Journal of Nonlinear and Convex Analysis
Volume 26, Number 6, 2025, 1629–1643

Yokohama Publishers
ISSN 1880-5221 ONLINE JOURNAL
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# EFFECT OF PERCEIVED TEACHERS' EMOTIONAL SUPPORT ON STUDENTS' ENGAGEMENT IN ONLINE MATH LEARNING

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Abstract. Background: The COVID-19 outbreak precipitated a swift transition to online education, highlighting the need to clarify factors that enhance students' engagement in online mathematics (math) learning (OMLE). Despite the critical importance of teacher emotional support (TES), its impact on MLE, especially during the pandemic, remains understudied. This study addresses the void by investigating the mediating influence of math anxiety and students' belief in their academic abilities.Research Objectives: The current research delves into the interaction of TES and students' engagement in online OMLE. Specifically, it examines the structural interplay between TES, math anxiety, students' self-efficacy in their capabilities, and students' OMLE. Methods: An online questionnaire survey was conducted on 1208 Chinese middle school students using the Math Anxiety Scale, Math Self-efficacy Scale, and Online MLE Scale, and quantitative analysis was conducted using structural equation modeling. Results and Contributions: The research results indicate that math anxiety and student self-efficacy act as a chain mediator of the impact of TES on students' OMLE. More importantly, math anxiety can affect students' self-efficiency in their abilities in the interaction between TES and MLE in online math education. This study explores TES's impact and potential mechanisms on middle school students' MLE in online environments, providing a new theoretical perspective for math education and a practical basis for optimizing online math teaching. Implications: The results of this study highlight the importance of TES for the OMLE of middle school students, revealing the key role of emotional support in reducing math anxiety and enhancing students' mathematical self-efficacy. Unlike previous studies that focused on cognitive aspects, this study emphasizes the unique value of emotional support in online teaching, especially the positive impact of teachers' emotional care, providing a new emotional perspective for math online education and helping to improve students' OMLE and academic performance. These findings contribute to understanding how these factors may impact the OMLE in middle school students.

## 1. Introduction

The emergence of COVID-19 has strongly violated the educational framework of primary and tertiary educational institutions, forcing about 1.5 billion children and adolescents in 188 countries worldwide to switch to online teaching [3]. To ensure the orderly and stable implementation of remote learning for primary and secondary

2020 *Mathematics Subject Classification.* 97U50.

*Key words and phrases.* structural equation modeling, teachers' emotional support, math anxiety, students' self-efficacy, students' participation in online math learning.

The mid-term achievement of the key project of the Ministry of Education in the 14th Five Year Plan for National Education Science, titled "Research on the Generation Mechanism and Cultivation Strategy of Structured Teaching Ability for Primary School Teachers" (No. DHA230386).

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school students during the pandemic in China, a series of policy documents have been issued to provide detailed and standardized guidance for virtual learning in elementary and high schools. However, during the epidemic, the online study of primary and secondary schools faced many unexpected challenges that required urgent mitigation. Students conduct online learning around the clock and at a time through the Internet platform at home. For a long time, it has been believed that during online teaching, students fail to grasp teacher's intonations and mimics, thus losing the interaction of body language and eye contact between teachers and students. Moreover, there needs to be more teacher supervision and effective guidance. At the same time, due to insufficient preparation of students for online learning [49], students easily lose interest in online learning (the so-called burnout effect) and thus need more investment in online math learning [28]. Students' online math learning investment plays a crucial role in whether they can achieve math academic achievement in the online learning field.

The level of mathematic learning engagement (MLE) holds a significant influence on student's academic performance in the subject, and it serves as an effective measure of individual learning progress [7,16]. Mathematical engagement describes students' Behavioral intensity, affective quality, and use of cognitive strategies during mathematical academic activities [15]. As a complex process affected by cognition, motivation, and emotion, math learning engagement has yet to receive sufficient attention from researchers at home and abroad [17], and its influencing factors need to be further explored. At the same time, math learning engagement falls within the domain of learning engagement, and the research on its influencing factors is still in its infancy [17]. Louwrens and Hartnett (2015) reported that although student engagement in traditional face-to-face educational settings within the compulsory schooling sector has been clarified, this topic should be urgently studied for online and distance learning environments [32]. This study triggered great interest in researching online students' learning engagement.

