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Mathematical Creativity of Pre-service Teachers in Solving Non-routine Problems in State University in Laguna

Rose R. Andrade, Allen E. Pasia*

College of Teacher Education-Faculty, Laguna State Polytechnic University-San Pablo City Campus, Philippines

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Abstract Developing a creative individual is one of the goals of the mathematical education system. Mathematical creativity is viewed as a product and a process. Likewise, this varies among individuals. The current study focuses on creativity in mathematics, particularly in problem-solving of the pre-service mathematics teachers in a state university in Laguna. The researchers attempted to describe the level of mathematical creativity of these pre-service teachers based on its different domains: fluency, flexibility, and originality. To measure the level of mathematical creativity of the pre-service teachers, they solved a set of non-routine problem-solving tasks presented to them. It revealed that this group of pre-service mathematics teachers have a moderate level of fluency and flexibility but a low level of originality. This finding means that they followed step-by-step solutions to derive the correct answer to the problem. However, they tend to stick to the same and usual strategies to solve the problems. This further showed that the overall level of mathematical creativity of the respondents is moderate. Findings reveal that age has no significant relationship with the level of mathematical creativity. At the same time, academic achievement significantly relates to fluency and originality as mathematical creativity measures. It is found that males and females do not significantly differ in their level of mathematical creativity. Thus, it is firmly believed that mastery of various mathematical concepts and applications of different problem-solving strategies has yet to be developed among pre-service teachers in order to attain higher levels of mathematical creativity.

Keywords Non-routine Problems, Mathematical Creativity, Fluency, Flexibility, Originality, Pre-service Teachers

1. Introduction

The educational system worldwide has shifted its focus from memorizing to problem-solving [1]. In fact, problem-solving is one of the 21st-century skills that are being given significant weight in Mathematics education [2]. It is viewed as an individual's cognitive task of combining previous knowledge and skill to look for an unfamiliar solution to an unpredictable problem [3]. With the dynamic nature of today's technological world, the cultivation and development of problem-solving skills among students have grown relative importance. However, the fast-paced innovation pushes that problem-solving must be creative because the role of creative problem-solving in this digital era is truly indispensable. In the next generation, students would be confronted by an unknown predicament that requires the creation of possible antidotes [4].

Although there is no uniform definition of creativity, numerous works of literature have stated that it is the ability to provide work that is original, unique, and novel [5,6]. However, the question remains on how this creative problem solving can be developed. In Mathematics education, students' exposure to non-routine problems could be a contributing factor to hone such skill [6-8].

Non-routine problems are kinds of problems that require the use of different strategies and heuristics [9]. These problems are more difficult and complicated than routine problems because numerous approaches must be devised to solve an unfamiliar situation [10]. Thus, these problems require flexibility and strategic thinking to extend previous knowledge and concepts that allow having different pathways to a solution, leading to the enhancement of student's Mathematical creativity [11].

Creativity in Mathematics throughout the years is viewed by researchers in two ways: as a product and as a process. Sternberg and Lubart [12] define Mathematical creativity as the ability to produce original work. Sriraman [13] also affirms that Mathematical creativity is the capacity to exhibit a novel work. On the other hand, as Livne and Milgram [14] have noted, Mathematical creativity is the ability to think outside the box by looking for patterns and relationships that would yield an unexpected output. In this research, Mathematical creativity is characterized as a process using three major components: fluency, flexibility, and originality [15-19]. In discussing these three components, the researchers adopted the definition used by Haylock [20] and that of Fortes and Andrade [8] which includes first, fluency being the frequency of correct solutions and responses; secondly, flexibility as the number of different strategies or solutions; and, finally, originality being the uncommonness of the strategy or solution, employed in solving a problem as compared to a group.

Contemporary curricula have been putting major efforts to nurture the mathematical creativity of the students in all aspects. Western and Asian countries have taken action by integrating creativity into the curriculum [21,22]. Hong Kong, China, Japan, South Korea, and Singapore have given great emphasis on developing Mathematical creativity [21]. Further, a similar undertaking has been done by the Philippines [23]. However, despite the Philippines' educational reforms, the level of Mathematical creativity is still unsatisfactory, as evident in the Program for International Student Assessment [24]. One factor that can be examined is the level of Mathematical creativity of pre-service teachers. Teachers are the catalysts of change and, therefore, could provide invaluable aid in fostering mathematical creativity [25]. Several researchers confirmed that creative teachers could maximize the potential growth of students in terms of their knowledge, experiences, skills, and engagement in real-life tasks [18,26,27]. Further, Suastika [28] even emphasized that it is the duty of the Mathematics teachers to encourage students' creativity, and it is necessary for them to provide a conducive environment for the optimal development of such skill. Nonetheless, to prepare them in this significant role, investigation, and cultivation of mathematical creativity of future teachers is urgent and is gravely important.

Teacher education programs in higher education in the Philippines aim to produce creative students who are globally competitive and fully prepared to surpass the challenges of the future. But the questions to consider are: “How creative are they to meet these challenges?” or “Do they possess the expected level of Mathematical creativity?" The researchers believe that to fully equip our students and to appropriately provide sufficient intervention, one might look first to determine the level of Mathematical creativity of the pre-service teachers, the so-called shapers of students’ tomorrow. Moreover, pre-service teachers’ lack of knowledge and low level of competence could be disturbing in building Mathematical talents. But if these prospective Mathematics teachers could be given proper introduction and tasks aiming to develop Mathematical creativity during their training and discussion, then this problem could be prevented.

