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Original article

Whether and how adolescents' perceived teacher-student relationship counts for their math achievement? Evidence based on a large-scale investigation in the Chinese context

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Abstract:
As a critical aspect of classroom environment, teacher-student relationship (TSR) has been frequently linked to students' academic performance. However, the nature of this relationship in mathematics education remains equivocal, particularly during the critical secondary school years. Leveraging a nationally representative dataset of 158,156 eighth graders across 1,097 schools in five Chinese provinces, the present study analyzed the magnitude and mechanism underlying TSR-math achievement relationship, considering the mediating effects of math interest and self-efficacy. The results indicated that with gender controlled, (1) TSR was significantly and positively associated with students' math achievement; (2) both math interest and self-efficacy significantly mediated the TSR-math achievement relationship; (3) math interest and then self-efficacy serially mediated the TSR-math achievement relationship. The findings highlight the dual importance of nurturing supportive TSR for both math cognitive development and motivational enhancement. Besides, the Eastern mode of teacher-student interaction could afford a reference for the further establishment of TSR globally.

1. Introduction

A positive classroom environment has a crucial role in improving students' learning motivation and engagement, which in turn facilitates students' academic success (Ma et al., 2018). As a critical aspect of classroom environment, teacher-student relationship (TSR) has been demonstrated to present close associations with students' learning outcomes (Barile et al., 2012; Roorda et al., 2011; Wentzel, 2016). As Pianta (1999) and McCormick et al. (2013) suggested, TSR denotes a two-way interpersonal connection between the teacher and the student in both the classroom context and interpersonal interactions. Specifically, according to Virtanen et al. (2020), TSR emphasizes the affective aspect of interpersonal relationships and reflects a collection of emotional resources provided by teachers and perceived by students (Chen, 2005; Patrick et al., 2007; Tao et al., 2022). In this sense, teachers' behaviors like caring, support, warmth, closeness, etc., that interact with students in a daily learning environment constitute the broad TSR (Ma et al., 2018). In math, however, previous studies on the relationship of TSR with math achievement have yielded mixed results, especially during the secondary school years. TSR has been uncovered to predict math success in specific studies (e.g., Mikk et al., 2016; Riconscente, 2014), but weak or no association has also been observed in others (Barile et al., 2012; Muller, 2001; Krstić, 2015). Furthermore, the functioning behind TSR and math achievement is still unclear. Although some empirical research (e.g., Ahmed et al., 2010) has verified that motivational beliefs, especially values (e.g., interest) and expectancies (e.g., self-efficacy), play prominent roles in mediating the TSR-math achievement relationship, most previous research has possibly undervalued the more complex connections between their specific motivation con-

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structs. In this study, we primarily focused on math interest and math self-efficacy because of their high frequency in math classrooms and their importance to academic success, as well as the close relationship of interest with self-efficacy in math having been verified in past work (e.g., Rottinghaus et al., 2003).

Additionally, most prior work on TSR has been carried out in western settings, whereas relevant studies have rarely been investigated in the East. Although supportive TSR is advocated in different societies, the nature might be different under different cultural values and actual school implementation (Li & Du, 2013; Maulana et al., 2014), which would differentially promote students' math achievements across the East and West. Hence, this study investigates the relational magnitude and the underlying mechanism of TSR counting for students' math achievement through math interest and self-efficacy in the Chinese middle school context. Research in the Chinese cultural context may lay critical theoretical and empirical foundation for future examination on the cultural universality and specificity of TSR, motivation constructs, math achievement, and their integrated mechanisms and patterns across countries or cultures.

