Direct and Indirect Effect of Self-Efficacy, Anxiety and Interest on Algebraic Problem-Solving Achievement

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***Abstract**: This study examines the direct and indirect effects of some affective constructs, such as self-efficacy (SE), mathematics anxiety (MA) and mathematics interest (MI) on algebraic problem solving achievement (PSA). The sample of the study consists of 400 class IX secondary school students in Morigaon district of Assam, India. The instruments employed in this investigation were the SE scale, the MA scale, the MI scale and the algebraic PSA test. The relationship between affective constructs and PSA in algebra is investigated using two-stage structural equation modeling. The results reveal that SE is the only affective construct that had a direct effect on algebraic PSA, while MI has an indirect effect on algebraic PSA through SE. Also, MA has an indirect effect on algebraic PSA through MI and SE. The findings suggested that mathematics educator should adopt innovative strategies to make the subject matter more interesting and increase students' self-efficacy, which may reduce math anxiety. These will assist the students in enhancing their problem-solving abilities and their achievement.*

Keywords: Algebraic Problem-Solving; Mathematics Anxiety; Mathematics Interest; Self-Efficacy; Structural equation modeling.

INTRODUCTION

Algebra is regarded as a gateway to the elevated mathematical achievement and future opportunities (Foegen, 2008). Learning of algebra improves students' reasoning ability, critical thoughts and problem solving ability (Bell, 1996). Algebra is introduced informally at the elementary level when learning arithmetic, but it is explicitly used at the secondary level. In the Indian education system, algebra is introduced in grade 6 (age 11+). At the beginning stage, the main approach is conventional and places a strong emphasis on symbol manipulation. At the secondary level, algebra is widely discussed and at this stage, symbolic algebra is used for solving daily life problems through the development of algebraic expressions, polynomials, linear and quadratic equations, and their solutions (NCERT, 2005). Algebra occupies a major part of secondary mathematics (NCERT, 2005) and many students face difficulties due to its abstract nature at this stage (Kieran, 2006). Algebraic problem solving is one of the most challenging aspects of mathematics at the secondary level. Most of the nation puts ample stress on the application of mathematics in daily life and promote mathematical reasoning as well as problem-

solving techniques in their mathematics curricula (Faulkner et al., 2020). In spite of efforts made to provide mathematical problem-solving strategies, it is found that student achievement is not satisfactory (Holton et al., 1999, Wicaksono & Korom, 2022).

Achievements in mathematics lead to a world of abundant opportunities. But, unfortunately it has been witnessed that both developing and developed countries are plagued by the issue of poor achievement in mathematics (Ozcan & Gumus, 2019). Consciousness on the cognitive and affective constructs of the students would bring greater achievement in mathematical problem solving (Furinghetti & Morselli, 2009, Guenyari et al., 2022, Hoffman, 2010). The understanding of learning in the cognitive domain is thought to be aided by affective factors, which also significantly influence learning outcomes (Furinghetti & Morselli, 2009). Empirically, it has been established that several factors affect students' problem-solving achievement (Guven & Cabakar, 2013, Zan et al., 2006). Among these, the most influential affective factors connected to mathematical problem solving that are given the greatest importance and relevance in the mathematical domain are self-concept, self-efficacy, mathematics anxiety, mathematics interest and attitudes. Guven and Cabakor (2013) investigated the relationship between affecting factors and problem-solving achievements (PSA) of 7^{th} standard Turkish students. Their study reveals a moderate correlation between PSA and problem-solving beliefs, self-efficacy, and anxiety. Hoffman (2010) highlighted that mathematics anxiety (MA) and self-efficacy (SE) are significant factors in mathematical problem-solving. Several studies have shown an association between mathematical problem-solving and SE (Karaoglan Yilmaz, 2022; Kohen et al., 2019). Other studies also signify that anxiety have major effect on their mathematical achievement (Vukovic et al., 2013). Moreover, SE and MI have been recognized as the most influential factors in problem-solving (Niemivirta & Tapola, 2007). According to Heinz et al. (2005) mathematics interest (MI) is one of the most influential factors in mathematical achievement. In support, Köller et al. (2001) mentioned that interest influences mathematical achievement both directly and indirectly. They also point out that increasing interest in mathematics also increases its achievements. Students increasing interests typically result in increased SE (Bandura & Schunk, 1981) and SE has been found to be positively related to mathematics achievement (Zhang & Wang, 2020). It has also been established that while SE has been controlled, there is no incremental variance in MI (Lent et al., 1991). So SE is an important factor between MI and achievement. Moreover, Bandura (1977) and Bandura (1986) mentioned that students' MA can be controlled by higher SE. Therefore, there may be a relationship between MI and SE, which is related to PSA, as well as a relationship between MA and SE.

