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Self-concept, learning anxiety, and performance in mathematics learning: The moderating effect of teacher cognitive activation

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Abstract

Mathematics is a critical domain in education, and students' performance and motivation levels can vary greatly when learning mathematics. Using data obtained from PISA 2012 assessment on the US high school students' mathematics learning, this study examined the underlying mechanism through which mathematics self-concept affects students' mathematics performance. Utilizing a regression-based PROCESS macro, the study revealed that students' mathematics self-concept can have a significant impact on their mathematics performance by reducing mathematics learning anxiety. Additionally, an ordinary least squares regression indicated that the positive impact of mathematics self-concept on reducing mathematics learning anxiety was amplified by teacher cognitive activation. The findings of this study provide valuable insights into the importance of teacher support and student self-concept in promoting mathematics education. The results indicate that students' mathematics self-concept should be nurtured to help them develop a positive attitude towards mathematics and reduce anxiety levels, leading to better performance. Additionally, teachers can play a crucial role in helping students overcome mathematics learning anxiety by promoting cognitive activation.

Keywords: self-concept, cognitive activation, learning anxiety, mathematics learning

INTRODUCTION

While mathematics has increasingly become an important domain in education, there exists significant variation in students' mathematics achievements (Hung, 2020; Seymour & Hewitt, 1997; Wang, 2013; Wolters & Pintrich, 1998; Zimmerman & Martinez-Pons, 1990). One factor contributing to this variation is students' motivations in learning mathematics (Chiu & Xihua, 2008; Prast et al., 2018). Research based on the expectancy-value theory suggests that students' motivation is influenced, at least in part, by their perceived competence and the value associated with learning mathematics (Fong & Kremer, 2020; Wigfield, 1994; Wigfield & Eccles, 2000; Yurt, 2015). Consequently, prior studies have highlighted the importance of promoting self-beliefs, such as academic self-concept, to enhance students' perceived competence and motivation in learning mathematics (Bong & Skaalvik, 2003; Marsh, 2007). Mathematics self-concept, which reflects a student's perception of their ability in mathematics (Bong & Skaalvik, 2003; Martin & Mullis, 2013), has been found to be positively related to academic achievement in previous research (e.g., Arens et al., 2011; Guay et al., 2003; Marsh & Craven, 2006; Marsh & Martin, 2011). However, the underlying mechanisms through which mathematics self-concept contributes to improved academic achievement remain incompletely understood.

Moreover, while self-concept enhances perceived competence in learning (e.g., Arens et al., 2019; Parker et al., 2018), students are also influenced by the interaction with teachers (Lee, 2012; Ma et al., 2018; Marks & Louis, 1997; Wang, 2023). Previous research suggests that students' perceptions of the messages conveyed by their teachers have an impact on their motivations (Kim et al., 2010; Urdan & Midgley, 2003). However, the understanding of how self-concept interacts with teacher instructional approach to influence student mathematics performance is limited.

To bridge these gaps, this study examines the mediating role of mathematics learning anxiety on the connection between mathematics self-concept and

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Contribution to the literature

- This study aimed to investigate the mechanism by which mathematics self-concept influences students' mathematics performance.
- The results highlighted a significant connection between students' mathematics self-concept and their mathematics performance, with the former playing a crucial role in reducing mathematics learning anxiety, thus positively impacting performance.
- Furthermore, the study demonstrated that the positive influence of mathematics self-concept on reducing mathematics learning anxiety was strengthened when teachers employed cognitive activation in their teaching approach.

students' mathematics performance. Specifically, it is proposed that mathematics self-concept enhances students' perceived competence in learning mathematics, leading to a reduction in mathematics learning anxiety. With lower anxiety levels, students become more motivated to learn mathematics, resulting in improved mathematics performances. Moreover, this study investigates the moderating impact of teacher cognitive activation and proposes that students who experience cognitive activation from their teachers are more likely to benefit from their mathematics self-concept in reducing learning anxieties than those who do not receive such activation.

