Problem–Based Learning Approach in Preservice Teachers: Untold Stories

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ABSTRACT

Problem-based learning (PBL) fosters critical thinking skills (CTS) vital for achieving quality education for all (Sustainable Development Goals 4). This study investigates the experiences of purposely selected 20 first-year non-STEM mathematics preservice teachers at a State University in Negros Occidental in a PBL setting. This study employed concurrent triangulation mixed research methods and data collected through pre-tests, post-tests, and interviews. Pre-test results showed that the students were in the lower levels of CTS and performance in linear, quadratic, and polynomial functions problems. Most were Challenged Thinkers and performed at a minimal level. Post-test results showed that students improved their performance to Very Satisfactory as their level of CTS to be Advanced Thinkers. Focus group discussions (FGD) emphasized students' experiences with PBL. Results showed that PBL enhanced students' CTS and performance through exciting and challenging math problems, yet students find it tiring and time-consuming. They prefer teachers explaining step-by-step solutions.

Introduction

Ensuring universal access to fundamental educational skills remains the central goal of the education sector, serving as a cornerstone for equitable and sustainable global development. Aligned with the United Nations Educational, Scientific, and Cultural Organization's (UNESCO) Sustainable Development Goals (SDG4), extending high-quality education to all takes precedence. SDG 4 aims to " Ensure inclusive and equitable quality education for all." (Pritchett & Viarengo, 2021, p.1).

Consequently, the Philippines has steadfastly pursued educational advancements, prioritizing inclusivity and equity. Education is the foundation of the nation's vision outlined in AmBisyon Natin 2040—a roadmap fostering a prosperous society by 2040. Central to this vision is nurturing human capital development through lifelong learning. The objective is for Filipinos to lead "matatag, maginhawa, at panatag na buhay" (PDP 2017-2022, 2017, p. 7). Flores (2019) underscores that this entails elevating individual competencies and institutional capacities (p. 25).

Initiatives like Sulong Edukalidad and KITE (K- K to 12 Curriculum review and update; I- Improvement of the learning environment; T- Teachers' upskilling and reskilling; and E- Engagement of stakeholders for support and collaboration) have shaped DepEd's learning continuity plan. These frameworks influence primary education and the development of mathematical proficiencies aligned with the twenty-first century.

However, in higher education, students might need more essential skills. Furnishing them with 21st-century knowledge, especially critical thinking (Macaso & Dagohoy, 2022), is crucial for future educators. Mugut and Sumbalan (2019) emphasize equipping preservice teachers (PSTs) with critical thinking and logical reasoning skills, which are vital for addressing twenty-first-century teaching challenges. This concept aligns with the Philippine Development Plan's goal of quality education for all.

Connectedly, problem-based learning (PBL) facilitates acquiring 21st-century competencies. PBL, operating in real-world contexts, fosters knowledge, understanding, learning, and critical skills (Mustafa et al., 2019) in line with global education goals. PBL creates a supportive environment for acquiring mathematical and critical thinking skills (CTS) aligned with DepEd's framework (Alvionita & Supardi, 2020). It aligns with institutions' research agendas for quality education and instructional resource development.

Moreover, amplifying math education addresses preservice teachers' insufficient foundations, which is common among those ill-equipped for advanced math concepts (Appova & Taylor, 2020). Critical thinking and problem-solving gaps persist among preservice secondary teachers (Yilmaz & Bas, 2021).

Furthermore, teaching methods that encourage CT effectively improve students' academic achievement. Reynders et al. (2020) suggest that classroom activities, including term papers, homework, exams, and instruction, can help students develop CTS. Thus, the teacher should emphasize the students' active intellectual activity when teaching mathematics. Coronel et al. (2019) reported that students with higher critical thinking abilities exhibited higher learning achievement. However, students who performed poorly in mathematics showed a significant correlation between interest and performance.

Critical Thinking Skills and Mathematics Performance

In learning, the thinking activity involves students' whole being, feelings, and will (Mustafa et al., 2019). Critical thinking (CT) is the self-directed and self-regulatory judgment resulting from interpretation, analysis, evaluation, and inference. Integrating CT into the mathematical curriculum can impart knowledge and enhance student performance. Future educators could be role models for students by demonstrating how to apply critical thinking skills (CTS) to simplify a complicated subject (Wong & Kan, 2022).