On the other hand, Gupta and Maji (2022) examined the relationship of students' MA, SE and mathematics performance in Indian context. They found that anxiety have indirect effect on performance through SE. Moreover, Jasani (2022) carried out a study to determine the relationship between MA, SE, and algebraic performance. He found the indirect relationship between MA and PSA through SE. The relationship between attitude and algebraic PSA among secondary school

students in the Morigaon district of Assam was studied by Das and Ali (2023). Their investigation highlighted the positive relationship between attitude and algebraic PSA.

The research findings discussed above predict the relationship between affective factors and PSA. Majority of the studies related to some of the factors mentioned above have been done outside India. However, it is less clear how these constructs might interact in a model that includes both direct and indirect effects on each other. It is also noteworthy to mention that no research is done to establish the direct and indirect effect of these affective factors on algebraic problem-solving achievement in Indian context. Therefore, in order to bridge the relationship this investigation is conducted to offer both theoretical and empirical proof of the relationship between SE, MI, MA, and algebraic PSA.

LITERAURE REVIEW

Self-Efficacy and Problem Solving

Self-efficacy (SE) describes a person's confidence in their capacity to carry out the behaviours required to achieve specific problem (Bandura, 1997). This confidence has a significant impact on one's activity, effort, perseverance, determination, learning, and achievement (Bandura, 1986). Research demonstrated that SE significantly correlates with cognitive and affective constructs, together with learning achievement (Schöber et al., 2018). SE has generally been recognised as an influential factor of academic achievement (Hayat et al., 2020), particularly in mathematical problem solving (Pajares & Graham, 1999). Several researches unveil that mathematics SE and students' problem solving at high school standard is closely interrelated (Pajares & Miller, 1994). Students with higher self-efficacy (SE) put in greater effort, make more attempts at cognitively difficult tasks, have greater persistence in solving difficult problems and achieve better performance (Bandura, 1977, Karaoglan Yilmaz, 2022). A number of studies have established that SE is positively associated with mathematical problem-solving achievement (Lopez et al., 1997, Shimizu, 2022). Moreover, SE has been identified as the strongest predictor of problem-solving due to its substantial connection with problem-solving achievement (PSA) in mathematics (Pajares & Miller, 1994). Therefore, SE is considered as the most influential affective construct in the present study.

Mathematics Anxiety, Self-Efficacy and Problem-Solving

Mathematics Anxiety (MA) is defined as "the panic, helplessness, paralysis, and mental disorganization that arises among some people when they are required to solve a mathematical problem" (Tobias & Weissbrod, 1980). In such a psychological ambience, students may have negative thoughts towards the subject. This is one of the prominent reasons why students can't perform to the best of their ability. Thus, one of the affective factors of mathematical understanding is mathematics anxiety which also hinders students' problem-solving abilities (Guven & Cabakcor,

2013). Numerous empirical studies have revealed a negative relationship between math anxiety and performance, indicating that people with math anxiety would struggle to cope with it or solve problems (Ashcraft & Kirk, 2001, Namkung et al., 2019). Hoffman (2010) pointed out that higher MA is correlated with ineffective problem solving. So, to curb MA is a pre-requisite for inculcating problem-solving skills. In this context, SE may be the most relevant among the affective variables. The social learning hypothesis suggests that lack of SE may be the cause of MA (Bandura, 1977). On the other hand, anxiety levels can be controlled with the help of strong SE beliefs (Bandura, 1986). Therefore, we assumed that SE mediates the link between MA and PSA in the study. Therefore, in this investigation we considered MA to have a direct effect on PSA as well as an indirect effect through SE.

