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The Mathematics Self-Belief and Mathematical Creativity of Pre-Service Teachers:
The Mediating Role of Problem-Solving Skills

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Abstract
Problem-solving is the heart of mathematics which compels an individual to think critically, logically, and show creativity while solving various problems. It is also important to study the students' beliefs about mathematics to better understand how a student learns to solve problems. As a result, this study aimed to determine the mediating role of problem-solving skills between mathematics self-belief and mathematical creativity of mathematics pre-service teachers. Specifically, a descriptive-correlational with mediation analysis research design was employed. A cluster sampling method was utilized since 153 pre-service teachers from two campuses were used in the study. A self-report survey, test, and rubrics were used to gather data. The results revealed that a full mediation exists since the mathematics self-belief had no significant direct effect on the student's mathematical creativity. It also showed that mathematics self-belief had a significant effect on problem-solving skills, and problem-solving skills significantly affected the mathematical creativity of the students. Hence, mathematics self-belief indirectly affected mathematical creativity, confirming the full mediation effect of problem-solving skills. Future researchers may conduct a similar study by comparing the mathematics self-belief, problem-solving skills, and mathematical creativity of pre-service teachers according to year level.

Keywords
Mathematical Creativity, Mathematics Self-Belief, Pre-Service Teachers, Problem-Solving Skills

INTRODUCTION

Considering the quality of education in the Philippines, the framework of the K-12 Mathematics Curriculum invests an unending pursuit to produce holistically developed and effective problem-solvers. According to the National Council of Teachers of Mathematics [NCTM] (2023), problem-solving is a mathematical task with the intention of testing the student's mathematical understanding and development. With its focal importance across the curriculum, problem-solving is described as the heart of mathematics compelling an individual to think critically, logically, and creatively (Saragih & Habeahan, 2014).

In solving various problems in Mathematics, students are demanded to show creativity while using various strategies (Arifin, et al., 2021). According to Isyrofinnisak et al. (2020), mathematical creativity is the ability to generate new, different, and correct mathematical solutions to a problem with the application of mathematical principles. Concurringly, Simanjuntak et al. (2021) mentioned that problem-solving skills and mathematical creativity are positively correlated with one another. This reveals that good problem-solvers are better creative thinkers in mathematics. In reference to the role of problem-solving in developing mathematical creativity, Sinniah, et al. (2022) affirmed that problem-solving skills can also be strengthened by exposing them to non-routine problems in mathematics. Since creativity is embedded in problem-solving tasks, this demonstrates that the mathematical creativity of students can also be more developed through solving non-routine problems (Fortes & Andrade, 2019).

On the other hand, perception, motivation, experiences, and most especially beliefs are the factors that affect the problem-solving process and creative thinking in mathematics (Ozturk & Guven, 2016). In order to understand how a student learns to solve problems, it is necessary to investigate the mathematics self-belief. The Mathematics Self-belief is a non-cognitive construct that deals with students' dispositions, beliefs, and values in mathematics (Stankov & Lee, 2013). In addition, it provides a sound understanding of how the students' perceived mathematics self-belief influences their mathematics performance (Cueli, et al., 2023). Thus, it is also compelling for pre-service teachers to hold a positive level of mathematics self-belief.

Parallel to this, Andrade and Pasia (2020) asserted that there is a need among mathematics pre-service teachers to develop mathematical creativity and problem-solving strategies. Considering the multidimensional roles of teachers in the learning process, pre-service teachers must reflect and evaluate their beliefs to ensure that they are providing productive and equitable opportunities for students (NCTM Standards, 2020). Hence, a greater demand for well-equipped and imaginative pre-service teachers' preparations and training programs is needed to bring the country to the international benchmark.

The relevance of mathematics self-belief, mathematical creativity, and problem-solving skills have long been studied in the educational process. However, most studies up to date solely look at how these ideas relate to one another. Considering this information, a gap exists in the mediating effects of problem-solving in mathematics self-belief and mathematical creativity in solving non-routine problems. Along with the pivotal role of these concepts in mathematics instruction, there might have an effect when problem-solving skills mediate the mathematics self-belief and mathematical creativity of mathematics pre-service teachers.

