

Predicting Mathematics Anxiety: The Role of Mathematics Self-efficacy

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Abstract

The present paper examined the effects of the variables- perceived teacher math self-efficacy, perceived parental math self-efficacy, self-regulation, and student math self-efficacy on students' mathematics anxiety in higher education. Considering the importance of mathematics achievement and its relation to mathematics anxiety, the understanding of the factors that generate mathematics anxiety is essential. The objective of the present paper was to build an extrapolative model of college students' mathematics anxiety based on the variables-perceived parental mathematics self-efficacy, perceived teacher mathematics self-efficacy as the exogenous variables, and self-regulation and students' mathematics self-efficacy acting as the mediating variables, by using structural equation technique. The findings of the present study confirmed that mathematics self-efficacy is negatively and directly related to students' mathematics anxiety, self-regulation is directly and positively related to self-efficacy and perceived teacher self-efficacy is directly and significantly related to self-regulation.

Keywords: self-efficacy, self-regulation, mathematics anxiety, mathematics achievement

Mathematics is a fundamental discipline of knowledge as it occupies a key position in an individual's social, personal, and mental growth. The need of mathematics education in reasoning and logical thinking has been emphasized in The Secondary Education Commission (1952), the National Curriculum Framework (2005), as well as in National Policy on Education (1986, 2020).

According to Locke, reasoning skills are inculcated in children by learning mathematics. Mathematical skills are essential to augment curiosity and innovation, to become a participant of the technology-led world. Therefore, learning mathematical skills is essential for the well-being of students and individuals alike.

The importance of mathematics education from a social as well as an economic perspective has spurred research (Hembree, 1990; Ashcraft, 2002; Lavasani, Hejazi and Varzaneh, 2011) in the field of mathematics education which primarily focused on the role of various factors impacting the mathematics achievement of individuals. These researchers reported that among the many factors affecting mathematics achievement, mathematics anxiety plays a key role in the students' mathematical disposition, enrolment in colleges, and careers in STEM (Ashcraft and Rudig, 2012). Mathematics anxiety research has become more widespread as the researchers try to find the reason why a major portion of the country's population keeps themselves away from mathematics. Additionally, the National Council of Teachers of Mathematics (NCTM, 1989) identified mathematics anxiety as a problem and included it in its assessment practices, thereby enabling teachers to gauge students' mathematical dispositions.

Mathematics anxiety

Mathematics anxiety is defined as 'an unpleasant emotional state linked with facets of fear and dread directed towards certain outcomes' (Hembree, 1990) e.g., a mathematical task. Dreger and Aiken (1957), first presented the concept of mathematics anxiety and subsequently mathematics anxiety has warranted

a great deal of research in the context of learning processes (Tobias, 1983; Ansari & Derakshan, 2010; Cowden, 2010), classroom behaviour (Younger, Schneider, & Guirguis-Younger, 2008) and mathematics achievement (Ashcraft, 2002). A line of research has examined the bi-dimensional structure of mathematics anxiety-the affective dimension which is characterized by emotional responses associated with anxiety and the cognitive dimension that explains the 'worry' factor of mathematics anxiety (Wigfield & Meece, 1988; Bandalos *et al.*, 1995; Ho *et al.*, 2000). Factors such as (a) 'strict' classroom environment with a focus on the textual matter (Gresham, 2007); (b) teachers' mathematics anxiety and lack of subject knowledge (Ramirez *et al.*, 2018); (c) experiences in mathematics classes (Turner *et al.*, 2002); (d) lack of parental support (Macmull & Ashkenazi, 2019); and (e) teachers' assumptions of students' prior knowledge of concepts or use of incomprehensible mathematics vocabulary (Brady & Bawd, 2005) have been reported to be related to mathematics anxiety. Some authors (Luttenberger *et al.*, 2018) have also examined the relationship of mathematics anxiety with other interacting variables such as *self-efficacy* and *motivation* and have reported that personal variables like mathematics self-efficacy, self-regulation, and environmental variables like parental and teacher support affect mathematics anxiety significantly.

