Erzincan Üniversitesi Eğitim Fakültesi Dergisi

Erzincan University Journal of Education Faculty

2023 Cilt 25 Sayı 3 (488-496) https://doi.org/10.17556/erziefd.1218193

Araştırma Makalesi / Researh Article

An Exploratory Study on the Effects of Attitude and Self-Efficacy on Math Achievement as Mediated by Math Anxiety

Tutum ve Öz-Yeterliğin Matematik Başarısı Üzerindeki Etkilerinde Matematik Kaygısının Aracı Rolüne İlişkin Keşfedici Bir Çalışma

Muhammet Fatih Alkan[1] Şule Yılmaz Özkaya[2]

[1] Dr. Öğr. Üyesi, Tokat Gaziosmanpaşa Üniversitesi, Eğitim Fakültesi, Tokat, Türkiye

[2] Yüksek Lisans, Tokat Gaziosmanpaşa Üniversitesi, Lisansüstü Eğitim Enstitüsü, Tokat, Türkiye

Makale Bilgileri

Geliş Tarihi (Received Date)

12.12.2022

Kabul Tarihi (Accepted Date)

25.07.2023

Sorumlu Yazar

Muhammet Fatih Alkan

Tokat Gaziosmanpaşa Üniversitesi, Eğitim Fakültesi, Merkez/Tokat.

mfatihalkan@hotmail.com

Abstract: Although the impacts of math anxiety, attitude toward math, and math self-efficacy on math achievement have been well-defined in the relevant literature, the interrelations among these predictors to explain math achievement are understudied. This study examined the structural relationships among math achievement, math anxiety, math self-efficacy, and attitude toward math. Within this scope, a full mediation model involving math anxiety as the mediator in the relationship of math achievement with attitude toward math and math self-efficacy was proposed. Data collected from 470 middle school students were used for the analyses. Structural equation modeling and bootstrapping methods were used to investigate the proposed relationships. Moreover, various alternative models were tested to see whether the proposed model was empirically the best model to explain math achievement. The findings showed that the proposed model fit the data well and was superior to alternative models. Accordingly, attitude toward math and math self-efficacy had significant and positive indirect effects on math achievement as mediated by math anxiety. In conclusion, the study provided a meaningful model based on a strong theoretical and empirical background to explain math achievement.

Keywords: Math achievement, math anxiety, attitude toward math, math self-efficacy

Öz: İlgili alanyazında matematik kaygısı, matematiğe yönelik tutum ve matematik öz-yeterliğinin matematik başarısına etkisine yönelik birçok çalışma olsa da bu yordayıcı değişkenlerin matematik başarısını açıklarken kendi aralarındaki ilişkilere yönelik çalışma sayısı oldukça sınırlıdır. Bu çalışma matematik başarısı, matematik kaygısı, matematik öz-yeterliği ve matematiğe yönelik tutum arasındaki yapısal ilişkileri incelemiştir. Bu kapsamda, matematik kaygısının matematik başarısı ile matematiğe yönelik tutum ve matematik öz-yeterliği arasındaki ilişkide aracı rolünü içeren bir tam aracılık modeli önerilmiştir. Analizler için 470 ortaokul öğrencisinden toplanan veriler kullanılmıştır. Önerilen ilişkiler, yapısal eşitlik modeli ve bootstrapping yöntemleri kullanılarak incelenmiştir. Ayrıca önerilen modelin matematik başarısını açıklamak ve görgül açıdan en iyi model olup olmadığını belirlemek için bir dizi alternatif model de test edilmiştir. Sonuçlar, önerilen modelin veri ile iyi uyum gösterdiğini ve alternatif modellerden daha üstün olduğunu göstermiştir. Buna göre, matematiğe yönelik tutum ve matematik öz-yeterliği, matematik başarısı üzerinde anlamlı ve olumlu dolaylı etkilere sahiptir ve bu etkilerde matematik kaygısının aracılık rolü bulunmaktadır. Sonuç olarak bu çalışma matematik başarısını açıklamak için güçlü bir kuramsal ve ampirik temele dayanan anlamlı bir model sunmuştur.

Anahtar Kelimeler: Matematik başarısı, matematik kaygısı, matematiğe yönelik tutum, matematik öz-yeterliği

Alkan, M.F. & Yılmaz-Özkaya, Ş. (2023). An exploratory study on the effects of attitude and self-efficacy on math achievement as mediated by math anxiety. *Erzincan University Journal of Education Faculty*, 25(3), 488-496. https://doi.org/10.17556/erziefd.1218193

Introduction

Understanding and using math is extremely important since it is considered the language of nature and technology (Pohjolainen et al., 2018). Although the value of math is understood well, math skills have been in decline in Europe (Mustoe & Lawson, 2002). The situation is not better in Turkey. The PISA 2018 report shows that Turkey ranked 42nd out of 79 countries (Ministry of National Education [MoNE], 2019). On the other hand, the Ministry of National Education has started taking some steps to improve the math skills of students. In 2022, the "Math Campaign" was initiated in Turkey (MoNE, 2022). Accordingly, the campaign includes math workshops, math summer schools, material development, and teacher training. This attempt demonstrates the emphasis and interest given to math in Turkey. In addition to such projects as the "Math Campaign" of Turkey or the "Math-Bridge" of the European Commission (2011), a group of researchers has focused on ways to improve math ability using experimental design studies (e.g., Gula et al., 2015; Oppenheimer et al., 2020; Pohjolainen et al., 2018). On the other hand, another group of researchers attempted to reveal student-related variables that impact math achievement (MAch). The literature review has revealed that math anxiety (MA), math self-efficacy (MS), and attitude toward math (AtM) are among the variables that are significantly related to MAch (Cvencek et al., 2021; Yu et al., 2023; Živković et al., 2023). This study focused on the structural relationships among MAch, MA, MS, and AtM to further understand the mechanism underlying students' MAch.

Conceptual Framework

In this section, we provide a review of the theoretical and empirical literature on the variables impacting MAch and discuss possible relations among these variables and their relations with MAch.

Math Anxiety

Math anxiety (MA) is a common problem around the world and can be demonstrated at any age (Commodari & La Rosa, 2021). It can be described as a negative emotional response demonstrated by people while working with numbers, which deters math performance (Ashcraft, 2022; Suárez-Pellicioni et al., 2016). Feelings of apprehension, worry, aversion, and frustration characterize MA (Devine et al., 2012). Meta-analysis studies that synthesize the findings of various studies show that MA has been negatively correlated with MAch (Ma, 1999; Zhang et al., 2019). Other studies since the most recent meta-analysis have also provided evidence supporting this negative relationship (Commodari & La Rosa, 2021; Sorvo et al., 2022; Tomasetto et al., 2021). Although there is consensus about the negative relationship between MA and MAch, the direction of this relationship has been a matter of debate. In their literature review study, Carey et al. (2016) concluded that evidence regarding the direction of association between MA and MAch was conflicting, and they proposed a bidirectional relationship. However, in a recent study, Pantoja et al. (2020) analyzed this relationship by controlling students' math skills. They revealed that MA affects MAch independently of math skills. Similarly, Daker et al. (2021) conducted a study in which MA predicted MAch independently from math ability. Additionally, Weissgerber et al. (2022) supported this direction. Moreover, it has been evidenced that MA negatively influences working memory, which is responsible for learning math (Beilock & Carr, 2005), and this negative influence on working memory causes low math performance (Ashcraft & Kirk, 2001). Therefore, although the literature has some mixed findings about the direction of the effects between the two variables, more recent literature and empirical evidence show that MA is an antecedent of MAch.