Stankov et al. (2014) cited that the best non-cognitive predictor of mathematical achievement is mathematics self-belief. The scales under the mathematics self-belief cluster are mathematics self-confidence, mathematics self-efficacy, mathematics self-concept, and mathematics anxiety. Self-confidence in mathematics refers to the individual's belief or capabilities of success in accomplishing math tasks. Mathematics self-efficacy deals with the person's belief in persistence, determination, or perseverance when confronted with difficulties in mathematics. Mathematics anxiety refers to the person's feeling of tension, stress, fear, or worry in mathematics class and tasks. Lastly, the mathematics self-concept is defined as the individual's belief, feelings, or perception about his or her ability and skills in mathematics in comparison to classmates.

On the other hand, Gruntowicz (2020) noted that using problem-solving is an appropriate strategy for determining students' mathematical creativity. As stated by Schoevers et al. (2020), mathematical creativity is measured using the three constructs. The constructs of mathematical creativity such as fluency, flexibility, and originality served as the dependent variables of the study. Fluency emphasizes the student's ability to produce several ideas and alternatives to answer many questions effectively and correctly. Flexibility is characterized by the capacity of students to use several approaches in solving a problem. Lastly, originality is one of the measures of mathematical creativity which is the student's ability to produce non-standard solutions in solving a problem.

Moreover, the mediating variable is the pre-service teachers' problem-solving skills which are measured by the Identification of the problem, Definition of the problem, Exploration of alternative solutions, Application of solutions, and Looking back at the effects of solution or the IDEAL Problem-Solving Method, developed by Bransford and Stein (1993). It is intended to assist in identifying and understanding various problem-solving components- which can be very beneficial for students aiming to develop their problem-solving abilities. Hence, the IDEAL method offers teachers, parents, and other professionals a systematic framework and proof of intervention since it is intervention-focused and data-driven.

The study is also guided by the constructivist learning theory which emphasizes the guiding principles of how teachers teach and how learners acquire and construct knowledge (Kurt, 2021). Piaget's theory of constructivist learning theory is based on observation and scientific study about how students participate in discovering, learning, and performing activities (Bada & Olusegun, 2015). This theory further explains the beliefs and attitudes in the learning process which is recognized as the central tenant of this theory. This follows that it is important for every pre-service teacher to understand their different perspectives and attitudes in the learning process.