Moreover, several investigators have linked background characteristics such as age, gender, and academic achievement to creativity. In the study of Naderi et al. [29], age and gender differences concerning aspects of creativity significantly relate to academic achievement. Likewise, Piaw [30] revealed that gender has a great impact on students' creative thinking ability. However, Sayed and Mohammed [31] exposed that no gender differences in divergent thinking, but the grade-level effect was statistically significant. Furthermore, Bahar and Maker [32] stated that the scores in mathematical creativity might predict the mathematical achievement of the students. On the contrary, Ogunsaya et al. [33] found out that there is a low negative significant relationship between creativity and academic achievement. Hence, high achiever in education does not necessarily equate to being highly creative. Although these variables have been investigated in several studies, conflicting conclusions are very apparent. This study aims to verify the existing results and determine if age and academic achievement have a significant relationship on pre-service teacher’s mathematical creativity and if gender has a significant difference in fluency, flexibility, and originality as measures of mathematical creativity.

With the implication of creativity in today's world, several researchers have become interested in studying creativity in general [34,35,26,27]. However, the frequency of researches in analyzing Mathematical creativity is very scarce [36]. Hence, the researchers have encountered a limited number of studies measuring the mathematical creativity of students in the country. This study aims to fill the gap and contribute to the growing body of works in Mathematical creativity.

Mathematical Creativity

Several studies have been conducted to explore, describe, and measure the mathematical creativity of the students and the most pertinent to the present study are as follows:

In the study conducted by Borja [37], students got a high and low score in fluency and originality, respectively. On the contrary, according to Supriadi [38], pre-service elementary teachers got the highest score in flexibility but surprisingly achieved lowest in fluency. This implies that elementary teacher candidates have a fixed belief in mathematics and often encouraged to use a conventional algorithm. When they are faced with an unusual problem, struggle in solving becomes prevalent. Moreover, Suryana [39] asserted that originality is the most challenging component of mathematical creativity. This is in parallel to Lev and Leikin [6] that originality is for the students who have a high level of mathematical achievement. Further, Fortes and Andrade [8] stated that students had difficulty in generating a unique solution, and the students, in general, are considered moderately creative.

Mathematical creativity and Mathematical ability have been found to be positively correlated with one another [35]. Students with high Mathematical ability are highly creative students as well. Likewise, average Mathematical ability students have an average performance across fluency, flexibility, and originality [40]. Nevertheless, Baran et al. [41] have found out no significant relationship between creative thinking and Mathematical ability. From this, it could be derived that a high level of Mathematical ability does not predict the level of creativity.

Kozlowski et al. [27] highlighted that there is a difference in the creativity level between secondary and college students. Exposure to long years of schooling and struggling problems are the two major factors for the discrepancy in the level of mathematical creativity.

Teachers' competence, knowledge, and belief affect the atmosphere that could foster students' creativity and push them to go beyond what is expected [42]. Allowing students to take risks, make errors and to look for a non-standard solution must be the aim of every teacher. However, teachers' lack of knowledge, low level of competence, math anxiety, and fixed belief hinder the aim of reformed education in maximizing student's mathematical creativity [17]. This is inconsonant to the findings of Gelora et al., [26] that limited knowledge of the teacher adversely affects pedagogies that would promote this skill. Nadjafikhah, et al. [25] noted further that creative students could only be produced by creative teachers. Thus, it is deemed necessary that training that would promote creativity should be given to pre-service teachers as they are held responsible for honing the mathematical talents of students. If this is overlooked, the utmost goal of mathematics education and the future of 21^{st}-century learners are in jeopardy.

Given the above-mentioned circumstances and contrasting research findings, this study hopes to give light to these inconsistencies by investigating the pre-service teacher's mathematical creativity through non-routine problems.

2. Framework of the Study

The study is anchored in Constructivist Theory, which held the belief that the extension of previous knowledge matters to construct new insights. In the educational environment, the students are allowed to take risks, commit errors, and provide multiple perspectives in solving problems. This opportunity provides an avenue to attain the highest order of learning, such as heuristic problem solving, metacognitive knowledge, and creativity, which lead to the innovation of new knowledge and procedures.

Age, gender, and academic achievement in terms of General Weighted Average (GWA) serve as the independent variables of the study. Haylock [20] described fluency as the ability of the students to provide correct responses that are relevant to the mathematical situation, flexibility as the ability of the students to use diverse problem-solving heuristics and originality as the ability to use strategies that are unique and non-standard solution to solve a problem. In view of the foregoing, the concepts of fluency, flexibility, and originality in solving non-routine problems are likewise applied to measure mathematical creativity.

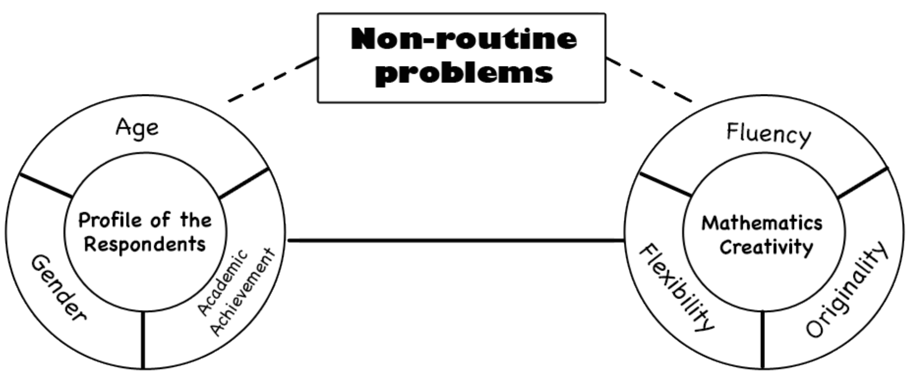

Figure 1. Graphical Representation of the Framework

Statement of the Problems

The main purpose of this research is to describe the mathematical creativity of teacher education students at a State University in Laguna. Specifically, the study sought to answer the following questions:

1. What is the overall level of mathematical creativity of pre-service teachers in solving non-routine problems?
2. What is the level of mathematical creativity of pre-service teachers in terms of:
    a. fluency,
    b. flexibility, and
    c. originality?
3. Is the academic achievement of the pre-service teachers significantly associated with their level of mathematical creativity?
4. Does the age of a pre-service teacher significantly relate to their level of mathematical creativity?
5. Does the level of mathematical creativity significantly differ among pre-service teachers when grouped according to their gender?