The role of mathematical skills in modern technological societies is unquestionable (Reynders et al., 2020). However, in the past decade, concerns about children's declining interest and performance in mathematics have been raised everywhere (Macaso & Dagohoy, 2022). Flores (2019) mentioned that students in the Philippines perform poorly in mathematics on the high school National Achievement Test (NAT). According to the

NAT, just 45 to 60 percent of high school students nationwide demonstrated mastery of the necessary mathematics competencies. Moreover, the result is below the 75 percent standard set forth by the Department of Education (Mustafa et al., 2019). Students' mathematics performance correlates to their critical thinking and problem-solving skills (Macaso & Dagohoy, 2022).

Problem-Based Learning

Problem-Based Learning (PBL) describes the most innovative instruction method in the history of education. PBL shows students authentic or well-structured problem presentations to help them construct new knowledge and re-learn previous ones to develop independent learning (Yilmaz et al., 2021). Also, Hendreiana et al. (2018) suggested that one of the helpful tools for developing creativity and critical thinking skills is PBL environments in classrooms.

Innovative teaching methods are crucial for the new curriculum. The spiral progression in K-12 math education hones problem-solving and critical thinking, showcasing adaptability (Major & Mulvihill, 2018). PBL uses real-world problems, fostering collaboration and skills aligned with the new curriculum's practical, interdisciplinary, and 21st-century skills. Incorporating PBL enriches learning and prepares students for life-long learning. However, effective implementation needs careful planning, teacher training, and continuing support (Bosica et al., 2021).

Consequently, Wong and Kan (2022) found that PBL lets students own their learning by selecting problems and integrating external variables. This method enhances their real-world problem-solving experience. Then, Mustafa et al. (2019) noted that PBL boosts critical thinking and motivation. Its structured approach drives student thinking and solution-seeking. Moreover, Hendriana et al. (2018) stated that collaborative PBL improves creativity, confidence, communication, and teamwork in problem-solving.

As shown by Bosica et al. (2021), PBL effectively improves math learning and outperforms conventional methods. Benedicto and Andrade (2022) suggest that PBL benefits Filipino students by promoting active engagement, critical thinking, and a deeper understanding of math concepts. Thus, PBL is a potent tool for enhancing Filipino math education, fostering comprehension, and preparing for 21st-century challenges (Lapuz & Fulgencio, 2020).

Problem-Based Learning (PBL) is a student-centered approach using open-ended problems to trigger learning. It fosters teamwork, communication, and holistic skill growth. PBL promotes critical thinking, research, and ongoing learning through collaborative involvement. However, grasping links between ideas demands logical, critical, and sequential thinking. Thus, CTS involves assessing, synthesizing, and judging information for informed decisions. These skills enable objective analysis, bias recognition, and innovative problem-solving. They promote autonomous thought and ongoing learning, which are essential in education, the workplace, and daily life.

This study highlights that learning occurs in social contexts, and teachers should present information in ways that help students comprehend it. Learning builds upon previous knowledge, and teachers should accommodate different interpretations due to diverse student backgrounds (Benedicto et al., 2022). The PBL module employed the constructivist theory by Bruner, impacting teaching, curriculum, and assessment. This theory underscores meaningful learning aligned with natural learning processes, addressing knowledge gaps in non-STEM Senior

High School (SHS) students who chose mathematics as a major at a State University in Negros Occidental. The goal is to equip educators to address insufficiencies, particularly in algebra. The study assesses performance, CTS, and problem-based learning experiences, emphasizing linear, quadratic, and polynomial functions.

Statement of the Problem

This study sought to address the following problems:

1. What is the preservice teachers' level of critical thinking skills before and after instruction using the PBL approach in each topic on functions?

2. What is the preservice teachers' mathematics performance before and after instruction using the PBL approach in each of the topics on functions?

3. What are the preservice students' experiences using the PBL approach in teaching linear, quadratic, and polynomial functions?