2. Literature review

2.1 TSR and math achievement

TSR is generally accepted as playing an essential role in student learning. Attachment theory (Bowlby, 1980) notes that supportive TSR could provide students with a secure base and inspire their active learning behaviors. Self-determination theory (SDT; Deci & Ryan, 2008; Deci & Ryan, 2012) argues the importance of teacher caring in fulfilling students' basic psychological needs, making them motivated, and advancing students' academic development. Highlighting the critical role of social relationships and socialization agents, social cognitive theory (Bandura, 1986) also claims a dynamic interplay behind human functioning between environments, individuals, and individual behaviors; adolescents presenting favorable social connections with teachers could reap benefits from such experiences, and tend to present superior social, emotional, and behavioral outcomes. However, there is no consensus regarding its effect on student gains in math in the secondary school stage. A robust body of research reported an optimistic prediction of TSR on math achievement. For example, Ahmed et al. (2010) recruited Grade 7 students and found that early adolescents who reported higher teacher support scored higher on math achievement. Moreover, Mikk et al. (2016) reported on the support of TSR for 15-year-olds' math achievement across 65 countries/districts participating in PISA 2009. Riconscente (2014) also argued that the teacher caring students perceived made unique contributions to ninth and tenth graders' math achievement with their initial math interest and self-efficacy and demographics being controlled. However, the weak or no correlation between the two was also uncovered in other research (e.g., Barile et al., 2012; Krstić, 2015). For instance, Krstić (2015) found that different from the promoting effect of teacher-student attachment on students' math marks in the fourth grade, attachment to math teacher merely influenced students' learning attitudes but not the math marks in the seventh grade; instead, instructional support played a more substantial effect in this stage. Similarly, Barile et al. (2012) pointed out that a good TSR might not be enough to improve students' math achievement in the high school stage; other factors, like teacher education and experience, communication style, and teacher effectiveness, might exhibit more significance on students' academic attainments.

Notably, different from the Western values advocating certain boundaries and space being kept in the personal communication and relationships between the teacher and the student (Wang & Du, 2014), similar to the parental role, and incorporating the spirit of sacrifice, the Eastern teacher's caring and support have been uncovered to run through the student's all intellectual as well as personal development (Pratt et al., 1999). This conforms to the argument by Wang & Du (2014) that the TSR in the East carries far more meaning than the pedagogical relationship and is far beyond the classroom. Limited empirical evidence has verified that TSR is significantly associated with students' math problem-solving performance (Zhou et al., 2019) in the Chinese middle school context. In this sense, we postulate a significant positive connection of TSR with math achievement in this study.

2.2 Roles of math interest (values) and self-efficacy (expectations) in linking TSR to math achievement

As suggested by expectancy-value theory (EVT; Wigfield & Eccles, 1992; Wigfield et al., 2006), values and expectancies, as the general framework for achievement motivation, play prominent roles in mediating the relationship of TSR with students' learning attainments. Values generally comprise intrinsic value (e.g., task interest), attainment value (i.e., task importance), and utility value (i.e., task usefulness) (Wigfield & Eccles, 2000), while expectancies (self-efficacy expectations) describe students' beliefs regarding their capacity to excel in impending or far-off tasks (Eccles et al., 1983). Through literature review in math, values were typically operationalized as subject-related interest, and self-efficacy usually represented expectancies. Studies have indicated that students' perceived teacher behaviors, especially teacher emotional support, is associated with junior and high school students' math interest and self-efficacy (e.g., Lee et al., 2009; Riconscente, 2014; Yıldırım, 2012). Meanwhile, math interest and self-efficacy have been confirmed as playing a joint function in promoting students' math achievement (Chiu & Xihua, 2008; Eccles et al., 1983). On this basis, some empirical research has examined the mediating effects of math interest and self-efficacy in linking TSR to math achievement. For instance, Ahmed et al. (2010) revealed that math interest and self-efficacy jointly and partially mediated the association between student-reported social support, especially from teachers, and seventh graders' math attainment. Together with theories mentioned above, this part of literature comprehensively constructs the theoretical framework for the interweaving associations among TSR, math interest, self-efficacy, and math achievement and lends empirical support to EVT. Nonetheless, few studies have

investigated these relationships in the Chinese context. As Oettingen & Zosuls (2006) suggested, cultural norms in East Asian and Western countries differ substantially and impact their students' motivation development and academic performances. Compared to the Western individualistic mindset, East Asian countries like China prefer a collectivist one, thus adolescents in this context would derive more value and self-appraisals from the messages and feedback by authoritative figures like teachers (Oettingen & Zosuls, 2006). In other words, the social persuasion from East Asian teachers would exhibit a more fundamental effect in shaping their students' self-efficacy and relevant motives and academic performances (Klassen, 2004). In this sense, a relational examination in the Chinese culture may highlight theoretical relationships, provide empirical evidence, and extend the field with various educational and cultural settings. Moreover, undervaluing the inner connection of math interest with self-efficacy, the complex interplay behind TSR, math interest, self-efficacy, and math achievement needs to be further scrutinized.