Math Self-Efficacy

As the pioneer researcher of the concept, Bandura (1997) has defined self-efficacy as people's conviction in their capacity to succeed in particular circumstances. Research demonstrates that self-efficacy strongly predicts achievement (Chen, 2003; Phan, 2012; Tian et al., 2018). Since self-efficacy is domain, task, and context specific (Cook & Artino, 2016), a student might have low self-efficacy in one course and high in another one. Thus, it needs to be measured by taking that specific context into consideration. Since achievement in the math context is targeted in this study, math self-efficacy (MS), which is the context-specific version of general self-efficacy, was focused on in the current study. In a similar way to general self-efficacy, MS refers to people's beliefs in their competency in math-related situations (Lane & Lane, 2001; Luttenberger et al., 2018). Findings from multiple studies demonstrate the relation of MS with students' MAch and performance (Larsen & Jang, 2022; Pajares & Miller, 1994; Sağkal & Sönmez, 2022; Skaalvik et al., 2015; Xu & Jang, 2017; Yurt & Sünbül, 2014; Živković et al., 2023). Higher levels of self-efficacy result in greater effort and determination (Recber et al., 2018), which leads to greater academic achievement. High self-efficacy is not only related to better performance but also leads students to endure longer on challenging problems (Hoffman & Schraw, 2009) and it affects MAch as much as mental capacity does (Pajares & Kranzler, 1995).

Attitude Toward Math

Attitude can be described as an inclination that impulses people to react positively or adversely to a situation (Aiken, 1970). The theory of Reasoned Action argues that attitude has been among the most important predictors of individuals' behaviors and performance (Ajzen & Fishbein, 1987). Positive attitude is considered to increase students' academic achievement and learning (Pinxten et al., 2014). Attitude toward math refers to individuals' positive or negative emotions about math (Adediwura, 2011). The pioneering study of Aiken and Dreger (1961) is among the earliest studies that showed the association between MAch and attitude toward math (AtM). Since then, interest in AtM has increased and numerous studies have confirmed the relationship between AtM and MAch (Adesoji & Yara, 2008; Moenikia & Zahed-Babelan, 2010; Pyzdrowski et al., 2013). To better understand the relationship between AtM and MAch, Chen et al. (2018) focused on the underlying neurocognitive mechanism of the association between these two variables. Accordingly, they revealed that the positive attitude caused a boost in the hippocampal system, which resulted in greater MAch.

The Relationships Among Study Variables

Almost a consensus about the effects of MA, AtM, and MS on MAch has been observed in the literature. Although these effects have been shown in various studies (e.g., Larsen & Jang, 2022; Pyzdrowski et al., 2013; Zhang et al., 2019), these studies included one or two of these variables, which prevented them from providing a more comprehensive understanding of the relationships among MA, AtM, and MS. Within this context, studies focusing on the relationship between MA and MS revealed that MA was negatively predicted by MS (e.g., Akın & Kurbanoğlu, 2011; Jain & Dowson, 2009; Meece et al., 1990; Pajares & Kranzler, 1995), meaning high MS led to a decrease in MA. Similarly, studies investigating the association between AtM and MA revealed that positive AtM can reduce MA (Aiken, 1976; Akın & Kurbanoğlu, 2011; Casanova et al., 2021). Therefore, based on the literature, it can be stated that AtM and MS have negatively predicted MA. In other words, the literature review reveals that MA mediates the predictor roles of MS and AtM in explaining MAch. These hypothesized relations are also consistent with the Control-Value Theory (Pekrun, 2006). According to this theory, individuals' beliefs in their competency impact the emotions related to a situation. For example, when students believe in their competency in math-related situations, they feel less anxious in such situations (Du et al., 2021; Forsblom et al., 2022). Despite the empirical and theoretical evidence and explanations about the nature of the relationships among these four variables, to our knowledge, no study has tested these effects in a single model. However, the knowledge of the relationships among these variables is important to explain how they affect MAch. Such knowledge can affect both research and practice. To address this gap, the current research aimed at examining the structural relationships among MAch, MA, MS, and AtM of middle school students. Within this scope, the following model was proposed to test these relationships based on the theoretical and empirical findings (See Figure 1).

Method

Research Design

In this research, the underlying factors of MAch were explored retrospectively. Therefore, a causal (co-relational) design, one of the ex post facto designs, was employed since it aims to identify the antecedents of a present condition (Cohen et al., 2005). In this research, MAch is the present condition while MA, AtM, and MS are antecedents. Although causal research is not always adequate to establish true causal relationships due to the lack of control or manipulation of variables, its strength lies in its exploratory and suggestive nature (Cohen et al., 2005). Therefore, the findings should be interpreted accordingly.

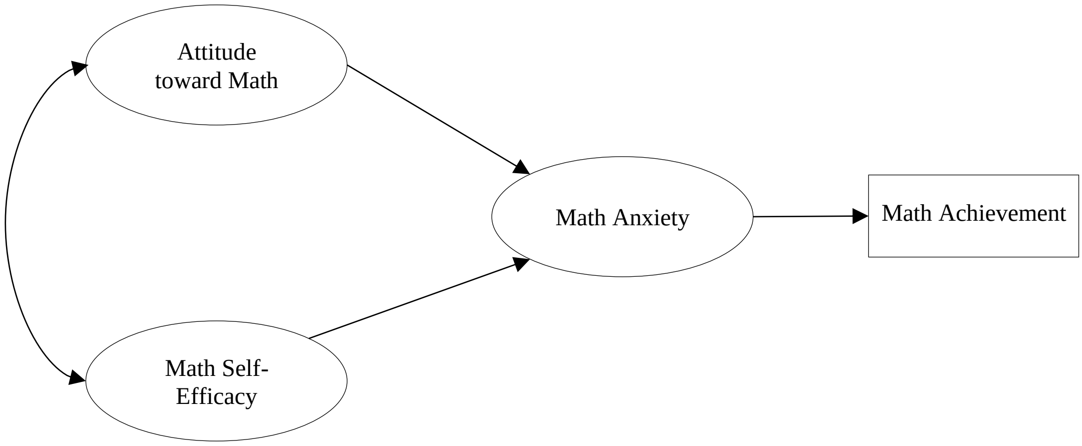

Figure 1. The proposed model

Population and Sample

Middle school students constituted the population of the study. Since there are over 5 million middle school students in Turkey, it was not feasible to reach all of them. Therefore, the convenience sampling technique was preferred since it was impossible to provide each individual from the population with an equal chance of selection, which is required for random sampling. According to Cohen et al. (2005), a sample size of 384 is the minimum number to represent such high numbers. So, the goal during the sampling was to exceed this number.