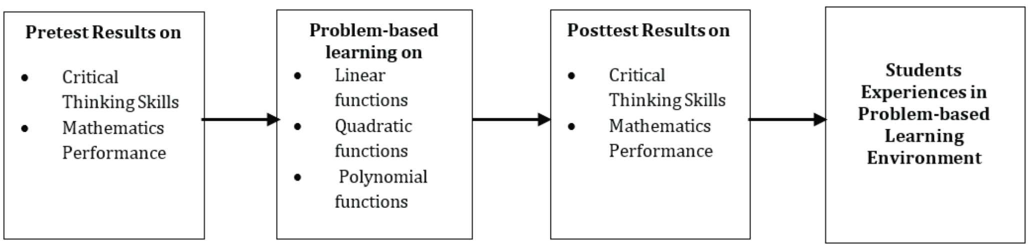
Theoretical and Conceptual Framework

This study assessed math preservice teachers' CTS and math performance using PBL. Jerome Bruner's constructivism, including vicarious learning (Arrastia-Chisholm et al., 2020), highlights dynamic learning through new idea development based on existing knowledge. Constructivism promotes student-centered, experiential, and collaborative education, fostering deep understanding and CTS development.

The following stages of CTS were from a reflective thinker who often approaches mathematical problems without much consideration. Second, the challenged thinkers question assumptions and biases that might affect their problem-solving. Third, beginning thinkers seek different approaches and strategies, showing openness to learning new concepts and methods to tackle problems. Fourth, practicing thinkers can break down problems into smaller components and apply relevant mathematical concepts. Fifth, advanced thinkers can utilize various mathematical tools to solve intricate problems. Lastly, accomplished thinkers can integrate multiple mathematical concepts seamlessly to develop insightful solutions (Elder &Paul, 2019; 2020).

Mathematics learning within a classroom is a collective, rather than individual, process. Furthermore, the study assumes that active engagement is vital and hence, this study explores CTS development during knowledge acquisition and retention. The acquired knowledge will categorize CTS levels and performance via pre-test and post-test results (Hendriana et al., 2018).

Figure 1
Schematic Diagram of the Study



Moreover, PBL is an instructional approach that fosters learning and cultivating 21st-century skills like CTS within real-world contexts (Benedicto et al., 2022). PBL seeks to create a supportive environment for students to gain mathematical competence, elevating their CTS and academic performance in math through collaborative learning.

Conceptually, this study sought to determine if PBL intervention can improve mathematics preservice teachers' CTS and performance in linear, quadratic, and polynomial functions who were non-STEM tracks in their Senior High School (SHS). Furthermore, this also sought to investigate the students' perceptions of using PBL as a pedagogy.

Methodology

Research Design

The study employed a concurrent triangulation of mixed methods research (MMR), wherein the researchers gather quantitative data (numerical data) and qualitative data (textual or narrative data) concurrently, often using different methods. This method could involve surveys, experiments, observations, interviews, focus groups, or content analysis (Cresswell, 2014, cited in Weimer, 2019).

In this study, researchers simultaneously examined quantitative and qualitative data collected independently. This dual analysis supports exploring each data type concerning the research question—quantitative data about preservice teachers' CTS levels and math performance. Qualitative data delve into students' PBL experiences, challenges, and benefits in problem-solving in linear, quadratic, and polynomial functions. This approach acknowledges individualized, subjective experiences and values unique perspectives on PBL.

Participants

The study involved twenty (20) first-year mathematics preservice teachers at a state university in Negros Occidental. They were purposively selected to cover different student groups (lower – 20%, middle – 60%, upper – 20%). This study addresses a research gap in CTS and math performance among preservice math teachers not from STEM programs but pursuing a math specialization. Students were categorized based on college and advanced algebra midterm grades. Three (3) participants were selected from the lower and upper groups, while four (4) were from the middle group for Focus Group Discussions to delve deeper into their experiences with problem-based learning. The focus group discussion (FGD) typically ranges from eight to ten participants (Gray, 2014), as well as in this study, to strike a balance between having enough participants from different groups of students to generate meaningful discussion and not overwhelming the group dynamics.

Research Instrument

The following research instruments were used in this study:

Problem–Based Learning Module

The researcher used Problem-Based Learning (PBL) as a teaching method in a module for special functions. It included six-week collaborative group activities from November 18, 2019, to January 17, 2020, with context-based problems covering linear, quadratic, and polynomial functions. The researcher personally implemented this module.