Mathematics self-efficacy

Mathematics self-efficacy is moored on the social cognitive theory (Bandura, 1986) which posits that self-efficacy is based on students' judgments of their capability to perform academic tasks, or their beliefs of their ability to accomplish such tasks. Bandura (1986) emphasized that people tend to refrain from taking up tasks that they believe will challenge their capabilities, and avoid such situations e.g., a mathematical task.

Mathematics self-efficacy has been defined as 'the confidence in one's ability to complete mathematical tasks' (Bandura, 1986 as cited in Pajares & Miller,

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1994). Authors (Schunk&Miller, 2002; Pajares& Miller, 1994; Meece 1990) have demonstrated that high mathematics self-efficacy results in better mathematics performance and that self-efficacious student expend more time, work harder when they come across a difficult task or a complex mathematical concept. Mathematics self-efficacy has also been found to impact students' mathematics ability, students with low self-efficacy have reduced computational accuracy. Researchers have reported that mathematics self-efficacy predicts of mathematics anxiety significantly in contrast to other variables like prior mathematics experiences, attitude towards mathematics, gender, age, socio-economic background (Hackett, 1985; Nunez-Pena et al, 2014). Most of the studies which establish a strong relationship between the constructs, mathematics self-efficacy and anxiety were conducted in school settings. Therefore, the present study aims to examine the effect of self-efficacy on mathematics anxiety of students enrolled in college mathematics courses.

Parent and teacher mathematics self-efficacy

Schunk (1991) reported that mathematics self-efficacy of important adults-teachers and parents are predictors of mathematics self-efficacy of schoolchildren. It is reported that excessive help from teachers' decrease student self-efficacy due to which the student fails to develop fluency in mathematical tasks and mathematical competencies. (Urduan& Midgley, 2003). Students' self-efficacy also reduces in a classroom environment where the emphasis is on social comparison and competition rather than learning, teamwork, and student interests (Anderman & Midgley, 1997; Anderman & Young, 1994). Student-centric pedagogy encourage critical thinking, classroom interactions among peers, and nurture an intellectually stimulating environment thereby supporting students' cognitive development (Duke, & Akey, 2004), by affecting students' self-efficacy positively (Meece et al. 2003). This study additionally explores the relationship between perceived mathematics self-efficacy of teacher and parent and that of the college students.

Generally, parents help children to build aptitude by providing an ecosystem comprising of some trials, encouragement, by setting high but realizable goals, and by including positive role models (Schunk, 1991). Parents involved in children's academic activities affect children's mathematics self-efficacy as children observe and assimilate their perception of their parents' mathematical ability (Bartley & Ingram, 2017). Studies have been conducted to explore the relationship between parental mathematics self-efficacy and school children's mathematics self-efficacy and the findings reveal that parents' mathematics self-efficacy contributed to the development of children's mathematics self-efficacy. Authors have also reported that parents play a crucial role in the development of children's mathematics self-efficacy as they are the primary role models for

their children (Vukovic et al, 2013; Maloney et al, 2015). A line of study has found that there is a significant decline in academic self-efficacy of students at the middle school and secondary school, especially in mathematics (Eccles & Wigfield, 2002) but, no studies have looked at the impact of parental and teacher's mathematics self-efficacy on the mathematics self-efficacy of students in college mathematics courses.

Furthermore, literature on mathematics anxiety reveals students' mathematics anxiety is related indirectly to students' self-regulation. In this context, Jain et al. (2009) reported mathematics anxiety is a function of the self-regulation, a multi-dimensional construct. They also suggested that the indirect effect of self-regulation on mathematics anxiety acting through self-efficacy is more significant than the direct effect of self-regulation on mathematics anxiety.