Mathematics Interest, Self-Efficacy and Problem-Solving

According to Ainley (2006), interest is defined as an affective situation that corresponds to the individual's perception of learning. Interest is the most important aspect of learning mathematics (Yu & Singh, 2018), which psychologically boosts students attention, cognitive processes, perseverance and affective participation. Research shows that students who are more interested in mathematics are able to employ effective mathematical techniques and methods (Fisher et al., 2012). Students' lack of interest in mathematics may hinder their learning ability, particularly in problem solving ability. One of the reasons for their poor achievement and discontinuation of learning is lack of mathematical interest (MI) (Schraw et al., 2001). It has been established that MI and achievement are positively associated at the secondary stage (Zhang & Wang, 2020). Also, interest in mathematics is a predictor of mathematical and academic achievement. Empirically, it has been revealed that high MI may lead to high SE and self-efficacy also has a positive connection with mathematical performance (Kohen et al., 2019). Moreover, students who have very high MI and SE they can perform well, when they faced difficulties in mathematical activities like reasoning or problem solving (Huang et al., 2019). Therefore, in this investigation we considered MI to have a direct effect on PSA as well as an indirect effect through SE.

The present study

In light of the existing literature, the purpose of this study is to establish the relationships between SE, MA, MI, and algebraic problem-solving achievement (PSA) by adding both direct and indirect effects to the hypothesized models. Going through the outcomes of various investigations, while it is endeavored to design a model in which these variables are taken collectively, it is hypothesized that SE has a direct impact on problem solving (Pajares & Miller, 1995). In addition to that, SE can act as a mediating variable between affective constructs and problem solving efficiency (Hayat et al., 2020, Ozcan & Gumus, 2019). According to Lent et al. (1991), SE can serve as a mediator between MI and mathematics achievement. Also, the structural modeling study of Zhang and Wang (2020) found MI has a direct effect on SE and an indirect effect on problem solving.

On the other hand, MA has been recognized as one of the most significant affective variables that

directly affect on interest (Huang et al., 2019) and a direct effect on SE (Bandura, 1977), as well as PSA in mathematics (Ashcraft & Kirk, 2001, Guven, & Cabakcor, 2013). The correlation between MA and SE has been demonstrated using both theoretical (Bandura, 1977) and empirical evidence (Griggs et al., 2018, Huang et al., 2019, Pajares & Miller, 1994). MA also has indirect effects through SE on PSA (Gupta & Maji, 2022, Ozcan & Gumus, 2019). Based on the findings, we therefore hypothesized the direct and indirect effects of affective factors on algebraic problem solving achievement (PSA). The hypothesized theoretical model is shown in Figure1.