THEORETICAL FRAMEWORK AND LITERATURE REVIEW

Expectancy-Value Theory, Mathematics Self-Concept, and Mathematics Performance

The expectancy-value theory suggests that people's motivations are predicted by two factors: expectancy and value. These motivations, in turn, impact individuals' choices, persistence, effort, strategy, and performance in tasks related to achievement, including academic achievement (Eccles, 1983, 2005; Wigfield & Eccles, 2000, 2002; Wigfield, Eccles, & Rodriguez, 1998; Wigfield, Tonks, & Eccles, 2004). Generally, the theory suggests that individuals are more motivated to engage in a task, such as learning mathematics, when they perceive a higher level of competence (i.e., high expectancy) and/or when the task holds attractive values.

Self-concept has been recognized as a significant source of competence (Comer et al., 1987; Hughes, 2011). According to Rosenberg (1979, p. 7), self-concept is "the totality of the individual's thoughts and feelings having reference to himself as an object." Academic self-concept specifically refers to students' self-perceptions of their competence in academic domains (Shavelson et al., 1976). Consequently, mathematics self-concept is defined as people's perceptions of their academic ability in learning mathematics (Bong & Skaalvik, 2003).

Prior research consistently demonstrates a positive relationship between students' mathematics self-concept and their mathematics achievement (Marsh, 2007; Marsh & Martin, 2011; McWilliams et al., 2013; Pietsch et al., 2003). This positive association is established because self-concept generates positive motivational behaviors in learning, including enhanced competence and perceived value (Arens et al., 2019; Marsh & Craven, 2006; Marsh et al., 2017). According to Arens et al. (2011), self-concept comprises two distinct components: one related to competence and the other one related to affective perception. Thus, students with higher self-concept in an academic area, such as mathematics, have a higher desire to achieve success in that subject (Guay et al., 2010). Consequently, they are more likely to exert effort to increase their chances of success compared to those with lower self-concept. Therefore, this study posits that self-concept can enhance students' perceived competence and value in learning mathematics, thereby fostering stronger motivation and ultimately leading to improved performance in mathematics learning.

Learning Anxiety as a Mediator

Although many researchers have argued against perceiving mathematics as inherently more complex or tedious than other subjects (Hannula et al., 2016), many students still lack the motivation to engage in mathematics learning. Motivation in mathematics is influenced by students' perceived value and competence in the subject (Wigfield & Eccles, 2000). Ames (1992) posited that motivation reflects an individual's beliefs about what is important, ultimately shaping their level of engagement in a given pursuit. Consequently, a lack of motivation leads to reduced engagement in learning, which generally results in lower academic performance (Shernoff et al., 2014). As students often perceive mathematics as an important but complex subject to learn, many struggle with the anxieties associated with learning mathematics (Ramirez et al., 2018).

Learning anxiety in mathematics refers to the feelings of tension and unease that hinder individuals from effectively manipulating numbers and solving mathematical problems in various academic and everyday situations (Richardson & Suinn, 1972). This anxiety arises from a combination of individual factors and environmental factors (Chang & Beilock, 2016; Ma & Xu, 2004; Spielberger & Vagg, 1995; Zeidner, 1991). Individual factors, such as students' perceived intrinsic

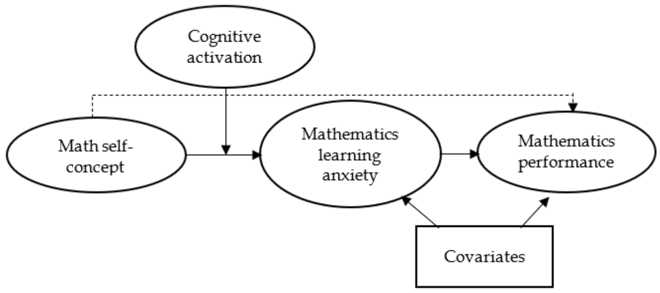

Figure 1. Theoretical model (Source: Author's own elaboration)

or instrumental interests in mathematics (Ames & Archer, 1988) and physiological reactions linked to the processing of negative emotions (Chang & Beilock, 2016), can influence students' motivation to learn and subsequently influence their anxiety levels. Environmental factors, including parental support (Vukovic et al., 2013), parental mathematics anxiety (Maloney et al., 2015; Soni & Kumari, 2017), mathematics teachers' anxiety and classroom activities (Beilock et al., 2010), and students' perception on the classroom environment (Fast, 2010), can also influence student's perceived competence and value, thereby shaping their learning behaviors (Chouinard et al., 2007; Lavigne et al., 2007).