2.3 The role of self-efficacy in linking math interest to math achievement

As indicated by Bandura (1995), learning interest as an internal factor impacts the formation of students' self-efficacy beliefs, aligning with Pajares and Johnson's (1994) argument that the interest students developed from the engaging activities would make them feel competent and continue to learn, hence strengthening their self-efficacy. Wentzel (1998) also noted that even if individuals are confident about their competence in accomplishing a task and believe they can control the outcomes, they may not take action unless they have a reason or incentive to do so. Furthermore, a recent meta-analysis revealed a strong correlation between interest and self-efficacy in math, which is notably stronger compared to other subject areas (Rottinghaus et al., 2003). All these arguments uncover the relevance of subject-related interest in self-efficacy development. Coupled with the pivotal role of self-efficacy in math achievement (e.g., Cleary & Kitsantas, 2017; Kitsantas & Ware, 2011), existing research collectively establishes the connection between math interest, self-efficacy, and math achievement, enlightening that math interest may exert an indirect influence on math achievement by boosting self-efficacy. As the empirical evidence, a significant mediating effect of self-efficacy on the positive association of math interest with math achievement has been confirmed by Zhang & Wang (2020) with middle school students in China. Combining with SDT stating that students' perceptions of teacher behaviors are linked to their subjective task values (Deci & Ryan, 2008, Deci & Ryan, 2012), there might be a clear pathway that supportive TSR promotes students' greater math interest, then boosts higher self-efficacy, which ultimately contributes to superior math achievement. However, to the best of our knowledge, there is a paucity of research that has addressed this exact path, especially within the framework of EVT in the Chinese context.

2.4 Gender differences in TSR, math interest, self-efficacy, and math achievement

There have been well reported closer relationships with girls compared to boys by teachers in previous studies (e.g., Ganley & Lubienski, 2016; Hajovsky et al., 2017). From the academic risk perspective (Hamre & Pianta, 2001), it is anticipated that TSR would have a more pronounced positive impact on boys' academic engagement and achievement than girls', given their higher risk of behavioral and academic problems. In contrast, gender role socialization theory (Ewing & Taylor, 2009) asserts that girls may benefit more from close TSRs than boys, as positive interpersonal relations are more highly valued by girls and are more congruent with their gender role norms. Regardless of the stance, it is certain that gender may mix TSR and mathematics performance and even the relationship between both. Additionally, numerous studies have demonstrated gender differences in math interest (e.g., Frenzel et al., 2007; Lichtenfeld et al., 2007), self-efficacy (e.g., Else-Quest et al., 2010; Pajares, 2005), and achievement (e.g., Gallagher & Kaufman, 2005; Ganley & Lubienski, 2016). In this sense, gender should be considered as a critical controlling variable in investigating the integrated relationship among TSR, interest, self-efficacy, and achievement in math.

2.5 Current study

Building upon the aforementioned theoretical and empirical foundations, as well as the ambiguous research findings regarding the relationship between TSR and math achievement, in conjunction with the unique oriental cultural traditions, the present study utilizes a large-scale sample to investigate the magnitude of TSR accounts for math achievement and explore the underlying mechanism of how TSR, interest, self-efficacy, and achievement in math relate to each other in the Chinese math classroom context. A multiple serial mediation model (see Fig. 1) was constructed, and structural equation modeling would be adopted to evaluate the potential paths (Anderson & Gerbing, 1988). Because students' perceptions may be more effective than external observations or reports in impacting their subsequent learning behaviors (Maulana & Helms-Lorenz, 2016), the student-perceived TSR in the math learning climate was focused on in the present study. The research questions proposed for investigation are as follows:

RQ1: To what extent does TSR account for math achievement?

RQ2: Are math interest and self-efficacy involved as mediators in the relationship between TSR and math achievement?

RQ3: Is there a significant serial mediating effect of math interest and self-efficacy in linking TSR to math achievement?

