflict and tension between teachers and students for student cognitive development based on multilevel evidence, providing different angles for addressing practical issues related to teacher-student interactions. Obviously, it is urgent to take effective measures to help teachers to communicate with students who may be experiencing difficulty with their teachers. To cultivate strong and supportive teacher-student relationships, which can help to reduce conflicts and promote academic success, there are lots of measures that teachers could take to foster a positive and supportive learning environment, such as using group projects or collaborative activities between teachers and students, creating open and effective communication between teachers and students, listening to their students and take the time to understand their perspectives and feelings, and show a genuine interest in their students' lives and well-being, etc. Even in a large classroom with lots of students, teachers could conduct one-to-one interaction, show personal attention, give positive feedback, and build trust via chat software or other flexible ways after class. Secondly, this research examined the mediating role of self-efficacy between TSR and mathematical problem solving ability, in an effort to more comprehensively provide implications for effective and comprehensive interventions to promote student mathematical performance, because self-efficacy is a predictor that is more manipulable than some other significant factors of academic performance such as SES. From this point, teachers can recognize students' achievements and offer positive reinforcement and praise to students, in order to make them feel valued and respected and then increase their self-efficacy and motivation. At last, the overall empirical findings are fairly satisfactory in ascertaining the belief that the influence mechanism of the different aspects of TSR on student development is powerful and complex, especially in different conditions of school climate. To be specific, the pursuit of a well-regulated school climate would provide a powerful safeguard for teaching and learning, but may impair individuals' initiative and autonomy, and even weaken the positive impact of self-efficacy on student cognitive development, which give stakeholder a deeper understanding of the origins and causes of mathematics underachievement and the dynamic and complex relations among schools, teachers, and students to take effective and targeted measures from the school level.

Conclusion

(a) After controlling the factors of gender and SES, teacher-student closeness had a significant and positive effect on mathematical problem solving ability, while the direct impact between teacher-student conflict and mathematical problem solving ability was nonsignificant.
(b) Mathematical self-efficacy played a partial mediating role in the relationship between teacher-student closeness and mathematical problem solving ability, moreover, self-efficacy completely mediated the link between teacher-student conflict and mathematical problem solving ability.
(c) School climate moderated the indirect link between TSR and mathematical problem solving ability. On the one hand, the conditional indirect effect of teacher-student closeness on mathematical problem solving ability via self-efficacy at a low level of school climate was higher than the effect at a high level of school climate, which suggested the supportive role of good TSR for those students that suffered in a negative school climate. On the other hand, the conditional direct effect of teacher-student conflict on mathematical problem solving via self-efficacy at a high level of school climate was stronger that the effect at a low level of school climate, which indicated the protective impact of positive school climate for those students perceived conflict and tension with their teachers.

Funding This study was funded by the Collaborative Innovation Center of Assessment Toward Basic Education Quality (CICA-BEQ) at Beijing Normal University (grant number BJZK-2021A1-20014) and Ministry of Science and Technology of China (grant number STI 2030—Major Projects 2021ZD0200500).

Data availability The data that support the findings of this study are available from Collaborative Innovation Center of Assessment toward Basic Education Quality but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of Collaborative Innovation Center of Assessment toward Basic Education Quality.

Declarations

The study was reviewed and approved by the research committee in Beijing Normal University, as well as by the committee in local government. All subjects and their parents were provided with written informed consent.

Conflict of interest The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

References

Baity, N. (2021). The effect of creative problem solving learning models on problem solving ability in learning motivation and student self-efficacy view. *International Journal of Social Science and Human Research*, *04*. https://doi.org/10.47191/ijsshr/v4-i3-30

Baker, J. A., Grant, S., & Morlock, L. (2008). The teacher-student relationship as a developmental context for children with internalizing or externalizing behavior problems. *School Psychology Quarterly, 23*(1), 3–15. https://doi.org/10.1037/1045-3830.23.1.3

Bandura, A. (1977). *Social learning theory*. Prentice Hall.

Bandura, A. (1978). Self-efficacy: toward a unifying theory of behavioral change. *Advances in Behaviour Research and Therapy, 1*(4), 139–161. https://doi.org/10.1016/0146-6402(78)90002-4

Bandura, A. (1997). *Self-efficacy: the exercise of control*. Worth Publishers.

