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The Effects of Teachers' Error Orientations on Students' Mathematics Learning: The Role of Teacher Emotions

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Abstract: Several attempts have been made to explore the factors influencing teacher emotions, most of which focus on external factors such as student behaviors and classroom teaching. However, research on the links between internal factors and teacher emotions is scant. Based on the control value theory, this article explored the influence of junior secondary mathematics teachers' error orientations on their emotions, and how teachers' error orientations and emotions were related to students' mathematics learning strategies. A sample of 70 junior high school mathematics teachers and their students (N = 2453) in mainland China participated in this study. Confirmatory factor analysis and multilevel structural equation modeling were used to analyze the data. The results showed that teachers' positive error orientation increased their positive emotions and reduced their negative emotions, whereas teachers' negative error orientation increased their negative emotions and reduced their positive emotions. Regarding the effects of teacher emotions, teachers' positive emotions increased students' positive mathematics achievement emotions and reduced their negative emotions. Meanwhile, students' negative mathematics achievement emotions significantly reduced their adoption of desirable mathematics learning strategies. The findings highlight the importance of teachers' positive error orientation and positive emotion for students' mathematics learning.

Keywords: teacher error orientations; teacher emotions; mathematics achievement emotions; mathematics learning strategies; multilevel analysis

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1. Introduction

Teaching is an emotional practice [1]. Teachers' emotions not only affect teachers' well-being but also affect the quality of their teaching [2,3] and student learning performance [4] in the long term. Therefore, it is particularly important to clarify the causes of teachers' emotions and how they promote student learning. The control value theory provides a theoretical framework for studying the antecedents and consequences of emotion. The theory states that the core of emotion is individuals' control and value appraisal of events [5]. In terms of value appraisal, previous research mainly focused on the impact of students' mathematics learning value on achievement emotion [6–9], and the impact of mathematics teachers' social utility value on their emotions [10]. Although these studies elaborate on the important role of value appraisal in stimulating individuals' emotions, they only explored the impact of their value on emotion from a positive perspective. Some negative factors such as errors in mathematics learning also affected emotions. Errors are often seen as evidence of an individual's lack of knowledge and ability [11]. Errors are therefore often understood as a negative factor that needs to be avoided and prevented [12,13]. When people think that making errors is shameful and should not happen, it is likely to lead to negative emotions. However, if individuals regard errors as learning opportunities and realize the value of errors in promoting individuals' progress, it is possible to stimulate their positive emotions. In this study, error is defined as a general view of the mistakes made by teachers and students in teaching and learning. The teachers' value appraisal of errors reflects their error orientations. However, only a few studies have explored mathematics teachers' error orientations. These studies mainly focused on investigating and analyzing the teachers' error orientations based on types of errors [14], objects of errors [15], and functions and handling strategies of errors [16]. Although these studies have drawn valuable conclusions, there is a lack of attention to the relationship between teachers' error orientations and emotions. It could not be ignored that teachers' error orientation reflects the teachers' belief in dealing with errors, and may have an indirect effect on their emotions through the teachers' self-regulated of learning (SRL) and self-regulated teaching (SRT). Teachers' belief systems may affect the process of their SRL to SRT and the practical experience with SRL to SRT can positively affect teachers' emotion (e.g., passion) [17]. Simultaneously, teachers' error orientations may also affect their emotions indirectly through their handling of unexpected situations in class. If teachers have positive beliefs toward unexpected events in the classroom, they can take the benefits of it to communicate mathematics with students [18]. In this situation, when errors occur as unexpected events in the classroom, teachers are more likely to produce positive emotions and lead students to enjoy mathematics learning. Sometimes, when errors in the classroom affect the teachers' normal teaching progress, mathematics teachers feel troubled about deviating too far from the lesson plan and see the changes as threats [19]. In this situation, teachers may have negative emotions.

So far, numerous studies on the influencing factors of teacher emotions have focused on external factors, such as student behaviors [20–26], teacher–student relationships [27], and classroom instruction [2]. However, the internal factors (such as personal goals and motivations) also affect teachers' emotions as much as the external factors [3,10]. The error orientations of teachers mentioned above are a new entry point for the study of teacher emotions. Teachers with a positive error orientation regard errors as a springboard for learning. They strive to create a comfortable atmosphere for students to make a variety of errors in the classroom, actively discuss errors with students, and help students obtain the abilities of deep thinking and reasoning from their errors. Such an error-tolerant atmosphere creates a learning environment full of trust and positive emotions, and inspires the potential of teachers and students [15]. In this environment, students may maintain active and creative thoughts, and have an 'Aha!' moment. They are more likely to obtain a sense of achievement which leads them to generate more positive emotions towards learning. Teachers may experience more positive emotions while teaching and be more encouraged to achieve their teaching objectives. In contrast, teachers with a negative error orientation usually do not tolerate errors in their classrooms, which is likely to create a harsh learning environment as they are more likely to show disappointment in the students making the errors. They often correct students' errors by explaining the correct answers [15]. In such an environment, students become afraid to make errors and are likely to have negative emotions. These negative emotions caused by teachers' negative error orientation may prevent opportunities for learning by discussing errors in the classroom.

