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CRITICAL THINKING SKILLS AS PREDICTORS OF STUDENTS' PERFORMANCE IN A PROBLEM-BASED LEARNING ENVIRONMENT

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Abstract

Background: This study aimed to determine the students' critical thinking skills (CTS) as predictors of students' mathematics performance in a Problem-Based Learning (PBL) environment.
Methods and Findings: This study employed a descriptive-qualitative research approach. The data collected was pretest, posttest, and interviews. Pretest results showed that the students had lower levels of CTS and performance. Posttest revealed that students improved their mathematics performance to Very Satisfactory as their level of CTS improved, generally evaluated as Advanced Thinkers. Regression analysis showed that CTS is a significant predictor of performance (all β's> 0; all p's < 0.001). Focus group discussions were employed to highlight students' experiences with PBL.
Conclusion: PBL can improve students' critical thinking skills and performance in teaching functions. There is a direct relationship between CTS (X) and performance (Y). Teachers can adapt PBL modules as teaching-learning pedagogy to teach other math topics.

Keywords: Problem-Based Learning, Critical Thinking Skills, Mathematics Performance.

Introduction

Ensuring a quality education for all students is one of education's top priorities. It is vital for equitable and sustainable global development (SDG) [11]. SDG4 of the United Nations Educational, Scientific, and Cultural Organization (UNESCO) is to "provide inclusive and equitable high-quality education for everyone" [8].

The Philippines has spent decades pursuing significant educational reforms to enhance education at all levels and address issues of inclusion and equity [4]. Education is the foundation of AmBisyon Natin 2040, the government's blueprint for a prosperous and healthy society. Education contributes to the growth of human capital by fostering environments that encourage lifelong learning. All Filipinos should have "matatag, maginhawa, at panatag na buhay" (PDP 2017-2022, 2017, p. 7). This development emphasizes "not only physical infrastructure but improving individual competencies and building institutional capacities" (p. 25) [8].

Students must develop 21st-century skills like critical thinking to ensure quality education [6]. This expectation intensified when these students were future educators. The Philippine Development Plan for quality education for everyone will fulfill to equip preservice teachers (PSTs) with the abilities and strategies to think critically and reason logically [7].

Strengthening mathematics education addresses the problem of preservice teachers entering programs without adequate mathematical backgrounds and ultimately entering the classroom without the knowledge and abilities required to equip them in higher math courses [1]. Various research mentioned that preservice secondary teachers have poor critical thinking and problem-solving skills [10].

This study aims to fill this gap by examining the critical thinking abilities and mathematics performance of mathematics preservice teachers (PST's) at a state university in Negros Occidental to prepare them for their future responsibilities. The students' weak algebraic backgrounds were evident from experience, so this topic was chosen. The goal is to assess students' performance, critical thinking abilities, and experiences in PBL, focusing on the

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linear, quadratic, and polynomial functions. And the module developed in this study can be used as a reference for conducting classes in a PBL environment.

Statement of the Problem

This study utilized PBL to examine mathematics preservice tecahers (PST's) critical thinking skills (CTS) and mathematics performance in linear, quadratic, and polynomial functions.

Specifically, it sought to address the following problems:

1. What is the PST's level of critical thinking skills before and after instruction using the PBL approach in linear, quadratic, and polynomial functions?
2. What is the PST's mathematics performance before and after instruction using the PBL approach in linear, quadratic, and polynomial functions?
3. Is the level of a PST's critical thinking skills a significantly predictor of their mathematics performance in linear, quadratic, and polynomial functions?

What are the PST's perceptions of using the PBL approach in teaching linear, quadratic, and polynomial functions?

Method

This study employed descriptive research with a qualitative approach. Descriptive-qualitative research aims to give a detailed account of specific experiences that individuals or groups have experienced [2]. This research describes the CTS, mathematics performance, and experiences of 20 first-year mathematics preservice teachers in a PBL environment.