The sample of the study involved 470 middle school students. 246 students were female (52.3%). The age varied between 9 and 15 (*M*=12.31, *SD*=1.26). 7th graders were the largest group among the participants (*n*=180, 38.3%). Mothers of participants were mostly primary school graduates (*n*=158, 33.6%), while fathers were mostly middle school graduates (*n*=149, 31.7%). Further details can be seen in Table 1.

Table 1. Description of participants

Variable	*n*	%
Gender		
Female	246	52.3
Male	224	47.7
Grade Level		
5th Grade	112	23.8
6th Grade	57	12.1
7th Grade	180	38.3
8th Grade	121	25.7
Mother Education Level		
No schooling	43	9.1
Primary School	158	33.6
Middle School	161	34.3
High School	82	17.4
Undergraduate School	23	4.9
Unknown	3	0.6
Father Education Level		
No schooling	19	4
Primary School	116	24.7
Middle School	149	31.7
High School	123	26.2
Undergraduate School	55	11.7
Unknown	8	1.7
Total	470	100

Survey

A survey was created to gather the data for the study. It was composed of four parts, which aimed to measure demographics and MAch, MA, MS, and AtM, respectively. The demographics involved six questions to gather participants' math scores from the last math course, gender, grade, age, and parent's education level. Students' math course scores are calculated based on their exam results, performance, and projects that have been carried out throughout the semester (MoNE, 2013). For the remaining three parts of the survey, the validated instruments were used.

MA was measured by the instrument developed by Bindak (2005). It was composed of 10 items, which are scored from 1 (never) to 5 (always). The higher scores obtained from the scale indicate a higher MA. A sample item from the survey was "When I think of mathematics, I think of complex and incomprehensible things." The Cronbach alpha coefficient was .84 in both Bindak's (2005) and current study.

Umay's (2001) instrument was employed to measure MS. It was composed of 14 items, which are scored from 1 (never) to 5 (always). The higher scores obtained from the scale indicate a higher MS. A sample item from the survey was "I think that I can use mathematics effectively in my daily life." The Cronbach alpha coefficient was reported as .88 by Umay (2001). In the current study, it was found .70.

Lastly, Aşkar's (1986) instrument was employed to measure AtM. The instrument was composed of 20 items, which are scored from 1 (not applicable at all) to 5 (completely applicable). The higher scores indicate more positive attitudes. A sample item from the survey was "I like math." Aşkar (1986) found the Cronbach alpha coefficient as .89, which was .92 in the current research.

Data Collection

Researchers collected the data at the end of the 2021-2022 Spring semester to obtain students' latest math scores. Data collection was carried out at five different middle schools. Upon the ethical and institutional approvals, researchers contacted the school administration and created appointments for the time when the students were available. One of the researchers went to schools and collected data at the appointed time in the classroom. The purpose and expectations were explained to students before the data collection. Only the volunteers took part in the study. The survey was administered as pen-and-paper. The survey was completed in around 20 minutes.

Data Analysis

In the current research, .05 was determined as the alpha value (Cohen, 1988). Correlations and Cronbach alpha coefficients as well as the descriptive statistics were estimated using IBM SPSS 25. To test the effects of AtM and MS on MAch mediated by MA, the two-step process was used during

Structural Equation Modeling (SEM) (Anderson & Gerbing, 1988). Firstly, the quality of the model specification was evaluated by testing the measurement model. Then, the mediating effect of MA was tested by adding the structural relations to the model using maximum likelihood estimation since a good fit was observed when the results of the measurement model were checked (Anderson & Gerbing, 1988). IBM AMOS 24 was used to conduct SEM. The significance of mediation was tested by adopting the Bootstrap estimation strategy with 10000 samples with 95% bias-corrected bootstrapped confidence intervals (CIs) since the bootstrap procedure yields the most accurate CIs for indirect effects (MacKinnon et al., 2004). The latent variables had too many items, which was likely to inflate measurement errors. To prevent that, the item parceling method with the item-to-construct balance approach was used to obtain parcels. Using this approach enabled us to equally distribute the items into parcels regarding the difficulty and discrimination (Little et al., 2002). Accordingly, MA and MS had three item parcels while AtM had four item parcels.

The model fit was evaluated based on normed chi-square ($\chi 2$/df), comparative fit index (CFI), goodness-of-fit index (GFI), Tucker-Lewis index (TLI), root mean square error of approximation (RMSEA), and standardized root mean square residual (SRMR). The criteria indicating acceptable fit for indices were $\chi^2/df \leq 5$ (Schumacker & Lomax, 2004), CFI $\geq$.90 (Marsh et al., 2004), GFI $\geq$.90 (Hair et al., 2006), TLI $\geq$.90 (Baumgartner & Homburg, 1996), RMSEA $\leq$.10 (MacCallum et al., 1996), and SRMR $\leq$.10 (Kline, 2005). Moreover, Akaike's information criterion (AIC) and expected cross-validation index (ECVI) values were used to compare models. Smaller values in both indices indicate a better fit of the model (Byrne, 2010).

Research Ethics

The common ethical standards and the 1964 Helsinki Declaration were followed throughout the procedures in the current research. Informed consent was provided by all participants. This research was carried out with the approval obtained from the Social Sciences and Humanities Research Ethics Committee of Tokat Gaziosmanpaşa University on 17/06/2022 numbered 09.28.

Findings

Descriptive Statistics

Before conducting the main analyses, mean scores, standard deviations, skewness and kurtosis values, and Pearson correlations among the study variables were examined. The skewness and kurtosis values were within Kline's (2011) criteria of ±2 and ±3, respectively. The correlation analysis revealed that all study variables were significantly intercorrelated. MAch was positively and significantly correlated with MS (r=.314, p<.05, 95% CI [.228, .401]) and AtM (r=.352, p<.05, 95% CI [.267, .437]), while MA was negatively and significantly correlated with MAch (r=-.414, p<.05, 95% CI [-.497, -.332]), MS (r=-.420, p<.05, 95% CI [-.502, -.337]), and AtM (r=-.530, p<.05, 95% CI [-.607, -.453]). Finally, MS was positively and significantly correlated with AtM (r=.579, p<.05, 95% CI [.505, .653]). All the correlation coefficients were below Kline's (2005) criteria of .90 (See Table 2 for the details).