As aforementioned, mathematics self-concept plays a crucial role in fostering students' sense of competence and perceived value in mathematics learning. With an increased sense of competence, students perceive learning mathematics as a less stressful process (Jain & Dowson, 2009; Lee, 2009). With more perceived values, students are likely to develop more positive emotional responses to mathematics learning. Thus, mathematics self-concept is expected to be negatively associated with mathematics learning anxiety. As anxiety levels decrease, students become motivated to engage in various mathematics learning activities, investing more time and effort in learning mathematics (Ashcraft, 2002; Pekrun et al., 2009). As a result, their mathematics performances is likely to improve. Taken together, this study expects that learning anxiety mediates the relationship between mathematics self-concept and mathematics performance.

Cognitive Activation as a Moderator

In general, cognitive activation refers to "an instructional practice that encourages students to engage in higher-level thinking and thus to develop an elaborated knowledge base" (Lipowsky et al., 2009, p. 529). In mathematics learning, teachers are expected to help students develop connections between conceptual understanding and mathematical facts, procedures, ideas, and real-world examples (Hiebert & Grouws, 2007). To achieve this goal, teachers need to introduce new concepts based on students' prior knowledge or experiences (Rivet & Krajcik, 2008). This is considered the conceptual level of instruction. Another key element of promoting conceptual understanding in mathematics instruction is to build knowledge at the cognitive level (Lipowsky et al., 2009). In this situation, students not only rely on prior knowledge or associations with mathematics facts to understand a mathematical concept but also on cognitive functioning and processing that may contribute to conceptual understanding (Hiebert & Grouws, 2007).

Prior research generally confirms that cognitive activation provides support for students and generates interest and develops confidence in the learning process. For example, cognitive activation can create a supportive learning environment in the classroom so that students can develop more motivation to learn (Förtsch et al., 2017). In addition, as Chi and Wylie (2014) suggested, students are cognitively activated when acting at the constructive level. Compared to active and interactive learning, constructive learning requires students to be self-directed, and learning is often a cumulative process (Corte, 2004). As a result, students will perceive more interest in a learning process and thus devote more effort to this process (Krapp, 2002). For example, by analyzing videos of mathematics classes, Klieme et al. (2009) found that cognitive activation was positively correlated with both students' interests in mathematics and learning achievement. Moreover, constructive learning activities, such as collaborative problem-solving and problem-based learning, help students develop a deep conceptual understanding of the content, which makes them more confident about their learning abilities (Hmelo-Silver, 2004).

Therefore, students develop more interest and confidence in learning mathematics if they receive cognitive activation from their teachers than when such instructional support is not in place. As a result, when cognitively activated, students' mathematics self-concept will be more likely to lead to less learning anxiety in learning mathematics. Thus, the present study anticipates that cognitive activation can enhance the effect of self-concept on reducing learning anxiety in mathematics.

The Present Study

This study first explores how mathematics self-concept influences student learning anxiety in mathematics, which in return affects students' mathematics performance. It is anticipated that mathematics learning anxiety mediates the relationship between mathematics self-concept and mathematics performance.

Second, the study investigates the moderating effect of teacher cognitive activation on the relationship between self-concept and mathematics learning anxiety. Specifically, it is expected that teacher cognitive activation can enhance the impact of self-concept on reducing learning anxiety. The theoretical model examined in this study is presented in **Figure 1**. Overall, this study proposes the following hypotheses:

H1. Mathematics self-concept is positively related to mathematics performance.