Bandura, A. (2002). Social cognitive theory in cultural context. *Applied Psychology: An International Review, 51*(2), 269–290. https://doi.org/10.1111/1464-0597.00092

Barile, J. P., Donohue, D. K., Anthony, E. R., Baker, A. M., Weaver, S. R., & Henrich, C. C. (2012). Teacher–student relationship climate and school outcomes: implications for educational policy initiatives. *Journal of Youth and Adolescence, 41*(3), 256–267. https://doi.org/10.1007/s10964-011-9652-8

Berkowitz, R., Glickman, H., Benbenishty, R., Artzi, E., Raz, T., & Astor, R. (2015). Compensating, mediating, and moderating effects of school climate on academic achievement gaps in Israel. *Teachers College Record, 117*, 1–34. https://doi.org/10.1177/016146811511700703

Berkowitz, R., Moore, H., Astor, R. A., & Benbenishty, R. (2017). A research synthesis of the associations between socioeconomic background, inequality, school climate, and academic achievement. *Review of Educational Research, 87*(2), 425–469. https://doi.org/10.3102/0034654316669821

Birch, S. H., & Ladd, G. W. (1997). The teacher-child relationship and children's early school adjustment. *Journal of School Psychology, 35*(1), 61–79. https://doi.org/10.1016/S0022-4405(96)00029-5

Bliese, P. (2010). Within-group agreement, non-independence, and reliability: implications for data aggregation and analysis. In K. J. Klein, & S. W. J. Kozlowski (Eds.), *Multilevel theory and methods in organizations* (pp. 43–55). Jossey-Bass.

Braten, I., Samuelstuen, M. S., & Strømsø, H. I. (2004). Do students' self-efficacy beliefs moderate the effects of performance goals on self-regulatory strategy use? *Educational Psychology, 24*(2), 231–247. https://doi.org/10.1080/0144341032000160164

Bronfenbrenner, U., & Morris, P. (1998). The ecology of developmental processes. In W. Damon, & R. M. Lerner (Eds.), *Handbook of child psychology* (pp. 993–1028). Wiley.

Burić, I., & Sorić, I. (2012). The role of test hope and hopelessness in self-regulated learning: relations between volitional strategies, cognitive appraisals and academic achievement. *Learning and Individual Differences, 22*(4), 523–529. https://doi.org/10.1016/j.lindif.2012.03.011

Cai, H., Gu, X., & Wong, L. H. (2017). An investigation of twenty-first century learners' competencies in China. *Asia Pacific Education Review, 18*(4), 475–487. https://doi.org/10.1007/s12564-017-9509-2

Cassady, J. C. (2014). Predicting problem solving ability from metacognition and self-efficacy beliefs on a cross validated sample. *European Cent Res Train Dev UK, 2*(1), 49–70.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Routledge. https://doi.org/10.4324/9780203771587

Cornelius-White, J. (2007). Learner-centered teacher-student relationships are effective: a meta-analysis. *Review of Educational Research, 77*(1), 113–143. https://doi.org/10.3102/003465430298563

Deci, E. L., & Ryan, R. M. (2000). The "what" and "why" of goal pursuits: human needs and the self-determination of behavior. *Psychological Inquiry, 11*(4), 227–268. https://doi.org/10.1207/S15327965PLI1104_01

Deci, E. L., & Ryan, R. M. (2008). Self-determination theory: a macrotheory of human motivation, development, and health. *Canadian Psychology/Psychologie Canadienne, 49*(3), 182–185. https://doi.org/10.1037/a0012801

Enders, C. K. (2010). *Applied missing data analysis* (Illustrated edition). The Guilford Press.

Guo, M., Leung, F. K. S., & Hu, X. (2020). Affective determinants of mathematical problem posing: the case of chinese Miao students. *Educational Studies in Mathematics, 105*(3), 367–387. https://doi.org/10.1007/s10649-020-09972-1

Hajovsky, D. B., Mason, B. A., & McCune, L. A. (2017). Teacher-student relationship quality and academic achievement in elementary school: a longitudinal examination of gender differences. *Journal of School Psychology, 63*, 119–133. https://doi.org/10.1016/j.jsp.2017.04.001

Hattie, J. A. C. (2008). *Visible learning: a synthesis of over 800 meta-analyses relating to achievement*. Routledge.