Self-regulation

Self-regulation in an academic setting has been conceptualized as i) the meta-cognitive schemes for planning, observing, and adapting cognition (e.g., Brown, et al. 1983; Corno, 1986; Zimmerman & Martinez- Pons, 1988), ii) the organisation and guideline of efforts on classroom academic tasks and iii) the actual cognitive strategies that students use to learn, remember, and understand the instructional material (Zimmerman & Martinez-Pons, 1988). Mostly, academic self-regulation approaches represent the stages for processing information. Researchers have reported self-regulation and students' mathematics self-efficacy are directly related (Brown & Hirschfeld, 2007; Tanner & Jones, 2003). Generally, the self-efficacy of students increase when they apply the self-regulatory approaches to learn and this leads to better academic achievements.

Rationale of the study

Few studies have examined the effect of parental mathematics self-efficacy, teacher mathematics self-efficacy, and self-regulation on mathematics anxiety of college students though; it has been observed that parental mathematics self-efficacy, teacher mathematics self-efficacy, self-regulation led to increased mathematics self-efficacy in younger pupils, which reduces their mathematics anxiety.

In this context, the two key research questions are: (1) how do mathematics self-regulation, perceived teacher self-efficacy, and perceived parent self-efficacy affect college students' mathematics self-efficacy, and (2) how is college students' mathematics self-efficacy linked to their mathematics anxiety?

The objective of this study was to examine mathematics anxiety based on self-regulation and mathematics self-efficacy. Mathematics anxiety was conceptualized as having two dimensions -the affective dimension and the cognitive dimension. The theory postulated that perceived parental mathematics

self-efficacy, perceived teacher mathematics self-efficacy, and self-regulation will influence students' mathematics self-efficacy and the latter construct would affect mathematics anxiety. Structural equation modeling technique was used to examine a sequence of dependence relationships between the identified latent constructs.

Method

Design

Based on past research on mathematics anxiety, we identified six latent constructs that fit the context of the present study. Multiple-item scales are used to measure the construct(s) of interest, as the constructs are not directly measurable. The specific indicator variables associated with each latent construct have been identified, from similar studies that endorse the context of this study.

The six latent constructs have the following operational definitions.

- Students' mathematics self-efficacy (SSE) - Students' confidence in their ability to complete mathematical tasks.
- Students' perception of teacher's mathematics self-efficacy (TSE)-Students' perception of teachers' confidence in their ability to complete mathematical tasks.
- Students' perception of parental mathematics self-efficacy (PSE) - Students' perception of parents' confidence in their ability to complete mathematical tasks.
- Students' self-regulation (SR) - The actual cognitive approaches that a student follows to learn, remember, and understand mathematical concepts.
- Mathematics anxiety (MAA) – The affective dimension associated with mathematics anxiety explains the emotional response.
- Mathematics anxiety (MAC) -The cognitive dimension associated with mathematics anxiety that explains the 'worry' part.

We used a survey method to collect data from various college students in India. After reviewing existing scales and modifying some questions to suit the population of the study, a multi-item scale was prepared. Typically, the items were measured on a 7-point, or a 5-point scale anchored with "strongly agree" (1) and "strongly disagree" (7 or 5) respectively.

The six latent constructs are measured with forty items. In the multi-item scale, 3 items measure perceived teachers' mathematics self-efficacy (TSE) and perceived parental mathematics self-efficacy (PSE) each, 4 items indicate self-regulation (SR), 10 items measure the cognitive dimension of mathematics anxiety (MAC), 12 items measure the affective dimension (MAA) and 8 items measure students' mathematics self-efficacy (SSE). The specific responses to the items were pooled so that participants with the most favorable responses resulted in the highest totals while those having the

least favorable (or unfavorable) responses got the least scores.

The population for the study constitutes students in various mathematics courses in the degree/diploma or higher level in India. The sample was collected from 175 students.

