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Analyzing the Impact of Problem-based Learning on Mathematical Creativity of Grade 8 High School Students from Pilgrim Christian College

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ABSTRACT

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Problem-Based Learning is an approach where students learn concepts and skills by solving complex and real-world problems with emphasis on active engagement, critical thinking, and collaboration. This quasi-experiment investigated the pre-test and post-test scores of the forty-four grade 8 students from Pilgrim Christian College and the impact of problem-based learning to their mathematical creativity. The students belong to two sections, which were the experimental and control group. The researcher used a teacher made test that was validated and an adapted scoring rubrics for mathematical creativity. The statistical techniques that were used includes normality, linear regression, homogeneity of regression slopes and variances. The test was conducted with ANCOVA, however, assumptions failed so Mann-Whitney U test was used. Analyze data

shows that the test is statistically significant and mean-ranks indicate that the experimental group have higher post-test scores than the control group, which means that students who were taught using problem-based learning demonstrated higher scores in mathematical creativity than those who received conventional instruction. Therefore, the evidence supports PBL as an effective strategy for nurturing mathematical creativity among grade 8 students from Pilgrim Christian College.

INTRODUCTION

Mathematics is integrated into daily life, influencing activities from domestic budgeting to making decisions in various scenarios. Math abilities amplify individual development, problem-solving skills, and intellectual capacity, citing the need for effective teaching strategies towards developing these abilities (Maloney, 2023). Abd Algani (2022) observed the use of mathematics in other real-life scenarios, pointing out that math serves as a significant contributor toward society's development. Likewise, Kozlowski et al. (2019) said that creative thinking in mathematics is a topic that has overreach, as its implications can be connected to a great deal of progress in society.

Even though mathematics significance is enormous, students find it hard to connect math with real-life experiences since it is abstract to them. According to Wakhata et al. (2022), the attitude leads to less appreciation and interest in the subject. To mitigate this issue, Santillán (2016) advocates for the use of innovative learning methods that make math more familiar and engaging for students. According to Joklitschke et al. (2021) there is an increasing interest in mathematical creativity in the field of research. Like Education systems in Southeast Asia now focus on building the creative thinking capacity of students to meet the challenges of rapidly changing times in a digital world. A study of Rocena and Joaquin (2021) about comparing the mathematical creativity of Filipino and Japanese students in terms of solving mathematical problems showed that Japanese students have greater flexibility, originality, and fluency than the Filipino students in solving mathematical problems. This difference between the students highlights the need for the reform of the education system in the Philippines to improve creative abilities in mathematics of the students. A research by Assmus and Fritzlar (2018) further highlights the importance of originality in mathematical creativity, as they suggest that creating novel approaches to problem-solving is necessary to the growth of the students. A meta-analysis conducted by Manaf et al. (2022) demonstrated a positive correlation between academic achievement and creativity which highlights the value in integrating creative thinking into the teaching of mathematics.

In Filipino setting, a number of studies have explored the effectiveness of problem-based learning in mathematical abilities. Roble et al. (2021) experimented on Differential Calculus students from the University of Science and

Technology of Southern Philippines using the creative constructs, and the study found that problem-based learning and problem-posing significantly enhanced mathematical flexibility and fluency. The same goes with the study of Andrade and Pasia (2020) about the mathematical creativity of pre-service teachers in solving non-routine problems in State University in Laguna. Likewise, Andal and Hermosa (2024) tested the impact of PBL methods on the creative thinking abilities of Grade 12 students in Contemporary Philippine Arts, and they found significant enhancements in fluency, flexibility, originality, and elaboration.

Based on these studies, there remains a gap of information regarding the application of problem-based learning in order to enhance the mathematical creativity of Filipino secondary high school students. Although problem-based learning has been successful in other educational settings, its impact on the mathematical creativity of Filipino students remains to be fully explored to date. This research aims to fill the gap by investigating the impact of problem-based learning on the mathematical creativity of Pilgrim Christian College Grade 8 students, adding to the literature with more effective instructional strategies.

FRAMEWORK

The study is anchored on Leikin's (2009) Theory of Creative Mathematical Thinking, which conceptualizes mathematically creative individuals as being capable of generating creative, diverse, and contextually appropriate mathematical ideas or solutions. The theory focuses on key creativity factors, such as fluency, flexibility, and originality, all of which are essential in successful mathematical problem-solving. This theory is also connected with Constructivist Theory, which is foundationally believed that prior knowledge is of utmost relevance in the formation of new understandings (Lamina, 2024). An education culture is one in which students can risk, fail, and present multiple methods for solving problems. Thus, it enables to achieve the highest tiers of education advancement like heuristic problem-solving, metacognitive knowledge, and creativity, all of which foster creating new knowledge and processes. Also, as a learning model, PBL has a number of elements, or, strategies, that help support to be popular among students. Moreover, PBL focuses on hands-on instruction, rather than fact memorization for students which challenges students to think at higher order skills (analyzing, creating, defending, or evaluating). Students practice stating and responding to questions, expressing support for each other's views and collaborating in small groups which builds good social skills. They also find PBL experiences more enjoyable, inspiring, and engaging (Affandy et al., 2024).