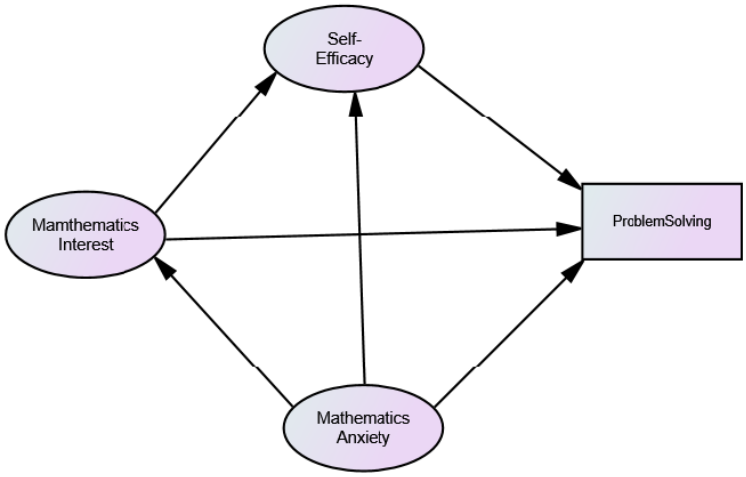

Figure 1. Hypothesized theoretical model

METHODS

Sample

The sample consists of 400 class IX students in the Morigaon district of Assam, India. The sample is randomly selected from the secondary schools in the district.

Instruments

In the study, the SE scale, MI scale, MA scale, and the algebraic problem solving achievement (PSA) test are used to gather the data. The scales MI, MA, and SE are adopted from PISA 2012 (OCED, 2013).

Self-Efficacy

The mathematics SE scale consists of five items and was adopted from PISA 2012.The items are, "I feel confident enough to solve algebraic word problems in my mathematics class"; "I am confident in calculating $P(x) = x^2-4x+3$ at $x=1$"; "I believe I can solve equations easily"; "I believe I am the type of person who can do mathematics" and "I believe I can understand the content in a mathematics course". These five items are given a 5-point rating. The scale of the Likert type ranges from "5-strongly agree" to "1-strongly disagree". Results of Confirmatory factor analysis (CFA) had acceptable fit indices (Chi-squared ($\chi 2$)/degree of freedom (df) =2.33, $p< 0.001$, Goodness of Fit Index (GFI) =0.99, Adjusted Goodness of Fit Index (AGFI) =0.97, Root Mean Square Error of Approximation (RMSEA) =0.06, Comparative Fit Index (CFI) =0.99), and Tucker-Lewis index (TLI) =0.98. The internal consistency (Cronbach's alpha) of the scale at 0.86 is acceptable.

Mathematics Interest

The MI scale was assessed with five items and adopted from PISA 2012. The scales are namely, "I do mathematics because I enjoy it"; "I would like solve algebraic problem"; "I enjoy reading about mathematics"; "I am always interested to solve algebraic word problems"; and "I am interested in the things I learn in mathematics". The MI is a 5-point Likert-type scale ranging from "5-strongly agree" to "1-strongly disagree". CFA had acceptable fit indices ($\chi 2$ /df =3.57, $p< 0.001$, GFI = 0.98, AGFI=0.95, RMSEA=0.08, CFI=0.98, and TLI= 0.96). The internal consistency of the scale at 0.82 is acceptable.

Mathematics Anxiety

The mathematics anxiety scale is also consisting of five items and adopted from PISA. "I get nervous when taking a mathematics test"; "I worry that I will not be able to get a good grade in my mathematics course"; "I feel helpless when doing a mathematics problem"; "I become very nervous doing mathematics problems" and "I often worry that it will be difficult for me in mathematics classes". The MA is a 5-point Likert-type scale ranging from "5-strongly agree" to "1-strongly disagree". CFA had acceptable fit indices ($\chi 2$ /df =6.5, $p< 0.001$, GFI = 0.97, AGFI=0.91, RMSEA=0.11, CFI=0.94, and TLI= 0.89). The internal consistency (Cronbach's alpha) of the scale at 0.78 is acceptable.

Algebraic Problem -Solving achievement

Students' algebraic problem solving achievement (PSA) is measured by a test. The test consists of 20 multiple choice items based on the course syllabus of class IX standard SEBA (Secondary Education Board of Assam) text book. The test items were validated with the help of an expert mathematics teacher and two other educators with more than 10 years of experience. The reliability Cronbach alpha is 0.89 acceptable. One example of the sample question is-

"The taxi fare in a city is as follows: For the first kilometer, the fare is Rs 8 and for the subsequent distance it is Rs 5 per km. Taking the distance covered as x km and total fare as Rs y, write a linear equation for this information".