Research Design

The descriptive method of research is used to describe the level of mathematical creativity of the pre-service teachers in terms of fluency, flexibility, and originality gathered from the students' solution and interview. Likewise, this method was used since there was an intention to determine the significant association among age, academic achievement, and mathematical creativity and a test of significant difference between male and female students' level of mathematical creativity.

Participants

This study was participated by 37 Pre-service Teachers at a State University in Laguna. The respondents were chosen through purposive sampling with Mathematics as an area of specialization. Table 1 below shows the distribution of the respondents according to age, gender, and academic achievement.

As shown in the table, most of the pre-service teachers in this study are female whose ages range from 19 to 21. The academic achievement here is measured by the general weighted average of the pre-service teachers in the past two semesters. They have a very satisfactory academic achievement. This means that these pre-service teachers' grades range from 1.50 to 2.50. In this grading system, 1 is the highest possible grade, and 5 is the lowest possible grade of a student.

Data Gathering Procedure

The problem-solving test was administered to thirty-seven (37) students of the fourth year and third-year college students that compromise the population of BSED-Major in Math in a state university in Laguna. The six non-routine problems used by Fortes and Andrade (2019) were given in one session. In this session, six problems were answered by students for two hours. After solving the problems, there was a group interview. Three mathematics professors were asked to analyze and score the students' solutions using a scoring rubric (with 5 points as the highest score per problem). The mean scores were used to describe students' mathematical creativity as high (with a grand mean of 20.6 – 30), moderate (having a grand mean of 10.6 – 20.5), and low (grand mean is within the range 1 – 10.5).

Table 1. Distribution of the Pre-Service Mathematics Teachers Gender, Age and Academic Achievement

		Age							Academic Achievement		
		19	20	21	22	23	24	27	Excellent	Very Satisfactory	Satisfactory
Gender	Male	1	8	1	1	0	0	1	0	5	6
	Female	3	14	6	1	1	1	0	4	13	9
Total		4	21	7	2	1	1	1	4	18	15

Data Gathering Instruments

A problem-solving test was used to gather information and support the data analyses of the students' solution in each non-routine problem. A scoring rubric was used to determine whether and to what extent solutions exhibited fluency, flexibility, and originality.

Statistical Tool

Descriptive statistics such as frequency, percentage, and mean are used in this study**.** Kendall's tau is used to determine a significant association between the mathematical creativity of the pre-service teachers and their age and academic performance. Each of the domain of the mathematical creativity and the overall level of mathematical creativity was tested for normality using the Shapiro Wilk test. The test showed significant departure from normality of age W(37)= .677, p=.000, academic achievement W(37)=.915, p=.008 and originality W(37) =.910, p=.006. On the other hand, Shapiro Wilk showed that fluency (W(37)=.980,p=.719), flexibility (W(37)=.956, p = .153), and over-all mathematical creativity(W(37)=.978, p=.646) are normally distributed.

An independent samples t-test was used to determine whether males and females significantly differ in their fluency, flexibility, originality, and over-all level of mathematical creativity, an independent samples t-test was used. These data sets are continuous data, and the normality of each group's distribution was tested using Shapiro Wilk. For the male group, the following is the result of the test of normality. Fluency (W(37)=.960, p=.776), flexibility (W(37) =.901, p=.188), originality (W(37)=.895, p=.163, and over-all mathematical creativity (W(37)=.895, p=.163). For the female group, the result is as follows fluency (W(37)=.973, p=.709), flexibility (W(37) =.950, p=.235), originality (W(37)=.903, p=.109), and over-all mathematical creativity (W(37)=.977, p=.801). Since these data sets did not violate the assumption of normality, then the independent samples t-test was appropriate to be used.

3. Results and Discussions

This section presents the level of mathematical creativity in terms of fluency, flexibility, and originality. This also includes the overall mathematical creativity of mathematics teacher education students.

On Overall Mathematical Creativity

It can be gleaned from the table the mean of the three measures of mathematical creativity and the overall level of mathematical creativity of pre-service mathematics teachers. The assessment of mathematical creativity was based on the students' fluency, flexibility, and originality [15-19]. The fluency referred to the number of correct responses that students presented. Flexibility would mean the different types of responses that are measured, and originality was calculated by comparing a student's solutions with the solutions provided by all the students in the group.

The table also shows that pre-service mathematics teachers are moderately creative in terms of fluency and flexibility. This means that they can perform procedures following a series of relevant steps and can implement different types of responses to solve a certain problem. However, this table also displays the low level of originality of the pre-service teachers in solving non-routine problems. This means that most of the pre-service teachers used the same methods or solutions or calculations in solving a particular problem. Borja [37] put forward that most students know how to successfully solve a certain problem but failed to generate a unique solution as Fortes and Andrade [8] implied on their study, that this scenario might be attributed to the students' comfort to dwell on a strategy that they already know and the lack of initiative to verify their answers.

Solving problems in mathematics, especially non-routine, requires a student to be abstract and generalize mathematical content [43,45] and to make connections between unrelated ideas [44,45]. It is rooted in a strong foundation on the content knowledge of the student. The lack of such content knowledge would disable the students to perform a variety of responses that are both relevant to the success of solving the problem and uncommon to the rest of the students in their class.