H2. Mathematics learning anxiety mediates the relationship between mathematics self-concept and mathematics performance.

H3. Cognitive activation strengthens the negative relationship between mathematics self-concept and mathematics learning anxiety.

METHOD

Data Source, Participants, and Procedures

The dataset used in this study was obtained from an international database: Organization for Economic Cooperation and Development's (OECD) Program for International Student Assessment (PISA) 2012. PISA 2012 was used because it offers comprehensive information about students' mathematics learning behaviors, home environment, and teacher information. Thus, it provides rich data for investigating the questions proposed by the present study. The participants in this study were the US 15-year-old high school students. Although PISA 2012 database provides information for multiple countries, the US was chosen as a primary focus of the study because American students have long been concerned about their lower mathematics performances compared to peers in other countries (Ker, 2017; Mullis et al., 2012; Stevenson et al., 1990, 1993). The US students are also found to lack motivation in learning mathematics (Chen & Stevenson, 1995; Herges et al., 2017), providing an ideal context for this study. The original PISA 2012 US national sample consists of 4,978 students. However, due to the missing values, a portion of the sample was excluded. The final sample used in this study consisted of 2,275 usable observations. As discussed later, a robustness analysis was performed to assess the potential sample selection bias due to omitted missing values. Among the participants, 49.67% (n=1,130) reported being male. In terms of race, the majority (57.17%) identified as White, followed by 21.61% who identified as Hispanic, 10.08% as Black or African American, 5.15% as Asian, 4.14% who identified with more than one race, and 1.85% of respondents identified as others.

Measures

Measuring dependent variables

Mathematics performance: The measure of mathematics achievement in this study was obtained from the cognitive assessment, which was "PISA mathematics literacy items". PISA mathematics literacy was a two-hour paper-based test testing student mathematics knowledge and assessing the application of knowledge in mathematics to problems within a real-life context (Kastberg et al., 2021). The mathematics assessment consisted of 85 items, with approximately half of the items multiple-choice, about 20.00% closed or short response types, and about 30.00% open-constructed responses. PISA 2012 employed an imputation methodology to derive five plausible values for overall mathematical literacy. The final estimate of overall mathematical literacy in this study is calculated as the arithmetic average of the five plausible values obtained using the imputation methodology.

Mathematics learning anxiety: PISA student mathematics anxiety (five items) was used to measure students' mathematics learning anxiety (see **Appendix A**). These items were responded to using a 4-point Likert scale (from 1 "strongly agree" to 4 "strongly disagree"). Items were reversely recoded such that higher scores indicate higher levels of learning anxiety.

Measuring predicting variables

Mathematics self-concept: PISA 2012 created a scale of student mathematics self-concept (five items) to assess students' perceptions about their mathematics abilities. The items are presented in **Appendix A**. These items were responded to using a 4-point Likert scale (from 1 "strongly agree" to 4 "strongly disagree"). For easier interpretation, scores of items were transformed by subtracting them from five. As a result, higher scores in the data for this study indicated a higher self-concept about mathematics abilities.

Cognitive activation: Cognitive activation scale in PISA 2012 was used to measure teacher cognitive activation. The original scale has nine items. However, four of them were dropped due to low factor loading (<0.60). These items were answered on a 4-point Likert scale (from 1 "strongly agree" to 4 "strongly disagree"). Items again were inversely recoded for easier interpretation. Higher scores consistently indicated students perceived that their teachers were more willing to cognitively activate student thinking.

Measuring control variables

To control for the extraneous effects, a set of control variables were included in the model. First, I controlled ***gender*** because previous studies have suggested that boys differ from girls in their mathematics learning anxiety and competency, resulting in different performances (Leyva, 2017). In this study, gender was measured using a dichotomous variable with 1 indicating girl and 2 indicating boy. Moreover, I controlled for students' home learning environment that can potentially affect their learning outcomes. Specifically, I controlled for ***socio-economic index of occupational status*** (SQ ISEI) of a student's father and mother (i.e., mother's SQ ISEI and father's SQ ISEI),

home educational resources, and ***parents' highest educational level***. All data were measured using information obtained from the PISA 2012 student questionnaire.

