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RESEARCH ARTICLE

The Mediating Role of Mathematics Anxiety in the Relationship Between High School Students' Metacognitive Awareness and Mathematical Resilience

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Abstract

The present study examined the mediating role of mathematics anxiety in the relationship between high school students' metacognitive awareness and mathematical resilience. For this aim, a hypothetical model was proposed. The sample included 421 high school students. Data were collected through the "Metacognitive Awareness Scale," "Mathematical Resilience Scale," and "Revised Mathematics Anxiety Rating Scale." A structural equation model was used to test the hypothetical model. Our study results show that: (a) metacognitive awareness affects mathematical resilience significantly and positively; (b) there is a significant and negative relationship between metacognitive awareness and mathematics anxiety; (c) there is a significant and negative relationship between mathematics anxiety and mathematical resilience; (d) mathematics anxiety has a mediating role in the relationship between metacognitive awareness and mathematical resilience and that metacognitive awareness will contribute positively to mathematical resilience by reducing mathematics anxiety. Based on the results, we could say that the development of metacognitive awareness in learners will positively affect affective factors such as mathematics anxiety and mathematical resilience. We recommend that teachers, parents, and all stakeholders supporting learning consider these cases.

Keywords: High school students, mathematical resilience, mathematics anxiety, metacognitive awareness

Introduction

In order to understand the nature of mathematics learning, there is a need to examine affective and cognitive factors (Leder & Forgasz, 2002). Realizing the relationship between cognition and affect is critical in understanding and appreciating mathematics education (Zan et al., 2006). Therefore, it is necessary to investigate cognitive and affective factors together to develop an understanding of mathematical learning (Leder & Forgasz, 2002). While students' cognitive competencies affect their confidence in learning mathematics, affective factors are more decisive in choosing advanced mathematics study and mathematics-related careers (Frenzel et al., 2007). Therefore, affective factors affect the quality and degree of future mathematical participation (Grootenboer & Marshman, 2016).

The affective domain has several interrelated dimensions (Lomas et al., 2012). Although there is no consensus, McLeod (1992) stated that the affective domain includes a wide variety of emotions and beliefs beyond the cognitive domain and defined beliefs, attitudes, and emotions as elements of the affective domain. In addition, DeBellis and Goldin (1997) stated that values are also an element of the affective domain. Subsequent research on the affective domain focused on constructs such as interest, motivation, and mood (Zan et al., 2006). More recent studies include concepts such as self-efficacy, identity, and anxiety as elements of the affective domain (Lomas et al., 2012).

Affect is an integral part of intelligence (Roth & Walshaw, 2019) and therefore an integral part of learning mathematics (Hannula, 2006). Research on affect in mathematics education is gradually increasing (Zan et al., 2006). Researches generally examine the interactions of affective factors with cognition, problem-solving, achievement, engagement, teaching and learning processes (Grootenboer & Marshman, 2016). Despite increasing research on the affective domain in mathematics education, the effect of affective factors on mathematics learning is still unclear (Hannula et al., 2014). It is mentioned in the researches that most individuals have negative affective views toward mathematics and acquire most of these negative views during their school years (Grootenboer, 2010).

Mathematical affect, engagement, learning, and achievement are interrelated (Grootenboer & Marshman, 2016). Emotions toward mathematics, interest in mathematics, response, and using it in individual life are effective. Students who develop positive emotions toward mathematics are in a position to learn mathematics better. One of the goals of mathematics education is to enable students to develop positive emotions that help them use mathematics successfully and learn more mathematics (OECD, 2013a).

Metacognition

Flavell defines metacognition as "an individual's own cognitive processes and products or knowledge about them" (Flavell, 1976, p. 232).

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Following Flavell's definition, metacognition became the focus of educational sciences research, and explanations for the concept continued. Metacognition is expressed as the individual's awareness of their thinking processes and being able to control these processes (Baker & Brown, 1984); the ability to control and manage the individual's thinking processes (Reeve & Brown, 1985); a high-level process in which the individual implements the stages of planning, monitoring, and evaluation in the problem-solving process (Sternberg, 1986); controlling cognition by determining the factors affecting cognition (Butterfield et al., 1995). The definitions emphasized control and regulation of cognitive processes. Therefore, metacognition is the whole of processes that follow, interpret, evaluate, and control cognitive actions.

Individuals' learning how to learn is related to acquiring metacognitive skills (Wilson & Conyers, 2016). Metacognitive skills are strategies used to control cognitive processes consciously or automatically before, during, or after a cognitive activity (Flavell, 1976, 1979). Brown (1978) expressed metacognitive skills as predicting, monitoring, controlling, and adjusting learning attempts and stated that these skills are helpful for problem-solving. According to Schraw and Moshman (1995), three fundamental metacognitive skills, planning, monitoring, and evaluation, are effective in all cognitive tasks.