In short, teachers' error orientations have the potential to influence teachers' and students' emotions. Moreover, prior studies have found that teachers' emotions would influence students' emotions [22,28–30]. Therefore, based on the analysis of the influence of teachers' error orientations and emotions on students' achievement emotions, we further explored the mediating role of teacher emotions.

In the literature, control value theory is usually adopted to explain students' achievement emotions, but few studies have used this theory to explore teacher emotions and the influencing factors. Pekrun has pointed out that the theory applies not only to students' emotions but also to the study of teachers' emotions [31] because teachers' emotions affect their teaching practice, personality development, and mental health as effectively as the emotions affect students' academic achievement and well-being. The control value theory indicates that teachers can generate pleasant emotions only when they feel value [32]. If teachers value errors, they are more likely to regard errors as learning motivation and tools to promote reflection and explore the nature of mathematics. Teachers believe that the explanation, analysis, and discussion of errors can improve students' reasoning, critical thinking, and metacognition and promote students' deep understanding and mastery of mathematics knowledge. Teachers' positive appraisal of errors is also likely to support their students to continuously learn from errors [15]. If teachers have a negative appraisal of errors, they are likely to believe that errors should not occur. They tend to see errors as evidence of failure, which in turn leads to negative emotions such as anxiety, shame, and stress. Thus, from the perspective of control value theory, this study attempts to explore the effect of mathematics teachers' error orientations on their emotions and student learning.

Teachers' error orientations vary among individuals. Some teachers insist that "strict teachers are good teachers" [33]. They consider that errors are shameful and should be avoided. Once an error occurs, teachers should treat it strictly to ensure that students do not make the same error next time. Only a teacher who treats errors strictly like this can significantly improve students' performance. On the contrary, some people argue that teachers who are too strict may be less able to support student learning [34]. If teachers regard errors as learning opportunities, they are likely to analyze the causes of errors, and to improve student learning from the current level to a higher level. Such teachers hold a more positive view of students' errors, so they may be more likely to cultivate positive, confident, and creative students.

What kind of error orientations will have a better effect on teachers' emotions and students' mathematics learning? Little work has been conducted to address this question. Scholars have yet to theorize and examine the relationship between teachers' error orientations and emotions, and the mechanism through which teachers' error orientations promote students' mathematics achievement emotions and learning strategies. Therefore, providing empirical evidence about the links between teachers' error orientations, emotions, and students' mathematics learning may contribute to knowledge building and practical improvement. Specifically, following the perspective of control value theory, this study attempted to answer the following three questions:

1. What is the relationship of mathematics teachers' emotions to their error orientations and students' mathematics achievement emotions?
2. Do teachers' emotions play a mediating role between their error orientations and students' mathematics achievement emotions?
3. To what extent do students' mathematics achievement emotions relate to their mathematics learning strategies?

2. Literature Review

2.1. Teacher Error Orientations

Error orientations refer to an individual's attitudes towards coping with errors at work, which are mainly used to measure how one thinks about and copes with errors at work [35]. Matteucci et al. divided error orientations into types, namely, negative and positive error orientations [16]. Teachers with negative error orientations treat errors more rigidly. They consider errors as a sign of failure or inability, which in turn triggers individuals' negative emotions, such as anxiety, shame, and pressure. These teachers tend to avoid communicating errors with students [15,36]. In contrast, teachers with positive error orientations regard errors as an integral part of learning processes and the cornerstone of knowledge building [37], and thus they are more tolerant of errors and have fewer negative emotions when they make mistakes. These teachers believe that communicating errors with students is a natural part of learning, and that individuals should learn from their errors [15]. Therefore, teachers with positive error orientations are happier in a mathematics classroom, whereas teachers who treat errors more negatively are less content in mathematics teaching [36].

In recent years, researchers have become increasingly interested in teachers' error orientations, and some studies indicate that cultural differences are an important factor affecting teachers' error orientations. That is, teachers' error orientations may vary in different cultural contexts. For example, American teachers' error handling strategies are more positive. "They show a positive disposition toward students who make mistakes. Their responses are mitigated and often include a compliment to the student for having tried." As a result, the emotional atmosphere in the classroom is usually positive and relaxed [38]. Comparatively, Italian teachers' error handling strategies are more negative. "They tend to respond to students' mistakes by openly showing their disappointment. Their responses are often harsh and include ironic comments" [38]. Therefore, the emotional atmosphere in the classroom tends to be negative and stressed. Researchers also summarized the differences between teachers' error handling strategies in other cultures. For example, British teachers showed positive error handling strategies and tended to protect students' self-esteem and avoid negative feedback. French teachers, however, showed negative error handling strategies, "responding directly to students' mistakes and sometimes yelling at students" [39]. Russian teachers have positive error handling strategies and believe that errors are an important part of learning and can be solved in public. Japanese and Chinese teachers are more active in error handling strategies and will spend a lot of time discussing these errors with students. Japanese teachers believe that errors play a positive role in teaching. They often ask students to share their solutions with the class during mathematics classes. Chinese teachers attach importance to creating a "risk-free" environment for students to make errors. They use errors to encourage students to discuss mathematical concepts [40]. Chinese teachers attribute it to the cultural belief that "failure is the mother of success".