Structural equation modeling

This technique is useful in testing theory and the dependence relationships between latent constructs. Using the structural equation model building program in STATA, a two-step approach analysis of two conceptually distinct latent-variable models: measurement and structural was carried out.

Measurement model

On the basis of the literature review and the proposed conceptual theory, the relationships among the identified constructs and validation of the psychometric properties of the scales were supported through a measurement model. Since prior research had established the reliability and validity of the questionnaire, so the measurement properties were tested in the confirmatory mode. All the latent constructs were allowed to correlate with all the other constructs and the factor loading of one indicator per construct was fixed to one. The model consisted of 40 indicator variables (indicators) that assess the six latent constructs. The measured variables loaded only on one construct each i.e., cross-loadings were not allowed. The error terms were not allowed to relate to any other measured variable, and the measurement model was reported as congeneric.

In the present study, the proposed model had 95 free parameters, of which 40 were factor loadings, 21 represented factor variance and covariance terms, and 34 represented error variance terms. The total number of unique variance, and covariance terms was 820. The model was identified as an over identified one because the degrees of freedom exceeded the free parameters.

The measurement model is described in Figure. 1.

The standardized factor loadings (Table. 1) of the items measuring the six constructs were all statistically significant and the estimated standardized loadings were greater than 0.5, indicating that the items converge on the respective latent constructs. Table.1 displays the estimated average variance extracted (AVE) and construct reliability (CR) of the six latent constructs considered in the present study. The AVE estimates of TSE, SSE, MAC and MAA are 0.5 and higher which suggested adequate convergence. The AVE of SR and PSE are 0.34 and 0.42 respectively, which implied that, on average, 66% and 58% respectively, of the latent constructs SR and PSE remain unexplained by the items used to measure them (Hair et al, 2017). Construct reliability estimates were used to indicate convergent validity in SEM models. Except for PSE, the remaining five constructs had CR estimates of 0.7 and higher which specified the internal consistency of the scale.

Structural model

The structural model was set up to verify the relationships (H1-H5) among the six identified

constructs, and to examine the predictive validity of self-efficacy on the dimensions of mathematics anxiety. Based on the theory and review of literature,

