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Examining the roles of problem posing and solving, mathematical creativity, and attitude on academic achievement

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ABSTRACT

This paper presents the findings to provide practical frameworks that explain the different variables that affect students' academic achievement. A quantitative approach was adopted, specifically using partial least squares structural equation modeling (PLS-SEM) to examine the causal relationships between problem posing skills, problem-solving skills, mathematical creativity, and attitude towards mathematics on academic achievement. Data were collected using the following adopted instruments: the problem-posing task, the scale for mathematical problem-solving skills, the mathematical creativity self-efficacy perception scale, and the attitude towards mathematics scale. Students' grades in mathematics were used to represent their academic achievement. Conducted with 192 grade 9 students, this study investigated the direct and indirect effects of the exogenous variables. The results reveal that problem posing skills have a strong effect on academic achievement. On the other hand, problem-solving skills, mathematical creativity, and attitude towards mathematics mediate the effect of problem posing skills on academic achievement, with problem-solving skills emerging as the strongest mediator. This study supports the reliability and validity of the proposed conceptual model, which is feasible for further investigations.

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1. INTRODUCTION

There are several factors that relate to the level of academic achievement in mathematics. Juniati and Budayasa [1] suggest that both cognitive and affective factors play an important role in academic achievement. Research indicates a certain degree of correlation between cognitive and affective factors. Skagerlund *et al*. [2], for example, argue that a negative attitude towards mathematics may burden one's working memory while completing mathematical problems. Either way, the interaction between these two factors significantly influences one's academic achievement in mathematics [3].

Cognitive abilities are strongly linked with academic achievement in mathematics [4]. The exercise of cognitive abilities determines how efficiently a mathematical task can be done [5]. A few of the cognitive abilities that are commonly tied with academic achievement in mathematics include problem-solving [6] and mathematical creativity (e.g., [7], [8]). In addition, problem-posing is seen as an essential cognitive skill in fostering student academic achievement in recent times [9]. Problem-posing skill is the ability to pose, generate, or reformulate problems, which is found to be an effective skill in deepening students' knowledge and grasp of the concepts in mathematics [10]. Evidence leads to the claim that problem-posing skills allow for the development of holistic learning outcomes, including problem-solving skills [11] and mathematical creativity [12]. Problem-solving skills allow for the construction of thoughts and knowledge in finding appropriate responses to a situation [13], while mathematical creativity enables students to overcome fixation in mathematical problem-solving tasks, thereby increasing their ability to deal with high-level problems [14].

Meanwhile, affective factors are also associated with academic achievement [15]. Specifically, attitude towards mathematics is one of the major contributors to the level of academic achievement in the subject [16], [17] and a positive attitude increases one's engagement and desire to learn [18]. Núñez *et al*. [19] support this claim by explaining that attitude is a stable form of students' consolidated responses against a variety of learning stimuli in mathematics.

Literature confirms the significance of variables such as problem-posing and problem-solving skills, mathematical creativity, and attitude towards mathematics in influencing students' learning outcomes in the subject. Several cognitive and affective factors shape how students engage with and perform in mathematics, yet many instructional models fail to integrate these variables in a comprehensive and coherent manner. While these constructs have been individually explored, there remains limited empirical evidence examining their complex interrelationships. Moreover, few studies have attempted to investigate how these variables collectively contribute to students' academic achievement in mathematics. Understanding these relationships can contribute to theory building and inform instructional practices by clarifying the roles these factors play in shaping academic outcomes. In particular, the interplay among problem-posing and problem-solving skills, mathematical creativity, and attitude towards mathematics remains underexplored, despite their potential as interconnected constructs that significantly influence achievement. Addressing this gap is essential to developing more effective and responsive teaching strategies that promote deeper mathematical understanding and improved student performance. Specifically, this study aimed to test the causal relationships among the variables in the proposed conceptual model, including problem posing, problem solving, mathematical creativity, attitude towards mathematics, and academic achievement, thereby informing more effective and holistic instructional practices.

2. LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

Various attempts have been made to understand and predict mathematics academic achievement. Theories have been tested to explain how students' academic achievement in mathematics is affected by variables like problem-posing and solving skills, mathematical creativity, and attitude toward the subject. However, in previous studies, these causal relationships are examined in isolation.