Procedure

We began gathering the data with the principals' and class teachers' consent. Students who expressed a willingness to participate in the study were approached. They were required to complete the SE, MI, and MA scales and then an algebraic PSA test. All participants were made aware that the information we gather would be kept confidential. The participants completed the whole data collection process within 50 minutes. The SPSS 26.0 version was used to calculate the descriptive statistics and AMOS 18 for the hypothesized effects.

Data analysis and validation

The collected data has been arranged for analysis, the descriptive statistics are used. The Pearson correlation was computed to establish the relationship between SE, MI, MA, and algebraic PSA. After that the hypothesized relationship between the construct (Figure 1) has been tested with the help of two-stage structural equation modeling (SEM), as recommended by Anderson and Gerbin (1998). At first examine the model fit indices whether it is acceptable or not. Secondly, the direct and indirect effects are analyzed using AMOS.23 for the casual relationship. Moreover, parsimonious model is also used for the least number of paths. The model fit indices ($\chi 2$ /df, GFI, AGFI, RMSEA, CFI and TLI) are adopted to assess the Hypothesized model. The values of GFI, AGFI, RMSEA, CFI, and TLI greater than 0.90 are often considered acceptable, and RMSEA values less than 0.08 indicate a reasonable fit (Byrne, 2016, Hu & Bentler, 1999, Kline, 2016).

RESULTS

Preliminary analysis

In Table 1, the descriptive statistics and correlations of the studied variables are shown. The correlation results of the variables (MI, MA, SE, and PSA) are significantly correlated at the 0.01 level, as predicted theoretically. From Table 1, it is seen that algebraic PSA has a significant positive correlation with SE ($r= 0.81$, $p < 0.01$), MI ($r= 0.74$, $p < 0.01$), and a negative correlation with MA ($r= -0.65$, $p < 0.01$). Also, SE has a positive correlation with MI ($r= 0.78$, < 0.01) and a negative correlation with MA ($r= -0.61$, $p< 0.01$), There is a negative correlation of MI with MA ($r=- 0.62$, $p< 0.01$).

Table 1. Descriptive statistics and Pearson correlation of latent constructs.

	SE	MI	MA	PSA
SE	1	0.795**	-0.561**	0.799**
MI		1	-0.600**	0.763**
MA			1	-0.619--
PSA				1
Mean	3.5	3.37	2.9	11.6
Standard Deviation	0.75	0.64	0.55	5.39

** p< 0.01

Measurement model

In the measurement model, three latent constructs are formed by the 15 observed constructs (the SE, MI, and MA scales). To assess the validity of the constructs of the three related scales, CFA has been used. The CFA results indicated the fit indices are in the acceptable range of the two-stage measurement model ($\chi 2$ /df =2.09, p< 0.001, GFI=0.95, AGFI=0.93, RMSEA=0.05, CFI=0.96, and TLI=96) (Byrne, 2016; Hu & Bentler, 1999; Kline, 2016).

Structural model

The initial model has been examined (Figure 2) with and found acceptable fit indices (Table 2). Though it has been found acceptable fit, $\chi 2$ /df =2.07, p< 0.001, GFI=0.94, AGFI=0.92, RMSEA=0.05, CFI=0.96, and TLI= 0.96 (Hu & Bentler, 1999), but some path of the model is not significant. The insignificant path from MA to SE and MI to problem solving achievement (PSA) has been removed from the initial model and the revised model was rested. The revised model (Table 2 and Figure 3) also found acceptable fit, ($\chi 2$/df =2.04, p< 0.001, GFI=0.94, AGFI=0.92, RMSEA=0.05, CFI=0.96, and TLI=0.96) (Hu & Bentler, 1999).

Table 2. Goodness of fit indices of initial, revised and final models.