Reliability and Validity

To examine the reliability of the measures, I first obtained the values of composite reliability (CR) for all scales. The results in **Appendix A** show that all CR values exceed 0.70, indicating good reliability (Joseph et al., 2010).

To assess the validity of the measures, a confirmatory factor analysis was performed (Anderson & Gerbing, 1988). The results yielded an acceptable model fit ($\chi_{[372]}{}^2$=2,413.69, p<0.001, CFI=0.93, TLI=0.93, RMSEA=0.06). In addition, all items were loaded significantly on their corresponding constructs, which indicated that the measures have acceptable convergent validity (Anderson & Gerbing, 1988). Moreover, the average variance extracted (AVE) values were all greater than 0.50 and greater than the squared correlations between the corresponding pairs of constructs. These results suggested that the measures have acceptable discriminant validity (Fornell & Larcker, 1981).

Data Analysis Approach

To test the mediating effect of mathematics learning anxiety, a regression-based PROCESS macro in SPSS was used to examine if there is any indirect effect of self-concept on mathematics performance through mathematics learning anxiety. To test the moderating effect of cognitive activation on the relationship between mathematics self-concept and math learning anxiety, an ordinary least squares regression was used. To reduce the threat of multicollinearity, the continuous predicting variables (i.e., self-concept and cognitive activation) were standardized before generating the interactions. The variance inflation factors for all variables in the full model were below 2.34, indicating that multicollinearity is not likely to be a threat in the study.

RESULTS

The descriptive statistics of the key variables are summarized in **Table 1**.

Table 2 presents the hypotheses testing results. Among the control variables, boys have higher math anxiety compared to girls (β=3.82, p=0.190). Father SQ (β=0.82, p<0.001), mother SQ (β=0.31, p=0.020), home educational resources (β=4.48, p<0.001), and the highest educational level of parents (β=4.30, p<0.001) have a positive impact on student math performance.

Main Effects of Self-Concept

In **H1**, it is posited that self-concept has a positive relationship with student mathematics performance. The result from **Table 2** showed that the effect of self-concept on mathematics performance is positively significant (β=32.98, p<0.001). Therefore, **H1** was

Table 1. Descriptive analysis results & correlation matrix

Variables	Mean	SD	1	2	3	4	5	6	7	8	9
1. Mathematics performance	498.26	1.76	1.00								
2. Mathematics learning anxiety	-0.16	0.02	-0.42	1.00							
3. Mathematics self-concept	-2.09	0.02	0.45	-0.80	1.00						
4. Cognitive activation	-1.96	0.01	0.06	-0.19	0.21	1.00					
5. Gender	1.50	0.01	0.07	-0.13	0.12	0.04	1.00				
6. Father SQ ISEI	45.44	0.47	0.34	-0.08	0.08	0.02	0.00	1.00			
7. Mother SQ ISEI	50.73	0.44	0.26	-0.08	0.07	0.02	0.01	0.33	1.00		
8. Home educational resources	0.00	0.02	0.21	-0.14	0.13	0.15	-0.02	0.24	0.24	1.00	
9. Educational level of parents	4.97	0.03	0.27	-0.06	0.08	0.04	0.03	0.43	0.52	0.26	1.00

Note. SD: Standard deviation & Correlations with an absolute value greater than 0.03 are significant at the p<0.05 level