2.1. Problem-posing skills to problem-solving, mathematical creativity, attitude, and mathematics academic achievement

Problem-posing skill is a cognitive process of understanding the task, constructing the problem, and expressing the problem [20]. With this, the skill is closely associated with other cognitive abilities that are useful in performing mathematical tasks. In a meta-analysis conducted by Kul and Celik [21], it was found that engaging students in problem-posing strategies has large effects on problem-solving skills, creativity, attitude towards mathematics, and academic achievement. However, it is important to note that problem-posing skills are interchangeable to success in problem-posing tasks. The findings of Kul and Celik [21] mean that problem-posing skills facilitate understanding of math concepts and processes and increase positive attitude and self-efficacy in problem-solving [22].

Students' success in navigating structured, semi-structured, and free problem-posing activities improves their problem-solving skills. This notion is confirmed by Polat and Ozkaya [23], who report an increase in problem-solving skills among students engaged in problem-posing tasks compared to those who are not. Moreover, problem-posing is considered an efficient activity to observe fluency, flexibility, and originality-the three common indicators of mathematical creativity [24]. This implies that students with a high level of problem-posing skills tend to exercise mathematical creativity in solving mathematical problems. In fact, Arabaci and Baki [25] claimed that creativity is observable among gifted and non-gifted students in a problem-posing-based environment which may indicate that problem-posing skills facilitate the development of fluency, flexibility, and originality.

In addition, studies have attested to how problem-posing elicits a positive attitude towards mathematics [26]. Engaging students in problem-posing tasks develops positive attitudes through active involvement. The same reasoning is confirmed by Arikan and Dede [27] in their finding that problem-posing tasks significantly improve students' attitudes in mathematics.

Lastly, problem-posing skills constitute a deeper understanding of mathematics since performing mathematical tasks is highly problem-solving in nature. As a result, studies show that problem posing skill also effectively enhances academic achievement. For example, Kovacs *et al*. [28] indicated a correlation between success in problem posing and mathematics grades among sixth graders. These results support previous investigations on the possible effect of problem-posing on students' academic achievement [29]. Therefore, the following hypotheses are constructed:

- Hypothesis 1 (H_1): problem-posing skills positively affect problem-solving skills.
- Hypothesis 2 (H_2): problem-posing skills positively affect mathematical creativity.
- Hypothesis 3 (H_3): problem-posing skills positively affect attitude towards mathematics.
- Hypothesis 4 (H_4): problem-posing skills positively affect academic achievement.

2.2. Problem-solving skills to mathematics academic achievement

Problem-solving is fundamental to mathematics and predicts mathematical thinking [30]. Solving mathematical problems requires not only procedural fluency but also higher-order thinking skills such as analysis, interpretation, reasoning, and reflection [31]. As emphasized by Rani *et al.* [32], there is a strong correlation between students' problem-solving skills with their academic achievement in mathematics.

Mathematics, by nature, encompasses a wide range of problem-solving activities—ranging from solving word problems, identifying patterns, interpreting graphs, constructing geometric figures, and proving theorems. The ultimate goal of mathematics instruction is to develop students' cognitive and affective domains in a way that enhances their problem-solving capacities. Problem-solving ability, therefore, becomes a key determinant of students' success in mathematics. As Sinaga *et al*. [6] noted, students' understanding of how to approach and resolve mathematical problems significantly influences their learning outcomes. This is further supported by Toraman *et al*. [33], who found a positive correlation between problem-solving skills and academic achievement in mathematics.

In this context, instructional approaches that emphasize the development of problem-solving abilities tend to yield improved academic outcomes. For example, Albay [34] conducted a true experimental study that investigated the effect of a problem-solving-based teaching strategy on students' academic achievement in algebra. The findings demonstrated that engaging students in varied problem-solving tasks led to deeper conceptual understanding and enhanced mathematics performance.

Therefore, the following hypotheses are constructed:

- Hypothesis 5 (H_5): problem-solving skills positively affect academic achievement.
- Hypothesis 6 (H_6): problem-solving skills have a positive intermediary effect on the relationship between problem-posing skills and academic achievement.

2.3. Mathematical creativity to mathematics academic achievement

There is now a growing recognition of the importance of mathematical creativity in mathematics education. In several studies, mathematical creativity is presented in terms of three components: fluency, flexibility, and originality [35]. Fluency is the ability to come up with several possible solutions. Flexibility is the ability to approach the same problems with different techniques. Originality refers to the novelty of ideas generated as a response to a mathematical problem.

Previous studies have linked the impact of encouraging mathematical creativity to academic achievement in mathematics. Joklitschke *et al*. [36] found that fostering divergent thinking and innovative approaches to problem-solving improves students' deeper understanding of mathematical concepts and their competence. Creative students are able to solve novel problems, thus enriching knowledge application. In support of this view, a study of Hamid and Kamarudin [8] used mathematical creative approach (MCA) and results showed that it enhances the performances of students in solving mathematical problems, leading to higher academic achievement scores as indicated in pre-test and posttest of math achievement test results. Therefore, the following hypotheses are constructed:

- Hypothesis 7 (H_7): mathematical creativity positively affects academic achievement.
- Hypothesis 8 (H_8): mathematical creativity has a positive intermediary effect on the relationship between problem-posing skills and academic achievement.