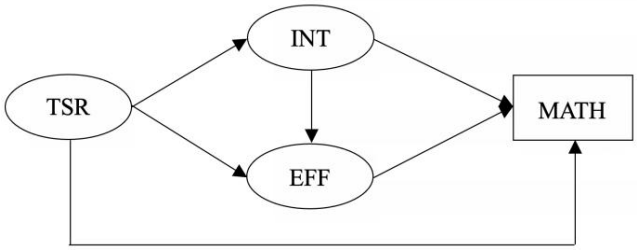

Fig. 1. The present theoretical framework.

Notes: INT=math interest; EFF=math self-efficacy; MATH=math achievement.

3. Method

3.1 Participants

The 'Regional Education Assessment Project', a large-scale and comprehensive survey conducted throughout China and ethically approved by the Ethics Committee of Beijing Normal University, served as foundation for this study. The participated schools were sampled using the Probability Proportionate to Size method, taking into account all hierarchical variables nested at the school level. Both school principals and students consented to participate in the study. Prior to the survey, teachers informed the students about the procedures without offering any incentives. The initial sample for this study consisted of 158156 eighth-grade students from 1097 schools across 145 districts/countries in five provinces spanning the south, north, middle, and east regions of mainland China. 156661 students made up the final sample after deleting invalid data. Among them, 52.8% were males, and 47.2% were females.

3.2 Measures

Student questionnaires and standardized math tests together constituted the present survey. Among them, TSR, math interest, and self-efficacy were selected and modified from the PISA 2012 Student Questionnaire scales. To ensure the item quality, the project team invited first-tier teachers and experts in math education for review and revision. Besides, a pilot study with a small group of students was carried out to gauge their item understanding, and subsequent adjustments were furthered in response to their feedback.

TSR. The TSR scale was constructed using five modified items regarding classroom and school climate from the PISA 2012 student questionnaire, specifically, the student perceived positive emotional support from teachers (e.g., 'The mathematics teacher is very concerned about my physical and mental health.'). Students were asked to rate their level of agreement with the provided descriptions on a scale of 1 to 5, where 1 represented strong disagreement and 5 denoted strong agreement. The Cronbach's alpha coefficient for TSR was .94, indicating excellent internal data consistency.

Math Interest. Students' interest in math was assessed with four items drawn from the PISA 2012 student questionnaire, with a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). One example item was 'I am interested in the things I learn in math.' The math interest scale demonstrated a strong reliability coefficient of .95.

Self-efficacy. Also modified from the PISA 2012 student questionnaire, the math self-efficacy scale comprised eight items. This scale assessed students' confidence levels in handling a series of specific math problems. Students were just required to score their perceptions from 1 (very difficult) to 5 (very easy) but did not need to solve these problems. The example item was 'Estimating the nearest integer to an irrational number.' The reliability coefficient of the self-efficacy scale was .94.

Math achievement. The standardized math tests in the present study were formulated based on the Math Curriculum Standard for Compulsory Education (2011 version) issued by the Ministry of Education of the People's Republic of China in 2012. The tests encompassed three content domains: number and algebra, graphics and geometry, and statistics and probability; and assessed students' cognitive abilities at three levels: knowledge, comprehension, and application. To guarantee the test quality, several rounds of test development were conducted (see Zhang & Wang, 2020). Two test volumes (A and B) were designed parallelly and randomly allocated to students. Based on the Rasch modeling procedure, students' raw scores were estimated as math ability values, then further converted into the scale scores with a mean of 500 and a standard deviation of 100. The Cronbach's alpha coefficients for tests A and B were .93 and .88, respectively.

Gender. As demonstrated above, gender variable has been considered as a critical factor in mixing performance in TSR, math interest, self-efficacy, and achievement, even their interrelations. Therefore, gender was controlled for in the present study to mitigate potential confounding effects on the results, with males assigned a code of 0 and females a code of 1.