However, such studies are mainly conducted in Western countries [14–16,41]. Meanwhile, mathematics teachers' emotions are also context-dependent, and the findings in Western countries may not apply to East Asian countries [2]. To date, far too little attention has been paid to Chinese mathematics teachers' error orientations. The old stereotype of the Chinese mainstream classroom is a cramming teaching system, and the Western classroom is known for more developed teaching styles as a student-based and open-minded approach. This mindset may be rooted in Chinese teachers' reliance upon traditional and ossified pedagogies to emphasize the development of students' ordinal and conceptual knowledge. In contrast, teachers in Western countries, such as the United States, focus on developing students' knowledge via creative and exploratory activities [42]. However, since curriculum reform was conducted on China's mainland in the early 21st century [43,44], some positive changes have taken place in the mathematical classroom [45]. The result of the assessments of the OECD Teaching and Learning International Survey 2018 shows that the Chinese teachers are more effective than British teachers in delivering accurate knowledge and motivating students' learning strategies via operating with students' cognition [46]. Chinese style pedagogy promotes the collective work of all students whereas Western style pedagogy values personalized and differentiated coaching [47]. Moreover, Chinese teachers think highly of questioning the facts and creating negative feedback for students, as they pay more attention to the errors in partially correct answers and overlook them to encourage and value students' work [48]. The Chinese teachers often lead students to consider and relate the errors with the mathematics concepts and encourage students to fix their misunderstandings by questioning the errors' occurrence [49]. American teachers question students' metacognition more often than Chinese teachers, and they provide opportunities and encourage students to express their thoughts in the classroom [48]. The reason why Chinese teachers present more strict attitudes toward errors than American teachers may be lead by the pressure of extreme competition for high grades in Gao Kao. In addition, the differences in the culture of emotions show that under the different social backgrounds, the teachers' emotions towards the same mathematical events varies [50]. Currently, there is little discovery on Chinese mathematics teachers' emotional experiences in the classroom [51]. Because of the examination requirements, the level of anxiety in mathematics teaching and learning is much higher in China than in Western countries [52].

Therefore, it is worth exploring the effects of mathematics teachers' error orientations on their emotions and on students' mathematics learning in Chinese classrooms.

2.2. Teacher Error Orientations, Teacher Emotions, and Student Mathematics Achievement Emotions

The existing literature on the influence of teacher emotions on student learning mainly focuses on students' interests [53] and achievement emotions [22,28,54,55]. In terms of the influence of teacher emotions on student emotions, little consensus has been achieved in the existing research. Several studies found that higher levels of teachers' enjoyment produce higher levels of student enjoyment [4,56]; the mathematics anxiety of female teachers increases the mathematics anxiety of female students in primary schools [30]; the enjoyment of middle school teachers in mathematics teaching has a positive impact on students' mathematics enjoyment [22,28]. However, some studies reported that "teachers' enjoyment in mathematics cannot predict students' enjoyment at the end of the school year, partly because teachers' enjoyment is relatively unstable" [36]. It is therefore worth examining what kind of influence teachers' emotions have on students' mathematics achievement emotions.

Meanwhile, little research has been done on the effects of teachers' error orientations on students' emotions, except for Tulis, who investigated the relationship between teachers' error handling strategies, classroom error atmosphere, and students' emotional responses from the perspective of students. The results showed that teachers' error handling strategies affect students' emotions [54].

In short, both teachers' emotions and teachers' error orientations may affect students' mathematics achievement emotions. This study further explores whether teachers' emotions play a mediation role in these effects.

2.3. Student Mathematics Achievement Emotions and Mathematics Learning Strategies

Learning strategies are a combination of cognitive skills that learners use to learn materials [55]. Weinstein and Mayer conceptualized learning strategies as cognitive strategies and metacognitive strategies [57]. Cognitive strategies refer to the psychological processes of acquiring, storing, organizing, and understanding information by connecting new and previous knowledge. Metacognitive strategies refer to the monitoring and regulation of cognitive activities and actual behaviors. A cognitive strategy is a basic strategy for acquiring knowledge, which is used to achieve cognitive progress [58], whereas a metacognitive strategy is used to monitor cognitive progress [59]. Cognitive strategies include surface learning strategies (e.g., memorization) and deep learning strategies (e.g., elaboration) [55]. Surface learning strategies involve rote learning without in-depth elaboration [60]. Deep learning strategies and metacognitive strategies promote a higher level of problem-solving achievement [9]. In Germany, the results of Trends in International Mathematics and Science Study showed that monitoring strategies (i.e., metacognitive strategies) dominate mathematics and science learning, far ahead of strategies such as memorization or elaboration [61].

In particular, the process of mathematics learning is inevitably accompanied by making and learning from errors. Although many times students maybe do not recognize their errors, we must maintain this mindfully. When students make errors and fail to succeed in solving complex mathematical problems, they are likely to feel anxiety, depression, and boredom. These negative emotions impede their persistence in the face of difficulties and their use of deeper cognitive and metacognitive strategies during problem solving. The negative emotions of students may harm their subsequent learning processes and learning results [9].