2.4. Attitude towards mathematics-to-mathematics academic achievement

Students' attitude towards mathematics significantly influences their academic achievement in the subject. Shah *et al*. [37] emphasized that among various attitudinal components, confidence and motivation are the most critical, as they drive students' sustained interest and engagement, especially when tackling complex mathematical concepts. Similarly, Wakhata *et al*. [38] highlighted that affective factors such as confidence, motivation, enjoyment, and perceived usefulness are strong indicators of students' success in learning specific mathematical content. These findings reinforce the need to address both cognitive and emotional dimensions in mathematics education. Furthermore, Fuson *et al.* [39] argued that early math knowledge is one of the strongest predictors of math grades in high school to college, suggesting that attitudes and academic outcomes are shaped over time. Collectively, these studies underscore the mutual relationship between affective factors, instructional practices, and academic achievement in mathematics. Therefore, the following hypotheses are constructed:

- Hypothesis 9 (H_9): attitude towards mathematics positively affects academic achievement.
- Hypothesis 10 (H_{10}): attitude towards mathematics has a positive intermediary effect on the relationship between problem-posing skills and academic achievement.

2.5. Conceptual model

This research constructed ten hypotheses with five main variables. The relationship of these variables is illustrated in the conceptual model diagram in Figure 1. The conceptual model serves as the basis for examining the direct and indirect relationships among the study variables.

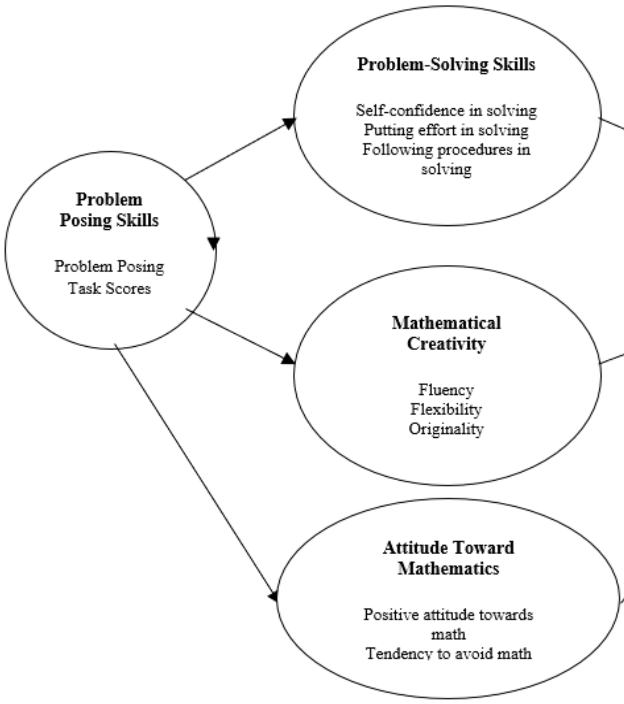

Figure 1. Diagram of the conceptual model

3. METHOD

A quantitative approach was adopted, with structural equation modeling (SEM) used as the primary analytical technique to validate the theoretical model and assess the interrelationships among constructs. SEM allows researchers to analyze and estimate complex interrelationships among several dependent and independent variables at the same time [40]. Specifically, this study aimed to test the causal relationships among the variables in the conceptual model, including problem posing, problem solving, mathematical creativity, attitude towards mathematics, and participants' academic achievement, thereby informing more effective and holistic teaching practices.

3.1. Sample and data collection

Participants who volunteered to be part of this study were 192 grade 9 students of one of the public schools in Dumingag, Zamboanga del Sur, Philippines. The participating school's population comprised 376 grade 9 students. Meanwhile, this study was conducted during quarter 2 of the school year 2024-2025 of the Philippines' public basic education school system calendar. Prior to the conduct of the study, the researchers ensured that permissions were secured from the authority of the participating school. After the consent, a face-to-face orientation was done with students to properly inform them of the study's objective and the nature of their participation. The inclusion criteria for this study were based primarily on students' willingness to participate. Although the data collection was facilitated through Google Forms, participation was conducted in person, ensuring that only those who voluntarily consented were included in the study. The participants stayed in their classrooms while they participated in the online survey. Assisted by some math teachers, two of the researchers were personally present during the conduct of the study. This step ensured that clarifications were made whenever students raised questions related to the procedure of the survey.