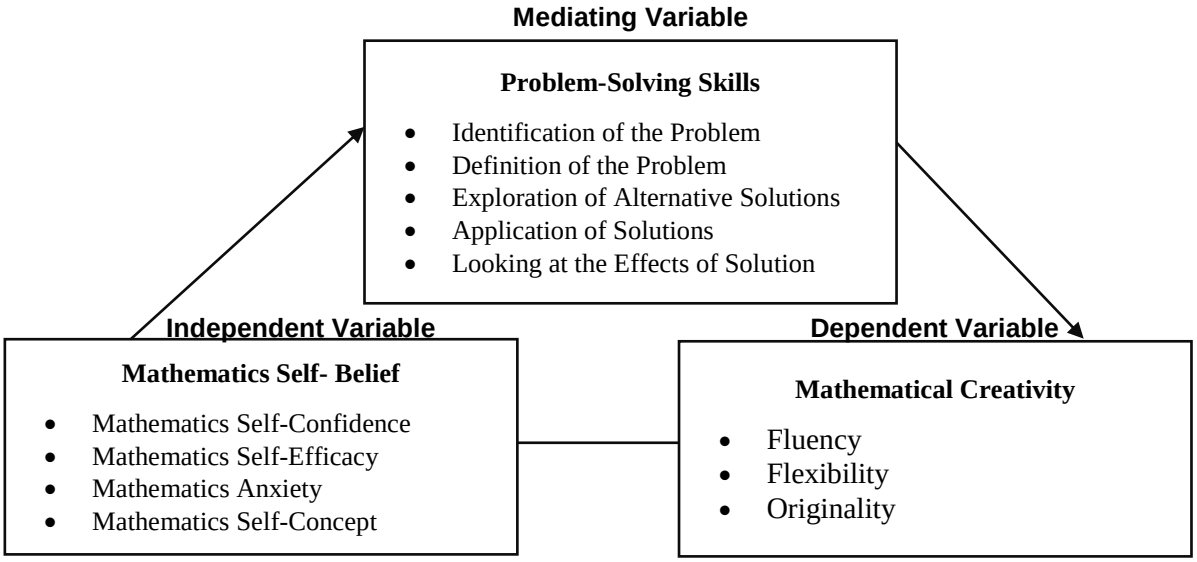

Fig. 1 The Research Framework

RESEARCH PROBLEMS

Specifically, this study intended to answer the given questions:

1. Does a significant relationship exist between mathematics self-belief, problem-solving ability, and mathematical creativity of the pre-service teachers?
2. Does a significant relationship exist between the problem-solving ability and mathematical creativity of the pre-service teachers?
3. Do problem-solving skills mediate the relationship between mathematics self-belief and mathematical creativity in solving non-routine problems?

MATERIALS AND METHODS

Descriptive-correlational with mediation analysis was employed in this study. Descriptive design is best used as research design since the aim of this research is to determine the characteristics, frequencies, trends, and categories of the respondents (McCombes, 2022). Since mathematics self-belief, problem-solving skills, and creativity are characteristics of the respondents in connection to mathematics, this design was utilized. As defined by Curtis et al. (2016), correlation design was used in examining the relationship among variables. Since this study wanted to examine the relationship among problem-solving skills, self-belief, and the mathematical creativity of respondents, the correlation design was applied. Finally, the use of mediation analysis is applicable to describe the causal effects of the independent variable on the dependent variable (Agler & De Boeck, 2017). Mediation analysis was utilized to determine whether the problem-solving skills explain the relationship between mathematics self-belief and mathematical creativity.

The respondents in this study were the mathematics pre-service teachers under the Bachelor of Secondary Education Major in Mathematics in two campuses in Laguna, Philippines. Clustered sampling is best used when the population is grouped into clusters (Sedgwick, 2014). In line with this, a cluster sampling technique was used for 153 mathematics pre-service teachers from the two campuses.

The variables of mathematics self-belief were analysed through mean and standard deviation. A reverse coding was performed on the responses in mathematics anxiety due to the existence of the negating statements. This process guarantees that it is concurrent with the other constructs of self-belief. Meanwhile, the problem-solving skills (poor, average, good, and excellent) and level of mathematical creativity (poor, average, good, excellent) were scored guided by the rubrics and analysed through frequency and percentages for each component.

To determine the relationship between mathematics self-belief and problem-solving, problem-solving and mathematical creativity, and mathematics self-belief and mathematical creativity Pearson Product-Moment Correlation was used. This was utilized since the result of the Kolmogorov-Smirnov normality test garnered a p-value greater than 0.05. Thus, the data were normally distributed.

A mediation analysis with Process Macro was used to determine if a mediating effect of problem-solving exists between mathematics self-belief and mathematical creativity. After analysis, findings were interpreted, and the necessary conclusions were provided.

RESULTS AND DISCUSSION

It can be inferred from Table 1 that a highly significant positive relationship existing between the pre-service teachers' problem-solving skills and self-confidence, self-efficacy, and self-concept with p-values $\leq$ .01. This demonstrates that pre-service teachers with higher levels of self-efficacy, self-confidence, and self-concept also have higher levels of problem-solving abilities.

Table 1 Test of Relationship of Mathematics Self-belief in Problem-solving and Mathematical Creativity

	Mathematics Self Belief				
	Self Confidence	Self-Efficacy	Mathematics Anxiety	Self-Concept	Overall
Problem-solving skills					
Identifying the problem	.612**	.648**	-.615**	.670**	.601**
Defining the problem	.637**	.680**	-.621**	.642**	.607**
Exploring alternative solutions	.556**	.646**	-.603**	.585**	.536**
Applying of solutions	.551**	.635**	-.547**	.607**	.570**
Looking at the effects of solutions	.573**	.597**	-.590**	.614**	.544**
Overall	.637**	.696**	-.647**	.676**	.620**
Mathematical Creativity					
Fluency	.517**	.600**	-.537**	.584**	.532**
Flexibility	.506**	.587**	-.552**	.553**	.497**
Originality	.355**	.392**	-.360**	.384**	.351**
Overall	.551**	.634**	-.579**	.611**	.554**