Three modules were developed. These are the following:

Table 1
List of Modules and Lessons per Module

Modules	Lessons
Module 1: Linear Function	• Lesson 1: Definition, Equation, Zeroes, and Graphs of Linear Functions (Standard form and slope-intercept form) • Lesson 2: Definition, Equation, Zeroes, and Graphs of Linear Functions (Point slope form and Two-point slope form)
Module 2: Quadratic Functions	• Lesson 1: Definition, Equation, Properties, and Graphs of Quadratic Functions • Lesson 2: Deriving $f(x) = ax^2 + bx + c$ from the quadratic function $f(x) = a(x - h)^2 + k$ • Lesson 3: Analysis of effects on the graph of the changes in a, h, and k in $f(x) = a(x-h)^2 + k$. • Lesson 4: Roots and Zeros of a Quadratic Function (factoring, completing the square, quadratic formula)
Module 3: Polynomial Functions	• Lesson 1: Definition and Equation of Polynomial Function • Lesson 2: Remainder and Factor Theorem • Lesson 3: Zeros of Polynomial Functions of Degree Greater than 2 (Number of Roots Theorem, Rational Root Theorem, Factor Theorem, Factoring, Synthetic Division) • Lesson 4: Graph of a Polynomial Function of Degree Greater than 2

Table 2

Sample Lesson, Competencies, Collaborative Activities, and Context-Based Problems of Linear, Quadratic, and Polynomial Functions

Topics	Competencies	Collaborative Activities	Context-Based Problems
Linear Function	1. Define the linear function.	*How much do you know?*	
Lesson 1: Definition, Equation, Zeroes, and Graphs of Linear Function (Standard Form and Slope Intercept Form)	2. Rewrite the standard form Ax + By = C to slope–intercept form f(x) = mx + b and vice versa. 3. Determine the trend and zeros of the linear function	Sean traveled from his mother's residence to his brother's house. Upon driving for 30 minutes, he found himself 72 kilometers distant from his brother's place. After a 42-minute drive, he was a mere 48 kilometers away. The duration of the journey and the distance from his brother's residence form a linear relationship.	Sean bought a pair of jeans and a pair of shoes. These cost him Php 500. a. Let x represent the cost of the jeans and y the cost of the shoes. Tabulate some possible combinations of the prices of each. Set the initial value of x = 50 pesos, and increase by 40 pesos each time.
		a. What is the independent variable?	b. What happens to y when x increases?
		b. What is the dependent variable?	c. What is the corresponding change in y for every increase in x?
		c. Draw the graph to represent this problem.	d. Plot the ordered pairs tabulated in (a).
		d. Write an equation expressing distance in terms of time driving.	e. Is it correct to connect the points? Why or why not?
		e. What does the slope represent, and what is the significance of this problem?	f. Write the equation showing the relationship between x and y.
		f. What is the time–intercept, and what does it represent?	
		g. What is the distance – intercept, and what does it represent?	
		h. How far is Sean from his brother's residence after driving for 45 minutes?	

Quadratic Function

Lesson 1:

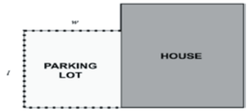
Definition, Equation, Properties, and Graphs of Quadratic Functions

1. Define and identify quadratic functions $f(x) = ax^2 + bx + c$.
2. Given a quadratic function, determine the:
   * Highest or lowest point (vertex),
   * Axis of symmetry, and
   * Direction of the opening of the graph.

How much do you know?

Illustrated in the diagram is Sean's intention to surround the rectangular parking lot adjacent to his house with a wire fence along three of its sides. Given a total wire length of 80 meters, determine the dimensions of the parking lot that will result in the maximum enclosed area.

Follow the procedure below:



a. In the given figure above, with "w" as width and "l" as length, what is the expression for the sum of the three sides of the parking lot?

b. Express the length of the parking lot in relation to its width.

c. Represent the parking lot's area (A) in terms of the width.

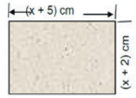
d. Complete the table with possible values of w and the corresponding areas (A).

Width (w)									
Area (A)									

e. What pattern have you noticed in relation to the area (A) with respect to the width (w)?

f. What is the independent variable? And the dependent variable?