3.2. Research constructs and instruments

This study adopted four instruments from different authors. First, the students' problem-posing skills were assessed based on their scores obtained in performing an adopted problem-posing task [41]. These tasks require students to pose easy, average, and difficult problems based on given illustrations. Second, students' problem-solving skills were self-reported and measured through an adopted scale for mathematical problem-solving skills from Erdem-Keklik. The instrument is a 5-point Likert scale that aims to measure problem-solving skills through three indicators, namely: self-confidence about solving problems, putting effort into solving problems, and procedure followed to solve problems. Third, a mathematical creativity self-efficacy perception scale was adopted to measure students' self-reported level of mathematical creativity [42]. The instrument is also a 5-point Likert scale that measures creativity through fluency, flexibility, and originality. Fourth, students' self-reported attitude towards mathematics was measured through an adopted attitude towards mathematics scale [43]. The instrument is a 4-point Likert scale that measures attitude through dimensions including positive attitude towards mathematics, tendency to avoid math, and negative attitude towards mathematics.

Finally, students' grades in mathematics were used to represent their academic achievement. Since this study was conducted during quarter 2 of the school year 2024-2025, the grade 9 students' academic achievement was measured through their grades obtained in quarter 1 of the same school year. Table 1 summarizes the construct description, indicators, coding, and data collected in the study.

Table 1. Summary of constructs description, their indicators, coding, and data collected

Construct	Indicators	Code	Data collected
Problem posing skills	Problem posing test scores	PP_Score	Problem posing task scores
Problem-solving skills	Self-confidence	PS_1	Scale for mathematical problem-solving skills
	Putting effort	PS_2	
	Procedure followed	PS_3	
Mathematical creativity	Fluency	MC_1	Mathematical creativity self-efficacy perception scale
	Flexibility	MC_2	
	Originality	MC_3	
Attitude towards mathematics	Positive attitude towards mathematics	AM_1	Attitude towards mathematics scale
	Tendency to avoid math	AM_2	
	Negative attitude towards mathematics	AM_3	
Academic achievement	Quarter grade	Q_Grade	Quarter 1 math grade

3.3. Data analysis

This study applied a deductive approach to the literature review to derive the conceptual model. The model synthesized the causal relationship between variables as described by the research hypotheses as shown in Figure 1. Since this study aimed at theory construction, the research model is reflective rather than formative [40]. To evaluate the quality of the reflective measurement models estimated by partial least squares-structural equation modeling (PLS-SEM) in terms of reliability and validity, the following steps were implemented as shown in Figure 2.

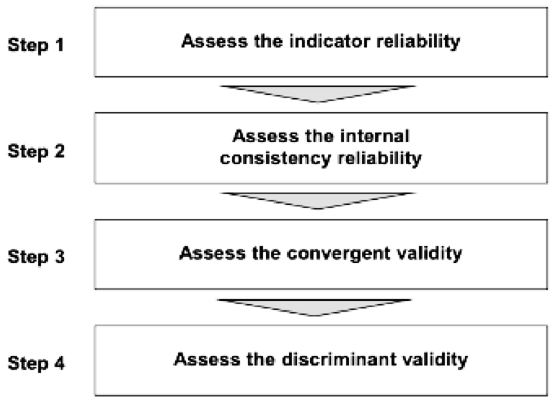

Figure 2. Reflective measurement model assessment procedure [40]

PLS-SEM was used to justify the derived model using the SEMinR package in R software ([44], [45]). PLS-SEM is a more suitable approach for causal model analysis [40]. Sarstedt and Danks [46] suggest the advantage of PLS-SEM in research that is geared towards deriving recommendations for practice.

4. RESULTS

4.1. Evaluation of the reflective measurement model

Before exploring the structural model, the quality of the reflective measurement model was evaluated in terms of indicator reliability. Indicator reliability was assessed through indicator loading. Hair *et al.* [40] suggested that acceptable indicator loadings should be greater than 0.708. As presented in Table 2, all indicator loadings are greater than 0.708, implying an acceptable indicator reliability. This means that there is a strong correlation between each of the indicators and the construct it represents.

At the construct level, internal consistency reliability was evaluated through composite reliability (CR) and Cronbach's alpha. Acceptable values for both metrics should fall within the range of 0.70 and 0.95 for both metrics [40]. As shown in Table 2, values for Cronbach's alpha and CR of constructs measured by multiple indicators, namely problem-solving skills, mathematical creativity, and attitude towards mathematics, fall within the acceptable range, indicating good internal consistency reliability. This implies a strong degree of association among indicators measuring these constructs. For single-item constructs such as problem posing skills and academic achievement, Cronbach's alpha and CR are inherently equal to 1 due to the absence of measurement error. Therefore, the model demonstrates satisfactory internal consistency reliability.