Control value theory provides a theoretical basis for understanding the relationship between academic achievement emotions and learning strategies [31]. Academic achievement emotions are the emotions experienced by individuals when they strive to be successful in performing academic activities [31]. Positive emotions (e.g., enjoyment, hope, and pride) enable individuals to elaborate on the materials at hand and to flexibly organize materials [62]. Therefore, positive emotions are usually associated with elaboration, organization, metacognition, and critical thinking [63]. In contrast, negative emotions (e.g., anger and anxiety) may consume the cognitive resources required for any information coding involving elaboration, organization, understanding, and decision-making [64]. Negative emotions can also undermine the use of deeper strategies and increase the use of more trivial surface learning strategies, such as simply retelling learning materials [65], thus weakening the use of deep strategies and metacognitive strategies. For example, students with test anxiety tend to rely on surface information processing strategies, which is negatively correlated with refinement and organizational strategies [66].

The relationship between students' achievement emotions and the use of learning strategies has not been fully understood in previous studies [58]. Some studies found a positive correlation between students' positive emotions and learning strategies, and a negative correlation between negative emotions and learning strategies [6,58]. However, a few studies demonstrated no significant correlation between those variables [67]. Because of these inconsistent results, many scholars have called for a more in-depth analysis of the relationship between students' achievement emotions and learning strategies [6,58]. Therefore, this study explored the effect of students' mathematics achievement emotions on their mathematics learning strategies.

In summary, based on previous research findings, we hypothesized the relationships between teacher error orientations, teacher emotions, and students' mathematics achievement emotions and mathematics learning strategies as follows:

Hypothesis 1 (H1). *Teachers' error orientations would positively predict teachers' emotions.*

Hypothesis 2 (H2). *Teachers' emotions would positively predict students' emotions.*

Hypothesis 3 (H3). *Students' emotions would positively predict students' mathematics learning strategies.*

3. Materials and Methods

3.1. Participants

To address the three research questions, this study conducted a questionnaire survey in junior secondary schools in mainland China. Before data collection, approval from the research ethics committee was granted, and all participants gave their informed consent. The study employed a two-phase survey design. We first selected the junior secondary mathematics teachers to participate in the study, and then chose all students in the classes taught by these teachers. During the data collection, 87 mathematics teachers participated in the questionnaire survey. After checking the responses, 17 teachers were excluded due to too much missing data. The final valid sample consisted of 70 mathematics teachers and 2453 students taught by them. The average number of student samples per teacher was 35.

3.2. Measurement

The teacher questionnaire comprised three parts with 36 items. The first part was the instruction, informing the subjects of the purpose of this study and the measures for ensuring privacy. The second part consisted of 24 items to investigate teacher error orientations. The third part consisted of 12 items which assessed teachers' positive (i.e., enjoyment) and negative emotions (i.e., anger and anxiety).

The student questionnaire consisted of three parts with 42 items. Similar to the teacher questionnaire, the first part informed the participants of the purpose of this study. The five items in the second part investigated students' mathematics learning strategies with a forced-choice format. The 37 items in the third part assessed students' mathematics achievement emotions, including positive (i.e., enjoyment and pride) and negative (i.e., anger, anxiety, and shame) achievement emotions.

3.2.1. Teacher Error Orientations

The error orientations questionnaire (EOQ) developed by Rybowiak et al. was used to test teachers' error orientations [35]. The EOQ mainly measures the orientations of individuals to deal with errors at work, that is, whether individuals regard errors as opportunities to promote work or as obstacles that should be avoided. When it was used in the present study, we adjusted the wording of the items to make them suitable for the context of classroom teaching. EOQ includes two factors, namely positive error orientation (13 items, e.g., "Mistakes assist me to improve my work") and negative error orientation (11 items, e.g., "I am often afraid of making mistakes"). The Cronbach's alpha values for positive error orientation and negative error orientation were 0.927 and 0.890, respectively.

3.2.2. Teacher Emotions

The teacher emotions scale (TES) developed by Frenzel et al. was used to assess teachers' enjoyment, anger, and anxiety during classroom teaching [68]. The scale has been translated into Chinese and successfully applied in previous studies [2,69]. The scale has 12 items assessing mathematics teachers' positive emotions (four items, e.g., "I enjoy teaching these students") and negative emotions (eight items, e.g., "Teaching these students frustrates me"). The Cronbach's alpha values for positive emotion and negative emotion were 0.911 and 0.891, respectively.

3.2.3. Mathematics Achievement Emotions

The 37-item Mathematical Achievement Emotions Questionnaire developed by Pekrun et al. was used to assess students' achievement emotions in mathematics learning [70]. The scale has been translated into Chinese and has been successfully applied in previous studies [71,72]. This scale assesses both positive and negative achievement emotions (15 items for positive emotions, e.g., "I look forward to my math classes"; 22 items for negative emotions, e.g., "I am annoyed during my math classes"). The Cronbach's alpha values for positive emotion and negative emotion were 0.945 and 0.947, respectively.

3.2.4. Mathematics Learning Strategy

The mathematics learning strategy questionnaire developed by the 2012 Programme for International Student Assessment was adopted [73]. The questionnaire has been translated into Chinese and successfully applied in previous research [74]. The questionnaire measures three learning strategies (i.e., memorization, elaboration, and monitoring) by four items with a forced-choice format, and each item included three mutually exclusive learning strategies in the original scale (e.g., metacognitive: "When I study for a mathematics test, I try to figure out what are the most important parts to learn"; elaboration: "When I study for a mathematics test, I try to understand new concepts by relating them to things I already know"; memorization: "When I study for a mathematics test, I learn as much as I can by heart").