The data in this study were analyzed using quantitative and qualitative methods. A rubric adapted from the California State Department of Education's: A Question of Thinking [9] was used to determine students' performance levels in solving non–routine problems involving special functions. The student's CTS level was analyzed using a rubric based on the theory of Elder and Paul [3]. And focus group discussions (FGD) on deepening students' experiences in PBL.

Results and Discussions

The research study's findings are presented, explained, and discussed in this section. The discussions are through determining the student's critical thinking skills (CTS), performance on their pretest and posttest results, CTS as predictors of mathematics performance, and an interview.

Students' Levels of CTS and Mathematics Performance Before and After Implementing A Problem-Based Learning Module

In Mathematics, critical thinking usually comes when students ask why rather than taking what they learn at face value. Table 1 shows the student's CTS level in the pretest and posttest results in all function topics under study. The pretest results showed that most students were at the *Challenged Thinker* level before implementing Problem-Based Learning. Specifically, for the linear function, 95% of the students were *Challenged Thinkers*, and 5% as *Beginning Thinkers*. Additionally, 10% who solved the polynomial function problem were Challenged Thinkers, but 90% were Unreflective Thinkers regarding the quadratic function.

Posttest results showed that, in solving the linear function problem, 90% of the students leveled up to *Advance Thinkers* and 5% to *Accomplished Thinkers*, although 5% remained *Challenged Thinkers*. In quadratic function problems, from mostly *Unreflective Thinkers* (90%) and *Challenged Thinkers* (10%), 40% of the students improved to *Advanced Thinkers*, 45% to *Practicing Thinkers*, 5% to *Beginning Thinkers*, while only 10% remained as a *Challenged Thinker*. Furthermore, in polynomial function, while the students started as *Unreflective* (90%) or *Challenged* (10%) thinkers, nobody remained in either level but improved to at least *Beginning Thinker* (5%), with 90% of the students to *Advanced Thinker*s, and 5% to *Accomplished Thinker* levels.

Table 1: Number of Students in the Different Levels of Critical Thinking Skills

Critical Thinking Skills Indicator	Linear Function		Quadratic Function		Polynomial Function	
	Pretest/ Posttest	Pretest/ Posttest	Pretest/ Posttest	Pretest/ Posttest	Pretest/ Posttest	Pretest/ Posttest
	f	%	f	%	f	%
Accomplished Thinker	0/1	0/5	0/0	0/0	0/1	0/5
Advanced Thinker	0/18	0/90	0/8	0/40	0/18	0/90
Practicing Thinker	0/0	0/0	0/9	0/45	0/0	0/0
Beginning Thinker	1/0	5/0	0/1	0/5	0/1	0/5
Challenged Thinker	19/1	95/5	2/2	10/10	2/0	10/0
Unreflective Thinker	0/0	0/0	18/0	90/0	18/0	90/0
TOTAL	20/20	100/100	20/20	100/100	20/20	100/100

The pretest results show that students struggle in solving problems with special functions (see Table 2). Most students perform at the two lowest levels (No Response and Minimal) when solving problems involving quadratic or polynomial functions and the first three lower levels when solving problems involving linear functions.

After implementing the PBL modules, the results showed that students improved their performance levels. In solving linear function problems, 90% of the students leveled up to Very Satisfactory, 5% to Excellent, while 5% remained at the Minimal level. In quadratic function, 40% of the students improved to Very Satisfactory and 45% to Satisfactory levels, while 5% remained at the Partial level and 10% at the Minimal Level. Moreover, for polynomial function, 90% of the students improved to Very Satisfactory and 5% to Excellent, while 5% remained at the Partial Level.