Figure 1
Schematic Diagram of the interplay of variables of the study

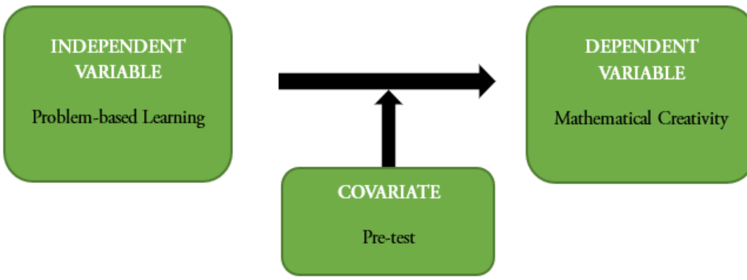


Figure 1 shows the diagram of pre-test post-test control group design. This is the visual representation of how the system works between the independent variable, which is

OBJECTIVES OF THE STUDY

This study sought to (1) determine the pre-test and post-test scores of the students and (2) examine whether there is a significant difference in the mathematical creativity scores between the control and experimental groups.

$H_0 =$ there is no significant difference on student's mathematical creativity scores between the control and experimental group
$H_1 =$ there is a significant difference on student's mathematical creativity scores between the control and experimental group
problem-based learning and dependent variable, which is the mathematical creativity.

METHODOLOGY

Research Design

The study used a pre-test post-test control group research design. Participants were assigned at random to either the experimental or control group. Every participant is measured at the start of the research, the experimental group received the intervention but not the control group, and then every participant is measured once again. The control group's existence enabled the researcher to determine any underlying differences between the groups, making it easier to link variations in pre- and posttest results to the intervention of interest (Dehghan Nayeri et al., 2023).

Participants

The target subjects of the study are the Grade 8 students of Pilgrim Christian College during the school year 2023-2024. There are only two Grade 8 sections, thus purposive sampling was used to gather data. However, the assigned control and experimental group was still randomized.

Data Collection

The data gathering method that the study used is Pre-test and Post-test. The researcher gave a pre-test to both the control and experimental group before intervention. After getting the results, the researcher applied the treatment to the experimental group and as for the control group they had their regular classes.

Research Ethics Protocol

All Grade 8 student participants were informed that their participation in the study was entirely voluntary. Although their names were written on the test papers, this was solely for the purpose of matching their pre-test and post-test scores during data analysis. The students were assured that their identities would be kept confidential in any public presentation or written report of the study and no individual student names or identifying details will be disclosed in any part of the final paper. Additionally, students were informed that they may request a copy of the summarized results of the study at any time.

Instrumentation

The researcher utilized a self-made test to score the mathematical creativity of the students and the Mathematical Creativity Rubrics of Kwon (2006) was used in the scoring. The four (4) item test was made according to the Grade 8 Mathematics curriculum with a focus on probability. The problems are open-ended which needs detailed solutions and explanations, promoting mathematical creativity through fluency, flexibility, and originality in solving problems.

In order to verify the validity of the instrument, a pilot-test was conducted to one of the Grade 9 Students from Pilgrim Christian College and an Exploratory Factor Analysis (EFA) was performed, which yielded a General Common Variance (GCV) of 62.75%, reflecting that the test items are reliable in measuring the desired construct of mathematical creativity. The instrument also had content validation carried out by the head of the research office, mathematics coordinator, and a mathematics teacher to determine if it is aligned with learning competencies and cognitive demand. The instrument's reliability was tested using Cronbach's Alpha (CA), and it obtained a score of 0.78, which is classified as having high reliability. It means that the instrument uniformly measures the construct on various administrations and samples of students.

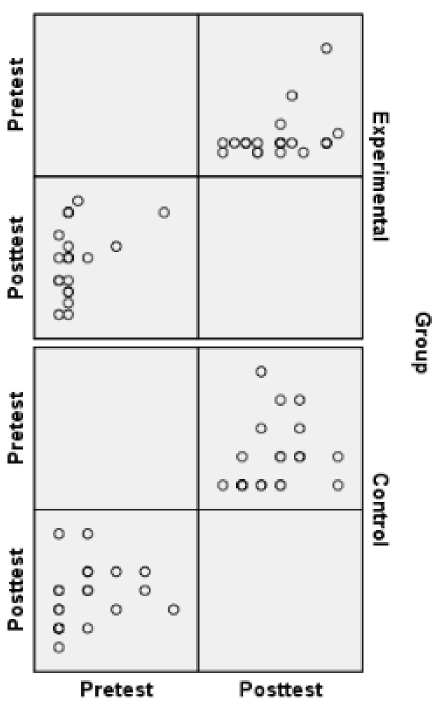
The rubrics quantified fluency, flexibility, and originality by assessing responses against correct answers with proper rules, such as no input (0 points), straightforward techniques (1 point), use of involutions (2 points), and employing over four basic operations or special mathematical symbols (3 points).