Measurement Model

Firstly, the quality of model specification was evaluated by conducting a confirmatory factor analysis on the measurement model. The fit indices revealed that the measurement model had a good fit with the data: $\chi 2$/df = 4.875, CFI= .948, GFI= .923, TLI= .927, RMSEA=.091 90% CI (.078, .104), and SRMR= .0485. The standardized factor loadings varied between .54 and .89.

Structural Model

In the second step, the fully and partially mediated models were tested. The fully mediated model (Model 1.1) included MA as the mediator and no direct paths from the AtM and MS to MAch. The fit indices demonstrated a good fit: χ^2/df = 4.679, CFI= .948, GFI= .922, TLI= .930, RMSEA=.089 90% CI (.076, .101), and SRMR= .0489, AIC=241.856, ECVI=.516 90% CI (.432, .616). All the direct paths were significant. Then, the partially mediated model (Model 1.2) included MA as the mediator and direct paths from the AtM and MS to MAch. Although the fit indices were highly similar (χ^2/df = 4.875, CFI= .948, GFI= .923, TLI= .927, RMSEA=.091 90% CI[.078, .104], and SRMR= .0485, AIC=244.131, ECVI=.521 90% CI[.437, .620]), none of the direct paths to MAch was significant. Moreover, the smaller values for the AIC and ECVI favored Model 1.1. Thus, Model 1.1 was selected over Model 1.2 (See Figure 2). The model accounted for 22% of the variance in MAch and 84% of the variance in MA.

Indirect Effects

10000 bootstrap samples with 95% bias-corrected bootstrapped CIs were utilized to see whether the mediation effects in Model 1.1 was significant. It was found that mediation effects from AtM through MA to MAch (b=.14, 95% CI [.003, .230]) and from MS through MA to MAch (b=.32, 95% CI [.219, .469]) were significant.

Alternative Models

Several alternative models were tested to see whether Model 1.1 was the best to explain MAch. Within this context, five different models in addition to Model 1.1 were tested. In all these models, MAch was the exogenous variable. Models 2 and 3 included one mediator variable, while Models 4, 5, and 6 involved two mediator variables. AtM was the mediator in Model 2, while MS was the mediator in Model 3. In Model 4, MA and AtM were mediator variables. In Model 5, AtM and MS were mediator variables. On the other hand, MA and MS were mediator variables in Model 6. Each model's path coefficients, fit indices, and AIC-ECVI values can be seen in Table 3.

Table 2. Descriptive statistics and correlations of study variables

Variable	*M*	*SD*	Skewness	Kurtosis	MAch	MS	AtM	MA
MAch	64.309	21.463	-.196	-.764	-			
MS	3.179	.852	.181	.066	.314*	-		
AtM	3.323	1.044	-.210	-.555	.352*	.579*	-	
MA	2.412	.928	.566	-.287	-.414*	-.420*	-.530*	-

*p < .05, n=470

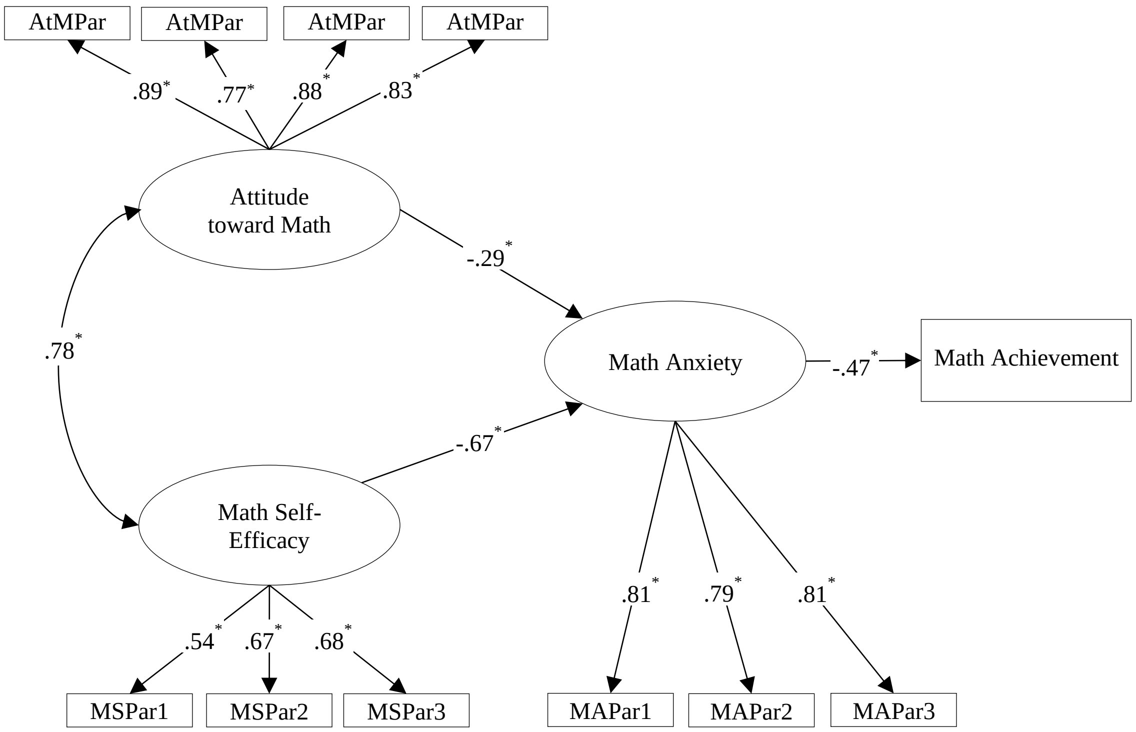

Figure 2. Standardized factor loadings and path coefficients
Note: $^*p$ < .05, *n*=470, AtMPar: Parcels of Attitude toward Math, MSPar: Parcels of Math Self-Efficacy, MAPar: Parcels of Math Anxiety

Table 3. Comparison of alternative models

	Model 1.1	**Model 1.2**	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**
	Full	Partial	Full	Full	Full	Full	Full
MA → MAch	-.47*	-.34			-.36*		-.34*
MS → MAch		.03		.48*		.33*	.17*
AtM → MAch		.11	.43*		.12	.17*	
MS → MA	-.67*	-.67*			-.95*		
AtM → MA	-.29*	-.29*					-.83*
MA → MS				-.77*		-.92*	
AtM → MS				.19*			.84*
MA → AtM			-.58*			-.82*	
MS → AtM			.26		.84*		
χ^2/df	4.679	4.875	5.042	4.750	4.772	4.762	6.232
CFI	.948	.948	.943	.947	.947	.947	.926
GFI	.922	.923	.918	.921	.922	.922	.896
TLI	.930	.927	.923	.929	.929	.929	.901
RMSEA	.089	.091	.093	.089	.090	.090	.106
CI for RMSEA	.076, .101	.078, .104	.080, .106	.077, .102	.077, .103	.077, .102	.093, .118
SRMR	.0489	.0485	.0541	.0474	.0468	.0504	.0593
AIC	241.856	244.131	256.718	244.753	245.660	245.257	305.509
ECVI	.516	.521	.547	.522	.524	.523	.651
CI for ECVI	.432, .616	.437, .620	.460, .651	.437, .623	.439, .625	.438, .624	.552, .767

Note: $^*p$ < .05, *n*=470, indicates direct effect, AtM: Attitude toward Math, MS: Math Self-Efficacy, MA: Math Anxiety, MAch: Math Achievement

Table 3 demonstrates that the fit indices of all models were mostly at acceptable thresholds. However, the examination of AIC and ECVI values supported Model 1.1 over other models since Model 1.1 had the smallest AIC and ECVI values.