Table 2: Number of Students in the Different Levels of Performance

Performance Indicator	Linear Function		Quadratic Function		Polynomial Function	
	Pretest/ Posttest	Pretest/ Posttest	Pretest/ Posttest	Pretest/ Posttest	Pretest/ Posttest	Pretest/ Posttest
	f	%	f	%	f	%
Excellent	0/1	0/5	0/0	0/0	0/1	0/5
Very Satisfactory	0/18	0/90	0/8	0/40	0/18	0/90
Satisfactory	0/0	0/0	0/9	0/45	0/0	0/0
Partial	1/0	5/0	0/1	0/5	0/1	0/5
Minimal	19/1	95/5	2/2	10/10	2/0	10/0
No Response	0/0	0/0	18/0	90/0	18/0	90/0
TOTAL	20/20	100/100	20/20	100/100	20/20	100/100

Critical Thinking Skills (CTS) as Predictors of Students' Performance

According to the findings, CTS and performance seem to be closely associated. This relationship was further investigated to determine whether these two factors were statistically significant. Linear trends were evident in the preliminary analysis using scatterplots.

Table 3 presents the most relevant statistics regarding the different regression models for the linear, quadratic, and polynomial problems. It is to be noted that these models apply only to the problems and results presented in this study.

Table 3: Summary of the Relevant Statistics of the SLR Analysis for All Types of Function Problems of This Study for the Posttests

Function	Adjusted R^2	df_1, df_2	F (df_1, df_2)	p-value	β_0	p-value (β_0)	β_1	p-value (β_1)
Linear	0.863	1, 18	121.032	<0.001	1.429	0.192	2.929	<0.001
Quadratic	0.932	1, 18	262.548	<0.001	-0.094	0.922	4.665	<0.001
Polynomial	0.817	1, 18	85.868	<0.001	5.242	0.001	3.242	<0.001

Linear function

The Simple Linear Model (SLM) for the Posttest Linear Function problem shows a relatively strong correlation between the predictor and response variables. The fitted regression model was: $\hat{y} = 1.429 + 1.929x$, $1 \le x \le 5$. The overall regression showed an adjusted R-squared value of 0.863. The result means that 86.3% of the variation in the values of the performance raw scores in the population can be explained by its relationship with the predictor variable, CTS, leaving only a small percentage of 13.7% being accounted for by other variables that may also affect performance raw scores. The regression was also statistically significant [$F(1,18) = 121.032$, $p < 0.001$], indicating that CTS significantly predicted the performance raw score, with $\beta 1 = 2.929$, $p < 0.001$. Then, it shows that whenever CTS moves up by 1 level, there is a corresponding increase in the performance raw score by 2.929 or approximately 3 points.

Quadratic function

The SLM for the Posttest Quadratic Function problem shows a correlation between CTS and performance, stronger than the linear function problem results, with an adjusted R^2 of .932 or 93.2%. The fitted regression model was: $\hat{y} = -0.094 + 4.665x$, $1 \le x \le 4$. The regression was also statistically significant [$F(1,18) = 262.548$, $p < 0.001$], indicating that CTS significantly predicted the performance raw score, with $\beta 1 = 4.665$, $p < 0.001$. Moving up in CTS by 1 level generates a corresponding increase in the performance raw score by 4.665 or approximately 5 points.

Polynomial function

The SLM for the Posttest Polynomial Function problem, whose domain is from 2 (Beginning Thinker) to 5 (Accomplished Thinker), is given by $\hat{y} = 5.242 + 3.242x$, $2 \leq x \leq 5$, which is significant [$F(1,18) = 85.868$, $p < 0.001$]. The correlation between CTS and performance, as reflected by an adjusted R^2 is .817 or 81.7%, which is still relatively strong. The SLR model may also be used to predict the performance raw scores of a student with CTS within the set of values in the domain. The coefficient, $\beta 1 = 3.242$ ($p < 0.001$), could be interpreted as the expected increase in performance raw score between 3 and 4 when a particular student moves up one level of CTS.