Table 2. Mediating effect of learning anxiety

Variables	C	SE	T	p	LLCI	ULCI
Constant	510.62	13.47	37.92	<0.001	484.21	537.03
Self-concept	32.98	3.10	10.64	<0.001	26.90	39.05
Mathematics learning anxiety	-9.89	2.32	-4.26	<0.001	-14.44	-5.33
Gender	3.82	2.93	1.30	0.190	-1.93	9.56
Father SQ ISEI	0.82	0.10	7.88	<0.001	0.62	1.02
Mother SQ ISEI	0.31	0.14	2.27	0.020	0.04	0.57
Home educational resources	4.48	1.10	3.20	<0.001	1.73	7.24
Educational level of parents	4.30	1.44	2.99	<0.001	1.48	7.11
Indirect effect of self-concept through mathematics learning anxiety	10.39	2.55			5.40	15.37
n	2,275					
R-squared	0.33					
F-statistics	122.06***					

Note. C: Coefficient & SE: Standard error

Table 3. Moderating effect of cognitive activation

DV: Mathematics learning anxiety	Coefficient	Standard error	*T*	*p*
Constant	-0.06	0.10	-0.62	0.540
Self-concept	-0.82	0.01	-55.13	<0.001
Cognitive activation	-0.02	0.01	-1.54	0.120
Self-concept*cognitive activation	-0.04	0.01	-2.75	0.010
Gender	-0.08	0.03	-3.19	<0.001
Father SQ	0.00	0.00	-0.40	0.690
Mother SQ	0.00	0.00	-0.49	0.630
Home educational resources	-0.03	0.01	-2.43	0.020
Educational level of parents	0.04	0.01	2.62	0.010
N	2,275			
R-squared	0.64			
F-statistics	341.95***			

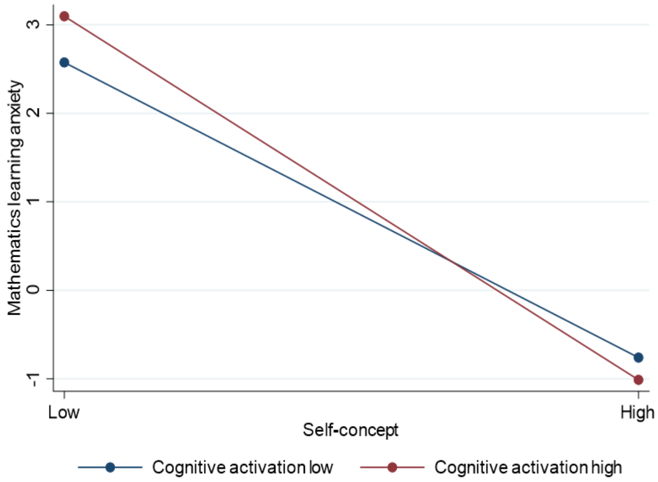

Figure 2. Moderating effect of cognitive activation (Source: Author's own elaboration)

supported. This evidence provided preliminary support, suggesting that mathematics self-concept has the potential to enhance students' motivation in mathematics, ultimately resulting in improved performance in the subject.

Mediating Effect of Learning Anxiety

A PROCESS macro in SPSS 26.0 was performed to formally test the mediating effect of mathematics learning anxiety on the relationship between mathematics self-concept and mathematics performance. The results summarized in Table 2 indicated that mathematics learning anxiety had a significant negative impact on mathematics performance (β=-9.89, p<0.001). Furthermore, using the bootstrapping technique with 5,000 samples, the results from the PROCESS procedure showed that the indirect effect of self-concept on mathematics performance through learning anxiety was also significant (β=10.39, p<0.001, LLCI=5.40, ULCI=15.37). Overall, the results provided support for **H2**.

Moderating Effects of Cognitive Activation

H3 suggested that teacher cognitive activation can strengthen the negative relationship between self-concept and student learning anxiety. The result from Table 3 indicated that the interaction of cognitive activation and self-concept is negative and significantly related to mathematics learning anxiety (β=-0.04, p=0.010). This evidence indicates that cognitive activation is more effective in reducing learning anxiety through better self-concept. To better interpret this result, this interactive effect was plotted in Figure 2.