Consider a rectangle surface of the table with width (x + 2) cm and length (x + 5) cm.



a. What is the area of the rectangular surface?

b. How do you find the area of the rectangular surface?

c. The area forms an equation?

d. If yes, what is the highest degree? And how many terms?

e. What general equation can you make based on the area of the rectangular surface?

		g. Compare the equation of a linear function with the equation you obtained in this problem. h. From the table of values (d), plot the points and connect them using a smooth curve. i. What do you observe about the graph? j. Does the graph represent a linear function?	
Polynomial Function Lesson 1: Definition and Equation of Polynomial Function	1. Recognize a polynomial function based on a provided set of relationships. 2. Find the degree of a given polynomial function, 3. Find the quotient of polynomials by • algorithm • synthetic division	*How much do you know?* Sean's room has the following dimensions: height = $3x - 6$ m, length = $x + 2$ m, and width = $2x - 3$ m. Its volume is 45 cubic meters. a. Which mathematical equation symbolizes the volume of Sean's room? b. Describe the equation you obtain in (a). c. What is the actual dimension of Sean's room?	Sean plans to craft a confetti box from a cardboard sheet of dimensions 12 inches by 20 inches. This involves cutting congruent squares from the corners and folding up the remaining sides. a. What is the intended representation of the independent variable? b. What is the intended representation of the dependent variable? c. What mathematical representation symbolizes the scenario? d. What are the optimal dimensions for the four identical squares to be removed from the cardboard sheet to maximize the box's volume? e. What are the measurements of the box that achieves the highest volume?

Tests

The pre-test and post-test were the same test consisting of three situations with five questions. Each problem targeted the learning competencies for linear and quadratic functions and four for polynomial functions. These provided the data for analysis.

Rubrics

The rubrics used to assess participants' critical thinking skills were based on Elder and Paul's "Critical Thinking Development: A Stage Theory" (2019, 2020) and the use of rubrics derived from "The California State Department of Education A Question of Thinking" (1989, as cited in Shavelson & Baxter, 2020) to evaluate students' pre-test and post-test performance.

Focus Group Discussion (FGD) Guide

This instrument was a structured FGD guide for qualitative analysis. The interview explored students' experiences with PBL in linear, quadratic, and polynomial functions. It delved into the PBL impact on problem-solving, critical thinking, and readiness for advanced subject problem-solving.

The five mathematics and education experts validated the abovementioned instruments using Guzon's criteria (2009, cited in Leonares, 2016). The inter-rater reliability test involving five math specialists yielded an agreed 80% reliability index for the pre-test and post-test teacher-made tests (Glen, 2023).

Data Gathering Procedure

This study involved 20 preservice mathematics teachers in college and advanced algebra courses during the first semester of 2019-2020. The research began with university approval. The researchers explained the research goals, methodology, and study expectations on the first day of class. Participants who agreed signed consent forms—the second day included a 90-minute pre-test with student solutions. Pre-test items were not discussed during or after lectures. Concept discussions followed the pre-test, but not specific questions, to align with post-test consistency using the same instruments.

The study employed PBL to teach specific function topics under investigation. The class encouraged discussions, interactions, group activities, and formative tests. Students collaborated in pairs or trios. After group work, individual quizzes gauged critical thinking and performance. Homework was solved on the board, addressing errors and encouraging corrections. Students had to present and explain their solutions.

A post-test was conducted at the end of the semester, evaluating students' answers using researchers' rubrics. Lastly, a two-hour focus group discussion took place, including ten (10) selected students from the three (3) groups.

Data Analysis

The study employed quantitative and qualitative methods to analyze the data. A rubric derived from the California State Department of Education's: A Question of Thinking (1989, as cited in Shavelson et al., 2020) assessed students' performance in solving non-routine problems related to functions under study. The evaluation of students' critical thinking skills level using a rubric based on the theory by Elder and Paul. The analysis of students' output involved utilizing the mentioned rubrics. Frequency counts and percentages answered the problem 1 and 2 statements. The researcher also conducted focus group discussions (FGD) to transcribe the students' experiences with problem-based learning (PBL) to address SOP 3.

Ethical Considerations

This research strictly adheres to ethical guidelines. Before the study, the researcher obtained approval from the institutional research review board (IRRB) by submitting the proposal for local In-research in-house review. The investigation commenced only after meeting all institutional requirements and receiving IRRB clearance. The researcher maintained the security of the data to ensure participant anonymity, dignity, and privacy. After the study, the data sheets were properly disposed of to maintain confidentiality.