In this study, mathematics learning strategy is a categorical variable. There are six categories as follows: memorization, elaboration, metacognition, memorization with elaboration, memorization with metacognition, and elaboration with metacognition.

3.3. Data Analysis

SPSS 23.0 was used to conduct descriptive statistics, correlation, and reliability analysis. Confirmatory factor analysis (CFA) was used to test the measurement model. Considering the nested nature of the data, multilevel structural equation modeling (MSEM) based on the maximum likelihood robust estimator (MLR) was used to address the research questions. In this study, teacher error orientations and teacher emotions were treated as teacher-level (Level 2) variables, whereas students' mathematics achievement emotions and learning strategies were seen as individual-level (Level 1) variables. The premise for multilevel mediation is that mediated effects are influenced at Level 1 and Level 2.

For the first research question:

(a) One regression model was used to test hypothesis 1, that is, the effect of teacher error orientations on teacher emotions.
(b) One multilevel regression model was used to test hypothesis 2, that is, the effect of teacher emotions on student mathematics achievement emotions.

For the second research question:

(a) One multilevel regression model was used. The independent variable significantly influences the dependent variable in the model. In this study, teacher error orientations significantly affected student mathematics achievement emotions.
(b) One multilevel mediation analysis was used to investigate whether teacher emotions mediated the effect of teacher error orientations on student mathematics achievement emotions.

For the third research question:

(a) Multinomial logistic regression analysis [75] was used to test hypothesis 3, that is, the effect of students' mathematics achievement emotions on their mathematics learning strategies.

Thus, we accounted for variation in measurement errors across levels using Mplus 8.0 [75]. The data of this study had a nested structure. Students at Level 1 were nested in teachers at Level 2. The Level 1 structure (students' mathematics achievement emotions and mathematics learning strategy) was based on students' responses, whereas the Level 2 structure (teachers' error orientations and emotions) was based on teachers' responses. Therefore, it was appropriate to use MSEM to solve the research problem.

We calculated the intra-class correlation (ICC) of each index of the Level 1 variables to judge the size of the intra-class variation components. As suggested, if the intra-class variation components are large enough (ICC > 0.05), it is necessary to use multilevel structural equation modeling [76]. The results showed that the ICC of mathematics positive and negative emotion were 0.092 and 0.115, respectively, indicating that the differences between groups cannot be ignored [77]. Mathematics learning strategy was not included in the multilevel model due to its very small Level 2 variance (ICC < 0.05), so we analyzed it with a single-level model.

4. Results

4.1. Descriptive Statistics and Correlations

Table 1 presents the descriptive statistics of mathematics teachers' emotions and error orientations, and students' mathematical achievement emotions and mathematics learning strategies. Because teacher error orientations and teacher emotions were the Level 2 variables, they were not related to the Level 1 variables. At the top of Table 1, the means and standard deviations of mathematics teachers' two types of emotions and two types of error orientations, and students' two types of mathematical achievement emotions are presented. The 70 mathematics teachers experienced both positive and negative emotions during teaching. Positive emotion (M = 3.904, SD = 0.896) and positive error orientation (M = 4.048, SD = 0.735) were rated as more frequent, and negative emotion (M = 2.339, SD = 0.882) and negative error orientation (M = 2.533, SD = 0.786) were rated as less common. According to Table 1, the average score of students' positive emotion (M = 3.952, SD = 0.748) was higher, and that of their negative emotion (M = 2.178, SD = 0.747) was lower. The interrelation between teachers' positive error orientation and positive emotion was moderate (0.542). Teachers' positive emotion had a significant and negative relationship with their negative emotion and negative error orientation, and teachers' positive error orientation also had a significant and negative relationship with their negative emotion, ranging from −0.276 to −0.336. Additionally, teachers' negative error orientation was significantly and positively related to their negative emotion. However, the correlation between teachers' negative error orientation and their positive error orientation was not statistically significant. The correlation coefficient between students' positive emotion and negative emotion was significant at the level of 0.01. The rest of Table 1 presents the number and proportions of students endorsing one of six learning strategies for five items of learning strategies use. The results showed that students were more likely to use elaboration and metacognition compared to memorization use. Nearly one-third of the students adopted the “Combination” class (e.g., memorization with elaboration, memorization with metacognition, elaboration with metacognition) of learning strategies when learning mathematics. This is the basis of the mediation analysis in the next step.

Table 1. Descriptive statistical of teacher variables and student variables.

	M	SD	1	2	3	4	1	2
Group-level								
Teachers’ positive error orientation	4.048	0.735	-					
Teachers’ negative error orientation	2.533	0.786	−0.228	-				
Teachers’ negative emotion	2.339	0.882	−0.276 *	0.326 **	-			
Teachers’ positive emotion	3.904	0.896	0.542 **	−0.336 **	−0.314 **	-		
Individual-level								
Students’ negative emotion	2.178	0.767	-	-	-		-	
Students’ positive emotion	3.952	0.748	-	-	-		−0.505 **	-
Mathematics Learning strategies								
Memorization	253	10.3%						
Elaboration	755	30.8%						
Metacognitive	787	32.1%						
Memorization with Elaboration	160	6.5%						
Memorization with Metacognitive	209	8.5%						
Elaboration with Metacognitive	289	11.8%						

Note: ** $p < 0.01$; * $p < 0.05$.