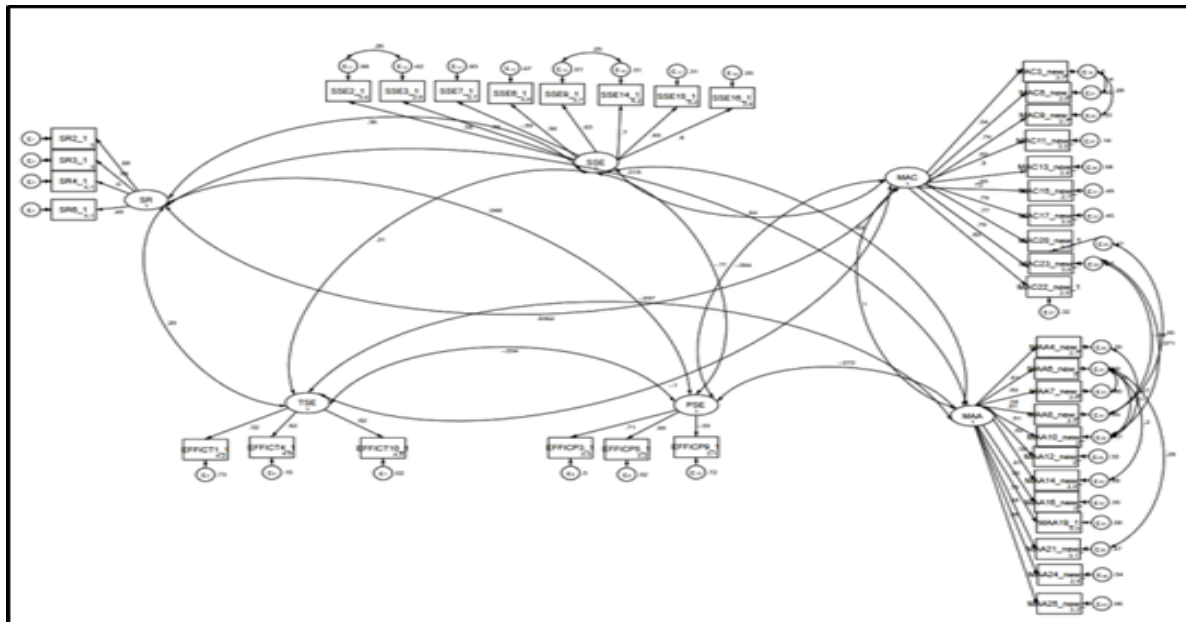


Figure1: Measurement Model

Table 1: Construct reliability and average variance extracted

Item	Construct	Loadings	Communalities	AVE	CR
SR 2	SR	0.61	0.37		
SR3	SR	0.59	0.35	0.34	0.67
SR4	SR	0.60	0.36		
SR6	SR	0.53	0.28		
EFFICT1	TSE	0.52	0.27		
EFFICT4	TSE	0.92	0.85	0.58	0.86
EFFICT10	TSE	0.62	0.38		
EFFICP3	PSE	0.71	0.50		
EFFICP5	PSE	0.69	0.48	0.42	0.31
EFFICP9	PSE	-0.53	0.28		
SSE 2	SSE	0.58	0.34		
SSE3	SSE	0.77	0.60		
SSE6	SSE	0.61	0.37		
SSE7	SSE	-0.57	0.33	0.48	0.77
SSE9	SSE	0.66	0.44		
SSE14	SSE	0.74	0.55		
SSE15	SSE	0.79	0.62		
SSE 16	SSE	0.76	0.58		
MAC3	MAC	0.57	0.32		
MAC5	MAC	0.76	0.58		
MAC9	MAC	0.83	0.68	0.53	0.93
MAC11	MAC	0.90	0.80		
MAC13	MAC	0.65	0.42		
MAC15	MAC	0.72	0.53		
MAC17	MAC	0.73	0.53		
MAC20	MAC	0.78	0.60		
MAC 22	MAC	0.82	0.68		
MAC 23	MAC	0.78	0.61		
MAA4	MAA	0.83	0.69		
MAA6	MAA	0.64	0.41		
MAA7	MAA	0.61	0.37		
MAA8	MAA	0.81	0.65		
MAA10	MAA	0.91	0.84		
MAA12	MAA	0.82	0.67		
MAA14	MAA	0.59	0.35		
MAA16	MAA	0.81	0.66		
MAA19	MAA	0.56	0.31		
MAA21	MAA	0.80	0.65		
MAA24	MAA	0.69	0.47		
MAA25	MAA	0.57	0.33		

the following relationships are specified.

H₁: Perceived parental mathematics self-efficacy is positively related to self-regulation.

H₂: Perceived teacher mathematics self-efficacy is positively related to self-regulation.

Table.4 reports the model fit for the structural model, chi-square value 1526.961 with 722 degrees of freedom, RMSEA value 0.080, CFI value 0.827, TLI value 0.814, and SRMR value 0.079. The results imply there is negligible change in the overall model