Table 2. Overall Mathematical Creativity of Pre-Service Mathematics Teachers

Mathematical Creativity	Mean	Std. Deviation	Levels of Creativity
Fluency	17.41	4.35	Moderate
Flexibility	15.03	4.34	Moderate
Originality	7.62	2.15	Low
Overall	13.35	3.09	Moderate

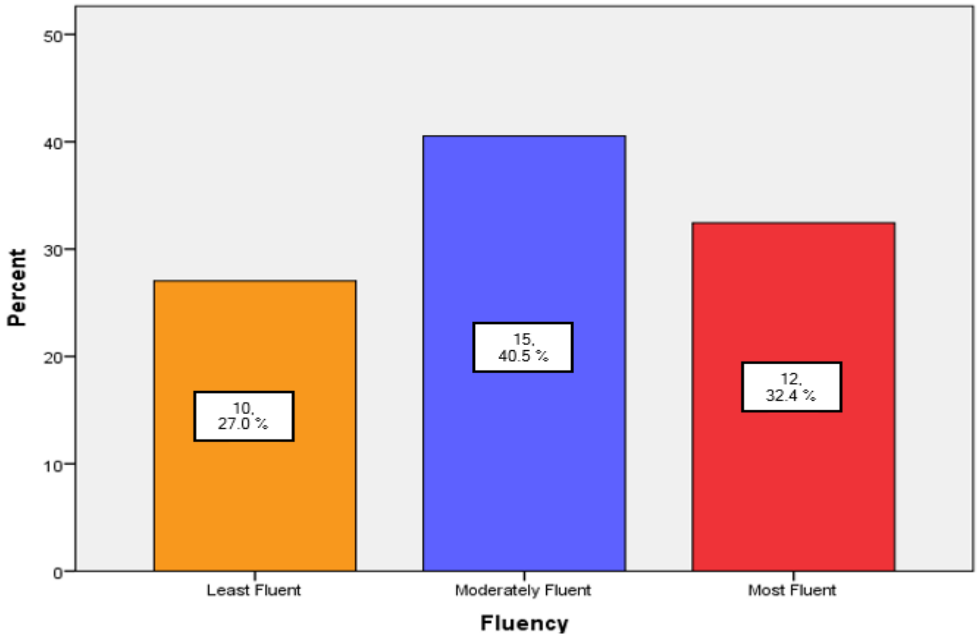

Figure 2. Level of Fluency as Measure of Mathematical Creativity

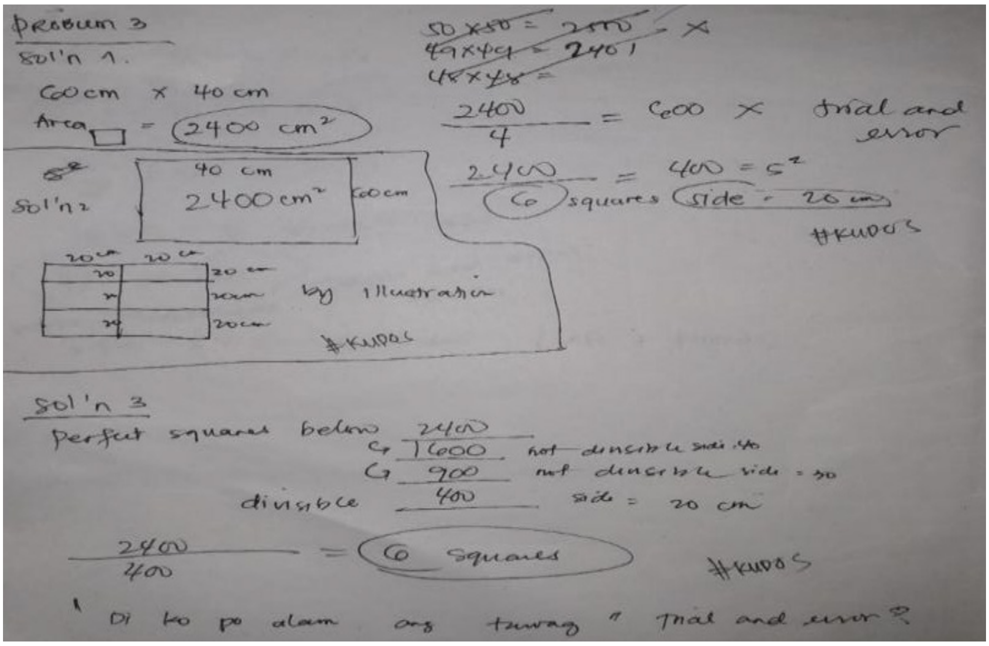

Figure 3. The solution of Student Kudos in Problem 3

On Fluency

Figure 2 shows the level of mathematical creativity in terms of fluency. A student is fluent based on the consistency and correctness of his/her solutions to a problem. Most of the students are moderate to most fluent in giving solutions to the given non-routine problems.

Student Kudos is considered as one of the most fluent students who presented a solution in Problem 3.

The student (Kudos) had presented several ways to answer the problem. In the student's first solution, the original dimensions of the rectangle were multiplied to get the area of the entire figure. Then, that [original area] was divided by a number [4] and see if the resulting number is a perfect square. The process continued until the quotient is a perfect square. As proof of the students' high level of fluency, another solution was given. This time, illustration aided the student in successfully solving the solution. First, the student drew the given rectangle and tried to divide each side into lengths that are common to both dimensions. Let say, since 20 can divide both 40 and 60 exactly, then counting the number of squares gave the correct answer to the problem.

Finally, a solution similar to the second solution was presented by student Kudos. The student tried dividing the original area [2,400] by some perfect square numbers [1600, 900, 400] until the original area is exactly divisible by the latter. This student has exemplified the high level of fluency in solving non-routine problems since she had presented a number of relevant and unrepeated ideas [46]. These ideas are deemed appropriate responses in relation to the problem.

In addition, it can be noticed that still 27% of the teacher education students specializing in mathematics are considered least fluent.

Student X44 is considered the least fluent for getting a score of 10 in all six (6) non-routine problems. It can be noticed that she had an attempt to answer the Problem1. The figure shows the solutions to the problem.