Students Experiences in a Problem–Based Learning Environment

On PBL as a method of learning

Problem-Based Learning (PBL) as a pedagogical approach is a new teaching method for most participants. During the Focus Group Discussion (FGD), it was evident that many participants expressed their honest thoughts on the novelty of the teaching strategy employed in the College and Advance Algebra course. In particular, all participants stressed that their Senior High School (SHS) tracks were Technical-Vocational-Livelihood (TVL) and Humanities and Social Sciences (HUMSS). On the other hand, almost all of the student participants claimed that they found PBL very interesting and challenging. Since there are different groups in the heterogeneous class, namely the high, middle, and low, varied responses were apparent. For the middle and low groups, PBL was beneficial because of the collaborative work done in solving problems.

Students also claimed they learned more concepts and developed mathematical skills through feedback and peer tutoring. This result implies that PBL as a teaching strategy helps students improve their CTS and performance even if they have a mismatch in their SHS tracks in ensuring quality education in a non-threatening classroom environment.

Bridging the gap: student's prior knowledge

Academic preparedness requires students to have procedural proficiency and deep conceptual understanding. Unfortunately, the participants showed inadequate learning of concepts about functions primarily because their training in TVL and HUMSS tracks was not the same as those of the STEM track. Because of this difference in exposure to SHS, the participants had to exert more effort in developing their critical thinking and independent learning skills.

The participants mentioned that PBL aided them in developing their CTS through self-directed study, group sharing, and discussions. PBL teaches students to become partners in the teaching-learning process, where they accept responsibility for much of their learning, function well in teams, handle new and changing situations, and develop skills for lifelong learning. Therefore, PBL can help students think critically and analyze and solve real-world problems that will better prepare them for careers outside the classroom.

The waterloo of PBL

One common criticism of PBL is that students cannot know what might be vital for them to learn, especially in areas without experience [5]. This is true when the mathematical background of the participants from their SHS was superficial, manifesting in a lack of adequate understanding of the mathematical concepts. The student's comprehension level and prior knowledge determine representations by the participants of the problems using mathematical models.

Adopting the PBL approach may not be able to cover as much material as a traditional lecture-based course, so teachers need special diversity training to deal with heterogeneous groups and rigidities in presenting the lessons. Participants find PBL advantageous in improving mathematical and problem-solving skills. All shared the same sentiment that their learnings are more advanced if teachers can explain and correct the incorrect answers and show the necessary steps and processes.

Conclusion

Problem-based learning (PBL) can improve students' CTS and performance in teaching linear, quadratic, and polynomial functions. This seemingly direct relationship between CTS (X) and performance (Y) is verified by the significantly positive values of the coefficients (β_1) of x in the regression analyses involving the results of the posttest on problem-solving involving the three functions (all $p < 0.001$). Therefore, a student's CTS can predict their mathematics performance.

PBL is just one of the diverse teaching–learning pedagogy that can help develop students' CTS and performance from lower to higher/highest levels. The Researcher hopes this study will impact how teachers innovate in delivering lessons to improve CTS and performance, ensuring quality education in the Philippines and adhering to global standards.

Recommendations

Based on the obtained data results and conclusions on critical thinking skills (CTS) as predictors of students' performance in a problem-based learning (PBL) environment, the following recommendations were proposed:

Mathematics Teachers may actively integrate a PBL approach in teaching and learning to improve students' CTS and mathematics performance.

The Students may support the numeracy drive through participation with other learners for the basic math skills needed for the tertiary level.

The University Administrators may utilize the result of this study as a reference in implementing programs to improve mathematics education specific to mathematics preservice teachers' needs and a basis to support the mathematics teachers by providing teachers training/webinars on the implementations of PBL

The Deans may use the findings of this study in revisiting the guidelines on accepting new entrants for mathematics preservice teachers and creating programs for students who were not STEM strands in their Senior High School.

The Researcher may use this study to coordinate a teacher support program for Mathematics teachers with the partnership of the University's Training Office and other agencies that can propose sustainable projects intended for the improvement of students' CTS and performance

Future researchers may utilize this study's findings to obtain data on the improved implementation of the PBL module. And other aspects that influence whether teachers are prepared to employ the PBL paradigm would be the future direction for **further research**.

Conflict of Interest

There is no conflict of interest between the subject matter or materials discussed in this manuscript.

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