3.3 Data analysis

A multiple mediation analysis was utilized to scrutinize the relationship of TSR with math achievement and the mediating roles played by math interest and self-efficacy. Considering that participant selection involved cluster sampling, the data structure needed to be first identified via intra-class correlation coefficients (ICC1). If ICC1 exceeds .1, a substantial inter-group difference is thus suggested and a multilevel analysis should be considered (LeBreton & Senter, 2008). Then confirmatory factor analysis (CFA) was performed to validate the measurement model. Typically, CFI and TLI larger than .90 are regarded as acceptable, and RMSEA and SRMR below .08 suggest a reasonable fit (Hu & Bentler, 1999). Besides, the bias-corrected bootstrap test was utilized to assess the significance of the mediation model (Cheung & Lau, 2008), with the data being resampled and replaced 10,000 times. It is worth noting that missingness processing is necessary before formal data analysis. All the cases with missingness on each variable were less than 5%. The missing mechanism was examined with Little's MCAR test (Little & Rubin, 2019), and the result showed that missing values were not entirely random (χ^2=5533.32, df=2031, p <.001). On this basis, Full information maximum likelihood was performed to handle

missingness with Mplus 8.3.

4. Results

4.1 Descriptive and correlational statistics

CFA was initially performed to assess the scales' measurement properties. Results showed that all 32 items (of TSR, math interest, and self-efficacy) showed reasonably high factor loadings and met Hensler et al. (2009)'s minimum requirement of 0.7. Table 1 displays the means, standard deviations, and correlations between variables. All variables were significantly related with each other, except for the non-significant correlation of gender with self-efficacy, thus supporting the primary interrelations among key constructs, as well as the necessity of controlling gender in the tested model. Then the gender variable was regressed on the final outcome variable, i.e., math achievement in this study.

Table 1. Descriptive and correlational statistics between variables.

Variable	Correlation				
	1	2	3	4	5
1 g	1				
2 TSR	.02**	1			
3 INT	-.07**	.59**	1		
4 EFF	.00	.55**	.55**	1	
5 MATH	.03**	.26**	.30**	.35**	1
Mean	1.47	3.61	3.33	3.74	569.10
Standard deviation	.50	.98	1.13	.94	77.16

Notes: g = gender; **p <.01.

4.2 Model testing

Before the formal analysis, ICC1 was first calculated. The results suggested that ICC1 was 27.1% for math achievement, 5.0% for math interest, and 8.7% for self-efficacy. The between-class variances for math achievement were significant. Or put another, there was data dependence due to cluster sampling. Thus, as Muthén & Muthén (1998-2017) recommended, "TYPE = COMPLEX" was used in Mplus 8.3 to conduct the chi-square test of model fit and compute standard errors.

The relational magnitude between TSR and math achievement was then analyzed, and the model fit was good: χ^2 (14)=13811.82, p<.001; CFI= .96; TLI= .94; RMSEA= .08; SRMR= .02. The results showed that overall, TSR was significantly and positively linked with math achievement (β= .26, p<.001), suggesting that supportive TSR was conducive to superior math achievement, after controlling for gender.

Further, math interest and self-efficacy were involved as mediators in the relationship between TSR and math achievement with gender controlled (Fig. 2). The model fit indices were: χ^2 (147)=73066.83, p<.001; CFI= .95; TLI= .94; RMSEA= .06; SRMR= .03, indicating a good fit of the theroretical model to the data. The results showed that TSR was positively associated with both math interest (β= .62, p<.001) and self-efficacy (β= .34, p<.001); further, there were positive associations of math interest (β= .17, p<.001) and self-efficacy (β= .26, p<.001) with math achievement, as well as a significant positive relationship of math interest to self-efficacy (β= .36, p<.001). Besides, the direct relationship between TSR and math achievement was nonsignificant when taking both mediators into account (β= .01, p= .10), meaning a complete mediation effect of math interest and self-efficacy in linking TSR to math achievement.

Additionally, a bias-corrected bootstrap test was employed to assess the statistical significance of the mediation effects (Table 2). The results showed that with gender controlled, three indirect paths were all significant, as the 95% confidence intervals did not include 0. This suggests that math interest and self-efficacy played multiple and serial mediating effects in associating TSR with math achievement. The model explained 15.3% of the variance in math achievement, and the three indirect paths accounted for 97.31% of the total effect. In specific, the indirect paths 'TSR → math interest→ math achievement' and 'TSR → self-efficacy → math achievement' accounted for 40% and 34.62% of the total effect, respectively, indicating that both math interest and self-efficacy played vital roles in linking TSR with math achievement. Meanwhile, the serial path (i.e., TSR → math interest → self-efficacy → math achievement) explained 22.69% of the total effect, suggesting that math interest and then self-efficacy serially bridged the relationship of TSR to math achievement, which is also an essential path behind the functioning.