The reflective measurement model was also evaluated through average variance extracted (AVE) to check for convergent validity. Cheung *et al.* [47] recommended a minimum AVE of 0.50 for acceptable convergent validity. Table 2 shows that the AVE for all constructs exceeds 0.50, implying that the constructs explain more than 50 percent of the variance of their indicators. This further confirms that the model exhibits acceptable convergent validity.

Table 2. Convergent validity of the reflective measurement model

Construct	Indicators	Factor loading	Cronbach's α	CR	AVE
Problem posing skills	PP_Score	1.000	1.000	1.000	1.000
Problem-solving skills	PS_1	0.874	0.888	0.930	0.815
	PS_2	0.935			
	PS_3	0.899			
Mathematical creativity	MC_1	0.851	0.895	0.935	0.828
	MC_2	0.913			
	MC_3	0.963			
Attitude towards mathematics	AM_1	0.950	0.914	0.945	0.851
	AM_2	0.883			
	AM_3	0.934			
Academic achievement	Q_Grade	1.000	1.000	1.000	1.000

Furthermore, the measurement model was evaluated in terms of discriminant validity. Rönkkö and Cho [48] argued that heterotrait-monotrait ratio (HTMT) is essentially the same as a disattenuated correlation between unit-weighted composites under the assumption of parallel reliability. Disattenuated correlations have long been used to evaluate discriminant validity, with a recommended threshold value of 0.90 [49]. Table 3 shows that the majority of the HTMT ratios are below 0.90, indicating good discriminant validity. However, the HTMT ratio between problem-solving skills and academic achievement exceeds the threshold at 0.941. This inflation is due to the absence of measurement error in academic achievement, being a single-item construct, rather than a lack of discriminant validity. Therefore, the measurement model still satisfies the criteria for discriminant validity.

Table 3. Discriminant validity using HTMT for measurement model evaluation

Construct	Problem posing skills	Problem-solving skills	Mathematical creativity	Attitude towards mathematics	Academic achievement
Problem posing skills	--				
Problem-solving skills	0.838	--			
Mathematical creativity	0.728	0.827	--		
Attitude towards mathematics	0.599	0.643	0.832	--	
Academic achievement	0.848	0.941	0.895	0.778	--

Based on the result of the measurement model evaluation, all the model evaluation criteria are met. The result means that the construct measures are reliable and valid. This further suggests that including them in the structural model analysis is suitable. For this reason, the reflective measurement model is appropriate for further PLS-SEM analysis, and thus, it is reasonable to proceed with the evaluation of the structural model [40].

4.2. Evaluation of the structural model

Issues on potential collinearity were examined using the variance inflation factor (VIF). Hair *et al*. [40] noted that higher VIF values reflect a stronger degree of collinearity, with values of 5 or more suggesting potential collinearity issues. On the other hand, if the value of VIF is between 1 to 5, it specifies that the variables are moderately correlated to each other [50]. As presented in Table 4, all VIF values are below 5, suggesting low collinearity among predictor constructs.

Table 4. Collinearity analysis

Construct correlation	VIF
Problem posing skills and academic achievement	3.021
Problem-solving skills and academic achievement	3.605
Mathematical creativity and academic achievement	3.458
Attitude towards mathematics and academic achievement	2.432

The structural model was then assessed in terms of the significance of path coefficients. The bootstrapping procedure was done to calculate the t-values and confidence interval at α=0.05. This approach increases the validity of outcomes, including the path coefficients [40]. Table 5 shows that all t-values are greater than 3.29, indicating 0.001 level of significance for each of the hypothesized direct effects. The findings imply that H_1, H_2, H_3, H_4, H_5, H_7, and H_9 are all valid hypotheses, i.e., every predictor has a positive significant effect on the predicted construct. For instance, the analysis shows that problem posing skills positively affects problem-solving skills (H_1). A similar conclusion is applicable to all other hypothesized direct effects. Meanwhile, results show that problem-solving skills has the strongest direct effect on academic achievement (β=0.432).

In terms of relevance, Table 5 shows that all path coefficients are positive. This strengthens the validity of the hypothesized direct effects and further demonstrates the positive impact of each of the predictor constructs. Specifically, a one-standard deviation increase in the predictor construct implies an increase in the endogenous construct by the value of the path coefficient. For instance, problem posing skills has the strongest impact on academic achievement (β=0.806), whereas attitude towards mathematics has the least impact on academic achievement (β=0.185).