4.2. The Effects of Teacher Error Orientations on Teacher Emotions

The first research question focuses on the impact of teachers’ error orientations on their emotions. As shown in Table 2, the results showed some significant effects of teachers’ error orientations on their emotions. Teachers’ positive error orientation significantly and positively predicted their positive emotion (*Coef.* = 0.972, $p < 0.001$; the coefficients in this study are non-standardized coefficients), and significantly and negatively predicted their negative emotion (*Coef.* = −0.598, $p < 0.01$). Teachers’ negative error orientation significantly and negatively predicted their positive emotion (*Coef.* = −0.724, $p < 0.01$) and significantly and positively predicted their negative emotion (*Coef.* = 0.489, $p < 0.001$). These results support Hypotheses 1.

Table 2. Effects of teacher error orientations on teachers emotions.

	Teacher Positive Emotion		**Teacher Negative Emotion**	
	Coef.	***S.E.***	***Coef.***	***S.E.***
Teacher positive error orientation	0.972 ***	0.226	−0.598 **	0.200
Teacher negative error orientation	−0.724 **	0.231	0.489 ***	0.108

Note: *** $p < 0.001$; ** $p < 0.01$.

4.3. The Influence of Teacher Emotions on Student Mathematics Achievement Emotions

The first research question also explores the effect of teacher-level teachers’ emotions on individual-level students’ mathematics achievement emotions. MSEM analysis was conducted using the Mplus software to obtain the path coefficients. The results are shown in Table 3. Teacher emotions had a significant effect on student negative emotion but had no significant effect on student positive emotion. Among them, teachers’ positive emotion significantly and negatively predicted students’ negative emotion (*Coef.* = −0.101,

$p < 0.001$), and teachers' negative emotion significantly and positively predicted students' negative emotion (*Coef.* = 0.156, $p < 0.01$), supporting Hypotheses 2.

Table 3. Effects of teacher emotions on student mathematics achievement emotions.

	Student Positive Emotion		**Student Negative Emotion**	
	Coef.	***S.E.***	***Coef.***	***S.E.***
Teacher positive emotion	0.073	0.093	−0.101 ***	0.024
Teacher negative emotion	−0.126	0.085	0.156 **	0.058

Note: *** $p < 0.001$; ** $p < 0.01$.

4.4. The Mediating Role of Teacher Emotions in the Influence of Teacher Error Orientations on Student Mathematics Achievement Emotions

The second research question attempts to explore the mechanisms through which teachers' error orientations are related to students' mathematics achievement emotions. We examined whether teachers' emotions played a mediating role in the effect of teachers' error orientations on students' mathematics achievement emotions. Firstly, the effects of the teacher-level independent variables (teacher error orientations) on the individual-level dependent variables (student achievement emotions) were analyzed. The results are shown in Table 4. Teachers' error orientations had no significant impact on students' positive emotion but had a significant impact on students' negative emotion. Among them, teachers' positive error orientation had a significant negative effect on students' negative emotion (*Coef.* = −0.122, $p < 0.05$), and negative error orientation had a significant positive effect on students' negative emotion (*Coef.* = 0.156, $p < 0.001$).

Table 4. Effects of teacher error orientations on student mathematics achievement emotions.

	Student Positive Emotion		**Student Negative Emotion**	
	Coef.	***S.E.***	***Coef.***	***S.E.***
Teacher positive error orientation	−0.122 *	0.059	0.022	0.025
R^2	0.065	0.069	0.019	0.039
Teacher negative error orientation	0.156 ***	0.038	−0.009	0.044
R^2	0.227 *	0.108	0.019	0.096

Note: *** $p < 0.001$; * $p < 0.05$.

Secondly, based on the significant effects of teachers' error orientations on students' negative emotion, we tested whether teacher emotions played a mediating role in this process. The results of multilevel mediation analysis (Table 5) showed that when teachers' positive emotion was added to the model, the interpretable R^2 of students' negative emotion increased significantly, compared with the results shown in Table 4. The model explains 20.9% of the variation in students' negative emotion, indicating that the mediating effect of teachers' positive emotion was significant.

Table 5. Me diating analysis results of teacher positive emotion in the effect of teacher positive error orientation on student negative emotion.

	Teacher Positive Emotion (Mediator)			**Student Negative Emotion (Dependent Variable)**		
	Coef.	***S.E.***	***p*-Value**	***Coef.***	***S.E.***	***p*-Value**
Teacher positive error orientation	0.972	0.220	0.000	0.007	0.073	0.925
Teacher positive emotion				−0.108	0.043	0.012
R^2	0.379	0.134	0.005	0.204	0.089	0.022

As proposed, teachers' positive error orientation was strongly and significantly related to their positive emotion (*Coef.* = 0.972, $p < 0.001$). At the same time, teachers' positive emotion had a significant and negative relationship with students' negative emotion (*Coef.* = −0.108, $p < 0.05$). However, the direct effect of teachers' positive error orientation on students' negative emotion was not significant (*Coef.* = 0.007, $p = 0.925$; see Table 5), whereas the indirect effect of teachers' positive error orientation on students' negative emotion via teachers' positive emotion was significant (Estimate = −0.105, $p < 0.05$, 95% LLCI = −0.207, 95% ULCI = −0.002). The final multilevel structural equation model is shown in Figure 1.