Hayes, A. F., & Rockwood, N. J. (2020). Conditional process analysis: concepts, computation, and advances in the modeling of the contingencies of mechanisms. *American Behavioral Scientist, 64*(1), 19–54. https://doi.org/10.1177/0002764219859633

Hernández, M. M., Valiente, C., Eisenberg, N., Berger, R. H., Spinrad, T. L., VanSchyndel, S. K., Silva, K. M., Southworth, J., & Thompson, M. S. (2017). Elementary students' effortful control and academic achievement: the mediating role of teacher-student relationship quality. *Early Childhood Research Quarterly, 40*, 98–109. https://doi.org/10.1016/j.ecresq.2016.10.004

Ho, E. S. C. (2005). Effect of school decentralization and school climate on student mathematics performance: the case of Hong Kong. *Educational Research for Policy and Practice, 4*(1), 47–64. https://doi.org/10.1007/s10671-005-1546-7

Hu, L. T., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: conventional criteria versus new alternatives. *Structural Equation Modeling, 6*, 1–55. https://doi.org/10.1080/10705519909540118

Hughes, J. N., & Cao, Q. (2018). Trajectories of teacher-student warmth and conflict at the transition to middle school: Effects on academic engagement and achievement. *Journal of School Psychology, 67*, 148–162. https://doi.org/10.1016/j.jsp.2017.10.003

Hughes, J. N., Wu, J. Y., Kwok, O., Villarreal, V., & Johnson, A. Y. (2012). Indirect effects of child reports of teacher-student relationship on achievement. *Journal of Educational Psychology, 104*(2), 350–365. https://doi.org/10.1037/a0026339

Hughes, K., Bullock, A., & Coplan, R. (2014). A person-centred analysis of teacher-child relationships in early childhood. *The British Journal of Educational Psychology, 84*, 253–267. https://doi.org/10.1111/bjep.12029

James, L. R. (1982). Aggregation bias in estimates of perceptual agreement. *Journal of Applied Psychology, 67*(2), 219–229. https://doi.org/10.1037/0021-9010.67.2.219

James, L. R., Demaree, R. G., & Wolf, G. (1993). rwg: an assessment of within-group interrater agreement. *Journal of Applied Psychology, 78*(2), 306–309. https://doi.org/10.1037/0021-9010.78.2.306

Jerome, E. M., Hamre, B. K., & Pianta, R. C. (2009). Teacher–child relationships from kindergarten to sixth grade: early childhood predictors of teacher-perceived conflict and closeness. *Social Development, 18*(4), 915–945. https://doi.org/10.1111/j.1467-9507.2008.00508.x

Jiang, C., Hwang, S., & Cai, J. (2014). Chinese and singaporean sixth-grade students' strategies for solving problems about speed. *Educational Studies in Mathematics, 87*(1), 27–50. https://doi.org/10.1007/s10649-014-9559-x

Ladd, G., & Burgess, K. B. (2001). Do relational risks and protective factors moderate the linkages between childhood aggression and early psychological and school adjustment? *Child Development, 72*(5), 1579–1601. https://doi.org/10.1111/1467-8624.00366

Lee, J. (2021). Teacher-student relationships and academic achievement in confucian educational countries/systems from PISA 2012 perspectives. *Educational Psychology, 41*(6), 764–785. https://doi.org/10.1080/01443410.2021.1919864

Li, C., Song, Y., Wang, Q., & Zhang, B. (2021). How does self-control affect academic achievement of adolescents? The dual perspectives of teacher-student relationship and mastery approach goals. *Youth & Society*, 1–17. https://doi.org/10.1177/0044118X211030949

Li, Y. (2018). Teacher-student relationships, student engagement, and academic achievement for non-latino and latino youth. *Adolescent Research Review, 3*(4), 375–424. https://doi.org/10.1007/s40894-017-0069-9

Lin, W., Yin, H., Han, J., & Han, J. (2020). Teacher–student interaction and chinese students' mathematics learning outcomes: the mediation of mathematics achievement emotions. *International Journal of Environmental Research and Public Health, 17*(13), 4742. https://doi.org/10.3390/ijerph17134742