Metacognitive skills help using metacognitive information strategically to perform a cognitive action (Desoete, 2008). These skills involve higher-order thinking processes and are difficult to acquire spontaneously. Students need to be exposed to metacognitive skills to develop them (Ader, 2019). Metacognitive skills are best learned when embedded within a particular field and taught systematically by a teacher (Pressley & Harris, 2006). To activate students' metacognitive skills, teachers need to clearly present and discuss these skills in their classrooms (Kistner et al., 2010). Therefore, both teachers and students need to be explicitly trained to acquire metacognitive skills (Kramarski, 2018).

Metacognition is essential for understanding an academic task, determining a strategy for a solution, and evaluating the effectiveness of the chosen strategy (Flavell, 1979). Metacognition is central to the learning process and critical to achieving success (Alexander, 2008). Hartman (2001) stated that metacognitive teaching has an active role in the most effective way of teaching. Metacognition includes awareness of knowledge, actions, and control processes (Shilo & Kramarski, 2019), while mathematical metacognition consists of the individual's ability to evaluate their mathematical skills and limitations and their beliefs about the nature of the mathematical task (Garofalo & Lester, 1985).

Metacognition, which provides active control of cognitive processes, is one of the crucial predictors of mathematical performance (Kuzle, 2018; Ohtani & Hisasaka, 2018; Zhao et al., 2014). Because it involves identifying, controlling, and using strategies that affect mathematics performance (Lucangeli et al., 2019). A meaningful mathematics teaching should develop metacognition along with cognitive skills (Mevarech & Fridkin, 2006). Because metacognition can provide awareness of how different cognitive processes work and the cognitive processes that are active in learning mathematics (Cornoldi et al., 2015). Therefore, the development of metacognitive skills will positively affect mathematical problem-solving performance. Desoete et al. (2001) found that individuals with metacognitive experience performed better in mathematics. Students with poor metacognitive skills may be inclined to postpone studying for mathematics lessons (Desoete & De Craene, 2019). Students' failure in mathematics is not only due to a lack of knowledge. Their lack of awareness of how to activate and regulate their information and justify their actions can lead to failure (Shilo & Kramarski, 2019). Metacognition should be explicitly taught to students in order to develop and improve mathematical skills. Therefore, education should be designed in a way that students will be exposed to metacognitive-mathematical discourse (Desoete & De Craene, 2019). Low-performing students often need more metacognitive awareness (Kruger & Dunning, 1999). Students with metacognitive awareness can evaluate the task's requirements to be performed and determine and use the most appropriate strategies for the situation (Schraw et al., 2006).

Mathematical Resilience

Resilience has long been used in psychology literature to describe escaping negative consequences and succeeding despite difficulties (Lee & Johnston-Wilder, 2017). Luthar et al. (2000) expressed resilience as a dynamic process that includes developing positive adaptation despite difficulties. Resilience enables finding and using adaptive solutions to similar situations by overcoming negative and obstructive situations (Waxman et al., 2003). Wang et al. (1994), while defining academic resilience, expressed it as a high probability of success despite the negativities arising from the characteristics, conditions, and experiences of the individual. It can be said that mathematical resilience is a relatively new concept in the field of mathematics education. Mathematical resilience was used by Johnston-Wilder and Lee (2010) to describe a construct that would enable the development of a positive approach to mathematics. Mathematical resilience refers to a can-do approach to a new mathematical situation, the willingness to exert effort, and the ability to reach the necessary support to overcome obstacles to mathematical development (Lee & Johnston-Wilder, 2017).

Kooken et al. (2016) stated that mathematical resilience consists of three affective dimensions: value, struggle, and growth. Value refers to the understanding that mathematics is a field worth studying. Struggle means understanding that learning mathematics takes effort and that it is universal. Growth refers to the belief that each individual can improve their mathematical skills with effort and support. Mathematical resilience has common features with affective structures such as self-efficacy, confidence, and motivation. It helps to manage negative emotions that may arise when learning mathematics becomes difficult and protect them from their negative effects. Resilient students know that learning mathematics requires effort, support is always available when needed, and a sense of achievement can be experienced (Lee & Johnston-Wilder, 2017).