Discussion, Conclusion, and Recommendations

Although the effects of MA, AtM, and MS on MAch have been well-defined in the relevant literature, the interrelations among these predictors to explain MAch are understudied. Therefore, this research investigated the structural relationships among MAch, MA, MS, and AtM of middle school students. Accordingly, a model including MA as the mediator of the relationship between AtM, MS, and MAch was proposed and tested. SEM and bootstrapping methods were utilized to examine the indirect effects of AtM and MS on MAch, in addition to the mediating role of MA in these relationships. Moreover, the direct effects of AtM and MS on MA were examined as well as the direct effect of MA on MAch. The results confirmed the proposed model. AtM and MS had significant and positive indirect effects on MAch as mediated by MA. It means that middle school students with a more positive AtM and with a higher MS are more likely to obtain higher scores from math courses. AtM and MS had significant negative direct effects on MA, that is, an increase in MA and MS leads to a decrease in MA or vice versa. Finally, MA had a significant negative direct effect on MAch. This means that students with higher MA are more likely to get lower math scores. Research findings have been discussed in detail in the following paragraphs.

Firstly, all direct effects in the model were significant. AtM and MS negatively and significantly affected MA. These two variables accounted for a great portion of the variance in MA. These findings can be stated to be consistent with the relevant literature. In their study focusing on the structural relationships among MS, AtM, and MA within the mathematic context, Akın and Kurbanoğlu (2011) found that undergraduates' MS and positive AtM predicted MA negatively while negative AtM predicted MA positively. Their model accounted for nearly half of the variance in MA. When the relationships in the model were examined individually, it was observed that MA was negatively predicted by the students' MS. This finding is supported by the study conducted by Jain and Dowson (2009). They revealed that middle school students' MA was negatively predicted by their MS. This relationship is also supported by other studies (Filiz & Gür, 2020; Medikoğlu, 2020; Meece et al., 1990; Pajares & Kranzler, 1995). Similarly, MA was negatively predicted by AtM. This finding is consistent with the literature (Aiken, 1976; Akın & Kurbanoğlu, 2011; Casanova et al., 2021). On the other hand, the model proved that MA had a negative direct effect on MAch. It means that an increase in MA yielded a decrease in MAch. More anxious students had difficulty in getting higher achievement in math. This result is perfectly consistent with the literature. For example, Miller and Bichsel (2004) revealed that individuals with high levels of MA had lower math performance. Other studies also support this finding (Commodari & La Rosa, 2021; Ma, 1999; Sorvo et al., 2022; Tomasetto et al., 2021; Zhang et al., 2019).

Secondly, bootstrapping results showed that the indirect effects of AtM and MS on MAch were positive and significant, as mediated by MA. MS was a stronger predictor of MAch when compared with AtM. These findings mean that both MS and AtM decrease MA, which in turn increases MAch. As people's self-efficacy increases, they demonstrate greater effort, persistence, and resilience (Recber et al., 2018) and are more likely to persist longer on difficult problems (Hoffman & Schraw, 2009). Therefore, it is no surprise that MS affects MAch positively. This finding is consistent with the literature (Larsen & Jang, 2022; Pajares & Miller, 1994; Sağkal & Sönmez, 2022; Skaalvik et al., 2015; Xu & Jang, 2017; Yurt & Sünbül, 2014; Živković et al., 2023). On the other hand, attitude is also a strong predictor of behavior (Ajzen & Fishbein, 1987). The related literature shows that a weak but significant correlation between attitudes and achievement is usually found (Aiken, 1976). This situation was also the case in this research, which is supported by the findings of other studies (Abalı Öztürk & Şahin, 2015; Adesoji & Yara, 2008; Çavdar & Şahan, 2019; Moenikia & Zahed-Babelan, 2010; Pyzdrowski et al., 2013).

It should be noted that studies focusing on the underlying mechanisms of the brain to explain the aforementioned relationships reveal noteworthy findings. For example, Ashcraft and Kirk (2001) found that MA reduced the performance of working memory, resulting in poor performance on math problems. Moreover, Chen et al. (2018) revealed that a positive attitude increased the engagement of the hippocampal learning-memory system, resulting in greater math performance. These findings suggest that the performance of working memory might be a mediator variable between the actual math performance/achievement and other psychological variables. Thus, future studies are recommended to include the measurement of brain activity and examine the possible mediator role, which was beyond the scope of the current study.

The findings of the current study are important for a few reasons. Firstly, by testing a comprehensive model, this study revealed structural relationships among significant predictors of math achievement, which contributes to the literature by addressing this gap. Secondly, since MAch is highly valued and a great deal of effort has been spent to increase MAch (e.g., Gula, Hoessler, & Maciejewski, 2015; Oppenheimer et al., 2020; Pohjolainen et al., 2018), future practices can benefit from the findings of the current study. It has already been reported in various studies that interventions aimed at reducing MA improved MAch (Brunyé et al., 2013; Jansen et al., 2013; Park et al., 2014). Similar procedures aiming at increasing MS and AtM can be carried out. Such procedures are likely to not only reduce MA but also increase the MAch of students.

Although this study revealed empirical evidence about the antecedents of MAch, the findings should be approached with caution considering some limitations of the study. First of all, this study, like many others, used a self-report survey to collect data. Such data always bear the possibility of inaccurate responses. The sample of the study was composed of middle school students. Since random sampling was not possible, readers should be cautious about generalizing the results. Moreover, the results cannot be generalized to students at different school stages although the pattern of the relationships is similar across different school stages (Aiken, 1976). Thirdly, the data of the study had a cross-sectional nature, which means further longitudinal or experimental studies are required for the true casualty. Finally, the proposed model accounted for a great part of the variance in MA and a relatively small variance in MAch and had a good fit with the data. Moreover, apart from having a strong theoretical basis, the examination of alternative models supported the proposed model over others. However, this does not mean that our proposed model is the best model to explain MAch. In other words, there can be other variables and models to better explain MAch. So, future studies are recommended to test further models including other related variables. Although this study has some limitations, it currently provides a meaningful model based on a strong theoretical background to explain MAch. The study provided empirical evidence about the structural relationships between AtM, MS, and MAch as mediated by MA.