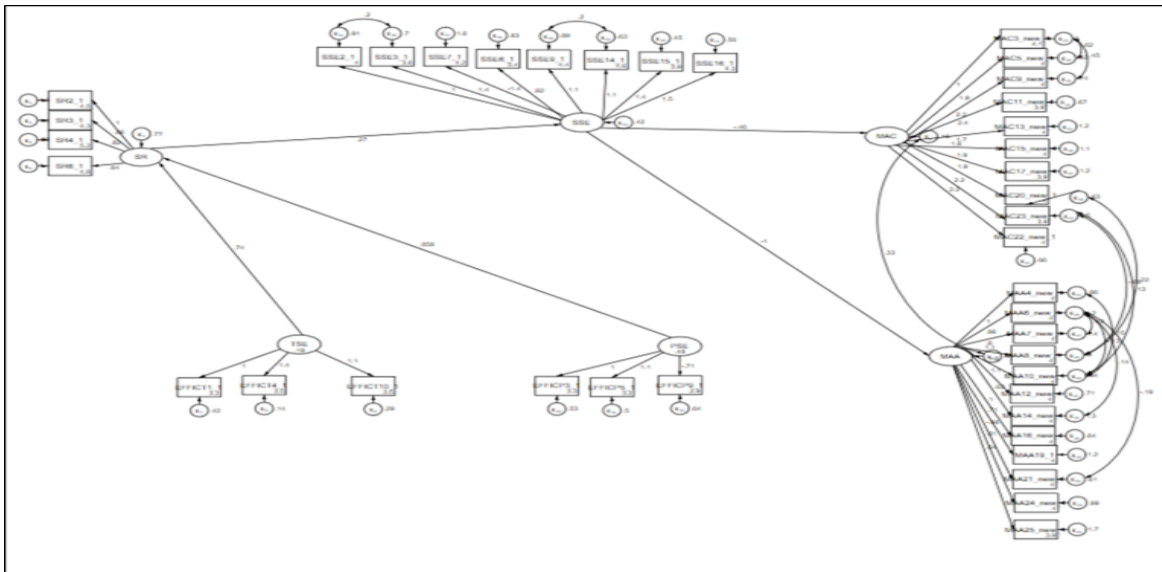


Figure 2: Structural model

H₃: Self-regulation is positively related to student mathematics self-efficacy.

H₄: Student mathematics self-efficacy is negatively related to the cognitive dimension of mathematics anxiety.

H₅: Student mathematics self-efficacy is negatively related to the affective element of mathematics anxiety.

Figure 2 presents the structural model that includes both measurement and structural components. Altogether there were forty three error terms, out of which forty were of the 40 items measuring six constructs and three of the latent constructs student self-efficacy (SSE), cognitive dimension, and affective dimensions of mathematics anxiety.

Results

The information in Table.3 shows the overall fit statistics of the measurement model (Figure.2). The chi-square is 1493.926 with 713 degrees of freedom (p<. 05) with a TLI of 0.817. The model CFI is 0.833 with an RMSEA of 0. 079 and with a 90% confidence interval of 0.074 to 0.085. The reported value of SRMR was 0.071, within the acceptable range of 0 to 0.08. These diagnostics indicated a good overall fit(Hair, Black, Babin & Anderson, 2010).

The relative improvement in fit of a postulated model as compared to the baseline model is measured by CFI (Bentler, 1990), which is a normed fit index with values between 0 and 1, a higher value indicates a better fit. The relative reduction in misfit per degree of freedom is measured by TLI (Tucker & Lewis, 1993), a non-normed index. The SRMR is defined as the difference between the observed correlation and the model implied correlation matrix.

fit from the CFA model.

Table.5 displays the structural path estimates. All but one structural path estimates were significant and in the expected direction. The estimate between SR and PSE is in the hypothesized direction (H1) but, not significant (p-value > 0.05).Although, the path between SR and PSE was not supported, the remaining four path estimates were consistent with the hypotheses, which was in line with the theory.

Discussion

The results indicated that perceived teacher mathematics self-efficacy as well as perceived parental mathematics self-efficacy, is directly and a positively related to students’ self-regulation. But, the direct influence of perceived parental mathematics self-efficacy on self-regulation is not significant. Earlier, Bartley & Ingram (2017) discussed the direct effect of perceived parental mathematics self-efficacy on self-regulation but, the result of this study provides new insight into the relationship between perceived parental mathematics self-efficacy and self-regulation. The implications are that the self-regulatory efforts of a college student are independent of the external environment.i.e. his/her parents’ mathematical ability, (as opposed to school children) rather, it is germane to his/her efforts to learn and master goals.