Cleveland-Innes and Campbell (2012) further suggested that TES plays a constructive role in alleviating academic exhaustion induced by physical seclusion and diminished teacher-student engagement in online learning environments [8]. The primary focus is on teachers' capacity to establish an inclusive and respectful classroom atmosphere by fostering positive interactions among students and between teachers and students. This entails being attentive to students' challenges, recognizing their emotions and viewpoints, and supporting their social and emotional well-being [19]. Teacher emotional support (TES) comprises three key factors: regard for adolescent perspective (RAP), teacher sensitivity (TS), and positive climate (PC). These factors are essential in fostering students' intrinsic learning drive [39]. A recent study [20] confirmed that high TES positively influence students' participation, which causal relationship was found valid for online learning environments by [46]. Therefore, examining TES's impact on their engagement in online math learning is of great theoretical and practical significance.

Teacher support is an important intervention for math anxiety. Research has shown that perceived teacher support can effectively reduce students' math anxiety [33], thereby improving students' self-efficacy [43]. Despite the increasing interest in the relationship between perceived teacher support, math learning engagement, and

math anxiety among students over the past decade [30]. However, until now, there is little evidence on how emotional support from teachers is related to students' academic engagement [42], especially in online math learning. Therefore, this study investigated the impact of TES on the participation of middle school students in math learning in online environments and explored potential mechanisms, aiming to provide a theoretical basis for effectively improving students' participation in online math learning.

## 2. Literature review

2.1. **Math Anxiety.** The characteristic of mathematical anxiety is that individuals experience a state of discomfort when faced with mathematical problems, such as fear, disgust, tension, worry, and frustration [10,18,45]. Studies have shown that math anxiety is commonly identified as a significant risk factor because individuals have low objective mathematical ability and subject mathematical effectiveness and even reduced involvement in engineering, technology, science, and math courses [47]. Meanwhile, higher math anxiety is closely associated with less than ideal math academic performance [14] and lower self-efficacy, motivation, engagement, and sense of achievement [43], leading to a greater emphasis on math. Low level of emphasis [23]. In unfavorable learning environments, this anxiety will intensify, further deepening math anxiety [4] and forming a vicious cycle. However, it is found that the Internet supports education by providing more information acquisition, better visual intelligence skills, and strengthening teacher-student communication [41,44]. Some students have also expressed concerns that online teaching methods may exacerbate their level of math anxiety. A big data analysis of undergraduate math final exams[21]. Iannacchione et al. (2023) further emphasized that although the impact of math anxiety in the classroom is well-known, it is currently unclear how these effects translate into the field of online learning.

Some researchers have adopted gamified learning strategies to effectively reduce online math anxiety and improve online learning motivation while reducing math anxiety [6,29]. Wang et al. (2021) further pointed out that teacher support, as a positive behavior, plays a crucial role in this situation [48]. Although emotional support is important for students, it may make them more emotionally sensitive and susceptible to setbacks and stress from poor grades [38]. Therefore, in the online learning environment, the impact of TES on students' math anxiety needs further verification.

2.2. **Math self-efficacy.** A crucial determinant of students' academic performance is their math self-efficacy, which significantly influences and predicts their achievements. Shen et al. (2013) demonstrated that self-efficacy was a notable predictor of students' contentment with remote education [42]. Doménech-Betoret et al. (2017) found that the correlation between students' satisfaction and academic engagement experience (AEE) was positive when examining the connection between academic confidence and achievement [11]. Joo et al. (2015) found that positive predictions of learning satisfaction and persistence were made by self-efficacy and the utilization of learning strategies [24]. Consequently, enhancing self-efficacy and utilizing learning strategies while reducing academic exhaustion within the learning setting will

positively impact students' contentment and persistence in their education endeavors. In a study conducted by Kumpikaite-Valiuniene et al. (2021), the association between academic stress, academic exhaustion, and self-efficacy was explored in students from countries including Poland, Turkey, Lithuania, and India [27]. Employing self-efficacy as a moderating factor, they uncovered a significant negative relationship between academic exhaustion and self-efficacy. The research implied that mitigating academic stress could enhance learners' self-efficacy, consequently alleviating academic exhaustion and enhancing learning outcomes. A recent study by Koutsimani et al. (2019) revealed that academic engagement experience (AEE) acted as a mediator in the influence of academic exhaustion on foreign language learning anxiety [26]. With academic exhaustion as a controlled variable, a substantial negative correlation was evident between one's confidence and anxiety in acquiring a foreign language. Self-efficacy partially mediated the relationship between academic fatigue and anxiety related to language learning, underscoring the significance of reduced levels of AEE in the onset of academic exhaustion. The above studies explore the factors influencing self-efficacy through students' learning variables. Whether positive or negative, educators' mentality may be transmitted to students, and this influence will ultimately affect students' self-efficacy, etc. [5,25].