Results and Discussions

This section reveals and discusses the study's findings, focusing on student critical thinking levels and performance from pre-test, post-test, and interview data.

Students' levels of Critical Thinking Skills and mathematics performance in Problem-solving before and after implementing a problem-based learning module

Pre-test and Post-test on Special Functions Problems

In Mathematics, students cultivate critical thinking by questioning and seeking thorough understanding, not merely accepting information. Table 2 depicts students' CTS levels, discerned from pre-test and post-test outcomes for the studied functions.

The pre-test results indicated that students predominantly exhibited lower levels of CTS. Before PBL implementation, most students were categorized as *challenged thinkers* for the linear function (95%), and 5% were *beginning thinkers*. For the polynomial function, 10% of the

Table 3

Number of Students in the Different Levels of Critical Thinking Skills

Critical Thinking Skills Indicator	Linear Function		Quadratic Function		Polynomial Function	
	Pre-test/ Post-test	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

students were *challenged thinkers*, and 90% were *unreflective thinkers* for the quadratic function.

In Table 3, the post-test results demonstrate significant improvements in students' critical thinking skills (CTS) when solving linear and quadratic function problems. The result suggests that the majority of students experienced an improvement in their CTS to the utmost three (3) levels, transitioning from being Challenged Thinkers to Advanced Thinkers. This result indicates that problem-based learning (PBL) plays a significant role in enhancing CTS development.

This study's result matches that of Bosica et al. (2021), which showed that PBL can enhance knowledge, critical thinking, and teamwork skills. Learning outcomes, as shown in the post-test results, showed much improvement. Moreover, PBL effectively improved students' CTS (Benedicto et al., 2022). This result also corresponds to Alvionita and Supardi's (2020) study that the CTS of students exposed to the PBL approach was higher than those not.

Table 4 illustrates the levels of mathematics performance among students, as observed through the pre-test and post-test results for functions under study.

The pre-test results reveal challenges the students face when dealing with special functions, as depicted in Table 4. Most students perform at the two lowest levels (No Response and Minimal) when solving problems involving quadratic or polynomial functions and at the first three lower levels when tackling issues related to linear functions.

The in-depth interview shed light on the potential cause of the low level of performance. The respondents revealed that they were in the Technical-Vocational-Livelihood (TVL) and Humanities and Social Science (HUMSS) tracks during their Senior High School (SHS), where the focus was not primarily on Mathematics. As a result, limited exposure led to decreased enthusiasm and initial disinterest in problem-solving. They found problems challenging and hesitated to attempt solving them.

The study's findings indicated that implementing PBL improved student performance by at least one (1) level to three (3) levels. These findings echo Major and Mulvihill's (2018) earlier work, highlighting

Table 4

Number of Students in the Different Levels of Performance

Performance Indicator	Linear Function		Quadratic Function		Polynomial Function	
	Pre-test/ Post-test	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

PBL's positive influence on problem-solving. Students initially found PBL challenging, but this changed with familiarity—one even remarked on the feeling of brain revitalization.

("...nabuhi man ang brain cells ko.") Participant 9 **(P9)**

*("...*my brain cells were revitalized*.")* **P9**

As presented, the student's critical thinking skills (CTS) and performance before implementing PBL modules were low. However, after the PBL, most students improved their CTS and performance; most were *Advanced Thinkers* and had *Very Satisfactory* performance levels, respectively.

After PBL in linear, quadratic, and polynomial functions, most students significantly increased their CTS from *challenged* to *advanced thinkers* and improved performance from *minimal* to *very satisfactory*. Despite groupings, students completed sub-problems (a) and (b) correctly in the pre-test but required assistance for the rest. The assessment rubric categorized lower-level students' math performance as minimal, signifying attempts beyond data copying but not leading to correct solutions with incorrect approaches or explanations. Conversely, a very satisfactory performance demonstrated correct solutions and strategies, requiring proper labeling when necessary (Elder & Paul, 2019).

The outcome suggests that math education should embed critical thinking to enhance skills and performance. Teachers should integrate CTS into math teaching, and teacher education programs should dedicate more time to nurturing students' critical thinking. This aspect will help future teachers exemplify effective thinking strategies, making the subject more approachable (Rico et al., 2021).