Liu, H., Liu, Q., Du, X., Liu, J., Hoi, C. K. W., & Schumacker, R. E. (2021). Teacher-student relationship as a protective factor for socioeconomic status, students' self-efficacy and achievement: a multilevel moderated mediation analysis. *Current Psychology*. https://doi.org/10.1007/s12144-021-01598-7

Loukas, A., & Murphy, J. L. (2007). Middle school student perceptions of school climate: examining protective functions on subsequent adjustment problems. *Journal of School Psychology, 45*(3), 293–309. https://doi.org/10.1016/j.jsp.2006.10.001

Ma, L., Du, X., Hau, K. T., & Liu, J. (2018). The association between teacher-student relationship and academic achievement in chinese EFL context: a serial multiple mediation model. *Educational Psychology, 38*(5), 687–707. https://doi.org/10.1080/01443410.2017.1412400

Mason, B. A., Hajovsky, D. B., McCune, L. A., & Turek, J. J. (2017). Conflict, closeness, and academic skills: a longitudinal examination of the teacher–student relationship. *School Psychology Review, 46*(2), 177–189. https://doi.org/10.17105/SPR-2017-0020.V46-2

McCormick, M., & O'Connor, E. (2015). Teacher–child relationship quality and academic achievement in elementary school: does gender matter? *Journal of Educational Psychology, 107*(2), 502–516. https://doi.org/10.1037/a0037457

McCormick, M. P., O'Connor, E. E., Cappella, E., & McClowry, S. G. (2013). Teacher-child relationships and academic achievement: a multilevel propensity score model approach. *Journal of School Psychology, 51*(5), 611–624. https://doi.org/10.1016/j.jsp.2013.05.001

Muris, P. (2002). Relationships between self-efficacy and symptoms of anxiety disorders and depression in a normal adolescent sample. *Personality and Individual Differences, 32*(2), 337–348. https://doi.org/10.1016/S0191-8869(01)00027-7

Özcan, Z., & Eren Gümüş, A. (2019). A modeling study to explain mathematical problem-solving performance through metacognition, self-efficacy, motivation, and anxiety. *Australian Journal of Education, 63*(1), 116–134. https://doi.org/10.1177/0004944119840073

Pajares, F., & Miller, M. (1994). Role of self-efficacy and self-concept beliefs in mathematical problem-solving—A path-analysis. *Journal of Educational Psychology, 86*(2), 193–203. https://doi.org/10.1037/0022-0663.86.2.193

Papanastasiou, C. (2002). Effects of background and school factors on the mathematics achievement. *Educational Research and Evaluation, 8*(1), 55–70. https://doi.org/10.1076/edre.8.1.55.6916

Pianta, R. C., Hamre, B., & Stuhlman, M. (2003). Relationships between teachers and children. *Handbook of psychology: Educational psychology* (Vol. 7, pp. 199–234). Wiley.

Pongsakdi, N., Laakkonen, E., Laine, T., Veermans, K., Hannula-Sormunen, M. M., & Lehtinen, E. (2019). The role of beliefs and motivational variables in enhancing word problem solving. *Scandinavian Journal of Educational Research, 63*(2), 179–197. https://doi.org/10.1080/00313831.2017.1336475

Reynolds, K. J., Lee, E., Turner, I., Bromhead, D., & Subasic, E. (2017). How does school climate impact academic achievement? An examination of social identity processes. *School Psychology International, 38*(1), 78–97. https://doi.org/10.1177/0143034316682295

Roorda, D., Koomen, H., Spilt, J., & Oort, F. (2011). The influence of affective teacher-student relationships on students' school engagement and achievement: a meta-analytic approach. *Review of Educational Research, 81*, 493–529. https://doi.org/10.3102/0034654311421793

Roorda, D. L., Jak, S., Zee, M., Oort, F. J., & Koomen, H. M. Y. (2017). Affective teacher–student relationships and students' engagement and achievement: a meta-analytic update and test of the mediating role of engagement. *School Psychology Review, 46*, 239–261. https://doi.org/10.17105/SPR-2017-0035.V46-3

Rudasill, K. M., Reio, T. G., Stipanovic, N., & Taylor, J. E. (2010). A longitudinal study of student-teacher relationship quality, difficult temperament, and risky behavior from childhood to early adolescence. *Journal of School Psychology, 48*(5), 389–412. https://doi.org/10.1016/j.jsp.2010.05.001