However, to the best of the authors' knowledge, no results on the impact of teacher support on social self-efficacy has been reported yet. Therefore, further research is needed to investigate online TES's impact and underlying mechanisms on students' mathematical self-efficacy.

Thus, the study primarily aims to explore the TES effect on students' involvement in online education. This is accomplished by investigating the structural correlation between TES, students' math anxiety, academic confidence, and engagement in remote math study. The ultimate goal is to clarify the following issues:

1. Does TES influences students' engagement in online learning by reducing students' math anxiety?
2. Does student confidence play a role in the relationship between TES and student engagement in online learning?
3. Is there a cascading mediating effect of math anxiety and students' self-efficacy on the impact of TES on students' engagement in online learning?

## 3. Main assumptions and theoretical model construction

3.1. **Teacher emotional support, math anxiety, OMLE.** TES enhances students' online math study engagement by reducing students' math anxiety. Some scholars believe that effective TES has the potential to alleviate any heightened psychological distress experienced by students [40], which will make students feel the teacher's concern and importance for their learning, ultimately leading them to have more self-efficiency in this online learning process [34]. In short, TES affects students' math anxiety, which affects learners' OMLE, implying that TES may affect learners' OMLE by mediating students' mathematical anxiety. Therefore, this study used the following first assumption.

**H1.** Math anxiety plays a role in how TES influences students' OMLE.

3.2. **TES, students' math self-efficiency, and OMLE involvement.** Aligned with self-determination theory (SDT), meets the fundamental psychological needs of learners, and boosting their intrinsic motivation plays a crucial role in cultivating students' self-efficacy [9]. Several researchers reported a correlation between TES and students' self-efficiency [31,36]. Moreover, within the realm of online education, math self-efficacy emerges as a pivotal personal trait influencing students' participation in online math education. A study by Zhen (2017) discovered a positive correlation between students' confidence in their academic self-efficiency and their utilization of OMLE [51]. Alamri et al. (2022) identified a connection between self-efficacy and the use of learning engagement, a notable predictor of learning engagement [2]. In summary, TES can affect students' math self-efficacy, subsequently impacting their OMLE. This study postulates that TES can influence students' OMLE using their mathematical self-efficacy. Therefore, the second assumption is made:

**H2.** Students' mathematical self-efficacy is an intermediary factor in how TES impacts their OMLE.

3.3. **Teacher emotional support, math anxiety, math self-efficiency OMLE.** In addition to TES, Mathematical anxiety is crucial to students' self-efficacy [1]. Mathematical anxiety causes students to have negative emotions, making them realize that they are difficult to complete their learning content and do not have enough confidence to cooperate and communicate with students and teachers. Another study by Jameson et al. (2014) shows that math anxiety has a negative predictive effect on students' self-efficacy [22]. In addition, there is direct evidence to explain the mechanism of math anxiety and students' self-efficacy affecting TES for students' online MLE. Therefore, we put forward the following hypotheses:

**H3.** Students' math self-efficacy and math anxiety collectively serve as intermediate factors in the impact of TES on students' remote MLE.

## 4. Methods

4.1. **Instrument.** OMLE [47] is often used in published articles to evaluate students' online math learning engagement. Li (2018) revised it to some extent in the context of Chinese culture and proved its validity as a good factor among Chinese students [30]. In this study, OMLE includes 26 items in three sub-dimensions, namely

- cognitive engagement (e.g., "I will check the homework in math class to ensure its correctness"), which represents that students use various learning strategies to comprehend and master learning materials;
- emotional engagement (for example,''I am looking forward to taking math classes') indicates the positive emotional reactions that students exhibit towards class activities, peers, and teachers in their learning, and the level of emphasis and interest in the learning content;
- behavioral engagement (such as "I finish my math homework before deadline") is a positive manifestation of students' engagement in classroom, academic, and other related activities.