Students Experiences in a Problem–Based Learning Environment

Positive Experiences of Non-STEM Mathematics Preservice Teachers on PBL

Problem-based learning (PBL) emerged as a novel pedagogical paradigm for most study participants. During FGDs, students openly shared views about this innovation in the College and Advanced Algebra courses. Most felt unprepared due to TVL and HUMMS tracks in Senior High School, affecting their readiness for advanced math subjects.

"*...sa una miss... sang pag hambal mo nga ma problem-based na ang method sang imu teaching...ginkulbaan ko...*" ("...at first miss...when you orient us about PBL that it will be your teaching method...I felt nervous...")**P6**

("...when you told us miss that we will have PBL as teaching-learning method... I felt like failing in the class because I am not used to problem-solving, and I was at TVL track during my Senior High School...") **P4.**

("...same with me, miss, because I am from HUMMS track...and math subject is not emphasized in our tracks...") **P5**

However, introducing PBL brought excitement and challenges, sparking diverse reactions in the class. PBL, featuring thought-provoking open-ended scenarios, provides multiple routes to solutions. Students tackle these challenges independently while collaborating with peers and the teacher as facilitator. According to **P2**:

"...abe ko ang PBL approach ka budlay gid kay bag-o gid sya para sa akon kag basi indi gd ko maka learn...pero sang na implement na sya sa klase, na sadyahan nako.."

("... I thought the PBL approach was complex because it was new to me, and I could not learn, BUT when implemented in the class, I found it fun and exciting…") **P2**

("...even though I am not a STEM track in my SHS, I felt excited to solve mathematical problems through this PBL approach because I can ask a guide from my groupmates…") **P7**

Participants observed that PBL facilitated the cultivation of critical thinking skills through self-directed study, group sharing, and discussions. PBL nurtures critical thinking, analysis, and real-world problem-solving skills, enhancing students' readiness for careers beyond the classroom. Additional student participants also shared their positive experiences with PBL:

"Para sa akon, ang PBL ka challenging kay damu ka problems nga e solve kag kinanglan mo gid ma minsar sang mga strategies nga gamiton para ma solve ang problem" **P9**

("I found PBL challenging because we encountered different problems for you to solve, and you will think critically and device different strategies to solve that particular problem.") **P9**

("Mathematical problems posted in the class were challenging because, at first glance, you can say that it is easy to answer; however, when you start solving it, you need to dig into the implied information in the situation to get the correct answer.") **P10**

Students conveyed that they acquired a more profound comprehension of concepts and enhanced their mathematical skills through feedback and peer tutoring. Collaborating with peers enhances creativity, confidence, communication skills, and problem-solving abilities (Hendriana et al., 2018). Moreover, PBL proves advantageous for students in the lower and middle groups.

"Sa PBL, makapamangkot ka sa groupmates mo kon isakto ang akon process kg sotluions sa mga problem nga ginahatag sa amon" **P4**

("In PBL, I can ask my groupmates to validate my processes and solutions to the problems given to us.") **P4**

("In PBL, I can share my ideas on how to solve the problems. We can discuss whether my ideas or interpretations regarding the problems were the same as my groupmates.") **P8**

PBL empowers students to engage actively in the teaching-learning process, assume ownership of their knowledge, collaborate effectively as team members, adapt to new situations, and foster lifelong learning skills (Wong and Kan, 2022)

Negative Experiences of Non-STEM Mathematics Preservice Teachers on PBL

Students provided feedback regarding the impact of different learning styles on their collaborative work. A student from the high group preferred uninterrupted problem-solving because they could not focus on their approach to solving the problem.

"Indi ko ya makafocus sa akon nga ubra kay ang mga groupmates wala patay pamangkot sa akon kon insakto ang ila nga ubra" **P4**

("I cannot focus on my work because some of my groupmates frequently ask me if they were on the right track in their solutions process.") **P4**

("As a student belonging to the High Group, during group activities, I felt that the learning of my groupmates is my

responsibility, and PBL is very tiring and time-consuming on my part.") **P6**

However, some students lacked confidence when presenting within teams, making discussions in larger groups challenging. Additionally, students felt more comfortable with board work when the teacher verified their answers. This student shows reliance on facilitators for detailed explanations. In contrast to Benedicto and Andrade's (2022) assertion, Filipino students can benefit from PBL to learn math because it promotes engagement, critical thinking, and a deeper understanding of concepts.