Table 5. Path analysis verification by bootstrapping

Path	Path coefficient (β)	t-value	2.5% CI	97.5% CI	Hypothesis
Problem posing skills → problem-solving skills	0.806 ***	24.693	0.739	0.867	H_1 accepted
Problem posing skills → mathematical creativity	0.688 ***	15.672	0.596	0.768	H_2 accepted
Problem posing skills → attitude towards mathematics	0.591 ***	10.877	0.479	0.692	H_3 accepted
Problem posing skills → academic achievement	0.239 ***	4.869	0.146	0.339	H_4 accepted
Problem-solving skills → academic achievement	0.432 ***	6.628	0.312	0.567	H_5 accepted
Mathematical creativity → academic achievement	0.218 ***	4.862	0.136	0.313	H_7 accepted
Attitude towards mathematics → academic achievement	0.185 ***	5.861	0.123	0.246	H_9 accepted

Note: *** significant at $p<0.001$.

The PLS-SEM path analysis diagram is presented in Figure 3. The diagram was generated in R using SEMinR package through bootstrapping. The explanatory power of the structural model was assessed using the coefficient of determination (R^2). Higher R^2 values indicate higher explanatory power, with 0.25, 0.50, and 0.75 are considered weak, moderate, and substantial, respectively [40]. Table 6 shows that academic achievement (R^2=0.919) has substantial explanatory power for problem posing skills. Problem-solving skills (R^2=0.650) and mathematical creativity (R^2=0.473) have moderate explanatory power for problem posing skills. Conversely, academic achievement exhibits moderate explanatory power on problem-solving skills (R^2=0.432) but weak explanatory power on mathematical creativity (R^2=0.218) and attitude towards mathematics (R^2=0.185). Finally, attitude towards mathematics (R^2=0.349) has weak explanatory power for problem posing skills.

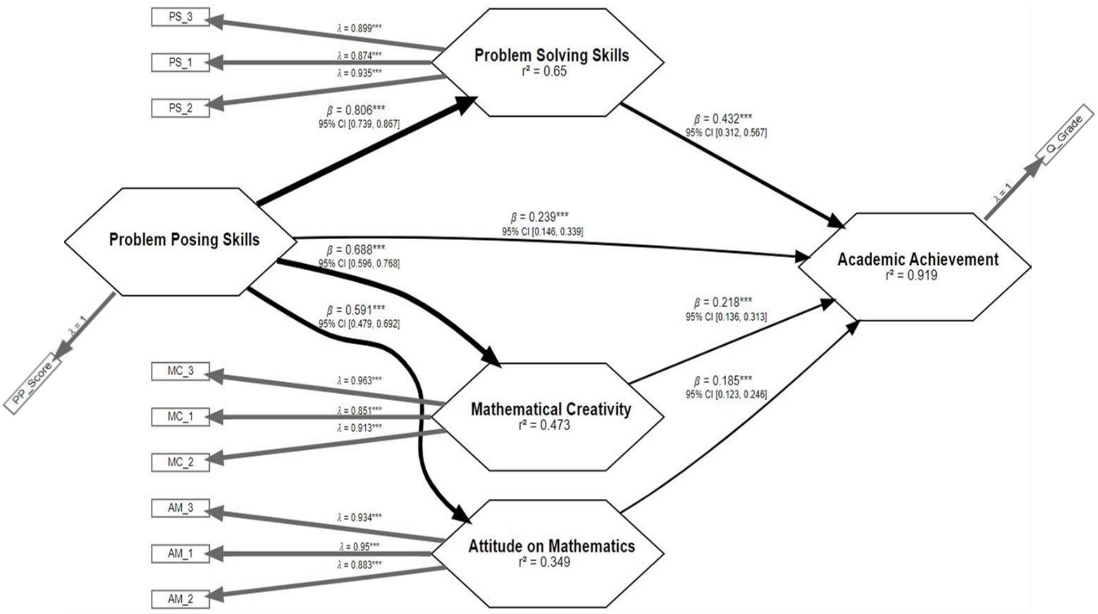

Figure 3. PLS-SEM path analysis diagram

Table 6. Coefficient of determination and effect size

Path analysis	R^2	Adjusted R^2	f^2
Problem posing skills → problem-solving skills	0.650	0.648	1.856
Problem posing skills → mathematical creativity	0.473	0.471	0.899
Problem posing skills → attitude towards mathematics	0.349	0.346	0.536
Problem posing skills → academic achievement	0.919	0.918	0.236
Problem-solving skills → academic achievement	0.432		0.643
Mathematical creativity → academic achievement	0.218		0.171
Attitude towards mathematics → academic achievement	0.185		0.175