Rate on a 5-point scale, where 1 signifies strong disagreement, and 5 signifies strong

agreement. Confirmatory factor analysis (CFA) showed a good fit, with the following indicators: $\chi^2/df = 2.231$, RMSEA=0.032, CFI=0.988, TLI=0.984, with a factor loading ranges from 0.708 to 0.796. Given the Cronbach's alpha value of 0.930, which signifies high internal consistency, and the KMO value of 0.954, the scale is deemed valid, rigorous, and highly reliable. We also designed 22 projects developed by Pinrich et al. (1990) to evaluate students' mathematical self-efficacy while using 18 projects to evaluate TES [37]. According to the questionnaire prepared by Du et al. (2020), we formed five items to assess math anxiety [12]. The above measurement indices are all measured with the five-point Likert scale. Pianta et al. (2009) developed a classroom assessment scoring system (CLASS) based on teachers' explicit behavior by observing the dynamic between teachers and students in classroom teaching scenarios and dividing TES behavior into emotional support, management support, and teaching support [37]. This system is the most widely used observation tool in foreign scholars' TES research.

4.2. **Data collection.** The main participants of the survey were students from five middle schools in Shaanxi Province, which belongs to the northwest region of China. Compared with the southeast coastal areas, the economy and education level in the northwest region need to be developed more. Purposive and convenient sampling was used to determine participants between 16 and 19 years old. After integrating all the scales into one questionnaire, the questionnaire was distributed to the respondents through the "Questionnaire Star" online platform. To improve the quality of the questionnaire, incentive measures have been taken to ensure that respondents complete the questionnaire seriously. We collected a total of 1289 questionnaires, of which 1208 were genuine and valid, accounting for 93.71% of the total. Each participant voluntarily participated in the survey. The number of students used for analysis was 1208, including 844 females, accounting for 69.87%, and 364 males, accounting for 30.13%.

4.3. **Descriptive analysis.** Initially, SPSS 23.0 was utilized to assess the reliability and validity of the measurement framework by assessing Cronbach's *alpha* coefficient and composite dependability. The reliability analysis results are presented in Table 1, demonstrating that all coefficients exceed the threshold of 0.7, indicating high reliability for the measurement model. The composite reliability of each sub-dimension, moreover, exceeds the 0.7 threshold. Subsequently, the validity of the measurement model was evaluated, focusing on convergent validity, discriminant validity, and content validity. The study utilized measurement items sourced from established international research and modified to suit the Chinese cultural context, ensuring good content validity. Convergent and discriminant validity were established using the average variance extraction (AVE) and its square root. Experts suggest that the AVE value typically surpasses 0.5, and the square root should exceed the absolute correlation coefficient involving latent and observable variables (Fornell and Larcker, 1981). Thus, establishing strong discriminant validity for the measurement model requires the internal correlation surpassing the external one. The AVE and its square root for the measurement model meet the requirements, as shown in Table 1, respectively, demonstrating strong convergent and discriminant validities for the measurement model.

TABLE 1. The AVE of the measurement model square root

| Latent variable | TES | MA | MSE | MLE |
|---|---|---|---|---|
| TES | 0.746 | | | |
| MA | -0.298** | 0.804 | | |
| MSE | 0.336** | -0.458** | 0.757 | |
| MLE | 0.350** | -0.328** | 0.334** | 0.746 |

## 5. Model test and results

5.1. **Model fitting testing.** To analyze the structural model and perform structural equation modeling (SEM), AMOS 22.0 software was utilized with the maximum likelihood method to estimate the model's parameters. The model fitting testing results are shown in Table 2, using the following evaluation indices: $\chi^2/df$, GFI (goodness-of-fit index), CFI (comparative fit index), NFI (normalized fit index), TLI (Tucker–Lewis index), and root mean square error of approximation (RMSEA). The results in Table 3 demonstrate sound model fitness, meeting such criteria as $\chi^2/df$ being below 5.0, GFI surpassing 0.90, AGFI exceeding 0.80, CFI being over 0.90, NFI being above 0.90, TLI exceeding 0.90, and RMSEA below 0.08.