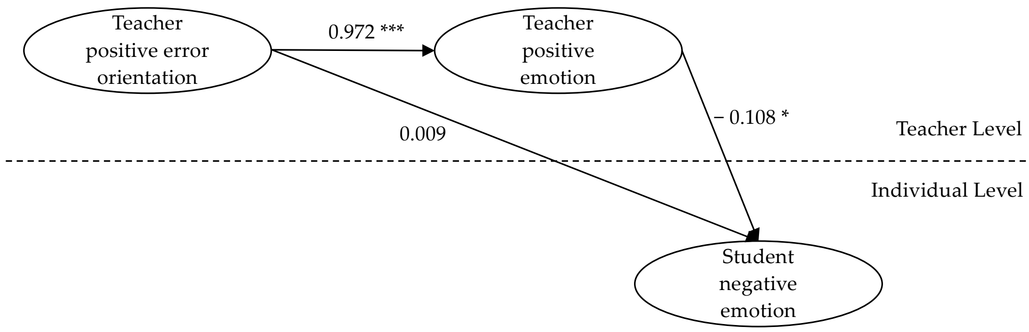

Figure 1. The effects of the teachers' positive error orientation on students' negative emotions through teachers' positive emotions. Note: *** $p < 0.001$; * $p < 0.05$.

4.5. The Influence of Student Mathematics Achievement Emotions on Learning Strategies

The third research question focuses on whether students' mathematics achievement emotions affect their mathematics learning strategies. Table 6 presents the estimated standardized coefficients of the multinomial logistic regression analysis. Class 1 (memorization) was used as the reference group to demonstrate the relative effects of being in Class 2 (elaboration), Class 3 (metacognition), Class 4 (memorization with elaboration), Class 5 (memorization with metacognition), or Class 6 (elaboration with metacognition).

Table 6. Effects of student mathematics achievement emotions on learning strategies.

	Student Mathematics Learning Strategies			
	Coef.	*S.E.*	*(Log Odds Ratio)*	*S.E.*
Class 2 Elaboration				
Teacher positive error orientation				
student positive emotion	0.673 ***	0.138	1.960 ***	0.270
student negative emotion	−1.169 ***	0.177	0.311 ***	0.055
Class 3 Metacognitive				
student positive emotion	0.184	0.132	1.202	0.159
student negative emotion	−0.787 ***	0.172	0.455 ***	0.078
Class 4 Memorization with Elaboration				
student positive emotion	0.296 *	0.135	1.345	0.181
student negative emotion	−0.656 **	0.216	0.519 ***	0.112
Class 5 Memorization with Metacognitive				
student positive emotion	0.226	0.115	1.253	0.144
student negative emotion	−0.483 **	0.175	0.617 ***	0.108
Class 6 Elaboration with Metacognitive				
student positive emotion	0.524 ***	0.133	1.689 **	0.225
student negative emotion	−0.998 ***	0.193	0.368 ***	0.071

Note: *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$.

As shown in Table 6, students' negative emotions were significantly negatively related to using other strategies compared to memorization use, indicating that high negative emotion students were less likely to report using strategies other than memorization. Students' positive emotion was significantly positively related to elaboration and elaboration with metacognition use compared to memorization use, meaning that high positive emotion students were more likely to report using elaboration and elaboration with metacognition than memorization. Students' positive emotion was not significantly related to the use of metacognition, memorization with elaboration, and memorization with metacognition compared to memorization use. These results partially support Hypothesis 3. That is, students' negative emotion reduced their use of elaboration and metacognition compared to memorization use.

5. Discussion

The present study extends the research on teacher emotions. It helps to reveal the black box of the roles of teachers' error orientations and teachers' emotions in students' mathematics learning. This study developed and tested a multilevel mediation model to examine teacher emotions as a mediator in the relationship between teachers' error orientations and students' mathematics achievement emotions. These results provide evidence for the hypothesis that teachers' positive error orientations can increase their positive emotions and reduce their negative emotions. These results also expand the scope of value appraisals in the control value theory. The control value theory holds that the core of emotion generation is the individual appraisals of control and value [5]. In line with this theory, this study found that teachers with positive error orientations had more positive emotions. These teachers may recognize the value of errors and believe that errors provide opportunities to advance learning. Meanwhile, these teachers may be more likely to encourage their students to try various strategies and achieve success in learning through thinking and discussing errors. All these actions can create a pleasant environment for teachers to generate positive emotions and make teaching more pleasant. In contrast, teachers who hold negative error orientations tend to avoid or cover up the errors, and emphasize the importance of correct answers. Because they do not see the value of errors and lack control over errors, these teachers are more likely to be nervous in the face of errors and thus experience negative emotions. In addition, past studies often used the control value theory to explore students' academic achievement emotion [6,78–80], whereas few studies adopted this theory to explore teachers' emotions and their influencing factors. In short, the model of teachers' positive error orientations predicting students' learning performance through increased teachers' positive emotions provides support for and expands the applicability of the control value theory in the context of mathematics teaching.