Data Analysis

The results for Shapiro-Wilk test show that the data from the dependent variable is normally distributed because the statistic for both control and experimental group is greater than the (alpha) which is 0.05. There is also no interaction between the covariate and the independent variable based on the result for the homogeneity of regression slopes. However, based on the graph shown below there is no linearity between the pretest and post-test of both the control and experimental group. Thus, the option would be to drop the covariate and run an independent-samples t-test, which is used to compare the means of two independent groups to determine if there is a statistically significant difference between them.

Figure 2

Linearity between Pre-test and Post-test Scores



Preliminary assumption testing was conducted, Shapiro Wilk test for normality and a Levene's test for equality of variance. Although, the assumption of test of normality was tenable for control and experimental at .05 alpha level, p = 0.076 and p = 0.193, respectively. The Levene's test for homogeneity of variance across groups say otherwise (the assumption is not met), F(1, 42) = 5.348, p = 0.026. If the homogeneity of variance across groups is violated, a non-parametric test like the Mann-Whitney U test can be used instead of the t-test. The Mann-Whitney U test does not assume normality and uses data ranks instead of raw values (Kim & Park, 2019).

RESULTS AND DISCUSSION

Table 1
Frequency table of the student's scores

Scores	Control Group				Experimental Group			
	Pretest		Posttest		Pretest		Posttest	
0	11	50%	0		5	22.7%	0	
1	6	27.3%	0		13	59.1%	0	
2	2	9.1%	1	4.5%	1	4.5%	2	9.1%
3	2	9.1%	6	27.3%	1	4.5%	1	4.5%
4	1	4.5%	4	18.2%	0		2	9.1%
5	0		5	22.7%	0		3	13.7%
6	0		4	18.2%	1	4.5%	0	
7	0		0		0		6	27.3%
8	0		2	9.1%	0		2	9.1%
9	0		0		0		1	4.5%
10	0		0		0		0	
11	0		0		1	4.5%	4	18.2%
12	0		0		0		1	4.5%
TOTAL	22	100%	22	100%	22	100%	22	100%

Table 2
Mean and Standard Deviation of the Scores

Groups	Pre-test		Post-test	
	Mean	Standard Dev.	Mean	Standard Dev.
Control Group	0.91	1.19	4.59	1.62
Experimental Group	1.59	2.46	6.95	3.01

Table 3
Mann Whitney U test

Null Hypothesis	Mann-Whitney U	p-value	Interpretation	Decision
The distribution of Post-test is the same across categories of Group	126.500	0.006	The test is statistically significant	Reject the Null Hypothesis

The study utilized pre-test post-test control group design in which the participants were randomly assigned to an intervention group that was administered the intervention or a control group that was administered standard instruction. These two groups were pre- and post-tested on a mathematical creativity test. This design, as suggested by Dehghan Nayeri et al. (2023), is easier to infer the effectiveness of the intervention as the pre-existing differences are controlled and the effect of instructional method is isolated. Early results of the pre-test revealed that both groups performed quite poorly in mathematical creativity. 50% of 22 students scored 0, and 27.3% scored 1, out of a possible 12 in the control group and 59.1% scored 1 and 22.7% scored 0 for the experimental group. The concentration of low scores bears witness to poor early creative mathematical thinking. This supports what Andrade and Pasia (2020) observed, which says that most learners underperform on non-routine mathematics due to excessive dependence on procedure activities in traditional classrooms.

After the intervention, the post-tests showed great improvement, particularly in the case of the experimental group. The scores of the control group ranged between 2 and 8, and the most frequent score was 3. The median score of the control group was 4.0. The experimental group generated a greater variety of scores; 27.3% generated a score of 7, and 18.2% generated a score of 11. The median score of the experimental group was 7.0. These results suggest that the students who were educated using problem-based learning learned a greater variety of strategies and employed more creative thinking than traditionally taught students. These results suggest that the students who were educated using problem-based learning learned a greater variety of strategies and employed more creative thinking than traditionally taught students. This aligns with findings from

Marbun (2023) and Bron and Prudente's (2024) meta-analysis, which reported that problem-based learning improved the motivation and mathematical creative thinking significantly of the students compared to traditional instruction. The control group mean score increased from a pre-test of 0.91 to a post-test of 4.59. While there was an increase, it was moderate. Experimental group increased more—by a mean of 1.59 in the pre-test to 6.95 in the post-test. Although means are reported for descriptive purposes, data were non-normally distributed, which violated assumptions of parametric tests. Therefore, a nonparametric alternative was used.