TABLE 2. Results of model-fitting testing

| | CMIN/DF | GFI | NFI | TLI | CFI | RMSEA |
|---|---|---|---|---|---|---|
| Fit criteria | $\leq 5$ | $\geq 0.9$ | $\geq 0.9$ | $\geq 0.9$ | $\geq 0.9$ | $\leq 0.08$ |
| Hypothesized model | 2.321 | 0.983 | 0.979 | 0.984 | 0.988 | 0.032 |

TABLE 3. Results of hypothesis testing and standardized path coefficient

| Predicted variable | Predictive variables | Path coefficient | C.R. | P |
|---|---|---|---|---|
| MA | TES | -0.357 | -10.644 | *** |
| MSE | TES | 0.275 | 7.545 | *** |
| MSE | MA | -0.477 | -13.074 | *** |
| MLE | TES | 0.293 | 7.455 | *** |
| OMLE | MA | -0.178 | -4.373 | *** |
| OMLE | MSE | 0.209 | 4.308 | *** |

5.2. **Hypothesis testing.** An analysis was conducted to analyze the significance of the path coefficients between variables in a statistical context, and the findings are presented in Table 3 and Figure 1. In this study, all p-values were assumed to be less than 0.05, indicating statistical significance. All path coefficients, except for negative path coefficients 1 and 3, are positive, and the CR values exceed 2 in (-1, 1). Significant and positive effects were observed on students' ability in online self-regulated learning (SRL) from TES, parents' autonomy support, and students' confidence ($p< 0.001$), implying a negative correlation between TES and students' mathematical anxiety. In contrast, students' confidence in their academic abilities

and students' remote MLE levels are positively correlated. And p< 0.001 shows that TES significantly positively affects students' confidence in their academic abilities. Finally, TES significantly inversely affects mathematical anxiety (p< 0.001). The more TES, the lower the students' Mathematical anxiety level.

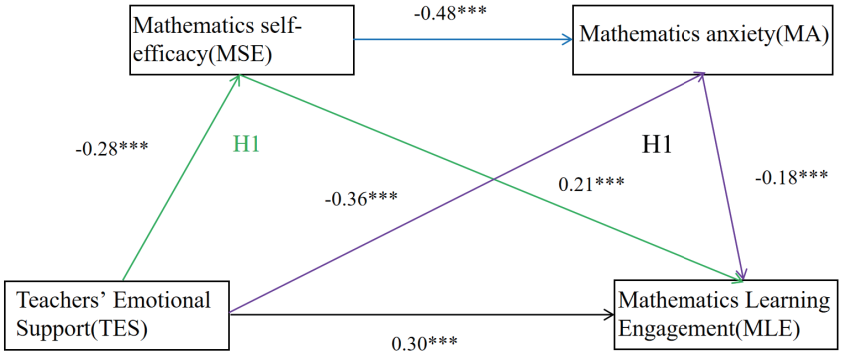


FIGURE 1. Model with standardized path coefficients (***p< 0.001)

## 5.3. **Analysis.**

5.3.1. *Analyses of direct effects, total indirect effects, and total effects between variables.* We delve into the study of TES's (TES) direct effects, total indirect effects, and total effects on students' engagement in remote MLE throughout the COVID-19 pandemic. Our analysis also considers the intermediary roles of MA and students' MSE. The direct effect of TES on MLE is significant, with a path coefficient of 0.293 (C.R. = 7.455, p< 0.001). This finding underscores the crucial role of TES in directly boosting students' involvement in online math learning. When students perceive emotional support from their teachers, they are prone to feel motivated and actively involved in the study process. Furthermore, our analysis reveals significant indirect effects of TES on MLE through the mediators of MA and MSE. Specifically, TES negatively influences MA (path coefficient of -0.357, C.R. of10.644, and p< 0.001), indicating that greater emotional support from teachers is linked to reduced math anxiety in students. Conversely, MA negatively affects MLE (path coefficient of -0.178, C.R. of -4.373, and p< 0.001), suggesting that increased anxiety hinders student engagement.

Additionally, TES positively affects MSE (path coefficient of 0.275, C.R. of 7.545, and p< 0.001), implying that TES boosts students' confidence in their ability to accomplish academic goals. MSE, in turn, positively influences MLE (path coefficient of 0.209, C.R. of 4.308, and p< 0.001), highlighting that students' confidence in their ability to accomplish academic goals is positively related to student engagement.