Author Contributions

The data was collected by the second author. Data analysis was performed by the first author. The authors contributed equally to the remaining parts of the study. The authors have read and approved the final version of the study.

Ethical Declaration

This research was carried out with the approval obtained from the Social Sciences and Humanities Research Ethics Committee of Tokat Gaziosmanpaşa University on 17/06/2022, numbered 09.28.

Conflict of Interest

The authors declare that there is no conflict of interest with any institution or person within the scope of the study.

References

Abalı Öztürk, Y., & Şahin, Ç. (2015). Matematiğe ilişkin akademik başarı, özyeterlik ve tutum arasındaki ilişkilerin belirlenmesi. *The Journal of Academic Social Science Studies*, *31*, 343-366. http://dx.doi.org/10.9761/JASSS2621

Adesoji, F. A., & Yara, P. O. (2008). Some student factors as correlates of achievement in mathematics in southwestern Nigeria. *European Journal of Scientific Research, 19*(3), 424-434.

Adediwura, A. A. (2011). The development and confirmatory factor analysis of a scale for the measurement of gifted students attitude towards mathematics. *World Journal of Education*, *1*(1), 52-62.

Aiken, L. R. (1970). Attitudes toward mathematics. *Review of Educational Research*, *40*(4), 551-596. https://doi.org/10.2307/1169746

Aiken, L. R. (1976). Update on attitudes and other affective variables in learning mathematics. *Review of Educational Research*, *46*(2), 293-311. https://doi.org/10.3102/00346543046002293

Aiken, L. R., & Dreger, R. M. (1961). The effect of attitudes on performance in mathematics. *Journal of Educational Psychology*, *52*(1), 19–24. https://doi.org/10.1037/h0041309

Ajzen, I., & Fishbein, M. (1987). Attitude-behavior relations: A theoretical analysis and review of empirical research. *Psychological Bulletin*, *84*(5), 888–918. https://doi.org/10.1037/0033-2909.84.5.888

Akın, A., & Kurbanoğlu, İ. N. (2011). The relationships between math anxiety, math attitudes, and self-efficacy: A structural equation model. *Studia Psychologica*, *53*(3), 263-273.

Anderson, J. C., & Gerbing, D. W. (1988). Structural equation modeling in practice: A review and recommended two-step approach. *Psychological Bulletin, 103*(3), 411-423.

Ashcraft, M. H. (2022). Math anxiety: Personal, educational, and cognitive consequences. *Current Directions in Psychological Science*, *11*(5), 181-185. https://doi.org/10.1111/1467-8721.00196

Ashcraft, M. H., & Kirk, E. P. (2001). The relationships among working memory, math anxiety, and performance. *Journal of Experimental Psychology: General*, *130*(2), 224–237. https://doi.org/10.1037/0096-3445.130.2.224

Aşkar, P. (1986). Matematik dersine yönelik tutumu ölçen likert-tipi bir ölçeğin geliştirilmesi. *Eğitim ve Bilim*(62), 31-36.

Bandura, A. (1997). *Self-efficacy: The exercise of control.* New York: W H Freeman & Company.

Baumgartner, H., & Homburg, C. (1996). Applications of structural equation modeling in marketing and consumer research: A review. *International Journal of Research in Marketing*, *13*(2), 139-161.

Beilock, S. L., & Carr, T. H. (2005). When high-powered people fail working memory and "choking under pressure" in math. *Psychological Science*, *16*, 101–105. https://doi.org/10.1111%2Fj.0956-7976.2005.00789.x

Bindak, R. (2005). İlköğretim öğrencileri İçin matematik kaygı ölçeği. *Fırat Üniversitesi Fen ve Mühendislik Bilimleri Dergisi*, *17*(2), 442-448.

Brunyé, T. T., Mahoney, C. R., Giles, G. E., Rapp, D. N., Taylor, H. A., & Kanarek, R. B. (2013). Learning to relax: Evaluating four brief interventions for overcoming the negative emotions accompanying math anxiety. *Learning and Individual Differences*, *27*, 1-7. https://doi.org/10.1016/j.lindif.2013.06.008

Byrne, B. M. (2010). *Structural equation modeling with AMOS: Basic concepts, applications, and programming.* New York: Routledge.

Carey, E., Hill, F., Devine, A., & Szücs, D. (2016). The chicken or the egg? The direction of the relationship between mathematics anxiety and mathematics performance. *Frontiers in Psychology*, *6*(1987), 1-6. https://doi.org/10.3389/fpsyg.2015.01987

Casanova, S., Vukovic, R. K., & Kieffer, M. J. (2021). Do girls pay an unequal price? Black and Latina girls' math attitudes, math anxiety, and mathematics achievement. *Journal of Applied Developmental Psychology*, 73, 101256. https://doi.org/10.1016/j.appdev.2021.101256

Chen, L., Bae, S. R., Battista, C., Qin, S., Chen, T., Evans, T. M., & Menon, V. (2018). Positive attitude toward math supports early academic success: Behavioral evidence and neurocognitive mechanisms. *Psychological Science*, *29*(3), 390–402. https://doi.org/10.1177/0956797617735528

Chen, P. P. (2003). Exploring the accuracy and predictability of the self-efficacy beliefs of seventh-grade mathematics students. *Learning and Individual Differences*, *14*(1), 77-90. https://doi.org/10.1016/j.lindif.2003.08.003

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences (2nd ed.).* Hillsdale, NJ: Lawrence Earlbaum Associates.

Cohen, L., Manion, L., & Morrison, K. (2005). *Research methods in education (5th ed.).* USA: Taylor & Francis.

Commodari, E., & La Rosa, V. L. (2021). General academic anxiety and math anxiety in primary school. The impact of math anxiety on calculation skills. *Acta Psychologica*, 220, 103413.