Perceived teacher mathematics self-efficacy influences students’ self-regulatory efforts significantly in the hypothesized direction; which implies that students’ motivation to plan their learning is not independent of the influence of the teacher’s self-efficacy. Though this is evident in younger students, this study further supports that a

teacher's self-efficacy has a positive impact on college students to an extent.

efficacy directly and negatively affects both the factors of mathematics anxiety; i.e. cognitive and

Table 3: Goodness-of-Fit Measures of the Measurement model

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Fit statistic	Value	Description
Likelihood ratio		
chi2_ms(713)	1493.926	model vs. saturated
p > chi2	0.000	
chi2_bs(780)	5443.346	baseline vs. saturated
p > chi2	0.000	
Population error		
RMSEA	0.079	Root mean squared error of approximation
90% CI, lower bound	0.074	
upper bound	0.085	
pclose	0.000	Probability RMSEA <= 0.05
Information criteria		
AIC	19123.403	Akaike's information criterion
BIC	19588.627	Bayesian information criterion
Baseline comparison		
CFI	0.833	Comparative fit index
TLI	0.817	Tucker-Lewis index
Size of residuals		
SRMR	0.071	Standardized root mean squared residual
CD	1.000	Coefficient of determination

Self-regulation has a positive and significant effect on mathematics self-efficacy, and mathematics self-

efficacy. The magnitude and the significant loading estimates between mathematics self-efficacy and

Table 4: Goodness-of-Fit Measures of the Structural model

Fit statistic	Value	Description
Likelihood ratio		
chi2_ms(722)	1526.961	model vs. saturated
p > chi2	0.000	
chi2_bs(780)	5443.346	baseline vs. saturated
p > chi2	0.000	
Population error		
RMSEA	0.080	Root mean squared error of approximation
90% CI, lower bound	0.074	
upper bound	0.086	
pclose	0.000	Probability RMSEA <= 0.05
Information criteria		
AIC	19138.438	Akaike's information criterion
BIC	19575.178	Bayesian information criterion
Baseline comparison		
CFI	0.827	Comparative fit index
TLI	0.814	Tucker-Lewis index
Size of residuals		
SRMR	0.079	Standardized root mean squared residual
CD	0.942	Coefficient of determination

both the dimensions of mathematics anxiety suggested that mathematics self-efficacy predicts mathematics anxiety significantly. Besides, we inferred from the results that higher mathematics self-efficacy is associated with a lower level of mathematics anxiety; specifically, if students are self-efficacious then they tend to worry less about mathematical tasks and are not scared when involved with mathematics.

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Table 5: Standardized path estimates of the Structural model

Structural equation model		Number of obs = 175					
Estimation method = ml							
Log likelihood = -9785.4138							
(1) [SR2_1]SR = 1							
(2) [MAC3_new_1]MAC = 1							
(3) [SSE2_1]SSE = 1							
(4) [MAA4_new_1]MAA = 1							
(5) [EFFICT1_1]TSE = 1							
(6) [EFFICP3_1]PSE = 1							
		OIM					
		Coef.	Std. Err.	z	P> z	[95% Conf. Interval]	
Structural							
SR	TSE	.737752	.2448373	3.01	0.003	.2578798	1.217624
	PSE	.058501	.146615	0.40	0.690	-.228859	.3458611
SSE							
	SR	.2699138	.0857482	3.15	0.002	.1018503	.4379772
MAC							
	SSE	-.4587183	.1229662	-3.73	0.000	-.6997277	-.217709
MAA							
	SSE	-.9989591	.1626949	-6.14	0.000	-1.317835	-.6800829

Thus, we concluded that teachers and academicians can reduce the development of students’ mathematics anxiety by escalating their mathematics self-efficacy more than any other factor. Moreover, as perceived teacher mathematics self-efficacy has a significant effect even for college students, so teachers play a significant role in the development of college students’ mathematics anxiety to an extent.

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