The total indirect effect of TES on MLE, mediated through MA and MSE, is substantial. The negative indirect effect through MA suggests that reducing math anxiety is a key mechanism by which TES indirectly enhances student engagement. Conversely, the positive indirect effect through MSE indicates that boosting students' academic self-efficacy is another important pathway. In summary, our findings demonstrate that TES directly impacts student engagement in online

math learning and indirectly influences engagement by reducing math anxiety and enhancing academic self-efficacy. These results have important implications for educational practices, emphasizing the need for teachers to provide emotional support (TES) to foster a positive learning environment that promotes student engagement, especially within the realm of online learning amid the COVID-19 pandemic and beyond.

5.3.2. *Analysis of the mediating effects.* The theoretical model adopted is the sequential mediation model. Currently, the research focuses on the pathways of TES - mathematical self-efficacy - students' online MLE, teachers' autonomous support - math anxiety - students' online MLE, TES - Mathematical anxiety - students' math self-efficacy-students' online MLE. Using MPLUS7.0 software, we analyzed the mesomeric effect through the bootstrapping method, with the results displayed respectively in Table 4. The relationship between variables, derived via the bootstrap approach, revealed a pronounce mesomeric effect at a significance level of 0.05.

Given that the estimated value of the 95% confidence interval excludes zero, the indirect impact is considered statistically significant. The three mesomeric effect paths are corroborated with the p-value for the indirect effect of the mentioned paths below 0.001 and the bootstrapping 95% confidence interval excluding 0 (see Table 4). To be specific, the indirect effect of TES on students' math anxiety online MLE path is most significant, indicating that math anxiety effect was the strongest.

Table 4. Findings from the analysis of mediating effects

| **Parameter** | **Estimate** | **Product of coefficients** | | **Bootstrapping 95% CI** | |
|---|---|---|---|---|---|
| | **(effect)** | **MSE** | **Z** | **Lower** | **Upper** |
| **Indirect effect** | | | | | |
| TES-MA-OMLE | 0.063*** | 0.016 | 3.938 | 0.034 | 0.097 |
| TES-MSE-OMLE | 0.058*** | 0.017 | 3.412 | 0.029 | 0.095 |
| TES-MA-MSE-OMLE | 0.036*** | 0.01 | 3.6 | 0.018 | 0.057 |
| **Direct effect** | | | | | |
| TES-OMLE | 0.293*** | 0.041 | 7.146 | 0.207 | 0.37 |
| **Total indirect effect** | | | | | |
| TES-OMLE | 0.157*** | 0.021 | 7.476 | 0.118 | 0.201 |
| **Total effect** | | | | | |
| TES-OMLE total | 0.45*** | 0.035 | 12.857 | 0.377 | 0.514 |

## 6. Discussion

According to our survey findings, it has been observed that the influence of TES on students' OMLE is predominantly mediated by two key factors: math anxiety

and math self-efficacy. The indirect total impact of TES over students' online MLE through these mediating variables is stronger than the direct influence. This implies that math anxiety and students' confidence in math study are essential mediators in the relationship between TES and students' online MLE. These two variables account for approximately 34.9% of the overall effect. Firstly, this study reveals that math anxiety is important in the relationship between TES and students' remote MLE. This is consistent with the findings of [42]. The TES has a significant indirect impact on students' OMLE and is moderated by math anxiety. Specifically, perceived TES can reduce students' math anxiety, thereby improving their online MLE. The TES has a negative predictive effect on students' math anxiety. In Chinese culture, TES is an important factor in promoting mental health, especially during COVID-19, which can reduce students' anxiety to a certain extent [13]. Therefore, the more emotional care teachers provide to students, the easier it is for them to feel comfortable, promote the occurrence of OMLE, and further effectively improve the online learning effectiveness and academic performance of middle school students. Furthermore, TES's influence on students' OMLE is mediated by students' math self-efficacy. As students perceive greater TES, their math self-efficacy is enhanced, resulting in an improved OMLE. Teachers' emotional support can affect students' self-confidence, consistent with previous research findings [50]. Interestingly, this is inconsistent with the study by Martin et al. (2015), which found that in classrooms with different TES levels, students exhibited similar levels of emotional and social engagement, regardless of their self-efficacy [35]. However, this also reflects indirectly that when teachers maintain a certain level of emotional support, students will always maintain high learning engagement, regardless of self-efficacy. Further research is needed to verify whether this conclusion suits online learning environments. It shows a positive correlation between TES and student learning engagement.