Mathematical resilience can be learned and developed. Thus, learners can overcome mathematical difficulties by facing them (Goodall & Johnston-Wilder, 2015). People who support learning have an impact on the development of mathematical resilience. Supporting a positive development requires awareness of affective factors. Teachers and supporters of learning can provide an environment that fosters resilience (Lee & Johnston-Wilder, 2017). Parents can improve themselves on how their children can learn mathematics most effectively (Goodall & Johnston-Wilder, 2015). Lee and Johnston-Wilder (2017) stated that the following four points should be considered in order to provide individuals with mathematical resilience: (a) developing a growth mindset, (b) understanding and experiencing that mathematics is valuable both individually and socially, (c) understanding that it takes effort and perseverance to progress in mathematics and learning to manage emotions in the learning process, and (d) knowing how to get support in case of need while learning mathematics and being aware of the value of cooperation.

It is desirable for every student to develop mathematical resilience (Kooken et al., 2016), and for this, teachers and families should work explicitly against negativities (Lee & Johnston-Wilder, 2017). Teaching about mathematical resilience allows the learner to use mathematics effectively, acquire new mathematical skills when needed, learn mathematics without developing negative emotions, and strengthen his/her career (Lee & Johnston-Wilder, 2017). The OECD (2013b) report states that some students are successful despite various disadvantages. These students have resilience, and students of all ages must gain mathematical resilience for good mathematical performance and success (Lee & Johnston-Wilder, 2017).

Students should encounter appropriately challenging learning opportunities to understand the need for mathematical resilience (Lee & Johnston-Wilder, 2017). If a student is not exposed to challenges while learning mathematics, he/she will be unprepared for struggle (Ward-Penny et al., 2011). Therefore, teachers should enable students to encounter challenging mathematical tasks and help them overcome difficulties. According to Lee and Johnston-Wilder (2017), it should be emphasized that there is no single way to perform a mathematical task in the development of mathematical resilience; each individual must start by using their current knowledge (McGowen & Tall, 2010), making mistakes is a part of learning (Mason et al., 2010).

Mathematics Anxiety

Mathematics is generally accepted to elicit strong emotional responses, especially anxiety (Punaro & Reeve, 2012). Mathematics anxiety has been defined as "a feeling of tension and anxiety that prevents the manipulation of numbers and solving mathematical problems in ordinary life or academic situations" (Richardson & Suinn, 1972, p. 551). Ashcraft (2002) defined mathematics anxiety as a feeling of tension, anxiety, or fear that interferes with math performance and stated that it could be in the form of an intense fear of mathematics or a mild tension.

Mathematical anxiety can include cognitive and emotional components (Ramirez et al., 2018). Mathematics anxiety interferes with remembering (Nardi & Steward, 2003), learning and teaching mathematics, and is commonly considered inhibitory (Dowker et al., 2016). It makes it difficult to concentrate during a mathematical task, negatively affecting effort and therefore performance (Passolunghi et al., 2019). Mathematics anxiety is associated with low-level numerical deficits but poses a risk to developing high-level mathematical skills (Maloney et al., 2011). Individuals with high mathematics anxiety perform slower and make more mistakes in the tasks that require computation (Ashcraft & Kirk, 2001). Mathematics anxiety negatively affects working memory while performing a mathematical activity and causes avoidance of mathematical tasks. Many individuals of all ages have anxiety that can negatively affect mathematical learning and performance (Dowker et al., 2016).

Both cognitive difficulties and social factors can cause mathematics anxiety (Maloney & Beilock, 2012). Núñez-Peña and Suárez-Pellicioni (2014) stated that mathematical difficulties, poor mathematical skills, and repeated failure experiences cause mathematics anxiety. Individuals' assessments of their mathematical competence may cause mathematics anxiety. Inferences about being bad at mathematics can trigger anxiety in the individual. On the other hand, anxiety causes the individual not to trust his/her mathematical ability (Dowker et al., 2016). Mathematics anxiety is also related to how mathematics is taught in the classroom and teacher behaviors (Finlayson, 2014). A success and result-oriented teaching approach will cause anxiety. Teachers should be able to manage emotions in the classroom, and students should be taught how to regulate their emotions and protect themselves from negative emotions (OECD, 2010). Giving too much importance to quickly recalling and ignoring understanding concepts in mathematics learning cause mathematics anxiety and avoidance in learners (Ashcraft & Krause, 2007).

Mathematics anxiety has both personal and social consequences (Johnston-Wilder et al., 2020). The consequences of mathematics anxiety can range from mild nervousness to extreme avoidance (Hembree, 1990). Avoidance leads to less exposure to mathematics, less practice, less mathematical competence, and, as a result, more anxiety. It can prevent an individual from taking advanced mathematics courses and career choices related to mathematics (Ashcraft, 2002).