The model's explanatory power was further by an investigation of the effect size (f^2). Values within the interval $0.02< f^2 \leq 0.15$ is considered a small effect; $0.15<f^2\leq 0.35$ is a medium effect, and $f^2>0.35$ is a large effect in terms of explanatory ability [36]. Table 6 reveals that problem posing skills has a large effect on problem-solving skills (f^2=1.856), mathematical creativity (f^2=0.899), and attitude towards mathematics (f^2=0.537). Similarly, problem-solving skills has a large effect on academic achievement (f^2=0.643), whereas problem posing skills has a medium effect on academic achievement (f^2=0.236). Both mathematical creativity and attitude towards mathematics exhibit medium effects on academic achievement (f^2=0.171 and 0.175, respectively). Therefore, the analysis confirms that the exogenous variables can explain the endogenous variables.

The intermediary effects, as hypothesized in H_6, H_8, and H_{10} were explored using bootstrap confidence intervals (CI) at a 5% level of significance. Table 7 shows that all CI for the hypothesized indirect effect do not include zero, implying significant indirect effects. Since problem posing skills has a significant effect on academic achievement (H_4 is valid), it follows that the intermediary effects are classified as partial mediations. The result suggests that problem-solving skills partially mediates the effect of problem posing skills to academic achievement (H_6), mathematical creativity partially mediates the effect of problem posing skills to academic achievement (H_8), and attitude towards mathematics partially mediates the effect of problem posing skills to academic achievement (H_{10}).

The total indirect effects of problem posing skills on academic achievement are significant, as the confidence interval suggests. This result implies that problem-solving skills, mathematical creativity, and attitude towards mathematics collectively mediate the influence of problem posing skills on academic achievement (0.608). However, among the three mediators, problem-solving skills plays the strongest intermediary role in the relationship between problem posing skills and academic achievement.

Furthermore, as shown in Table 8, the total effect of problem posing skills on academic achievement is significant (t=28.406). This means that considering the effects of all other variables in the model, problem posing skills produces a strong effect on academic achievement (0.848). Considering the total indirect effects (0.608), it can be concluded that the mediators played a major role in the strength of the total effect.

Table 7. Mediation effect of problem-solving skill, mathematical creativity and attitude on mathematics

IV	MV	DV	Specific indirect effect	95% CI	Hypothesis	Total indirect effect
Problem posing skills	Problem-solving skills	Academic achievement	0.348	[0.252, 0.468]	H_6 accepted	0.608 [0.545, 0.686]
Problem posing skills	Mathematical creativity	Academic achievement	0.150	[0.088, 0.228]	H_8 accepted	
Problem posing skills	Attitude towards mathematics	Academic achievement	0.109	[0.069, 0.155]	H_{10} accepted	

Note: IV=independent variable; MV=mediator variable; and DV=dependent variable.

Table 8. Total effect of problem posing skill to academic achievement

Total effect	Path coefficient (β)	t-talue	95% CI
Problem posing skills → academic achievement	0.848 ***	28.401	[0.783, 0.901]

Note: *** significant at p<0.001.

5. DISCUSSION

The main purpose of this study is to explore the different factors that affect the academic achievement of students in mathematics. The conceptual model hypothesized the complex causal relationships between different variables, including problem-posing and solving skills, mathematical creativity, and attitude towards mathematics. To provide an understanding of these relationships, direct effects and multiple intermediary relationships were examined.

Results revealed that problem-posing skills positively affect students' problem-solving skills, mathematical creativity, attitude towards mathematics, and academic achievement in mathematics (H_1, H_2, H_3, and H_4). These are consistent with the past studies conducted [25], [26]. Enhancing students' abilities to pose mathematical problems stimulates critical and analytical thinking abilities. Through this, students' connection to the subject can be improved, and their understanding of math concepts can be promoted.

The positive effect of problem-posing on problem-solving skills proves that the act of constructing valid and relevant math problems reflects the cognitive process of solving them. Similarly, the positive impact of problem-posing on mathematical creativity shows that students' capacity to pose problems is predictive of their ability to produce positive alternative solutions [51]. The favorable influence of problem-posing skills on students' attitudes toward mathematics highlights the emotional advantage of cultivating this ability. As students become more proficient in generating mathematical problems, they tend to show greater engagement and appreciation for the subject. Furthermore, the positive effect of problem-posing on academic achievement underscores the importance of integrating this skill into mathematics instruction. By fostering problem-posing, educators can support deeper conceptual understanding and enhance students' ability to apply knowledge effectively. Taken together, these findings point to the value of problem-posing as a foundational competency for promoting both cognitive and affective growth in learners.