"Nahuya ko magpakita sang akon asnwers sa groupmates kay nahadlok ko basis ala kg kadlawan ko nila" **P3**

("I felt shy to show my solutions to my groupmates because of the fear that my solutions were incorrect and they would laugh at me.") **P3**

("I am afraid to go to the board and show my solutions to my classmates because I feel inferior to my classmates.") **P1**

("PBL is good, but I prefer the most if the teacher discusses the lesson first and give examples with a step-by-step process of the solution so that I have a guide on how to solve the problem rather than establish the concept first on my own.") **P5**

This matter gains heightened significance when participants possess limited mathematical backgrounds from Senior High School, resulting in an insufficient grasp of mathematical concepts. Coronel et al. (2019) emphasized that expressing problems with mathematical models relies on comprehension and prior knowledge. If students struggle with understanding, their models can be inaccurate. A participant noted that PBL, though valuable, can be counterproductive if the mathematical model needs revision within provided time constraints.

"Sa PBL, useless lang ang effort mo kon sala ang mathematical model sang problem kay ma sulit kagid solve halin sa sugod". **P10**

("In PBL, your effort is useless when you start an incorrect mathematical model that represents the problems because you will repeat the process of your solutions.") **P10**

Opting for PBL may require educators to undergo specialized diversity training due to its broader content scope than traditional lectures (Lapuz & Fulgencio, 2020). Participants recognize PBL's benefits in enhancing math and problem-solving skills. They collectively concur that their learning advances further when teachers elucidate and rectify erroneous responses, offering precise guidance on steps and procedures. In contrast to (Bosica et al., 2021), students could learn mathematics well using a PBL technique and perform better than those taught using the conventional method.

Conclusion and Recommendations

The study aimed to investigate how students' experiences in a Problem-Based Learning (PBL) environment affected the development of their Critical Thinking Skills (CTS) and their academic proficiency with linear, quadratic, and polynomial functions. This inquiry focused on first-year Bachelor of Science in Education (BSED) math students enrolled in College and Advanced Algebra at a particular state university, employing PBL.

Initial pre-test findings indicated that most participants were *challenged thinkers* with minimal performance in linear, quadratic, and polynomial functions. Despite varying preceding term grades shaping their grouping, they embarked on the study with similar performance and CTS levels. After PBL-based special functions instruction, post-test results demonstrated significant CTS improvement among all Advanced Thinkers groups, garnering a collective Very Satisfactory performance rating. These results highlight the potential of the PBL approach in fostering better comprehension and CTS among participants, even when starting from similar performance levels. The PBL effectively enhanced their understanding of complex math concepts, leading to commendable progress. This outcome underscores interactive and context-driven methods like PBL in facilitating academic growth and achievement.

Insights from in-depth interviews through Focus Group Discussions (FGD) illuminated students' initial unfamiliarity with PBL pedagogy. Their lack of readiness for college algebra stemmed from prior Technical-Vocational-Livelihood (TVL) and Humanities and Social Sciences (HUMSS) tracks in Senior High School (SHS). This result could be a baseline for the teacher education department, specifically in mathematics, to have a program for non-STEM graduates motivated and dedicated to taking mathematics as a specialization.

As the course progressed, students' viewpoints evolved. PBL-facilitated special functions learning engaged their interest while challenging their critical thinking for effective problem-solving. Lower and middle student groups found substantial benefits, acquiring enhanced conceptual understanding and refined mathematical skills through feedback and peer tutoring.

Participants also endorsed PBL's role in fostering CTS through self-directed study and group interactions. However, students expected instructors to furnish comprehensive step-by-step processes and explanations during lesson discussions. This result implies that for the students, maximized learning should combine PBL and conventional teaching methods to deepen the understanding of the concepts.

Nevertheless, this study has limitations, primarily its exclusive focus on linear, quadratic, and polynomial functions. A comprehensive exploration of function topics across the semester would offer a holistic grasp of students' responses and attitudes toward PBL in varied function domains.

Monitoring the temporal aspect of learning procedures during PBL implementation is crucial. Due to its time-intensive nature, efficient, well-structured preparation becomes pivotal for successful execution. This consideration, alongside instructors' readiness to adeptly navigate the PBL paradigm, warrants robust attention for future research pursuits.

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