Goodness of fit	$\chi 2$ /df	GFI	AGFI	CFI	RMSEA	TLI
Initial model	2.07	0.94	0.92	0.96	0.05	0.96
Revised model	2.04	0.94	0.92	0.96	0.05	0.96
Final model	2.10	0.94	0.92	0.96	0.05	0.96

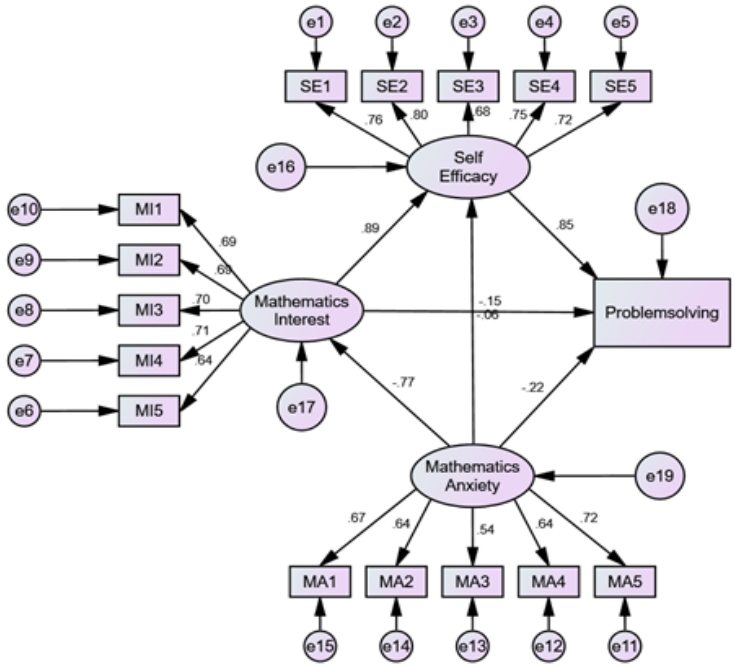

Figure 2. Standardized parameter estimates for initial model of algebraic PSA

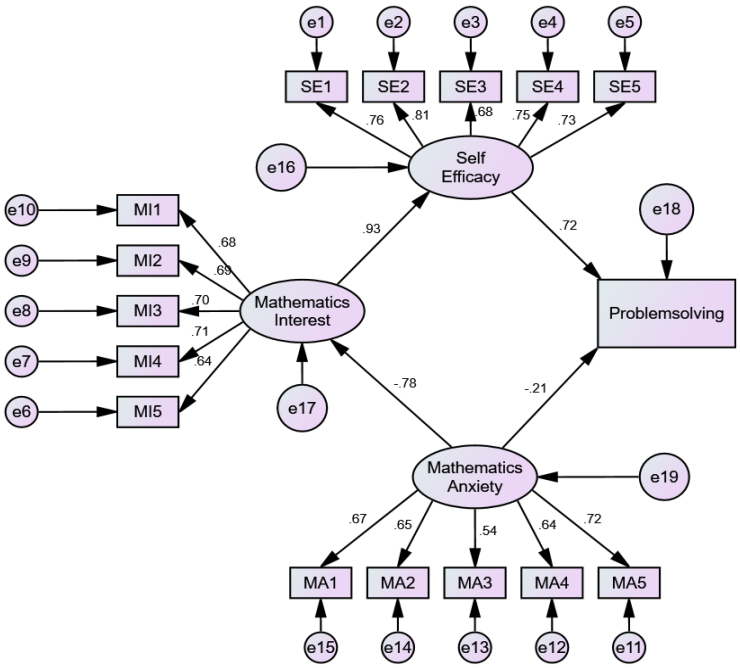

Figure 3. Standardized parameter estimates for revised model of algebraic PSA

Again for the parsimonious fit the model is preferred with less parameters or pathways. So, the path from MA to algebraic PSA is removed and the model is again tested. The final (simplified) model fit indices ($\chi 2/df$ =2.1, p<0.001, GFI=0.94, AGFI=0.92, RMSEA=0.05, CFI=0.96, and TLI=0.96) revealed the same fit indices, with the exception of a minor chi-square change. This final model (Table 2 and Figure 4), indicated that SE has a direct and positive effect on algebraic PSA (β=0.88, p< 0.001), MI has a direct and positive effect on SE (β=0.96, p< 0.001) and MA has a direct and negative effect on MI (β=-0.76, p< 0.001).