Early research shows East Asian students' excellent performance in mathematics from international assessments is the result of learning with memorization [81,82]. Our finding shows that most of the students used elaboration and metacognition, and one-third of the students used combination strategies (combined memorization with elaboration, memorization with metacognition, or elaboration with metacognition). This finding is consistent with the previous research results on students' use of learning strategies [83–85]. However, the variety in the use of learning strategies challenges the general view that East Asian learners mostly rely on rote learning. This may be related to the fact that China's new curriculum reform emphasizes critical and analytical thinking rather than passive and rote learning [45].

Contrary to our hypothesis, teachers' negative emotion had no significant effect on students' positive emotion. A possible explanation of this result may be that teachers follow the emotional display rules to express their emotions during the teaching process. Emotional display rules specify which emotional expressions are considered (in)appropriate in the classroom [86]. For example, the expression of anger or fear in the classroom is usually inappropriate for teachers. Teachers usually avoid showing strong negative emotions in teaching. Sometimes, teachers even pretend that they like the situation or feel angry [87]. Therefore, teachers' real negative emotions do not affect students' positive emotions in learning. In addition, this study found that teachers' positive emotions did not significantly affect students' positive emotions. This result supports the findings of a previous investigation [36]. This result may be explained by the fact that mathematics is a highly logical subject. When students enter junior secondary school, the learning content, mode of thinking, and the abstraction of mathematics change significantly compared to primary school mathematics. This change often makes it difficult for students to obtain achievement and feel enjoyment in mathematics learning [88]. Because of this, the results show that teachers' error orientation can not have a direct effect on students' positive emotions. This may be because teachers' error orientation has a chance to affect students' positive emotions indirectly. For example, teachers' positive error orientation (e.g., Learning from errors) establishes a positive culture of error in the classroom by establishing the types of error handling activities with expectation and support [89]. This trustworthy and emotion-rich learning environment may significantly improve students' positive emotions. In such an environment, students believe that they will not be laughed at when they make mistakes, so they are more likely to form positive emotions about mistakes [90].

This study found that students' negative emotion significantly reduced their use of mathematics learning strategies. That is, if students show more negative emotions, they are more likely to produce a surface cognitive strategy, such as memorization [65]. A possible explanation for this result might be that when negative emotions occur, students' thinking and reasoning will be impeded [91]. Students may not know which strategies to use in a negative emotional state [6]. For example, boredom as a negative inactivation emotion will hinder the use of cognitive learning strategies, because cognitive resources and task attention will be reduced [31,92]. On the contrary, enjoyment as a positive activation emotion, contributes to the use of learning strategies, because cognitive resources are retained and attention can be focused on tasks [31,92]. However, compared with the effect of positive emotions on the use of memorization strategy, positive emotions had a significant effect on the use of elaboration strategy and combined elaboration with metacognition strategy, but had no significant effect on the use of metacognition and combined memory with metacognition strategy. This may be because metacognition involves control and reflection on cognition. Although positive emotions help to integrate information from multiple inputs, the main role of positive emotions is promoting the use of flexible and in-depth cognitive learning strategies, such as elaboration and material organization [93,94]. In other words, emotions have a more significant effect on the individual's psychological process of information acquisition, storage, organization, summary, and understanding.

Four limitations of the present study should be noted. Firstly, the data collection method in this study was carried out in a cross-sectional way and was measured only at the same time point. This design cannot reveal the causal effects of teachers' error orientations and teachers' emotions on students' mathematics learning. In the future, researchers should adopt a longitudinal research design to reveal the causal relationships between the research variables. Secondly, this study only collected self-reported data. Future research can try to collect data in various ways, such as interviews, thinking-aloud, and classroom observation. Different data sources will provide rich information about the research variables for triangulation. Thirdly, hierarchical modeling has become a standard practice in the research of connecting teacher variables with student variables to a great extent [95], but there are sample size requirements for hierarchical data, especially the sample size at Level 2. MSEM estimation based on less than 80 groups may encounter convergence problems [96]. Therefore, MSEM research usually involves a considerable sample size at the teacher level. It is suggested that future research using MSEM enlarge the sample size at the teacher level. Finally, error orientation in this research is a general view of teachers' and students' attitude towards error in the classroom. If one can analyze two perspectives of teachers' error orientation towards themselves and toward students, we may get more meaningful and valuable findings. We suggest future research can make a more detailed study of teachers' error orientation from these two perspectives.

6. Conclusions

By investigating teachers' error orientations, this study fills the gap in the research in the field of teacher emotions, and enriches our understanding of the internal influencing factors of teacher emotions. These findings contribute to our understanding of teacher emotions and the mechanism through which teachers' error orientations and emotions influence students' mathematics learning. These findings respond to the call of Frenzel et al. for a more detailed and situational understanding of the relationship between teacher emotions and their influencing factors and student learning [97]. So far, few studies have used a multilevel structural equation model to test the antecedents and consequences of teacher emotions. Previous research mainly focused on the effects of teacher emotions at the individual level [4,20,25,98–103]. The findings of this research revealed the negative mediating role of teachers' positive emotion in the relationship between teachers' positive error orientation and students' negative emotion. Further, the result verifies that students' mathematics learning strategies can be promoted by strengthening their positive emotions. Our study shows that students' negative emotions significantly reduce their use of desirable mathematics learning strategies. The findings can be used in designing professional development programs for in-service teachers that aim to promote student learning by guiding teachers to develop positive error orientations.

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