Mathematics anxiety is an international phenomenon and appears to be associated with lower mathematics achievement and performance (Ma, 1999; Foley et al., 2017). The OECD (2013b) report stated that mathematics anxiety gradually increased, mathematics anxiety negatively affected mathematics performance, and high mathematics anxiety was associated with lower mathematics scores. Radišić et al. (2015) stated that although there are cultural differences in terms of mathematics anxiety, students with mathematics anxiety achieved lower mathematics results. International comparison researches generally show that a group of students in each country have mathematics anxiety (Beilock & Willingham, 2014). Mathematics anxiety is a common problem in many countries among individuals of all ages (Luttenberger et al., 2018).

Developing a broad awareness and understanding of mathematics anxiety can be effective in preventing it (Finlayson, 2014). There is a need to develop effective strategies to prevent and overcome mathematics anxiety (Dowker et al., 2016). Therefore, it is necessary to explicitly face mathematics anxiety (Finlayson, 2014). Lyons and Beilock (2012) stated that developing educational interventions to control reactions to negative emotions while performing a mathematical task may be effective in preventing mathematics anxiety. Research says little about how to deal with mathematics anxiety or the ideal ways to avoid it. Therefore, more research is needed (Dowker et al., 2016).

The Present Study

Mathematics is generally perceived as a subject that evokes negative affective reactions (Dowker et al., 2016). Affective factors have a diverse and complex structure (Batchelor et al., 2019). Continuing to reveal the relationship between these factors and cognitive factors will contribute to understanding the nature of mathematics learning and teaching. Investigating the relationship between cognition and affective factors can help to understand what makes learning mathematics difficult (Obersteiner, 2019). Research that examines new approaches is needed to encourage more students with different levels of ability to persist in learning mathematics (Kooken et al., 2016).

This study is aimed to examine the relationship between metacognitive awareness, which enables individuals to organize their learning (Hacker et al., 1998) and manage self-learning effectively (Ohtani & Hisasaka, 2018) and mathematical resilience, which is a relatively new concept in the field of mathematics education and is desired to be developed for every learner (Kooken et al., 2016), and should be taken into account in order to be successful in mathematics (Johnston-Wilder & Lee, 2010). In addition, the mediating role of mathematics anxiety in this relationship, which is related to mathematics achievement and interest in mathematics (Radišić et al., 2015) and which can make it

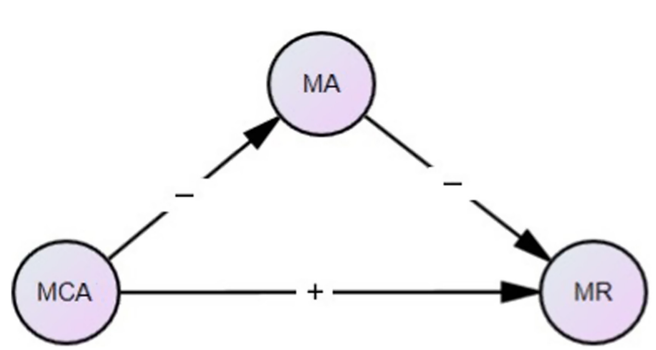

Figure 1.
Hypothetical Model (MCA: Metacognitive Awareness, MR: Mathematical resilience, MA: Mathematics anxiety).

difficult to develop mathematical resilience (Lee & Johnston-Wilder, 2017), was examined. For this purpose, a hypothetical model is proposed. The proposed model is presented in Figure 1.

Our assumptions for the proposed model are (a) there is a positive relationship between metacognitive awareness and mathematical resilience, (b) there is a negative relationship between metacognitive awareness and mathematics anxiety, (c) there is a negative relationship between mathematics anxiety and mathematical resilience, and (d) mathematics anxiety has a mediating role in the relationship between metacognitive awareness and mathematical resilience, and metacognitive awareness increases mathematical resilience by reducing mathematics anxiety.

Methods

Participants

The participants were chosen using convenient sampling, one of the nonrandom sampling methods. In this context, the study participants consist of 421 high school students aged between 14 and 18 who are studying in a state high school affiliated with the Ministry of National Education in Ankara in the second semester of the 2021–2022 academic year. Of these students, 272 (64.6%) were female and 149 (35.4%) were male. Additionally, 144 (34.2%) of the students were ninth graders, 114 (27.1%) were tenth graders, 107 (25.4%) were 11th graders, and 56 (13.3%) were 12th graders. The scores of the students obtained from the High School Entrance Exam vary between 400 and 484 (a maximum of 500 points can be obtained).

Measures and Data Collection

Data were collected with "Metacognitive Awareness Scale," "Mathematical Resilience Scale," and "Revised Mathematics Anxiety Rating Scale". Detailed information about the scales is explained below.