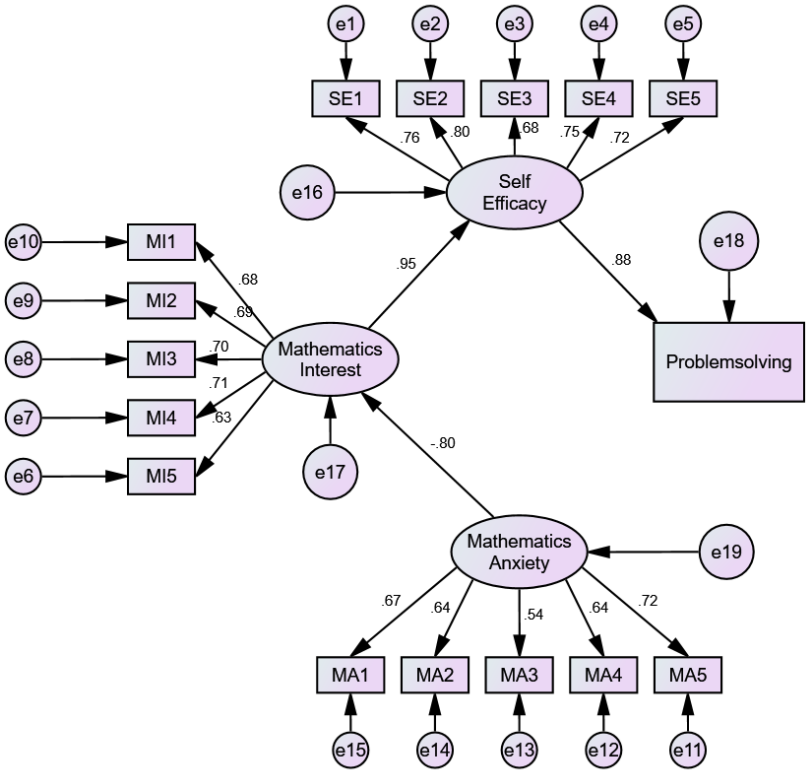

Figure 4. Standardized parameter estimates for final model of algebraic PSA

DISCUSSION

From the final model, only SE has a direct positive effect on algebraic PSA and mediates the effects of MI as well as MA. This result reveals that only SE is the most influential variable among the affective constructs. This result supports the theoretical justifications and empirical research on SE. Higher self-efficacious students do better because they put in more effort, make more attempts at cognitively difficult tasks, have greater persistence in solving difficult problems, and

achieve better performance (Bandura, 1977, Karaoglan Yilmaz, 2022, Pajares & Graham, 1999). According to Collins (1982), students with higher SE can solve more mathematical problems and are preserved until a problem is solved. Therefore, it can be explained that students with higher SE always have a positive relationship between problem solving and learning achievement. Numerous studies have highlighted the positive relationship between SE and PSA (Lopez et al., 1997, Shimizu, 2022). In a structural modelling study, Zarch and Kadivar (2006) also found that SE has direct effects on mathematics achievement. Moreover, the positive correlation between SE and algebraic performance has also been established in India among high school students by Jasani (2022), who mentioned that higher SE has higher algebraic achievement. Thus, SE serves as the most influential factor in mathematical achievement, especially in algebraic problem solving.