From the solution, it can be noticed that the student used the Trial and Error in solving the problem. The possible scores are each multiplied by 7, then add the products and see if the sum is equal to 356. At first, the sum is not 356, so he tried to multiply 13 by 9 and 2 by 11. This solution led to an incorrect answer. Throughout the solution, the student presented just multiplication and addition of numbers to come up with the answer. Fortes and Andrade [8], attributed low fluency in the inadequacy of knowledge on the concepts that are necessary to answer a problem.

On Flexibility

Most of the students are at least (21.6%) to moderate, flexible (62.20%). Flexibility is a measure of mathematical creativity that refers to the ability to produce ideas that use different approaches to solve a non-routine problem [46].

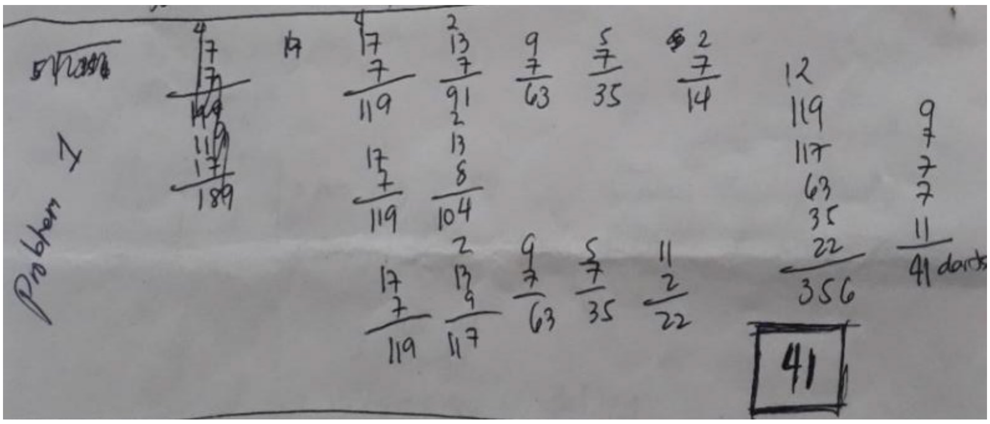

Figure 4. The solution of Student X44 to Problem 1

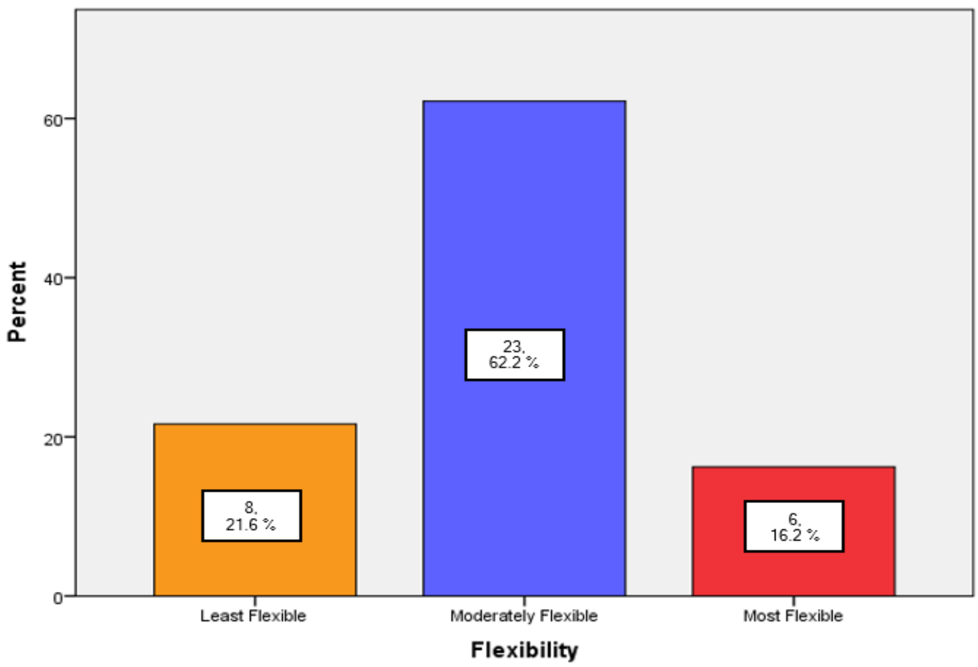

Figure 5. Level of Flexibility as Measure of Mathematical Creativity

Figure 6 shows the solution of student Kudos on the second problem. Here the students had implemented high flexibility in the solutions. Noticeably, the student had used an algebraic approach to solve the problem. She formulated an algebraic system of equation [linear] to find the number of responses of the boy. She represented the number of correct and incorrect responses by different variables and eventually formed two equations.

Another solution was presented, which is a guess and check approach. She tried multiplying numbers 50, 49, 48, …, 38 by 5, until she got an even number multiple of 5 that is greater than and closest to 172. The student had presented two approaches to produce solutions that are relevant to successfully solve the problem.

The student LF1026 is considered as least flexible in presenting the solution to problem number 2. In figure 7, she used the trial and error method in solving the problem. She tried to find the numbers of correct responses less than 50 then multiplied it by 5. Another number is multiplied by two, and the product was subtracted from the product in the previous procedure. However, she had not revisited the problem and mistakenly derived the answer based on a different total score as it is stated in the problem.