Metacognitive Awareness Scale

The scale was developed by Fırat Durdukoca and Arıbaş (2019). The scale consists of three sub-dimensions, namely personal awareness (eight items), organizational awareness (six items), and judgmental awareness (four items), and a total of 18 items. The scale has a structure that can be answered between "1 = Never" and "5 = Always." The Cronbach's α internal consistency coefficient value of the scale is .75. The total variance explained by the scale is 45.03%. The factor load values of the scale items ranged from .73 to .42. There is no reverse-scored item on the scale. A high score obtained from the scale means that the level of metacognitive awareness increases. As a result of confirmatory factor analysis, the goodness-of-fit indices were calculated as $\chi^2 = 198.02$, df = 131, χ^2/df = 1.5, $p < .001$, RMSEA = .045, SRMR = .06, NNFI = .91, CFI = .92, GFI = .92, and AGFI = .90. In this study, the Cronbach's α internal consistency coefficient value was calculated as .85. The goodness-of-fit indices were calculated as follows: $\chi^2 = 300.954$, df = 129, χ^2/df = 2.33, $p < .001$, RMSEA = .056, SRMR = .05, NNFI = .88, CFI = .90, GFI = .92, and AGFI = .90.

Mathematical Resilience Scale

The scale was developed by Kooken et al. (2016) and adapted into Turkish by Gürefe and Akçakın (2018). The scale consists of three sub-dimensions, namely value (eight items), struggle (six items) and growth (five items), and a total of 19 items. The scale has a structure that can be answered in the range of "1 = I strongly disagree" and "7 = I strongly agree." The Cronbach'sα internal consistency coefficient value of the scale is .87. The total variance explained by the scale is 58.11%. The factor load values of the scale items ranged from .86 to .52. Items in the development sub-dimension of the scale are reverse-scored. A high score obtained from the scale means being mathematically resilient. As a result of confirmatory factor analysis, the goodness-of-fit indices were calculated as $\chi^2 = 603.06$, df = 149, χ^2/df = 4.04, $p < .001$, RMSEA = .060, SRMR = .053, NNFI = .96, CFI = .97, GFI = .92, and AGFI = .89. The Cronbach's α internal consistency coefficient value was calculated as .86 in this study. The goodness-of-fit indices were calculated as $\chi^2 = 319.884$, df = 147, χ^2/df = 2.17, $p < .001$, RMSEA = .053, SRMR = .052, NNFI = .94, CFI = .95, GFI = .92, and AGFI = .90.

Revised Mathematics Anxiety Rating Scale: The scale was developed by Plake and Parker (1982) and adapted into Turkish by Akın et al. (2011). The scale consists of two sub-dimensions, namely mathematics learning anxiety (16 items) and mathematical assessment anxiety (eight items), and a total of 24 items. The scale has a structure that can be answered in the range of "1 = Never worries" and "5 = Always worries." The Cronbach's α internal consistency coefficient value of the scale is .93. The total variance explained by the scale is 50.1%. The factor load values of the scale items ranged from .89 to .37. There is no reverse-scored item on the scale. A high score obtained from the scale indicates a high level of mathematics anxiety. As a result of confirmatory factor analysis, the goodness-of-fit indices were calculated as $\chi^2 = 533.37$, df = 242, χ^2/df = 2.20, $p < .001$, RMSEA = .057, SRMR = .053, NFI = .96, CFI = .98, IFI = .98, and RFI = .96. The Cronbach's α internal consistency coefficient value was calculated as .95 in this study. The goodness-of-fit indices were calculated as $\chi^2 = 882.636$, df = 248, χ^2/df = 3.55, $p < .001$, RMSEA = .078, SRMR = .079, NNFI = .90, NFI = .88, CFI = .91, IFI = .91, and RFI = .86.

The scales were implemented online in line with voluntary participation and in a way that did not interfere with the teaching activities of the students.

Procedure

Structural equation modeling (SEM) was used in this study. Structural equation modeling enables the identification and testing of models defined by complex structural relationships (e.g., multiple indicators, measurement errors, and mediation) and includes latent variables (Heck & Thomas, 2020). It is a flexible modeling technique that tests proposed models by combining various statistical methods (Cheung, 2015). It shows the relationships between latent and observed variables in the proposed theoretical model. In other words, it reveals how latent variables are defined by observed variables (Schumacker & Lomax, 2004). In SEM, evaluation is conducted using various goodness-of-fit indices. There is no consensus on which goodness-of-fit indices will be used in the evaluation. Hu and Bentler (1998) suggest using TLI, CFI, or RMSEA indices along with SRMR. Kline (2016) stated that it would be sufficient to calculate χ^2/df, *p*-value, RMSEA, CFI, and TLI indices. Jackson et al. (2009) suggest using χ^2/df, *p*-value, one of the comparative fit indices (e.g., CFI, NFI, TLI), RMSEA, or SRMR. Acceptable values in the evaluation of the goodness-of-fit indices are suggested to be below 5 for χ^2/df value, below .08 for SRMR and RMSEA, and above .90 for CFI, NFI, and TLI (Byrne, 2016; Hu & Bentler, 1999; Kline, 2016).