Based on Figure 2, it can be observed that the regression line exhibits a steeper slope when teacher cognitive activation is higher compared to when it is lower. This finding indicates that students who received higher levels of cognitive activation from their teachers experienced a greater reduction in mathematics learning anxiety as a result of their mathematics self-concept, in contrast to students who received lower cognitive activation from their teachers. In other words, the impact of self-concept on reducing mathematics learning anxiety is more pronounced among students who benefited from higher levels of teacher cognitive activation. Therefore, **H3** was supported.

DISCUSSION

Mathematics is an essential subject that plays a crucial role in student's academic success (Seymour & Hewitt, 1997; Wang, 2013). However, students' performance in mathematics varies significantly, and many struggles with this subject (Hung, 2020; Wolters & Pintrich, 1998; Zimmerman & Martinez-Pons, 1990). Research has shown that students' self-concept in mathematics is closely related to their academic achievement in this subject (e.g., Arens et al., 2019; Marsh, 2007; Marsh & Martin, 2011). This study builds upon previous research and explored the role of domain-specific self-concept, specifically mathematics self-concept, in enhancing students' academic achievement in mathematics.

The study employed high school students' mathematics learning as a research setting and found that mathematics self-concept has a positive impact on students' academic achievement in this subject. This finding aligns with prior research in educational psychology, which emphasizes the significant role of self-concept in driving student academic success (Arens et al., 2019; Marsh, 2007; Marsh & Martin, 2011). It underscores the importance of fostering students' mathematics self-concept to enhance their performance in mathematics.

More importantly, this study further explored the underlying mechanism through which mathematics self-concept affects student mathematics performance. Although previous research has offered valuable insights into the association between mathematics self-concept and performance in mathematics (Marsh, 2007; Marsh & Martin, 2011; McWilliams et al., 2013; Pietsch et al., 2003), the underlying mechanisms behind this relationship remain unclear. The present study sought to address this gap in the literature by examining the mediating role of learning anxiety in the relationship between mathematics self-concept and mathematics performance. The findings indicate that mathematics self-concept influences learning outcomes in mathematics by reducing learning anxiety. Specifically, students with higher mathematics self-concept reported lower levels of learning anxiety, which in turn led to better performance in mathematics. These results provide new insights into the literature on mathematics self-concept and academic achievement by uncovering a specific mechanism through which mathematics self-concept impacts learning outcomes.

In addition, the present study has revealed an important contingency in the relationship between mathematics self-concept and mathematics learning anxiety. Specifically, the results demonstrated that the impact of mathematics self-concept on reducing learning anxiety is enhanced when teachers employ cognitive activation in the classroom. This finding builds on previous research that suggests cognitive activation provides students with increased support from their teachers (Förtsch et al., 2017; Hanze & Berger, 2007; Krapp, 2002) and fosters greater interest in learning (Baumert et al., 2010; Fauth et al., 2019; Klieme et al., 2009). This finding implies that when students feel more confident in their ability to learn math and are more engaged in the subject matter, they are more likely to overcome their anxiety and take action to improve their performance. Thus, by using cognitive activation strategies, teachers can help students to benefit more from their positive self-concept, which can ultimately decrease anxiety and lead to greater success in mathematics.

Lastly, this study incorporated a set of variables to control for extraneous effects. These control variables had diverse effects on student mathematics learning anxiety and performance. Consistent with previous research findings (Leyva, 2017), the results indicated that girls tend to experience higher levels of anxiety than boys, but this difference did not significantly impact their performance. In addition, both mother's and father's SQ ISEI were found to be associated with children's mathematics performance, indicating that higher socioeconomic status of parents is linked to better performance in mathematics. However, children's mathematics learning anxiety levels were not influenced by their parents' SQ ISEI. Moreover, the presence of better home educational resources was found to be beneficial in reducing mathematics anxiety and improving mathematics performance in students. Interestingly, it is noteworthy that higher educational levels of parents may elevate their children's mathematics learning anxiety while simultaneously improving their mathematics performance.

Limitations

The present study has several limitations that propose directions for future research. First, due to data limitations, this study focused only on the context of high school students learning mathematics. It will be interesting to explore if the propositions would hold for other populations such as elementary students or college students, or learning contexts, such as learning STEM-related subjects.