A Mann-Whitney U test was then conducted to identify the difference between the post-test score of the groups. The test has shown a statistical difference ($U = 126.5$, $p = .006$) as the experimental group had higher mean ranks than the control group. The rank-based effect size was also computed ($r \approx 0.43$), indicating a moderate effect. This finding support Lubis (2023), who found that problem-based learning improves mathematical creative thinking by encouraging the students to apply what they know in novel situations. Demonstrating this, Roble et al. (2021) discovered that problem-posing and problem-based activities both encourage students to ask and answer complex problems in various ways, creating new mathematical constructs. Furthermore, Kozlowski et al. (2019) stated that mathematical creativity is developed when students are able to search, make educated guesses, and think without fear of failure, conditions often lacking with traditional mathematics instruction but central to problem-based learning. Tursynkulova et al. (2023) found that problem-based learning significantly enhanced the creativity and problem-solving of the students in geometry, though the effects on logical reasoning were also combined to this, it suggests that problem-based learning's potential strongest benefit is in divergent and creative thinking.

In the study of Joklitschke et al. (2021), he found out that mathematical creativity is encouraged where there is freedom of action and autonomy for students, characteristics of the intervention used in this research. The study of Maulidia and Abidin (2020) also showed that PBL improved creativity and self-efficacy in both field dependent and field independent students, suggesting its broad applicability. The experimental group's significant improvement thus attests to the general education approach that pedagogical creativity is at the core of mathematical creativity development.

While the findings are promising, some limitations should be acknowledged. The small sample size ($n = 44$) limits the generalizability of the results. Despite random assignment, unmeasured variables such as learning style preferences or instructor influence may have affected outcomes. Additionally, the mathematical creativity test was scored by a single rater, which may have introduced bias. Future studies should consider using inter-rater reliability and possibly triangulate findings with qualitative data such as student reflections or written solutions.

It is also important to note that not all students in the experimental group reached high scores, showing individual differences in the effects of problem-based learning. Moreover, although all reported results were statistically significant, future research could further explore whether particular subgroups (e.g., based on gender, prior achievement, or learning style) benefit more from PBL.

In conclusion, the results of this study shows that problem-based learning is an effective teaching approach to promote mathematical creativity among students. The statistical analysis using Mann-Whitney U confirms the strength of the differences between the instructional groups in a nonparametric framework. The enormous gaps between the experimental and control groups emphasize the imperative to shift from teacher-centered to student-centered methods that promote active inquiry, creativity, and critical thinking in mathematics classrooms.

CONCLUSION

Analyzing the impact of Problem Based Learning (PBL) on the Mathematical Creativity of High School Students reveals a significant positive effect on students' creative abilities within mathematical domains. Studies exploring this relationship consistently demonstrate that PBL encourages students to engage actively in problem-solving processes, thereby promoting critical thinking, innovative approaches, and deeper understanding of mathematical concepts. By presenting real-world or complex problems, PBL challenges students to apply their knowledge in novel contexts, fostering creativity through exploration, experimentation, and collaboration. This educational approach not only enhances academic achievement but also cultivates skills crucial for lifelong learning and adaptation in an increasingly complex world. Therefore, the evidence supports that Problem Based Learning is an effective strategy for nurturing mathematical creativity among high school students.

TRANSLATIONAL RESEARCH

The results of this research on the effect of Problem-Based Learning (PBL) on Grade 8 students' mathematical creativity at Pilgrim Christian College can be shared through educational newsletters, school bulletins, scholarly journals, and especially local education forums for the information of researchers and most importantly, educators. The results may be used as a basis for reconsidering and further developing instructional strategies within the mathematics curriculum, especially in integration creative and student-centered strategies such as PBL. Internally, they can be translated into programs by the mathematics department, curriculum planners, and academic affairs office to improve teaching, develop intervention programs, and offer consistent professional development that encourages creativity in the mathematics classrooms which can enhance student participation and performance in math. Externally, education authorities, teacher training institutions, and schools can use the evidence to develop policies that encourage innovative pedagogies across various grade levels. This can attract education professionals interested in implementing evidence-based practices within their own settings. Lastly, such outcomes can be shared with existing and prospective teachers via orientations, in-service training, or learning action cells (LAC sessions) to better align teaching practices and make the institutional culture stronger that enhances creativity, critical thinking, and student-centered learning styles for math.

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