On the other hand, problem-solving skills, mathematical creativity, and attitude towards mathematics all have positive effects on academic achievement (H_5, H_7, H_9). These findings are also supported by previous research (e.g., [34]). Problem-solving skills equip students with the ability to break down complicated problems, think of innovative ways to address them, and apply these solutions successfully [52]. Students who learn to deal with complex problem situations are more likely to demonstrate an effective understanding of math concepts. This study's findings support that problem-solving ability exerts the greatest influence on academic achievement in mathematics.

Students who have high levels of mathematical creativity exhibit divergent thinking. This ability not only allows students to generate multiple solutions but also enables them to recognize and adapt familiar strategies in new contexts. Creativity in solving problems makes sense of the practical applications of abstract math ideas. In turn, the ability to understand how math concepts can be applied speaks volumes of students' conceptual understanding and achievement in the subject [53].

Mathematics academic achievement is also influenced by a student's attitude towards the subject. Despite differences in the measures of attitude proposed across literature, the majority of the studies conducted agree that students' attitudes toward math greatly determine how they perform in the subject [54]. A positive attitude sustains students' motivation in overcoming challenges in dealing with difficult tasks. Conversely, a negative attitude hampers students' analytical ability as they find no interest in working with a certain task.

This study found that the effect of problem-posing skills on academic achievement is partially mediated by problem-solving skills, mathematical creativity, and attitude towards mathematics (H_6, H_8, H_{10}). Problem-posing skills influence students and increase students' confidence, effort, and adherence to systematic procedures in solving problems. It also develops fluency, originality, and fluency, which are essential in dealing with complex mathematical tasks. In addition, problem-posing skills increase positive perceptions, engagement, and attitudes toward mathematics. The benefits that problem-posing skills offer collectively translate to a meaningful learning experience. In addition, the strength of the influence of the mediator variables significantly boosts the impact of problem-posing skills on achievement. It should also be noted that among all mediators, enhanced problem-solving ability serves the strongest link between problem posing skills and academic achievement in mathematics.

The findings of these studies suggest that in an effort to enhance students' academic achievement, educators should look carefully into the different factors affecting it. Particularly, classroom instructions must take into account the development of cognitive and affective factors relevant to mathematics. More importantly, this study advocates for the consideration of problem-posing skills as foundational skills needed for students' success in the subject.

6. CONCLUSION

This study elucidates the causal relationship of the related factors that affect academic achievement. It establishes the reliability and validity of the theoretical model. It also validates the causal and mediating roles of problem-posing skills, problem-solving skills, mathematical creativity and attitude towards mathematics on the academic achievement of students in mathematics. The results support the argument that addressing problem-posing skills increases analytical thinking and develops deeper conceptual understanding and involvement in mathematics. Of the mediating factors, problem-solving skills are considered the strongest link. This emphasizes a cognitive link between the process of constructing problems and solving mathematical problems. Additionally, mathematical creativity and positive attitudes had a significant impact on academic achievement. Hence, the paramount influence of cognitive and affective factors on student learning outcomes is highlighted. Furthermore, this study offers an understanding of paths through which problem-posing affects student learning outcomes. It provides empirical evidence for the critical role of problem posing in catering to both cognitive skills and affective disposition. The study's findings lay a sound framework for future research in mathematics education.

While this study offers compelling insights, certain limitations warrant consideration. The data collection was conducted through Google Forms, and although participation occurred in person, the nature of online self-report surveys may limit the depth of responses and carry the potential for social desirability bias. Furthermore, the research design, while strengthened by SEM, remains cross-sectional in nature. Thus, although directional pathways and mediating relationships were established, causal claims must be interpreted with caution.

It is recommended that subsequent investigations adopt longitudinal or mixed-method approaches to explore how problem-posing, problem-solving, and affective variables evolve over time and influence sustained academic achievement. Moreover, future studies should explore the inclusion of more diverse learner profiles, including those who exhibit disengagement or anxiety toward mathematics, to deepen our understanding of how affective factors mediate achievement across varying learner dispositions. These directions would further substantiate the central claim of this study—that both cognitive engagement and affective investment are essential to nurturing meaningful mathematical learning.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
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R : **R**esources
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O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. The authors state no conflict of interest.

DATA AVAILABILITY

The data that support the findings of this study are available on request from the corresponding author, [ICPB]. The data, which contains information that could compromise the privacy of research participants, are not publicly available due to certain restrictions.

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