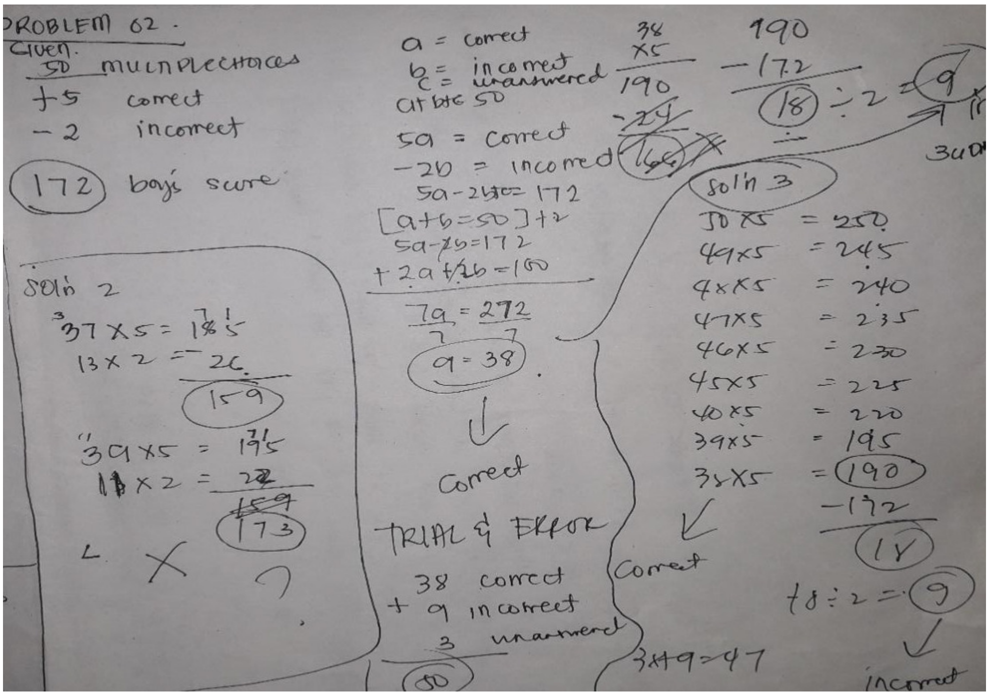

Figure 6. The solution of Student Kudos to Problem 2

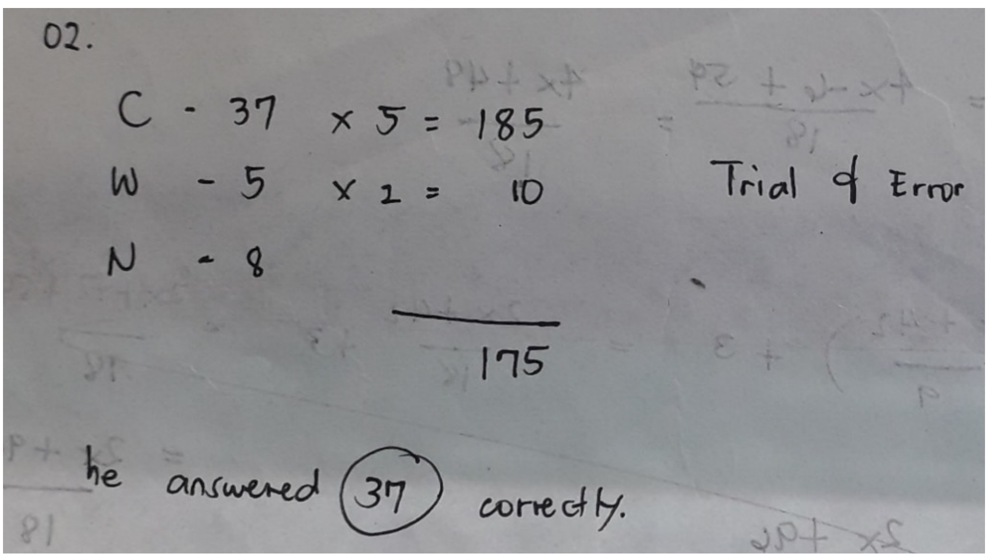

Figure 7. The solution of Student LF1026 to Problem 2

Another solution that is of the least level of flexibility is shown in Figure 8. The student [Unknown0214] implemented a solution that involves the use of basic operations. However, she made no explanation of the answer, aside from stating that a trial and error approach was used. Unknown0214 started with what she assumed as the initial number of stickers. She multiplied 42 by 1/3 but failed to add 2 to the product as she should have done according to the problem. According to [46], solutions that stemmed from a single approach are considered a low level of flexibility. In this case, since student Unknown0214 provided just a single solution and then she is considered to possess the lowest level of flexibility in solving Problem 5.

On Originality

Among the three measures of mathematical creativity, the originality is considered the most difficult component to satisfy. A student who has the most original solution should implement a solution that is not used by most of the students in the same class. However, if a student's solution is used by more than 90% of the class, then his/her solution is of least originality.

Apparently, most of the students (89.20%) provided the least original solutions to most of the problems. Only four students provided original solutions. This means that the students had presented an uncommon response to the given non-routine problems.