***. Correlation is significant at the 0.01 level (2-tailed)*

It shows that when pre-service teacher believes in their abilities in accomplishing tasks with persistence, determination, and perseverance they are also capable of developing greater degrees of problem-solving skills. Aside from that, learning at a higher level of education provides them confidence, thus allowing them to carry out mathematics activities such as problem-solving tasks successfully. On a similar note, the belief in their own ability and skills in mathematics in comparison with others enables them to perform better in problem-solving activities. As this belief increases, it will optimally increase their level of problem-solving skills. This demonstrates that as the level of self-confidence (Jusra & Iskandar, 2020), self-efficacy (Öztürk, et al., 2019), and self-concept increase (Galiano et al., 2017), their problem-solving skills also increase (Marsh et al., 2016).

Furthermore, there is also a highly significant positive relationship between self-confidence (Kharisudin et al., 2022), self-efficacy (Bales & Estomo, 2022), and self-concept (Romlah & Novtiars, 2018) with mathematical creativity. It simply suggests that if the pre-service teachers have high levels of self-confidence, self-efficacy, and self-concept, they will develop greater mathematical creativity. It can be attributed that there is already a positive belief in themselves in terms of self-confidence, self-efficacy, and self-concept in doing mathematics tasks, which implies that they can also develop higher levels of mathematical creativity. This indicates that mathematical creativity can be strengthened by showing capabilities for successful outcomes, persistence against difficult issues, and belief in their own skills and abilities in comparison with others. Once they exhibit these beliefs, they can develop greater degrees of mathematical creativity.

Contrary to this correlation, mathematics anxiety and problem-solving skills of students display a highly significant negative correlation (Irhamma et al., 2020; Das & Das, 2013; Aunurrofiq & Junaed, 2017). This means that when the pre-service teachers are tensed, worried, and feared of doing mathematics tasks, their level of problem-solving skills will decrease. This means that as mathematics anxiety increases problem-solving abilities decrease. Similarly, a highly significant negative correlation between mathematics anxiety and mathematical creativity. This demonstrates that when they are anxious about mathematics tasks, they are not capable of developing greater degrees of mathematical creativity. Similarly, Midhundas and Vijayakumari (2016) revealed that when there is an increase in level of mathematics anxiety, there is a decrease in the mathematical creativity level.

Based on the observation of the researchers, this can be inferred that when a pre-service teacher feels scared and stressed in solving problems, they will no longer try to continue and explore different approaches to accomplishing it. This will also hinder them to focus on doing the task and guessing will be more apparent in solving the problem, thus this will not allow them to show creativity in their tasks. Also, it is difficult for them to focus more and show their capabilities when they are clouded with negative emotions and anxiousness in mathematics.

Table 2 shows that there is a highly significant positive correlation between the phases of IDEAL problem-solving with the fluency, flexibility, and originality of mathematical creativity with p-values $\leq$ .01. However, the originality displays a low correlation in the problem-solving test. This demonstrates that when a pre-service teacher possesses a high level of problem-solving skills that also means that their mathematical creativity will be high.

Moreover, the mathematical creativity of students is more developed by giving them various problem-solving tasks (Nwoke, 2021). Letting them solve different problems also allows them to think of various strategies, approaches, and novel solutions which is increasingly important for fostering mathematical creativity. It can be inferred from this that they are already experienced in solving various problems as to why they are also capable of generating various strategies and approaches to solving them.

The most apparent in this table is the low correlation between problem-solving skills and the originality of their solutions. This indicates that despite their high level of problem-solving skills, it does not guarantee them to provide a non-standard or unique solution in solving the problem. Students are expected to use a variety of solutions and display originality when tackling different mathematical problems (Arifin et al., 2021). Given that creativity is ingrained in mathematical tasks and activities, it is vital to apply creativity to mathematics, especially when solving problems

(Kozlowski, 2019). As observed, when the respondents are solving the problems, most of them are answering the problem with one possible solution. This result shows that even though they have good problem-solving skills, they do not possess originality in solving them.