Though among the non-cognitive constructs, MI is the most important predictor of mathematics achievement, the study reveals that it has an indirect effect on algebraic PSA through SE. In the structural model, MI also mediates MA. Many empirical studies have explored the effects of students' MI on achievement, both in math problem-solving and other domains (Huang et al., 2019, Schraw et al., 2001). But the role of MI as a mediating variable and the other variables that mediate it are rarely studied. The study of Zhang and Wang (2020) mentioned that the positive link between MI and mathematical achievement is mediated by SE. Though, MI has no direct effect on PSA but the positive and direct effect of MI on SE and the direct positive effect of SE on PSA indicates that students with more MI tend to feel motivated to get engaged in an algebraic task, boost their capacity, and be able to use effective learning strategies, which may likely lead to good performance (Fisher et al., 2012, Yu & Singh, 2018). Thus, SE is the most influential predictor of algebraic PSA among the affective variables; it also serves as an important mediator. This result is consistent with the hypothesized role of SE theory (Bandura, 1986) and other recent studies (Zhang & Wang, 2020). The results indicate that students who are more interested in learning mathematics may eventually increase their SE, which may lead to improved problem solving.

In the final SEM model, MA is the only construct found to have both direct and indirect effects on algebraic PSA. The direct effect of MA on PSA is found to have a weak association in the revised model; the model fit indices are almost identical after eliminating it. This explains that the large effect of MI on the algebraic PSA is mediated by the other non-cognitive constructs in the model. In the final model, the result reveals that the effect of MA on algebraic PSA is mediated by MI and SE. Many investigations have shown that MA has a direct effect on SE (Guven & Cabakcor, 2013, Hayat et al., 2020), but no direct effect is found in this study. In contrast, Gupta and Maji (2022) found direct effects of MA on both SE and mathematical achievement in Indian school students. Literature has established a consistent and inverse association between problem solving and anxiety, highlighting the fact that this relationship is more complicated than it first appears to be (Ashcraft & Moore, 2009). This finding highlights the significance of examining variables in models where algebraic PSA is a dependent variable that mediates the effect of MA as an indirect predictor. The fact that MA is the sole variable in our model can offer valuable information about

how non-cognitive constructs should be incorporated. The model's casual association shows that decreasing MA raises MI and increased MI positively affects SE is a significant. Thus, increasing secondary school students' MI and SE can significantly improve their algebraic PSA, while increasing MA can have the opposite effect (Guven & Cabakcor, 2013, Hoffman, 2010).

CONCLUSIONS

The present study investigates the direct and indirect effects of affective constructs on algebraic PSA among secondary school students. The findings revealed that SE was the only non-cognitive construct that had a direct effect on algebraic PSA. The significant direct effect of SE indicates that students with higher SE have a significant contribution to algebraic PSA. Apart from this, MI and MA have indirect effects on PSA through SE in the model. The mediating role of SE indicates that reducing students' anxiety might increase their interest and self-efficacy, which might lead to better achievement in problem solving. In order to reduce anxiety and promote students' active participation in classroom transactions, teacher should substitute formative evaluation for high-stakes examinations. Teachers should be provided in-service training for the argumentation of problem-solving strategies by taking into account the affective factors during classroom interaction. Moreover, stakeholders and curriculum planners should design programs that will increase students' interest and self-efficacy.

The current study offers very helpful information and implications for mathematics educators to make the subject matter more interesting, increase students' efficacy and reduce math anxiety. These will assist the students in enhancing their problem-solving abilities and their achievement. The study contributes to the development of more literature by highlighting how SE, MI and MA predict algebraic PSA and how SE plays a major role in this process.

The findings of the study cannot be generalized to nationwide due to the constraint of small data sample. In the present study students self-reported data were used which might raise response bias. But, this study can be further investigated using larger and more diverse samples.

Acknowledgement

We would like to thank all the principals and class teachers for their moral support and consent. Also, thanks to all the students who have willingly participated in this study. Finally, we want to express our gratitude to the reviewers for their insightful comments on the improvement of this paper.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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