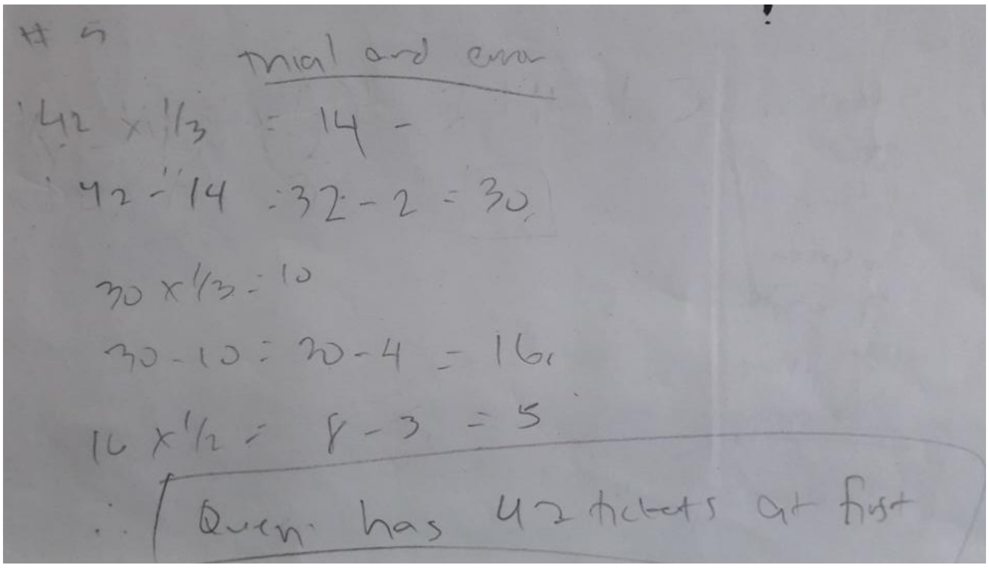

Figure 8. The solution of Student Unknown0214 to Problem 5

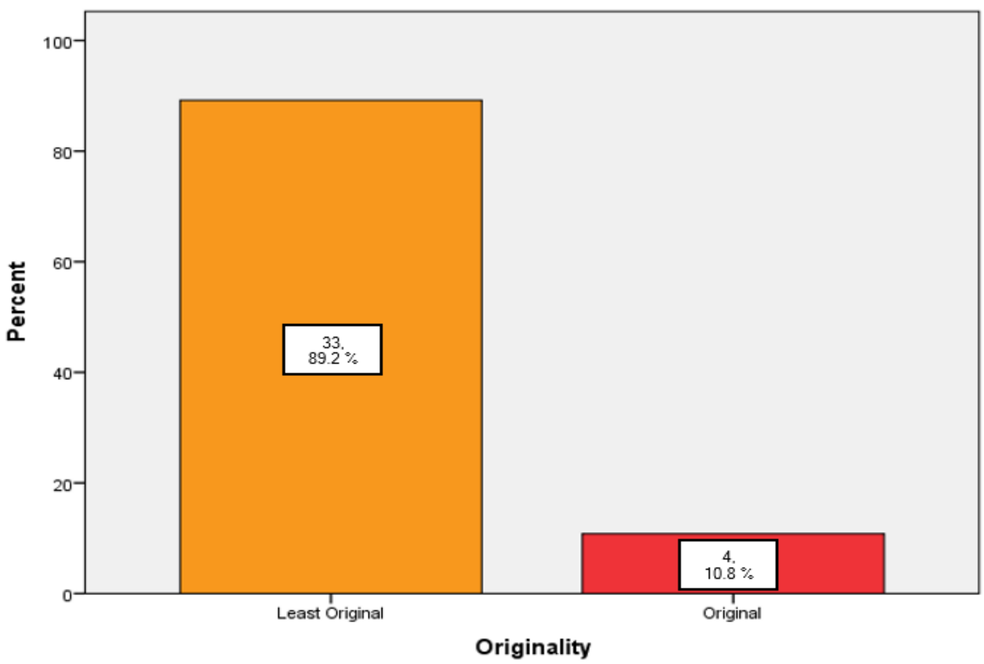

Figure 9. Level of Originality as Measure of Mathematical Creativity

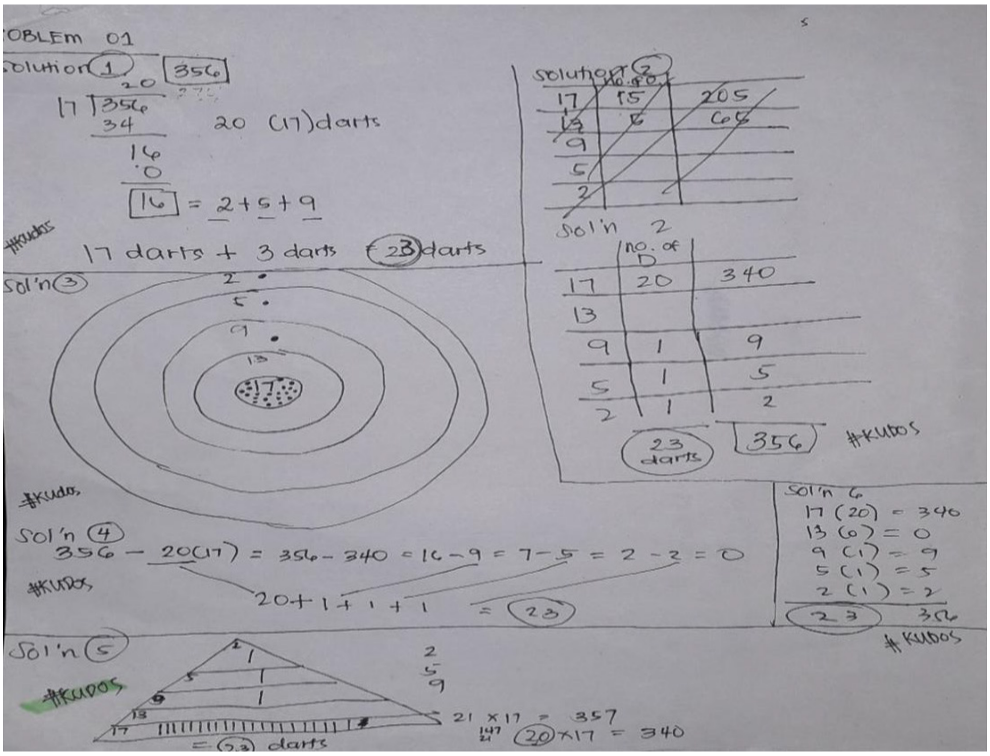

Figure 10. The solution of Student Kudos to Problem 1

Student Kudos has presented six (6) solutions to solve problem 1. Referring to Figure 10, the student used basic operations equations, illustrations/diagrams, and tabular solutions. Although these solutions seem common ways out to solve this problem, what made her solution original is the fact she is the only one in her class that utilizes the table-based solution, while the rest of the class used basic operation equations. In problem number 1, only one (1) used a tabular solution. In problem 5, only (2) students solved the problem using a backward solution while the rest used basic operation solutions. This made these students' solutions original.