5. Discussion

This study furthers the field by validating a theoretical model through which TSR counts for math achievement in the Chinese cultural context. The relevant findings help to understand to what extent and how supportive TSR counts for students' math achievement from a non-cognitive standpoint, i.e., considering the mediating effect of math interest and self-efficacy. More importantly, within the framework of EVT, it uncovers the interactive phenomenon between academic motives behind their bridging roles in linking TSR to math achievement, which prompts an in-depth understanding of the complex mental process behind TSR (or namely classroom climate) and outcomes.

5.1 TSR and math achievement

Going beyond prior work indicating mixed associations between TSR and secondary students' math achievement in the western contexts, the current study uncovered a significant positive association (β= .26, p<.001) between TSR and math achievement with a large-scale Chinese middle school sample, concurring with the earlier findings by Zhou et al. (2019). After entering the middle school stage, students face new academic challenges and have diverse psychological and emotional needs. The teacher in this stage, whether as a disseminator of knowledge or as a psychological tutor, acts a vital leading role in the academic and personal development

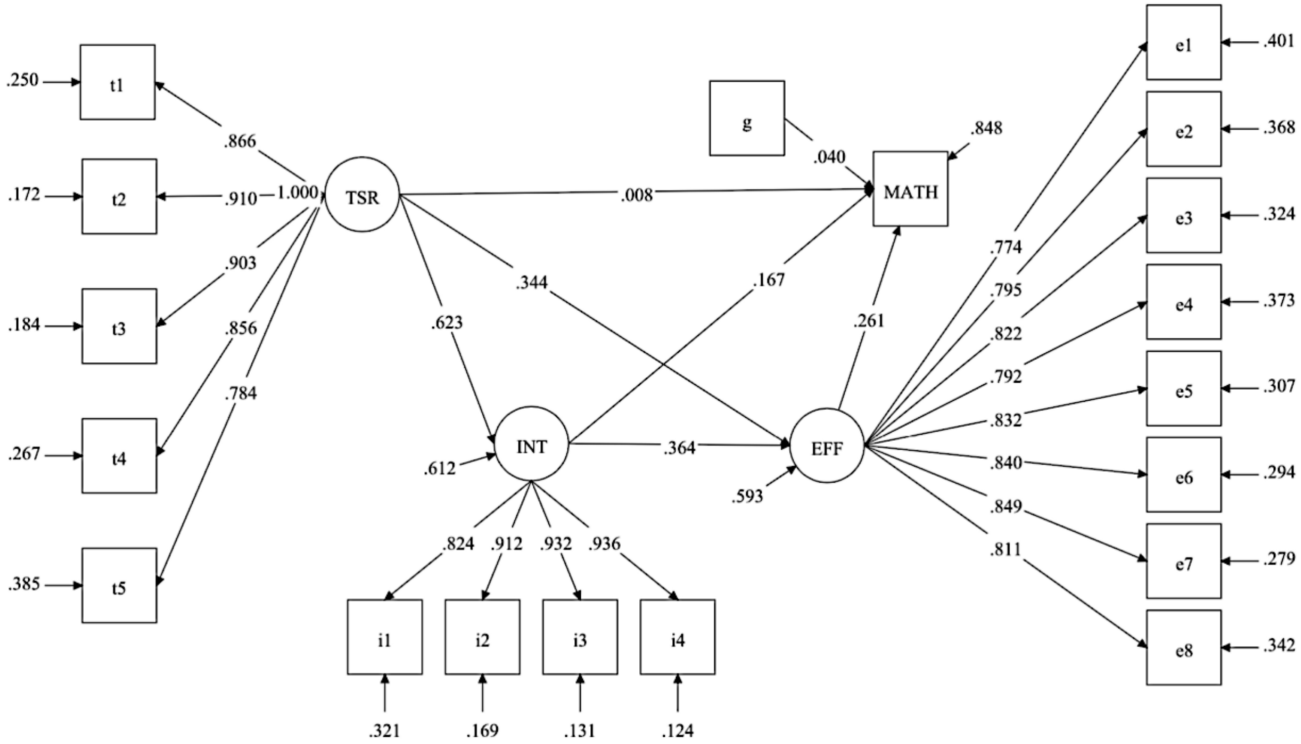

Fig. 2. Structural equation model indicating the relations among TSR, math interest, self-efficacy, and math achievement with gender controlled.