In determining the normal distribution of the data, the skewness and kurtosis values of the total scale scores were examined. Variance inflation factor (VIF) and correlation values were examined to decide whether there was multicollinearity between the variables. Determining the outliers *z*-scores, which $|z|>3.0$ indicate outliers (Kline, 2016), and Mahalanobis distances were examined. In the proposed model, bootstrapping (Hayes, 2018) was implemented to determine the significance of mediation. Before testing the proposed structural equation model, a measurement model including all the variables was created and tested. Analyzes were performed with IBM SPSS AMOS 24 and IBM SPSS Statistics 25 programs.

Ethics Approval

Ethical committee approval was received from the Kütahya Dumlupınar University Social and Human Sciences Scientific Research and Publication Ethics Committee (Approval No: 2022/06, Date: 02.06.2022). Written informed consent was obtained from student's parents who participated in this study.

Results

Descriptive Statistics

The mean (*M*), standard deviation (SD), skewness, and kurtosis values, along with correlation coefficients of the latent variables in the proposed structural equation model, are presented in Table 1.

Table 1 shows that there was a weak and negative significant relationship between MCA and MA ($r=-.285$, $p < .001$), a weak and positive significant relationship between MCA and MR ($r=.341$, $p < .001$), and a moderate and negative significant relationship between MA and MR ($r=-.431$, $p < .001$). The correlation coefficients between the variables were less than .85, and the calculated VIF value (1.088) was less than 10, indicating no multicollinearity (Kline, 2016). Additionally, the skewness and kurtosis values were less than |1|, indicating a normal distribution (Lei & Lomax, 2005).

Measurement Model

Before testing the proposed structural equation model, a measurement model including all the variables was created and tested. As a result of the analysis, the goodness-of-fit indices were calculated as $\chi^2=3265.727$, df = 1744, $\chi^2/df=1.87$, $p < .001$, RMSEA = .046, SRMR = .071, CFI = .90, TLI = .88, IFI = .89, and all path coefficients were significant. Based on this, it can be concluded that the measurement model has acceptable goodness-of-fit indices and is validated.

Table 1.
Intercorrelation and Descriptive Statistics of Latent Variables

	1	2	3	*M*	SD	Skewness	Kurtosis
1. MCA	–			65.68	9.62	–.271	–.046
2. MA	–.285**	–		57.76	20.73	.554	–.370
3. MR	.341**	–.431**	–	109.48	15.44	–.948	.993

Note: ***p* < .001.

Structural Equation Model

As a result of the analysis of the proposed structural equation model, the goodness-of-fit indices were calculated as $\chi^2=3404.303$, df = 1752, $\chi^2/df=1.94$, $p < .001$, RMSEA = .047, SRMR = .070, CFI = .90, TLI = .88, and IFI = .89, and all path coefficients were significant. Based on this, it can be concluded that the proposed structural equation model has acceptable goodness-of-fit indices and is validated. The path diagram of the proposed structural equation model is presented in Figure 2.

Figure 2 shows that the relationship between MCA and MR ($\beta = .35$, $p < .01$); MCA and MA ($\beta = -.33$, $p < .01$); and MA and MR ($\beta = -.50$, $p < .01$) were statistically significant.

Mediation Analysis

Determining the mediating role of mathematics anxiety in the relationship between metacognitive awareness and mathematical resilience, bootstrap analysis was performed with a 95% confidence interval and 5000 resamplings. The analysis results are presented in Table 2.

Table 2 shows that the direct relationship between MCA and MR was positive and significant ($\beta = .35$, $p < .01$, 95% CI = .190, .512), the direct relationship between MCA and MA was negative and significant ($\beta = -.33$, $p < .01$, 95% CI = −.465, −.207), and the direct relationship between MA and MR was negative and significant ($\beta = -.50$, $p < .01$,