Cook, D. A., & Artino, A. R. (2016). Motivation to learn: an overview of contemporary theories. *Medical Education*, *50*(10), 997–1014. https://doi.org/10.1111/medu.13074

Cvencek, D., Brečić, R., Gacesa, D., & Meltzoff, A. N. (2021). Development of math attitudes and math self-concepts: Gender differences, implicit–explicit dissociations, and relations to math achievement. *Child Development*, *92*(5), 1673-1678. https://doi.org/10.1111/cdev.13523

Çavdar, D., & Şahan, H. H. (2019). Matematik dersinde akademik başarı, öz yeterlik ve matematik dersine yönelik tutum arasındaki ilişkinin incelenmesi. *Necatibey Eğitim Fakültesi Elektronik Fen ve Matematik Eğitimi Dergisi*, *13*(2), 979-999. https://doi.org/10.17522/balikesirnef.605618

Daker, R. J., Gattas, S. U., Sokolowski, H. M., Green, A. E., & Lyons, I. M. (2021). First-year students' math anxiety predicts STEM avoidance and underperformance throughout university, independently of math ability. *npj Science of Learning*, *6*(17), 1-17. https://doi.org/10.1038/s41539-021-00095-7

Devine, A., Fawcett, K., Szucs, D., & Dowker, A. (2012). Gender differences in mathematics anxiety and the relation to mathematics performance while controlling for test anxiety. *Behavioral and Brain Functions*, *8*(1), 33. https://doi.org/10.1186/1744-9081-8-33

Du, C., Qin, K., Wang, Y., & Xin, T. (2021). Mathematics interest, anxiety, self-efficacy and achievement: Examining reciprocal relations. *Learning and Individual Differences, 91*, 102060. https://doi.org/10.1016/j.lindif.2021.102060

European Commission. (2011, June 23). *Math-Bridge: European remedial content for mathematics (Math-Bridge)*. https://joinup.ec.europa.eu/collection/education-culture-and-sport/document/math-bridge-european-remedial-content-mathematics-math-bridge

Filiz, A., & Gür, H. (2020). Matematikte özyeterlik algılar, motivasyonlar, kaygılar ve tutumlar arasında ilişki. *Balıkesir Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 23*(44), 783-804. https://doi.org/10.31795/baunsobed.704334

Forsblom, L., Pekrun, R., Loderer, K., & Peixoto, F. (2022). Cognitive appraisals, achievement emotions, and students' math achievement: A longitudinal analysis. *Journal of Educational Psychology, 114*(2), 346–367. https://doi.org/10.1037/edu0000671

Gula, T., Hoessler, C., & Maciejewski, W. (2015). Seeking mathematics success for college students: a randomized field trial of an adapted approach. *International Journal of Mathematical Education in Science and Technology, 46*(8), 1130-1148. https://doi.org/10.1080/0020739X.2015.1029026

Hair, J. F., Black, W. C., Babin, B. J., Anderson, R. E., & Tatham, R. L. (2006). *Multivariate data analysis.* Upper Saddle River: Pearson Prentice Hall.

Hoffman, B., & Schraw, G. (2009). The influence of self-efficacy and working memory capacity on problem-solving efficiency. *Learning and Individual Differences, 19*(1), 91-100. https://doi.org/10.1016/j.lindif.2008.08.001

Jain, S., & Dowson, M. (2009). Mathematics anxiety as a function of multidimensional self-regulation and self-efficacy. *Contemporary Educational Psychology*, *34*(3), 240-249. https://doi.org/10.1016/j.cedpsych.2009.05.004

Jansen, B. R., Louwerse, J., Straatemeier, M., Van der Ven, S. H., Klinkenberg, S., & Van Der Maas, H. L. (2013). The influence of experiencing success in math on math anxiety, perceived math competence, and math performance. *Learning and Individual Differences, 24*, 190-197. https://doi.org/10.1016/j.lindif.2012.12.014

Kline, R. B. (2005). *Principles and practice of structural equation modeling (2nd edition).* The Guilford Press.

Kline, R. B. (2011). *Principles and practice of structural equation modeling (3rd edition).* The Guilford Press.

Lane, J., & Lane, A. (2001). Self-efficacy and academic performance. *Social Behavior and Personality: An International Journal*, *29*(7), 687–693. https://doi.org/10.2224/sbp.2001.29.7.687

Larsen, N. E., & Jang , E. E. (2022). Instructional practices, students' self-efficacy and math achievement: A multi-level factor score path analysis. *Canadian Journal of Science, Mathematics and Technology Education*(21), 803–823. https://doi.org/10.1007/s42330-021-00181-3

Little, T. D., Cunningham, W. A., Shahar, G., & Widaman, K. F. (2002). To parcel or not to parcel: Exploring the question, weighing the merits. *Structural Equation Modeling*, *9*(2), 151-173. https://doi.org/10.1207/S15328007SEM0902_1

Luttenberger, S., Wimmer, S., & Paechter, M. (2018). Spotlight on math anxiety. *Psychology Research and Behavior Management*, *11*, 311–322. https://doi.org/10.2147/PRBM.S141421

Ma, X. (1999). A meta-analysis of the relationship between anxiety toward mathematics and achievement in mathematics. *Journal for Research in Mathematics Education,* *30*(5), 520–540. https://doi.org/10.2307/749772

MacCallum, R. C., Browne, M. W., & Sugawara, H. M. (1996). Power analysis and determination of sample size for covariance structure modeling. *Psychological Methods*, *1*(2), 130-149.

MacKinnon, D. P., Lockwood, C. M., & Williams, J. (2004). Confidence limits for the indirect effect: distribution of the product and resampling methods. *Multivariate Behavioral Research,* *39*(1), 99-128. https://doi.org/10.1207/s15327906mbr3901_4

Marsh, H. W., Hau, K. T., & Wen, Z. (2004). In search of golden rules: Comment on hypothesis-testing approaches to setting cutoff values for fit indexes and dangers in overgeneralizing Hu and Bentler's (1999) findings. *Structural Equation Modeling, 11*(3), 320-341.

Medikoğlu, O. (2020). İlkokul öğrencilerinin matematik öz yeterlik kaynakları ile matematik kaygı düzeyleri arasındaki ilişkinin incelenmesi. *Eğitim Kuram ve Uygulama Araştırmaları Dergisi, 6*(1), 35-52.

Meece, J. L., Wigfield, A., & Eccles, J. S. (1990). Predictors of math anxiety and its influence on young adolescents' course enrollment intentions and performance in mathematics. *Journal of Educational Psychology, 82*(1), 60–70. https://doi.org/10.1037/0022-0663.82.1.60

Miller, H., & Bichsel, J. (2004). Anxiety, working memory, gender, and math performance. *Personality and Individual Differences,* *37*(3), 591–606. https://doi.org/10.1016/j.paid.2003.09.029

Moenikia, M., & Zahed-Babelan, A. (2010). A study of simple and multiple relations between mathematics attitude, academic motivation and intelligence quotient with mathematics achievement. *Procedia - Social and Behavioral Sciences,* *2*(2), 1537-1542. https://doi.org/10.1016/j.sbspro.2010.03.231

MoNE. (2013). Millî Eğitim Bakanlığı Ortaöğretim Kurumları Yönetmeliği. *Resmi Gazete, 28758.*

MoNE. (2019). *PISA 2018 Türkiye ön raporu.* Ankara: T.C. Millî Eğitim Bakanlığı. http://pisa.meb.gov.tr/eski%20dosyalar/wp-content/uploads/2020/01/PISA_2018_Turkiye_On_Raporu.pdf

MoNE. (2022, May 17). *Matematik seferberliği başladı*. https://www.meb.gov.tr/matematik-seferberligi-basladi/haber/26241/tr

Mustoe, L., & Lawson, D. (2002). *Mathematics for the European engineer. A curriculum for the twenty first century.* Brussels: The European Society for Engineering Education. http://www.kmf.fgg.uni-lj.si/Matematika/Core%20Curriculum.pdf

Oppenheimer, S. B., Mills, J. I., Zakeri, A., Payte, T. R., Lidgi, A., & Zavala, M. E. (2020). An approach to improving student success in science, technology, engineering, and mathematics (STEM) career pathways. *Ethnicity & Disease*, *30*(1), 33-40. https://doi.org/10.18865/ed.30.1.33

Pajares, F., & Kranzler, J. (1995). Self-efficacy beliefs and general mental ability in mathematical problem-solving.