In conclusion, TES influences students' MLE through the mediation effect of math anxiety and students' self-confidence in math study. These two parameters appear as mediating variables, forming a mediation chain. TES indirectly influences students' online MLE through this chain.

## 7. Implications

MLE assumes paramount importance, particularly in online study environments. This study establishes a theoretical groundwork for forthcoming investigations into students' online math education. Additionally, the practical implications of this research are pivotal in bolstering students' academic performance in online math education. The abrupt shift to online teaching in China during the COVID-19 pandemic provided valuable insights that can inform subsequent online and hybrid teaching modalities. To foster active engagement in full-time online math learning and enhance students' knowledge acquisition, teachers must offer intentional emotional support, which is critical in cultivating students' online MLE skills.

Specifically, teachers should prioritize bolstering students' math self-efficacy and mitigating their math anxiety to provide comprehensive emotional support. To enhance math self-efficacy, teachers can offer ample emotional attention, assign tailored tasks, and instill in students the belief that they can master math. This

approach can assist students in overcoming the perception of math as a daunting subject and foster confidence in their mathematical abilities. Simultaneously, teachers must address mathematical anxiety through empathetic care. As the increase in math anxiety poses a barrier to successful online learning, it is imperative to recognize its significance as a component of the overall learning experience.

To this end, we recommend that teachers employ diverse strategies to alleviate students' math anxiety, ensuring they perceive comprehensive support. By doing so, students can gradually overcome anxiety, invest more cognitive and emotional resources in the learning process, develop learning plans, and share their knowledge. Moreover, TES should also consider the interplay between math anxiety and their math self-efficacy. For instance, teachers can mitigate math anxiety, enhance self-efficacy, impact online MLE performance, facilitate personalized learning plans, and encourage knowledge sharing. These concerted efforts aim to optimize students' online self-directed learning experiences.

## 8. Conclusions, limitations, and recommendations for future research

This study explored the interactions between TES, math anxiety, math self-confidence, and students' online MLE. In particular, it examined how TES affects online MLE of Chinese K-12 students through math anxiety and self-efficacy. Based on the experimental results obtained, the following two conclusions were drawn:

1) Math anxiety and self-efficacy are fundamental variables that operate as significant mediating factors, intricately influencing the transmission of TES to students' online MLE.

2) Math anxiety, in conjunction with students' math self-efficacy, collectively assumes a sequential mediating function in modulating the influence of TES on students' OMLE.

These research findings have practical significance for improving the effectiveness of online math learning for middle school students. Teachers need to invest more emotional support, and through positive emotional interaction with students, teachers can not only help students better understand mathematical knowledge but also promote their emotional sense of belonging and participation in virtual classroom environments rather than being limited to online teaching design, course content selection, and external technological environments. This is also the difference between this study and previous research.

This study acknowledges certain limitations. The sample data utilized in this research is derived solely from one province in China, thus potentially limiting its generalizability to all K-12 students across China. Consequently, this limited sample representation may impact the findings' universality. Another limitation pertains to expanding research efforts by involving a more diverse array of K - 12 students from varied cultural backgrounds to unveil the multifaceted factors influencing OMLE. Additionally, employing alternative research methodologies to delve deeper into these factors is imperative for a comprehensive understanding of the subject matter. In addition, online education has been ongoing for over two years during the COVID-19 pandemic. The answers may vary after the epidemic ends and online teaching becomes more routine. As a result, because the time of data

collection may affect the findings of this study, future studies could explore potential variations in results across the entire time span, as uniformity in outcomes may not be guaranteed. Finally, this study focused on three main variables and developed a model to explore how they influence students' ability in OMLE. The follow-up study envisages delving into additional student characteristics and external environmental factors, such as gender, family economic status, and parental support, to better understand how they influence students' online learning experience.

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*Manuscript received March 11, 2024*
*revised November 14, 2024*

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