Table 2. The Bootstrap test results.

Paths	Standardized	SE	Bias-corrected (95%)	
			Low	High
TSR→INT→MATH	.10***	.00	.10	.11
TSR→EFF→MATH	.09***	.00	.09	.09
TSR→INT→EFF→MATH	.06***	.00	.06	.06

Notes: ***p <.001.

of students (Zhang & Wang, 2020). A warm and supportive TSR can provide students with a strong feeling of security that inspires students' active classroom engagement and thus improves their academic performance (Ma et al., 2018), and even in turn their long-term advancement. Characterized and shaped by the large power distance between teachers and students, the TSR in Eastern settings can significantly strengthen the teacher's responsibility and commitment and formulate a closer relationship of the teacher with the student (Li & Du, 2013). This is supported by the findings of Fisher (1997), who identified those students from Asian backgrounds tended to have a more positive view of their teachers than those from other cultural groups, which powerfully affirmed the Asian teachers' sacrifice to the students and the student's recognition of the teacher support. In this sense, a close and even cohesive TSR and its significant positive association with students' math achievement are expected in the Chinese middle school stage.

5.2 TSR, math interest, self-efficacy, and math achievement

After identifying the relational magnitude of TSR with math achievement, this study further looked into the underlying functions of math interest and self-efficacy on the link. The mediation analysis was conducted, and the results suggested that, after controlling for gender, both math interest and self-efficacy acted as significant mediators in relating TSR to math achievement. In other words, student-perceived teacher emotional support indirectly made a difference in math achievement by boosting math interest and self-efficacy, concurring with the statement that the emotional security afforded by supportive TSR generally provides students strong motivational beliefs and, in turn, promotes students' active learning behavior and higher gains in math (Deci & Ryan, 2008, Deci & Ryan, 2012; Pianta et al., 2003). To be specific, students' perceptions of supportive TSR presented a significant relationship with students' interest and self-efficacy

in math, supporting previous research (e.g., Lee et al., 2009; Riconscente, 2014; Yıldırım, 2012) and SDT stating that students' perceived teacher behaviors are related closely with students' subjective task values and achievement-related self-beliefs (Deci & Ryan, 2008, Deci & Ryan, 2012). Social-cognitive theorists also argued that a permanent interaction between the individual and the environment underlies his or her learning and developmental processes, and teachers are believed to help learners in their development of competence beliefs, and also of their interests (Frenzel et al., 2010). These discussions together indicate that teachers' contribution to students' perception of being supported and encouraged is significantly related to students' math interest and self-efficacy. Meanwhile, interest (e.g., Reeve et al., 2015) and self-efficacy (e.g., Cleary & Kitsantas, 2017; Fast et al., 2010; Zhang & Wang, 2020) in math were significantly and positively linked with student achievement performance. Prior studies have uncovered students who are more interested in math would put forth more effort (Deci et al., 2001), spend more time in math-related activities (e.g., Schiefele, 2001), and exhibit a more in-depth cognitive processing and optimized self-regulation during math learning (Fisher et al., 2012), all of which contributed to sustained math learning and positive results (Reeve et al., 2015). Likewise, students with stronger efficacy beliefs would put in more effort (Sakiz et al., 2012), exhibit more endurance (Hoffman & Schraw, 2009), employ more metacognitive strategies (Butler & Winne, 2010) on math learning tasks, all of which contribute to superior student achievement in math. It can be said the critical bridging effects of math interest and self-efficacy in linking TSR with math attainment found in this study, align nicely with existing findings (e.g., Ahmed et al., 2010), and provide empirical evidence and promote the generalization of expectancy-value theory (Wigfield & Eccles, 1992; Wigfield et al., 2006) in the Chinese context. Noteworthy, despite the above consistencies with existing research, higher standardized path coefficients identified of TSR with math interest/self-efficacy, of math interest/self-efficacy with math achievement, and overall, of TSR with math achievement in this study relative to existing findings in Western contexts (see details for example in Ahmed et al., 2010; Riconscente, 2014; Yıldırım, 2012), also highlight the moderation of cultural tradition and norms on the functioning of TSR, motives, and math achievement, thus justifying the necessity to interpret the present results combined with the particular cultural context, and for future examination, to further scrutinize the universality and specificity of the relevant relations and functions though cross-cultural comparisons.