On Association of Age, Academic Achievement and Level of Mathematical Creativity

Table 3 shows the test of a significant association between the age and the level of mathematical creativity of the pre-service teachers in terms of fluency, flexibility, originality, and the overall level of mathematical creativity. Findings suggest that the age of the pre-service teachers is not significantly associated with their levels of fluency, flexibility, originality, the over-all level of mathematical creativity in solving mathematical problems. It is also revealed the significant relationship between the academic achievement of the pre-service and their level of mathematical creativity in terms of fluency and originality. This finding suggests that the students who have a higher level of academic achievement are also the students who are more fluent and manifest a higher level of originality in solving mathematical non-routine problems. This is a converse of the findings of Bahar and Maker [32] that mathematical creativity predicts academic achievement of the students. Furthermore, the academic achievement accounts for 7.89% and 10.4% of the variability in the levels of fluency and originality in solving non-routine mathematics, respectively.

Table 3. Test of Significant Association of Age, Academic Achievement and Level of Mathematical Creativity

	Fluency	Flexibility	Originality	Over-all Level of Mathematical Creativity
Age	-.154	-.107	-.025	-.135
Academic Achievement	-.281*	-.103	-.322**	-.225

*. Correlation is significant at the 0.05 level (2-tailed)

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

Table 4. Test of Significant Difference in the Level of Mathematical Creativity of the Preservice Teacher When Grouped According to Gender

Mathematical Creativity	Gender	Mean	SD	t-test for Equality of Means						
				t	df	Sig. (2-tailed)	Mean Diff	Std. Error Diff	95% Confidence Interval of the Difference	
									Lower	Upper
Fluency	Male	17.45	3.50	.044	35	.965	.07	1.59	-3.15	3.29
	Female	17.38	4.73							
Flexibility	Male	15.64	4.59	.550	35	.586	.87	1.58	-2.34	4.07
	Female	14.77	4.30							
Originality	Male	7.36	1.91	-.469	35	.642	-.37	.78	-1.96	1.22
	Female	7.73	2.27							
Over-all Level	Male	13.49	2.85	.171	35	.865	.19	1.13	-2.10	2.48
	Female	13.29	3.24							

Table 4 reveals that there is no significant difference between the level of mathematical creativity when the pre-service teachers are grouped according to their gender. This means that the levels of fluency, flexibility, and originality in solving non-routine mathematical problems of pre-service teachers across gender are statistically the same. In other words, male and female pre-service teachers have equal abilities in providing relevant and correct responses to and using diversity, unique and non-standard problem-solving heuristics on mathematical problem-solving tasks.

4. Conclusions and Recommendations

The main purpose of this research is to describe the level of mathematical creativity of teacher education students in solving non-routine problems. It was found out that these pre-service mathematics teachers have a moderate level of fluency and flexibility but a low level of originality. This confirms the previous studies that attempted to describe the mathematical creativity of the students. It is still indispensable to equip students with necessary content knowledge in mathematics so that they may be successful in tasks of solving mathematical problems such as non-routine problems. Although the respondents of this study are third and fourth-year pre-service mathematics teachers, the mastery of the application of content knowledge is yet to be harnessed.

This study also revealed that most of the pre-service mathematics teachers are fluent and flexible in solving non-routine problems. They follow step-by-step solutions to derive the correct answer to the problem. It is so because they had already finished all the specialized subjects which could be used to solve the given problems. However, it was also shown that these pre-service teachers stick to their usual solutions. This fact limits the originality of their solutions. As Leiken [47] suggested, they may use different representations of mathematical concepts, properties such as definitions or theorems on certain mathematical concepts, integrate different mathematical tools from other branches of mathematics or other fields. Nonetheless, they rarely reflect and explore a variety of other solutions there could have in order to solve the problem. Change of direction or approach occurs on some occasions on some non-routine problem, which explains a moderate to a high level of flexibility. However, their idea of solving the problem was not unique most of the time. They did not critically evaluate their solutions, which led to a less original solution.

The study also showed that age has no significant statistical relationship with the pre-service teachers' level of mathematical creativity. However, it was also revealed that the level of academic achievement has a significant relationship with the level of fluency in solving mathematical problems and originality of the strategies they used to solve the same problems. Moreover, there was no significant difference between males and females on their level of mathematical creativity.

To sum up, the teaching of mathematical content knowledge is essential in developing future mathematics teachers. Likewise, creative applications of mathematics in the exploration of problems are as well vital [48]. It is recommended here that a program of intervention may be developed and eventually be used in developing further competence of the pre-service teachers in creatively solving non-routine problems. The use of models in teaching problem solving may also be considered. Furthermore, Nadjafikhaha et al. [25] and Mann [49] stressed that the encouragement of mathematical creativity in combination with computational accuracy is important for students to further develop their mathematical ability and understanding. This is of great help for future mathematics teachers in doing their task of molding Filipino students to become good problem solvers and critical thinkers.

This study reflects the importance of engaging pre-service mathematics teachers to develop mathematical creativity. Thus, this recommends developing a framework for the analysis of pre-service teachers' mathematical creativity with regards to the three components, namely: fluency, flexibility, and originality. This also would like to recommend using interventions in teaching that would address the low level of originality among the pre-service teachers.

This study is limited to 37 pre-service mathematics teachers in a state university in Laguna. They answered a-six non-routine problem tasks. Thus, this study further recommends that the same study may be conducted widely on other teacher education institutions in all ages and year levels to provide a bigger picture of mathematical creativity among pre-service mathematics teachers.

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