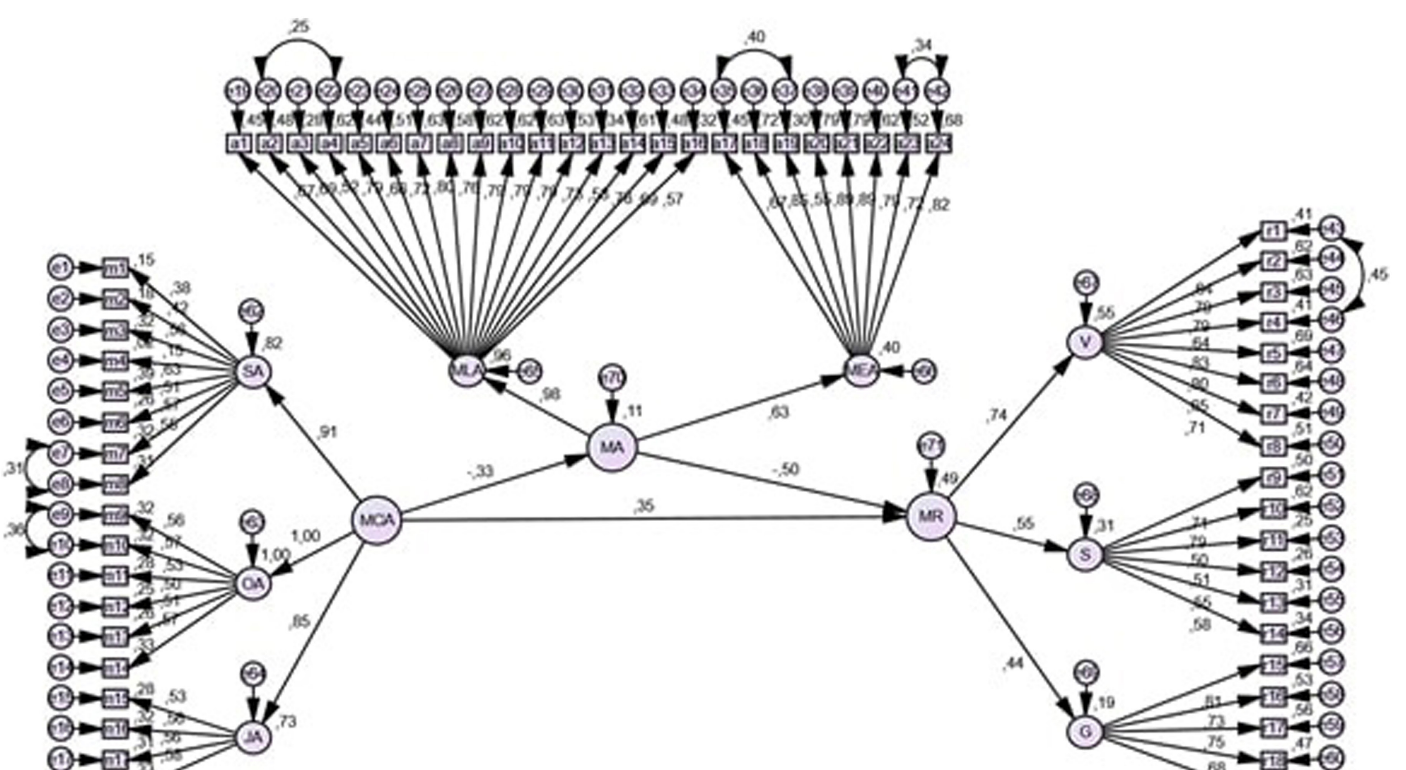

Figure 2.
Path Diagram of the SEM with Standardized Estimates.

Table 2.
Estimated Standardized Path Coefficients of the Structural Model

		Estimated	SE	R^2	% 95 CI Lower	% 95 CI Upper
Direct link	MCA → MR	.350*	.082	.27	.190	.512
	MCA → MA	−.332*	.066	.11	−.465	−.207
	MA→ MR	−.501*	.071	.49	−.639	−.357
Indirect link	MCA → MA → MR	.166*	.041	-	.094	.254

Note: *$p < .001$.

95% CI=−.639, −.357). In addition, it was determined that the indirect effect of MCA on MR through MA was positive and significant (β = .16, $p < .01$, 95% CI=.094, .254).

Discussion and Conclusion

This study examined the mediating role of mathematics anxiety in the relationship between metacognitive awareness and mathematical resilience. In order to explain the relationships between the related concepts, a structural equation model was proposed, and the assumptions based on the model were confirmed. Our study results showed that metacognitive awareness significantly and positively affects mathematical resilience. Cognitive and non-cognitive factors are in constant interaction for high-level learning (Farrington et al., 2012). Metacognitive skills are cognitive processes that direct an individual's cognitive activities and support learning (Mevarech & Kapa, 1996). Cognitive competence affects confidence and effort towards learning mathematics (Frenzel et al., 2007). Students who develop mathematical resilience know that various difficulties may be encountered in learning mathematics and that they must struggle to overcome them. Because struggle provides the opportunity to solve problems by combining experience and trial and error with cognitive functioning (Kooken et al., 2016). Therefore, acquiring metacognitive awareness will contribute positively to the development of mathematical resilience.