This study proposed that cognitive activation can potentially reshape the impact of self-concept on learning effort. While this finding offered valuable insights for improving teaching effectiveness in the classroom, it lacked insights about influences from the environment outside the classroom. For example, prior research suggests that the family environment can significantly influence student learning activities (e.g., Christenson et al., 1992; Halawah, 2006). It will be important to explore whether family-related factors can potentially influence the outcomes of self-concept. When the family environment is more supportive, students may perceive more guidance from their parents and thus develop more regulated and positive perceptions of learning.

CONCLUSIONS AND IMPLICATIONS

Self-concept is known to have significant implications for student learning, and recent research has revealed that mathematics self-concept may have differential impacts on learning effort and anxiety in mathematics. While many educators and students assume that a strong sense of self-concept in math will automatically lead to greater effort and reduced anxiety, this study highlights the importance of recognizing that self-concept may not have universal effects.

Both educators and students should realize that self-concept may not universally promote more effort or mitigate anxiety in learning. Instead, its value in promoting positive motivational behaviors depends on teachers' instructional effectiveness. This study showed that teachers can potentially benefit the student by offering cognitive activations in teaching practices.

Therefore, teachers need to understand that their teaching approaches may potentially help students enhance the positive effect of mathematics self-concept on reducing math anxiety. On the one hand, cognitive activation can directly help students to make learning efforts and develop their motivations for learning. On the other hand, when cognitively activated, students' mathematics self-concept will be more likely to lead to less learning anxiety in learning mathematics by providing support and generating interest.

Now that teachers have a better understanding of how cognitive activation can help students in their learning, it is important for them to develop their cognitive activation skills in the classroom. To effectively integrate cognitive activation techniques into their teaching practices, it is crucial for teachers to receive professional development opportunities that equip them with the necessary knowledge and skills. Schools should provide their teachers with ongoing training that focuses on the latest research, methods, and tools for promoting cognitive activation in the classroom. This training can include workshops, conferences, mentoring, and coaching sessions. Workshops specifically designed to improve cognitive activation skills would be beneficial for teachers to enhance their instructional practices. Additionally, for junior teachers, having senior teachers act as mentors and engage in discussions about cognitive strategies can be highly advantageous. By providing ongoing training opportunities and support, schools can empower teachers to effectively promote cognitive activation in their classrooms, thereby fostering optimal learning environments for students.

By investing in professional development opportunities for their teachers, schools can create a culture of continuous learning that benefits both educators and students. Teachers who develop their cognitive activation skills can create a dynamic and engaging classroom environment that motivates students to learn and achieve their academic goals. This, in turn, can lead to improved student performance, increased retention rates, and higher levels of academic success.

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Ethical statement: The author stated that the study did not require approval from an ethics committee. The study is conducted using publicly available databases for research purposes. The data that support the findings of this study are available in the Organization for Economic Cooperation and Development's (OECD) Programme for International Student Assessment (PISA) 2012 at https://www.oecd.org/pisa/pisaproducts/pisa2012database-downloadabledata.htm.

Declaration of interest: No conflict of interest is declared by the author.

Data sharing statement: Data supporting the findings and conclusions are available upon request from the author.

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APPENDIX A

Table A1. Measurement scales

Constructs	Items	Loading	CR	AVE
Learning anxiety			0.88	0.61
	Worry that it will be difficult	0.77		
	Get very tense	0.82		
	Get very nervous	0.78		
	Feel helpless	0.75		
	Worry about getting poor grades	0.77		
Self-concept			0.90	0.65
	Not good at math (reverse code)	0.75		
	Get good grades	0.75		
	Learn quickly	0.87		
	One of best subjects	0.83		
	Understand difficult work	0.81		
Cognitive activation			0.81	0.51
	Presents problems in different contexts	0.68		
	Helps learn from mistakes	0.78		
	Asks for explanations	0.68		
	Apply what we learned	0.71		
Gender	1=male; 2=female	NA		