Contemporary Educational Psychology, 20(4), 426–443. https://doi.org/10.1006/ceps.1995.1029
Pajares, F., & Miller, M. D. (1994). Role of self-efficacy and self-concept beliefs in mathematical problem solving: A path analysis. *Journal of Educational Psychology, 86*(2), 193–203. https://doi.org/10.1037/0022-0663.86.2.193
Pantoja, N., Schaeffer, M. W., Rozek, C. S., Beilock, S. L., & Levine, S. C. (2020). Children's math anxiety predicts their math achievement over and above a key foundational math skill. *Journal of Cognition and Development, 21*(5), 709-728. https://doi.org/10.1080/15248372.2020.1832098
Park, D., Ramirez, G., & Beilock, S. L. (2014). The role of expressive writing in math anxiety. *Journal of Experimental Psychology: Applied, 20*(2), 103–111. https://doi.org/10.1037/xap0000013
Pekrun, R. (2006). The control-value theory of achievement emotions: Assumptions, corollaries, and implications for educational research and practice. *Educational Psychology Review, 18*(4), 315–341. https://doi.org/10.1007/s10648-006-9029-9
Phan, H. P. (2012). Informational sources, self-efficacy and achievement: a temporally displaced approach. *Educational Psychology, 32*(6), 699-726. https://doi.org/10.1080/01443410.2012.708320
Pinxten M., Marsh H. W., De Fraine B., Van Den Noortgate W., & Van Damme J. (2014). Enjoying mathematics or feeling competent in mathematics? Reciprocal effects on mathematics achievement and perceived math effort expenditure. *British Journal of Educational Psychology, 84*(1), 152–174. https://doi.org/10.1111/bjep.12028
Pohjolainen, S., Nykänen, O., Venho, J., & Kangas, J. (2018). Analysing and improving students' mathematics skills using ICT-tools. *EURASIA Journal of Mathematics, Science and Technology Education, 14*(4), 1221-1227. https://doi.org/10.29333/ejmste/81869
Pyzdrowski, L. J., Sun, Y., Curtis, R., Miller, D., Winn, G., & Hensel , R. A. (2013). Readiness and attitudes as indicators for success in college calculus. *International Journal of Science and Mathematics Education, 11*, 529–554. https://doi.org/10.1007/s10763-012-9352-1
Recber, S., Isiksal, M., & Koç, Y. (2018). Investigating self-efficacy, anxiety, attitudes and mathematics achievement regarding gender and school type. *Anales de Psicología, 34*(1), 41-51. http://dx.doi.org/10.6018/analesps.34.1.229571
Sağkal, A. S., & Sönmez, M. T. (2022). The effects of perceived parental math support on middle school students' math engagement: The serial multiple mediation of math self-efficacy and math enjoyment. *European Journal of Psychology of Education, 37*(2), 341–354. https://doi.org/10.1007/s10212-020-00518-w
Schumacker, R. E., & Lomax, R. G. (2004). *A beginner's guide to structural equation modeling (2nd edition.* Lawrence Erlbaum Associates.
Skaalvik, E. M., Federici, R. A., & Klassen, R. M. (2015). Mathematics achievement and self-efficacy: Relations with motivation for mathematics. *International Journal of Educational Research, 72,* 129–136. https://doi.org/10.1016/j.ijer.2015.06.008
Sorvo, R., Kiuru, N., Koponen, T., Aro, T., Viholainen, H., Ahonen, T., & Aro, M. (2022). Longitudinal and situational associations between math anxiety and performance among early adolescents. *Annals of the New York Academy of Sciences, 1514*(1), 174-186.
Suárez-Pellicioni, M., Núñez-Peña, M. I., & Colomé, À. (2016). Math anxiety: a review of its cognitive consequences, psychophysiological correlates, and brain bases. *Cognitive, Affective, & Behavioral Neuroscience, 16*(1), 3–22. https://doi.org/10.3758/s13415-015-0370-7
Tian, Y., Fang, Y., & Li, J. (2018). The effect of metacognitive knowledge on mathematics performance in self-regulated learning framework—multiple mediation of self-efficacy and motivation. *Frontiers in Psychology, 9*(2518), 1-11. https://doi.org/10.3389/fpsyg.2018.02518
Tomasetto, C., Morsanyi, K., Guardabassi, V., & O'Connor, P. A. (2021). Math anxiety interferes with learning novel mathematics contents in early elementary school. *Journal of Educational Psychology, 113*(2), 315–329. https://doi.org/10.1037/edu0000602
Umay, A. (2001). İlköğretim matematik öğretmenliği programının matematiğe karşı özyeterlik algısına etkisi. *Journal of Qafqaz University*(8).
Weissgerber, S. C., Grünberg, C., Neufeld, L., Steppat, T., & Reinhard, M. (2022). The interplay of math anxiety and math competence for later performance. *Social Psychology of Education*. https://doi.org/10.1007/s11218-022-09700-y
Xu, Z., & Jang, E. E. (2017). The role of math self-efficacy in the structural model of extracurricular technology-related activities and junior elementary school students' mathematics ability. *Computers in Human Behavior, 68*, 547–555. https://doi.org/10.1016/j.chb.2016.11.063
Yu, X., Zhou, H., Sheng, P., Ren, B., Wang, Y., Wang, H., Zhou, X. (2023). Math anxiety is more closely associated with math performance in female students than in male students. *Current Psychology*. https://doi.org/10.1007/s12144-023-04349-y
Yurt, E., & Sünbül, A. M. (2014). A structural equation model explaining 8th grade students' mathematics achievements. *Educational Sciences: Theory & Practice, 14*(4), 1642-1652. https://doi.org/10.12738/estp.2014.4.2193
Zhang, J., Zhao, N., & Kong, K. P. (2019). The relationship between math anxiety and math performance: A meta-analytic investigation. *Frontiers in Psychology, 10*(1613), 1-17. https://doi.org/10.3389/fpsyg.2019.01613
Živković, M., Pellizzoni, S., Doz, E., Cuder, A., Mammarella, I., & Passolunghi, M. C. (2023). Math self-efficacy or anxiety? The role of emotional and motivational contribution in math performance. *Social Psychology of Education*, 1-23. https://doi.org/10.1007/s11218-023-09760-8