Our study results showed that there is a significant and negative relationship between metacognitive awareness and mathematics anxiety. Accordingly, increasing metacognitive awareness will help to reduce mathematics anxiety (or vice versa). DeBellis and Goldin (2006) stated that affective factors develop parallel with cognitive factors. Mathematics anxiety is an affective factor (Dowker et al., 2016) and an emotion that prevents manipulating numbers and solving mathematical problems (Richardson & Suinn, 1972). In other words, it could be said that it is an affective reaction that interferes with cognitive processes. In particular, it is stated that it interferes with performing mathematical tasks related to working memory (Ashcraft & Moore, 2009). Finlayson (2014) suggested that learners develop self-confidence, study mathematics, practice and receive support in case of need to overcome mathematics anxiety. Therefore, it could be stated that it is necessary to have metacognitive awareness. Accordingly, the acquisition of metacognitive awareness will contribute positively to the decrease of mathematics anxiety.

Our study results showed that there is a significant and negative relationship between mathematics anxiety and mathematical resilience. Developing mathematical resilience means having a sense of value, meaning, purpose, confidence in mathematics, and overcoming negativities toward mathematical competence (Johnston-Wilder et al., 2020). Mathematics anxiety causes individuals to lack confidence in their mathematical skills and avoid mathematics (Dowker et al., 2016). Accordingly, mathematics anxiety can make it difficult to develop mathematical resilience (Lee & Johnston-Wilder, 2017). Therefore, mathematics anxiety is effective in acquiring mathematical resilience to learners. Having a high level of mathematics anxiety will play a negative role in developing and acquiring mathematical resilience.

Our study results showed that mathematics anxiety has a mediating role in the relationship between metacognitive awareness and mathematical resilience, and that metacognitive awareness will contribute positively to mathematical resilience by reducing mathematics anxiety. Mathematics anxiety functions as a disability that causes negative educational and cognitive outcomes (Ashcraft & Moore, 2009). Success and interest in mathematics are associated with low mathematics anxiety (Radišić et al., 2015). An individual with mathematics anxiety typically performs on most cognitive tasks but underperforms on mathematical tasks (Maloney & Beilock, 2012). Mathematics anxiety uses working memory resources that help solve mathematics problems and perform at high levels in mathematics by causing negative thoughts. By distracting attention from the mathematical task, it impairs the task's relationship with working memory and, accordingly, cognitive performance (Ashcraft, 2002; Hembree, 1990). Since metacognition provides awareness of cognitive knowledge and skills, identification of factors affecting cognition, and active control of cognitive processes (e.g., Baker & Brown, 1984; Butterfield et al., 1995; Flavell, 1976, 1979; Desoete, 2008), the development of metacognitive awareness will enable the reduction of mathematics anxiety that interferes with mathematical cognition.

Affective factors play a critical role in learning and teaching mathematics (McLeod, 1994; Dowker et al., 2016). Affect is a part of mathematical activity and is a predictor of behaviors such as avoiding mathematics in the future, taking advanced mathematics courses, and choosing a career related to mathematics (Hannula, 2019). Also, affective factors are predictors of advanced cognitive factors (Buff, 2011) and are associated with taking advanced mathematics (Ma, 2006). Investigating the relationship and effects of cognitive and affective factors will help to understand the nature of learning mathematics (Leder & Forgasz, 2002). Based on our study results, we could say that the development of metacognitive awareness in learners will positively affect affective factors such as mathematics anxiety and mathematical resilience. We recommend that teachers, parents, and all stakeholders supporting learning consider these cases.

Limitations and Implications

The study findings should be interpreted in light of some limitations. The first is that the students are participating in the research study at a school in the city center. Generally, educated and financially well-off families reside in the area where the school is located. However, the socioeconomic and sociocultural characteristics of the students were ignored in the study. The second is that, as mentioned before, the students' High School Entrance Exam scores, for which a total score of 500 can be obtained, vary between 400 and 484. Therefore, students' academic achievements are relatively high, which was not considered in the study. Future research should consider the mentioned issues. Additionally, the theoretical model proposed in the study can be tested with data obtained from students studying in rural areas, secondary schools, or university students.

The role of metacognition and mathematics anxiety in learning and teaching mathematics has been widely studied. However, mathematical resilience is a relatively new concept, and studies are needed on this subject. So, the current study has critical implications. While the effect of mathematics anxiety on students' mathematical resilience is negative, the effect of metacognitive awareness is positive. In addition, metacognitive awareness positively affects students' mathematical resilience by reducing mathematics anxiety. Teachers should consider this result as those who teach mathematics, students as learners, and all instruction stakeholders. Increasing students' metacognitive awareness while learning mathematics will enable them to keep their mathematics anxiety at an optimum level and increase their mathematical resilience. Thus, a positive contribution will be made to students' mathematics performance.

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