Rudasill, K., Niehaus, K., Buhs, E., & White, J. (2013). Temperament in early childhood and peer interactions in third grade: the role of teacher-child relationships in early elementary grades. *Journal of School Psychology, 51*, 701–716. https://doi.org/10.1016/j.jsp.2013.08.002

Ruiz-Narezo, M., & Santibáñez Gruber, R. (2020). School climate and peer victimization. Involvement, affiliation and help perceived in school centers as protective factors against violent behavior in adolescent couples. *Sustainability, 12*(11), 4705. https://doi.org/10.3390/su12114705

Ryan, R. M., & Deci, E. L. (2002). An overview of self-determination theory: an organismic-dialectical perspective. In E. L. Deci, & R. M. Ryan (Eds.), *Handbook of self-determination research* (pp. 3–33). The University of Rochester Press.

Sakiz, G., Pape, S. J., & Hoy, A. W. (2012). Does perceived teacher affective support matter for middle school students in mathematics classrooms? *Journal of School Psychology, 50*(2), 235–255. https://doi.org/10.1016/j.jsp.2011.10.005

Skaalvik, E. M., Federici, R. A., & Klassen, R. M. (2015). Mathematics achievement and self-efficacy: relations with motivation for mathematics. *International Journal of Educational Research, 72*, 129–136. https://doi.org/10.1016/j.ijer.2015.06.008

Tan, Y., Fan, Z., Wei, X., & Yang, T. (2022). School belonging and reading literacy: a Multilevel Moderated Mediation Model.

Frontiers in Psychology, 13, 816128. https://doi.org/10.3389/fpsyg.2022.816128

Teng, Y. (2020). The relationship between school climate and students' mathematics achievement gaps in Shanghai China: evidence from PISA 2012. *Asia Pacific Journal of Education, 40*(3), 356–372. https://doi.org/10.1080/02188791.2019.1682516

Thapa, A., Cohen, J., Guffey, S., & Higgins-D'Alessandro, A. (2013). A review of school climate research. *Review of Educational Research, 83*(3), 357–385. https://doi.org/10.3102/0034654313483907

Trinidad, J. E. (2020). Material resources, school climate, and achievement variations in the Philippines: insights from PISA 2018. *International Journal of Educational Development, 75*, 102174. https://doi.org/10.1016/j.ijedudev.2020.102174

Voica, C., Singer, F. M., & Stan, E. (2020). How are motivation and self-efficacy interacting in problem-solving and problem-posing? *Educational Studies in Mathematics, 105*(3), 487–517. https://doi.org/10.1007/s10649-020-10005-0

Wentzel, K. R., Battle, A., Russell, S. L., & Looney, L. B. (2010). Social supports from teachers and peers as predictors of academic and social motivation. *Contemporary Educational Psychology, 35*(3), 193–202. https://doi.org/10.1016/j.cedpsych.2010.03.002

Xuan, X., Xue, Y., Zhang, C., Luo, Y., Jiang, W., Qi, M., & Wang, Y. (2019). Relationship among school socioeconomic status, teacher-student relationship, and middle school students' academic achievement in China: using the multilevel mediation model. *PLoS One, 14*(3), e0213783. https://doi.org/10.1371/journal.pone.0213783

Yildirim, S. (2011). Self-efficacy, intrinsic motivation, anxiety and mathematics achievement: findings from Turkey, Japan and Finland. *Necatibey Faculty of Education Electronic Journal of Science and Mathematics Education, 5*(1), 277–291.

Yildirim, S. (2012). Teacher support, motivation, learning strategy use, and achievement: a multilevel mediation model. *The Journal of Experimental Education, 80*(2), 150–172. https://doi.org/10.1080/00220973.2011.596855

Zhang, D., & Wang, C. (2020). The relationship between mathematics interest and mathematics achievement: mediating roles of self-efficacy and mathematics anxiety. *International Journal of Educational Research, 104*, 1–9. https://doi.org/10.1016/j.ijer.2020.101648

Zhou, D., Du, X., Hau, K. T., Luo, H., Feng, P., & Liu, J. (2020). Teacher-student relationship and mathematical problem-solving ability: mediating roles of self-efficacy and mathematical anxiety. *Educational Psychology, 40*(4), 473–489. https://doi.org/10.1080/01443410.2019.1696947