Table 2 Test of the Relationship between Problem-solving Skills and Mathematical Creativity

Problem-Solving Skills	Mathematical Creativity			
	Fluency	Flexibility	Originality	Overall
Identifying a Problem	.732**	.701**	.381**	.740**
Defining the Problem	.769**	.741**	.385**	.775**
Exploring Alternative Solutions	.754**	.720**	.352**	.751**
Applying Solutions	.936**	.804**	.389**	.887**
Looking at the Effects	.797**	.726**	.337**	.772**
Overall	.858**	.798**	.399**	.847**

***. Correlation is significant at the 0.01 level (2-tailed)*

The results from Table 3 revealed that a full mediation exists since the mathematics self-belief has no significant direct effect on the student's mathematical creativity with a p-value of 0.3854. It demonstrates that the measure of mathematics self-belief became insignificant as problem-solving was not introduced in its relationship with mathematical creativity. As studied by Pretz and McCollum (2014), self-belief can only be related to mathematical creativity only if there are tasks to be accomplished that students will show their creativity. This shows that the connection between self-belief and creativity will only exist if students are exposed to problem-solving.

Table 3 Mediation Analysis

Effect	Estimate	SE	95% Confidence Interval		t	p
			Lower	Upper		
Direct	.0766	.0880	-.0973	.2504	.8705	.3854
Indirect	.5064	.0671	.3694	.6365	7.5469	
Total	.8833	.1079	.6702	1.0965	8.1872	.0000
Effect	**Estimate**	**SE**	**95% Confidence Interval**		**t**	**p**
			Lower	**Upper**		
Belief → Problem	1.5863	.1634	1.2635	1.9092	9.7076	.0000
Belief → Creativity	.0766	.0880	-.0973	.2504	.8705	.3854
Problem→ Creativity	.5086	.0344	.4406	.5765	14.7929	.0000
Belief→ Problem → Creativity	.5064	.0671	.3694	.6365	7.5469	

On the other hand, the measure of mathematical creativity exists when students do problem-solving since they can display their creativity by means of applying various strategies and methods to solve non-routine problems. Furthermore, if problem-solving tasks were given to students, they will develop their mathematical creativity through these activities (Ardiansyah & Asikin, 2020). In line with this, Tyagi (2016) supported that mathematical creativity cannot be developed if they are not good problem-solvers. It can also be gleaned from the table that mathematics self-belief has a significant effect on problem-solving skills, and problem-solving skills significantly affect the mathematical creativity of the students. Hence, mathematics self-belief has indirectly affected mathematical creativity, confirming the full mediation effect of problem-solving skills.

FINDINGS AND CONCLUSIONS

A significant relationship was revealed between mathematics self-belief, mathematical creativity, and problem-solving skills. Similarly, problem-solving skills significantly relate to mathematical creativity. The study also revealed that mathematics self-belief has a significant effect on problem-solving skills, and problem-solving skills significantly affect the mathematical creativity of the students. Consequently, the only way to relate mathematics self-belief to mathematical creativity is through the existence of problem-solving skills. This demonstrates that establishing mathematics self-belief has an impact on the pre-service teachers' level of mathematical creativity through problem-solving skills. Since no studies have been found about the mediating role of problem-solving skills between mathematics self-belief and mathematical creativity, this study confirmed the full mediating effect of problem-solving skills in the relationship between mathematics self-belief and mathematical creativity of pre-service teachers.

RECOMMENDATIONS

Teachers may provide extension programs such as training intervention, mentoring sessions, and practice teaching activities as these tasks are optimal for developing mathematics self-belief. Similarly, they may consider giving routine and open-ended problems that will engage students to positively develop their problem solving in which they can showcase their creativity in mathematics. Further, the mathematics self-belief, mathematical creativity, and problem-solving skills of preservice teachers may also be compared across year levels by future researchers.

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DECLARATION OF CONFLICT
The authors declare that no conflict can be derived from this study.

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