6. Limitations

The current study has some limitations that should be cautioned. First, the self-reported data from students comprise the questionnaires measured in this study. Thus, prejudice from position may be inevitable, and it may potentially inflate the revealed relationships to some extent. More data combined with perspectives from teachers and qualitative inquiry are recommended to extend existing results. Second, with a cross-sectional design, this study is limited in revealing causality; the positioning of the variables depicted here is primarily constructed with existing theories and empirical evidence. Thus, more experiential/longitudinal designs, especially with students' earlier math experience controlled, are needed to support the causal relationship beyond this study. Additionally, researchers studying the quality of TSR typically conceptualize and evaluate it with various dimensions, including the positive, conflict, and occasionally, intimate, or dependent dimensions (Hughes et al., 2005). Likely, both values and expectancies include multiple constructs in the expectancy-value theory. However, this study only looked into some selected aspects; future studies may contribute to the field by covering more dimensions and constructs to reveal their comprehensive relationships.

7. Implications

Theoretically, this research revealed one detailed function among TSR, math interest, self-efficacy, and math achievement under the oriental education system and cultural tradition, which is of great significance for our understanding of TSR and math education in different contexts. Meanwhile, this study afforded empirical evidence with superior relevant relations in the oriental context, which hopefully lay the research foundation for the enrichment of the attachment theory, SDT, social cognitive theory, and expectation-value theory with cultural factors. Combining relevant research in the Western context, this study is also conducive to our dialectical reflection on different classroom environments and their connections with students' math learning processes.

Practically, the findings highlight the significance of supportive TSR for student learning and development, in terms of both academic achievement and motivations (math interest and self-efficacy). Indeed, the latter, serving as the critical mediators on the relationship between TSR and math achievement, also act as vital outcome variables of TSR. This enlightens teachers that instead of concentrating exclusively on math curriculum and instruction, they should also put efforts toward building and maintaining positive TSR and making dynamic adjustments in their actual interactions with students to stimulate students' high academic interests and strong competence beliefs and improve math performance. Besides, all teacher behaviors interacting with students constitute the TSR in a broad sense. Therefore, positive TSR can be generated on the one hand in the traditional classroom by introducing more cooperative and constructive learning activities and interactions, on the other hand in acceptable personal communication, through teachers' emotional warmth and daily caring provided for students. In this sense, the Eastern mode of teacher-student interaction could afford a reference for the further establishment of TSR globally. Hopefully, all these efforts would inspire students with stronger math interest and self-efficacy, motivate them with more active classroom engagement, and promote their math success.

8. Conclusions

To our best knowledge, with a large-scale Chinese middle school sample, the present study is the first empirical

investigation modeling TSR trajectories with math interest and self-efficacy to link gains in math. This study adds to the field by identifying a significant and close relationship of TSR with math achievement in the present Chinese context; and uncovering the significant mediating roles of both math interest and self-efficacy, as well as the serial mediating effect of the two, on the relationship of TSR to math achievement. As Hughes et al. (2008) indicated, beneficial intervention at any point in the influential nexus may favor students' learning trajectories. In this sense, this study revealed that a supportive TSR might be an essential starting point.

Ethical Approval Statement

Research ethics approval was obtained by the Institutional Review Board of Beijing Normal University. This study was conducted in accordance with the Academic Integrity Code of Beijing Normal University and the University of Hong Kong.

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Data availability statement

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Conflict of interest

The author declares no conflict of interest.

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